COST SAVING AND COST AVOIDANCE FROM THE PHARMACY AUTOMATION SYSTEM

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การหาต้นทุนที่ประหยัดและต้นทุนที่หลีกเลี่ยงได้ของระบบจ่ายยาอัตโนมัติ

นางสาว วรรณอร ปลอดกระโทก

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

สาขาวิชาเภสัชศาสตร์สังคมและบริหาร ภาควิชาเภสัชศาสตร์สังคมและบริหาร

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วรรณอร ปลอดกระโทก : การหาต้นทุนที่ประหยัดและต้นทุนที่หลีกเลี่ยงได้ของระบบจ่ายยาอัตโนมัติ (COST SAVING AND COST AVOIDANCE FROM THE PHARMACY AUTOMATION SYSTEM) อ. ที่ปรึกษาวิทยานิพนธ์หลัก : ผศ.ดร. ฐณัฏฐา กิตติโสภี, 108 หน้า.

วัตถุประสงค์ของงานวิจัยนี้เพื่อประเมินต้นทุนที่ประหยัดและต้นทุนที่หลีกเลี่ยงได้จากการใช้เครื่องจ่ายยาระบบอัตโนมัติที่ใช้ในการจ่ายยาผู้ป่วยในโรงพยาบาลบำรุงราษฎร์ โดยเปรียบเทียบกับระบบการจ่ายยาแบบเดิม และเสนอแบบจำลองของการหาค่าต้นทุนที่ประหยัดและต้นทุนที่หลีกเลี่ยงได้จากการใช้เครื่องดังกล่าว ระยะการวิจัยแบ่งเป็น 2 ช่วง (ก.ค-ธ.ค. 2550 และ ก.ค.-ธ.ค. 2551) โดยเก็บข้อมูลแบบย้อนหลัง ต้นทุนที่หลีกเลี่ยงได้คำนวณจาก ค่าใช้จ่ายจากการแก้ไขการจ่ายยาที่ผิดพลาด รวมถึงค่าชดเชยอื่นๆ โดยแบ่งความผิดพลาดและคำนวณค่าใช้จ่ายตามระดับความรุนแรง ส่วนต้นทุนที่สามารถประหยัดได้คำนวณจาก จำนวณเงินที่ประหยัดไปจาก 3 ส่วน คือ ค่าแรงงานคนที่ใช้การจ่ายยา การฝึกอบรมพนักงาน และค่ายาคงคลัง จากผลการศึกษาพบว่าความผิดพลาดจากการจ่ายยาลดลงประมาณร้อยละ 70 ซึ่งความผิดพลาดส่วนใหญ่เกิดขึ้นที่ระดับต่ำสุด ค่าใช้จ่ายจากความผิดพลาดจากการจ่ายยาระบบเดิมมีค่า 4,940 บาท ในขณะที่ค่าใช้จ่ายจากความผิดพลาดในระบบอัตโนมัตินั้นมีค่า 4,053 บาท ซึ่งสามารถหลีกเลี่ยงค่าใช้จ่ายได้จากค่ายาและค่าจัดยา 1,687 บาท ส่วนค่าชดเชยในกรณีที่เกิดความผิดพลาดไม่ได้นำมารวมในค่าใช้จ่ายที่เกิดขึ้นในกรณีนี้ เนื่องจากไม่สามารถระบุความผิดพลาด และสาเหตุที่ชัดเจนได้ ดังนั้นต้นทุนที่หลีกเลี่ยงได้จึงมาค่า 1,687 บาท ในระยะเวลา 6 เดือน ค่าใช้จ่ายด้านกำลังคนในการจ่ายยาของระบบใหม่เทียบกับระบบเก่า พบว่า ลดลง 303,996 บาท ค่าฝึกอบรมพนังงานใหม่ลดลง 176,000 บาท มูลค่าคลังยาลดลง 1,049,308 บาท เมื่อรวมค่าใช้จ่ายจาก 3 ส่วนดังกล่าว มูลค่าต้นทุนที่สามารถประหยัดในช่วง 6 เดือนที่ทำการศึกษามีมูลค่า 1,529,304 บาท สรุปได้ว่าแบบจำลองที่พัฒนาขึ้นนั้นทำให้สามารถพิจารณามูลค่าต้นทุนที่สามารถหลีกเลี่ยงได้จากใช้จ่ายที่เกิดจากความผิดพลาดจากการจ่ายยารวมถึงค่าใช้จ่ายที่เกี่ยวข้อง และมูลค่าต้นทุนที่ประหยัดได้จากค่าแรงงานคน ค่าฝึกอบรมและมูลค่าคลังยา

ภาควิชา เภสัชศาสตร์สังคมและบริหาร ลายมือชื่อนิสิต...
สาขาวิชา เภสัชศาสตร์สังคมและบริหาร ลายมือชื่ออ.ที่ปรึกษาวิทยานิพนธ์หลัก..
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The aims of this study were to assess effectiveness of the pharmacy automation system in term of cost saving and cost avoidance, medication filling errors reduction and to suggest a model of cost calculation. Data was collected retrospectively at the inpatient pharmacy department, the Bumrungrad International Hospital during 6 months separated period (July-December 2007, July-December 2008). Cost avoidance concerned costs of medication filling errors and other related costs, while cost saving referred to costs of dispensing labor, new staff training costs, and inventory costs. In an overall, the results revealed that the new pharmacy system with an automated drug filling was be able to reduce around 70% of medication filling errors. Under traditional dispensing system, the medication error and related costs was 4,940 baht, whereas the new system lost 4,053 baht during the 6-month study periods. Cost of claims and compensation could not include in this calculation because of unable to clarify of exact causes and details of such events. Thus, the automated system could avoid 1,687 baht of medications cost and drugs filling cost during the study. At the same time, the new automated system was able to save dispensing labor cost around 303,996 baht training cost saved 176,000 baht and inventory cost saved up to 1,049,308 baht. So, total cost saving was 1,529,304 baht. In the consideration of cost calculation model, it was concerned that all possible related costs directed to the implementation of the new robot in which; cost avoidance counted from medication filling errors cost (calculated depending on levels of severity) and cost of compensation resulting from dispensing deviations; cost saving could be computed from cost from dispensing labor, training costs, and inventory costs.

Department Social and Administrative Pharmacy Student's signature………………
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CHAPTER I

INTRODUCTION

Rational and Background:

Patient safety is relatively one important concern among medical care in many countries. It has an obvious effect to quality of care. Poor clinical outcomes are associated not only physical conditions but also they do costly [1]. Obviously, when each patient was given 10 daily doses of medication ordered by physicians, dispensed by pharmacists and administered by nurses, errors occurred even in the best hospitals. Cause and effects of health care malpractice are increasingly interested to evaluate. In addition to human error is inescapable, a zero error rate must be the goal of all concerned. With traditional medical management practices, patient experienced with adverse outcome can be seen. Human errors and inappropriate works seem to be involved this circumstance [1-3]. It is inevitable that these were concurrent with excessive expenditures [4, 5]. Many of these errors had no clinical significance and did not adversely affect the patients or extend their hospital stay, although they did affect the patient's confidence in the quality of health care system and its personnel. Overall, those stated problems have been a challenge of healthcare organization with respect to improve patient safety with the best managing resource utilization. Together with, consumers in the healthcare system are demanding in higher quality, safety, efficiency and value. Moreover, concerning on costs of health care problems has been deemed in attentions for a period of time. Study on costs of errors could help institutions arising awareness of excessive expenditure from professional practice deviations [5-8].

Modern technologies currently are becoming more important to address the issues of heightened interest in drug distribution and accuracy. In an age where technologies have been developed rapidly, and many see technologies as a way toward safer healthcare. It changes the way hospital pharmacy practices. They are understood as a good solution to human errors. Several interventions involving information technology had been shown to reduce medication errors considerably. Additionally, technologies have becoming more and more essential tools for performing tasks with respect to increase productivity and efficiency [9]. It is seemingly that technology interventions were possible to gain more advantages to the healthcare organizations. Not only safer patient cares but also save costs on spending extra cares [10-14]. Examples of technology were computerized physician order entry, computerized physician decision support, robot for filling prescriptions, bar coding, or automated dispensing device. It was recognized that several institutions had been recommended the use of technology to increase patient safety, minimize unintended errors and in the mean of best utilize optimal resources. For example, safety standard of the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) addressed the issues such as medication uses especially aim to preventing adverse events throughout the medical management process and avoid of human errors. With this awareness, the suggestion from JCAHO was to implement the technology to increase patient safety. Staffing effectiveness can also meet the JCAHO requirement as another indirect advantage of the automation machine [15]. Wide range of care services can be further served if the right technology is put in place. Nevertheless, because of substantial cost of the implementation of the machine, valuation of acquired benefits is intensively concern.

Medication errors and related injuries, say, give the impression to emphasize the safety issue. It was generally recognized as common occurrence events in the hospital which seemed to generate unnecessary harm and costs [16-18]. According to the medication errors given by National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) as “A medication error 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” [19]. The incidences are potentially to occur throughout the medical management process. These include prescribing, transcribing, dispensing and administrating [3, 20, 21]. Substantial numbers of individuals were subjects to affect the negative consequences accordingly [3, 22]. Nevertheless, most drug errors did not directly cause injury. Adverse drug events (ADEs) are recognized as suffering conditions result from medication errors. A report from the Institution of Medicine (IOM) shown that around 44,000-98,000 Americans die during admission in hospitals each year due to medical errors [1]. As noted, not all medication errors were harmful. Previous studies of the association had shown that less than 1% to 2.4% of medication errors can actually caused adverse events but, however, up to 7% were assessed as potential adverse drug events [5, 16, 22, 23]. However, injuries due to an error or correctable cause are preventable, in term of accepted practice, interception processes and best use of appropriate resources. Evidence suggested that approximately 28-56% of negative incidences were preventable [5, 22]. One study examined adverse events related to drug in inpatients at Paholpolpayuhasena hospital, Thailand found 34.20% of hospitalized patients had experienced with medication errors and 0.88% of total doses were accounted for preventable events [24]. It was obvious that if health professionals treat errors lightly simply because no harm was done to the patient, a potential serious error that caused injury or death would be inevitable.

Moreover, medication error rates indicated a discrepancy in each stage on medical management process. Lisby and colleagues illustrated the frequency of medication errors in the managed care system. The frequencies of ordering errors were 39%, transcription 56%, dispensing 4% and administration 41% [3]. With focusing on dispensing errors, it is an important point where pharmacists take the highest responsibility. The majority types of those errors involved incorrect drug, incorrect strength and also labeling. With content errors, they took into account around one-third to by half of the total dispensing errors [2, 21, 25, 26]. Even though, a slight number of dispensing errors were noticeable but with the higher volume of patients, busy working condition, time-constraints and limited staffing, the more error incidences was seemed to be simply [2]. Only few dispensing errors were intercepted by nurses before medication administration, many errors possible to reach hospitalized patients. Therefore, dispensing errors are an important target for patient’s safety intervention.

Several studies had focused on determination of human factors contributed to adverse events. Such errors can be occurred in common situations. It was likely that multiple tasks handle by several medical personnel provided the risk of incurring errors; from writing of the prescription by physician, transcribing orders by nurses, preparation of prescription by pharmacy staff and administrating by nurses. In dispensing process, the majority occurred errors were due to slip in picking products from the shelf when dispensing or mistake in making assumption about the products concerned. Some other human contribution factors to erroneous situations were reported such as individual’s physical conditions; feeling tried or unwell, interruption, look alike/sound alike items or exceed workload. Emphasizing to this point, pharmacists and technicians most take the responsibility and report of such errors. Interesting that most of the claims against pharmacies involved mechanical errors such as dispensing the wrong tablet or strength. So that, the pharmacy technicians are likely to be crucial point in developing a program in order to reduce medication errors [27]. More to the point, pharmacists should against themselves to be placed in a workload situation because it may prevent taking the time needed to proper dispense medication and counsel patients. It must be realized that the pharmacist should not be subjected to pressure for fast service, otherwise exhaustive and complete should be sought [2, 21, 26]. Medical related harms are not only impact physical condition problems and wellbeing, but also financial affair. There are either possible to result in prolonged the hospital stay or morbidity and, as well as, mortality. Hence, a large amount of money has been spending for further curing these conditions. There was a study on extra expenditure of hospitalized patients who experienced with ADEs during admission. It found that of those patients had 1.74 days additional length of stay and resulted in exceed cost of hospitalization of $2013 [5]. Another study of two tertiary care hospitals found patients with such condition had 2.2-4.6 more days in hospitals and associated cost of $3244 [4]. More to the point, in Thailand, two studies examined hospitalized patients who first admitted with disease conditions and, then unintended injured associated with medication occurred. Consequently, those conditions resulted in increased hospitalization and further treatment required. Choppradit found the incidence rate of 3.1 cases from 10,000 patients which 3.91 days increased in hospitalization, leading to extra expenditure of 543 baht [8]. Another study obtained the adverse event incidence rate of 1.76% from the overall patients which had additional length of stay was 1.25 days and cost 1,482.47 baht [7]. Although, some of those seemed correspond to small amount of money expended, a large volume of patient admissions, which potential to harm, can result in noticeably high expenditures. In a university hospital, estimated total cost was around $1.5 million per year with an average 3 adverse outcomes per patient and those cost of outcomes were ranging from $95 to $2640 [6]. The incidence of adverse drug events (ADEs) may cost approximately $ 5.6 million annually per hospital, depending on the hospital sizes [4]. With an estimation U.S. national lost cost as a result of adverse events in the U.S. were probable up to $50 billion [1].

Attentions had focused on patient safety and a wide range of reduction the likelihood of patient threatening circumstances. There had been subjected to formal study which supported to their effectiveness, such as medical safety program, or developing medical management process. Thereafter, emerging technology-based interventions have been critically impact health-care arena for a period of time. It was increasingly interested by many health care setting because its ease of use and high degree of reliability. Moreover, impact of technologies on patient safety outcomes had illustrated. Implementing technology devices along with the medication process were possible to reduce the occurrence of medication error rate up to 85% [9]. A suggestion estimated $1.4 million could save from medication error by introducing technological intervention [14]. The results revealed the error was decreased significantly and, as well as adverse drug events rates, with suggestion of other advantages such as saving staff time, economic advantage, and working efficiently [9, 14, 28].

One of the various innovative medical technologies intensively focused on mechanism for reducing potential problems, known as automation system. Automated technology is not only operating for safely productivity but it also important part of health care in term of efficiency use of human resources and a support to the limited capacity of human in performing tasks [29]. The automated pharmacy system (Swisslog) has replaced the traditional medication management process. Three main focal points are to reduce human error, working efficiency and good inventory control. This filling machine is a multifunction fully automated unit dose packaging, storage, dispensing system. The process is operated within the pharmacy department. The general workflow is individual unit doses automatically first packaged, bar-coded, labeled and then stored for future retrieval and dispending to patient. Dispensing medications are packed for a specific patient, 24 hours supply of unit doses grouped together orderly. The robot is possible to perform up to three tasks simultaneously. Other special feature of the automation involves in inventory management. Medication returned from the wards will be automatically restocked into the machine providing simplicity for inventory control. It improves documentation and eliminates the problem of dispensing of expired medication as the system operates first-in first-out items.

Several evaluations of technologies in healthcare had long been documented. From evidences of a number studies, beneficial distinguish outcomes could be noticed. The relevant results were direct to patient safety, working environment and financial affair. For instance, the automated dispensing machines operated for decentralized works which stored and retrieved drug on patient unit by nurses provided a significant reduction in medication error rates. For financial benefit, it reflected an annual positive return of $35,000 (in 1991 dollar) [30]. Another study at a 735-bed tertiary academic medical center where bar code system was implemented in the context of pharmacy dispensing, had documented the rates of dispensing errors and potential ADEs decreased by 36% and 63%, respectively [31]. Maviglia and the colleagues had proposed, from the hospital's perspective, a positive financial return on investment bar coding. The net benefit after 5 years was $3.49 million which total costs during the first 5 years were $2.24 million (in 2005 dollar), while annual ADEs saving from dispensing errors were $2.20 million. The result were from the significant reduction of potential ADEs by 63% [12].

With the more special attention to the automated assistant machine operated dispensing in pharmacy, provided relatively advantages. Although, the research of this kind of machine was rather rare available, the presented studies shown interesting results. A study of effect of a robotic prescription filling system (ScriptPro SP-200), for example, by Lin and his colleagues shown the installation of automation could save just about 0.56 minute filling time per prescription. This could also resulted in the pharmacy was able to handle the higher amount of daily prescription with decreased personnel [32]. Automated pharmacy station (APS) was one another similar drug filling machine that had been used in many healthcare organizations. Thereby, reports had documented its effectiveness as the system reduces the time needed to fill and verify unit dose medication carts, and ensures a high level of dispensing accuracy [28, 33]. One study examined automated pharmacy station (APS) worked for 510 beds of the University of Wisconsin Hospital (UW) had shown the high accuracy in operating performance, provided 99.8% of picking drug accuracy (88% of filling error reduction rate) and introducing the robot could save 3 technician FTEs needed for cart filling and restocking . However, there was no change in number of staffs but they had an opportunity of job redefinition. The report also revealed that staffs were happy about doing something different. Moreover, this robot was expected to save UW Hospital around $350,000 over its eight-year life span [34]. The automated picking machine resulted in less floor space occupied, 16% reduction in dispensing error rate and 19% reduction in staff time [25]. As well as, estimated economic advantage of implementing the machine could save the institution personnel cost about $ 1 million over 5 years [29].

In Thailand, there was a study on costs in comparison to the existing manual system of the automatic tablets counting machine. The results shown the total cost of the machine was higher than the conservative system almost 5 times, but the occurrences of medication errors decreased about 3 folds. The suggestion was created as it was worth to use the machine in the higher volume of items dispensed [35]. Focusing on the important of human resource, a study examined the direct cost of pharmacy unit, Nopparatrajchathani Hospital, Thailand, found the costs of staff payment took into account of the greatest amount of the total expenditure, 7,363,766.80 baht (51.81%) (in 1997 baht) [36]. So that, the implementation of automation was likely to provide economic advantages in reducing such costs involving staff working time and produce others more clinical approaches [33]. However, there was no such type of the robot has ever been evaluated in this country.

Regarding to the overall studies being previously mentioned, problems were common occurrence, while several solutions attempted to overcome such the problems. In Thailand, technological-based involvements have been progressively more bring in. Healthcare organizations prompted increasing use of automated technology. However, lack of knowledge about technology implementation that improves care and manages costs for specific organization, especially for this multifunctional automated robot. Although, obvious positive expected consequences can be perceived, there are always certainly arising the questions concentrate on investment worthiness; whether obtained return benefits are over amount of money being spend on employing the automation technology into service. It is especially when the availability of resources, manpower or funds are limited.

Clinical and economic impacts of medication errors can be profound. Outcomes assessment is deemed to the more understanding of a change in patients' health status resulting from health care interventions. It is believed that pharmacists were committed to ensure optimal outcomes of drug therapy and pharmaceutical care for their patients [37]. Managed care financing is further achievable by using outcomes information. Many pharmacy interventions were targeted for pharmacoeconomic evaluation [10, 12, 13, 38-40]. However, the more common research around this arena is cost analysis of healthcare problems or implemented interventions, regarding to concerning health care costs. Many highlighted on studying avoid waste and unnecessary costs for patients or within the institutions. Cost avoidance is typically defined as "dollar not spent from the outset", while cost savings imply as "dollar previously spent that are no longer spent" in numerous studies [39-46]. This study method, for example, can be applied for an assessment of automated point of use unit dose drug distribution machine. Cost savings in term of pharmacy labor costs were judged as an effectiveness indicator assessing the machine [11]. Drug costs avoided are one other common expenditure to determine when evaluating automation systems [10]. Calculation cost savings and cost avoidance are focused on all financial outcomes associated with interventions in patient care. Cost captures most were relevant to the drug acquisition and lab tests, the cost of a change in therapy and personnel costs such as physicians, nurses and pharmacists. Other included costs of hospital, physician visits, discontinued or avoided prescriptions, costs for special clinics, additional therapy, laboratory, contacts with health care professionals, staff productivity loss, and personnel costs.

Multiple factors affect on choices of the use of particular medical intervention; comparative efficacy, effectiveness, preferences and cost. Health Technology investments in health care settings that promote safety and prevent illness were also evaluated by economic outcomes. The focal point of economic evaluation is to determine on whether such intervention should be implement in term of worthiness. From the payer's perspective point of view, it is clear to make a decision on commercial projects with financial analysis. With the available information, its effectiveness can be measured the three main expected benefits on the operation of the machine in comparison to the manual procedure. Focusing on the changes within the two systems, medication filling errors, staffs benefit, and inventory control were proposed to be the main measured indicators. This analysis can then finally be done by the comparison of the different in cost of the two different dispensing in order to achieve total expenditure that can be saved or avoided, as a result of introducing the drug filling automation. Moreover, this informative data could suggest cost savings and cost avoidance model with respect to arising concern of other healthcare institutions on medication errors from financial view point. Plus, it was likely to provide advantage to healthcare decision-maker on investment such the robot in term of benefits that can be gained from the machine, especially in Thailand.

Bumrungrad hospital is a 480-bed tertiary hospital where the automation pharmacy robot was first implemented in Thailand since April 2008. It is located within the inpatient pharmacy department and is direct connected to the pharmacy computer system. The project was implementing in phases. Its inpatient pharmacy service dispensed approximately 2.5 million medication doses for 32,000 admissions annually. The hospital employed 28 full-time pharmacists, 58 full-time pharmacy technicians who are responsible for most of medication dispensation process. The aim of those health technologies was about to reduce the risk of dispensing errors and to provide efficient work to the system. However, in Thailand, no studies on direct expenditures and consequences of such the automation had been conducted in hospitals. Therefore, this thesis presented an economic study documenting the extent of these technology-assist systems from a hospital perspective by using the Bumrungrad hospital as a research setting.

Objectives of the Study:

1. To evaluate cost saving and cost avoidance from the use of the pharmacy automation system.

2. To study effectiveness of the pharmacy automation system from the reduction in medication filling errors.

3. To create a model of cost saving and cost avoidance from having the pharmacy automation.

Perspective of Analysis of the Study:

This study was analyzed costs saving and cost avoidance from having the filling robot within pharmacy department from the hospital's perspective.

Scope and Limitation of the Study:

There was a clear need for research to be set in the context of the direct costs associated with three main benefits expected to obtain from pharmacy automation system; medication errors, staff benefits, and inventory control. Effectiveness of the implementation pharmacy drug management robot was also monitored in comparison to the manual system. Thus, the findings were shown to be directly relevant and applicable to practice need in providing usefulness of economic information. This study was targeting toward the benefits and associated costs incurred by the automation associated with inpatients at the Bumrungrad international hospital during two separated periods, 1^{st} July to 31^{st} December 2007 (the manual system) and 1^{st} July to 31^{st} December 2008 (the automation system).

The Agreement Used in the Study:

The agreements set and used in this study were as follow:

1. Examining medication errors were only those relevant to filling errors found at in-patient dispensing process, observed from pre-dispensing errors, or nursing units, information retrieved from incident reports, otherwise were excluded.

2. Both dispensing practices were the same, except the part of filling medication changed according to the intervention.

3. Costs calculated by using charge price.

Definition Used in the Study:

A. The manual pharmacy dispensing system was an in-patient dispensing process that had been used before April 2008. It was a centralized dispensing system which all processes run by pharmacy personals. The process started with doctor order sheets from nursing units were scanned and sent direct to the IPD pharmacy computer system. After that, all prescriptions were keyed in by pharmacy staffs and had to verify by pharmacists. Authenticated prescriptions then were filled medications by pharmacist assistances and required re-inspection again by pharmacists and finally were delivered by carts to the wards.

B. The pharmacy automation system was an in-patient dispensing process with the use of automatic machinery. The machine was implemented since April 2008 which some parts of pharmacy practice had been changed and results in beneficial outcomes to the system. The pharmacy automation system is a multifunction which fully automated unit dose packaging, storage, dispensing and re-stocking system. Medications supply by the robot are unit doses of vial, ampoules, injections and small boxed item such as eye drops, ear drops, creams, ointments and inhalers, while the others are being dispensed manually by pharmacy technicians.

C. Dispensing effectiveness was defined as the obtained cost benefits resulted from the change of dispensing procedure in the following aspects;

1. Medication filling errors were a part of pre-dispensing error report system developed by the pharmacy department, Bumrungrad International Hospital. It was a self-reporting system by the staffs involved with the in-patient dispensing. These errors included incorrect drug, incorrect drug strength, incorrect drug quantity, incorrect drug labels, incorrect drug formulations, expired medication and omission. Moreover, the error included any incidences reports in which relevant to filling mistakes found by nurses before administrating process as well. In case of associated cost with medication errors emerged, it would be determined only evidentially related to pharmacy dispensing deviations.

2. Staff benefits included labor dispensing costs and associated cost with labor benefits, such as training for new pharmacy employees, and individual job training by experienced personnel in which partially lost current responsibilities. This

staff benefits were expected as a result of implemented the pharmacy drug filling automation.

3. Inventory control took account of drug inventory cost. Only inventory supplied for inpatient pharmacy department is considered.

D. Cost saving defined as money previously spent that are no longer spent in comparison of the two pharmacy dispensing systems. Costs from dispensing labor and improve inventory control were expected costs that can be saved from introducing the new machine.

E. Cost avoidance was costs specific to money not spent from the outset determining the difference between defined costs of the manual dispensing system and the pharmacy automation system. Medication errors and associated costs were considered as costs that would not be happened.

Anticipated Outcomes:

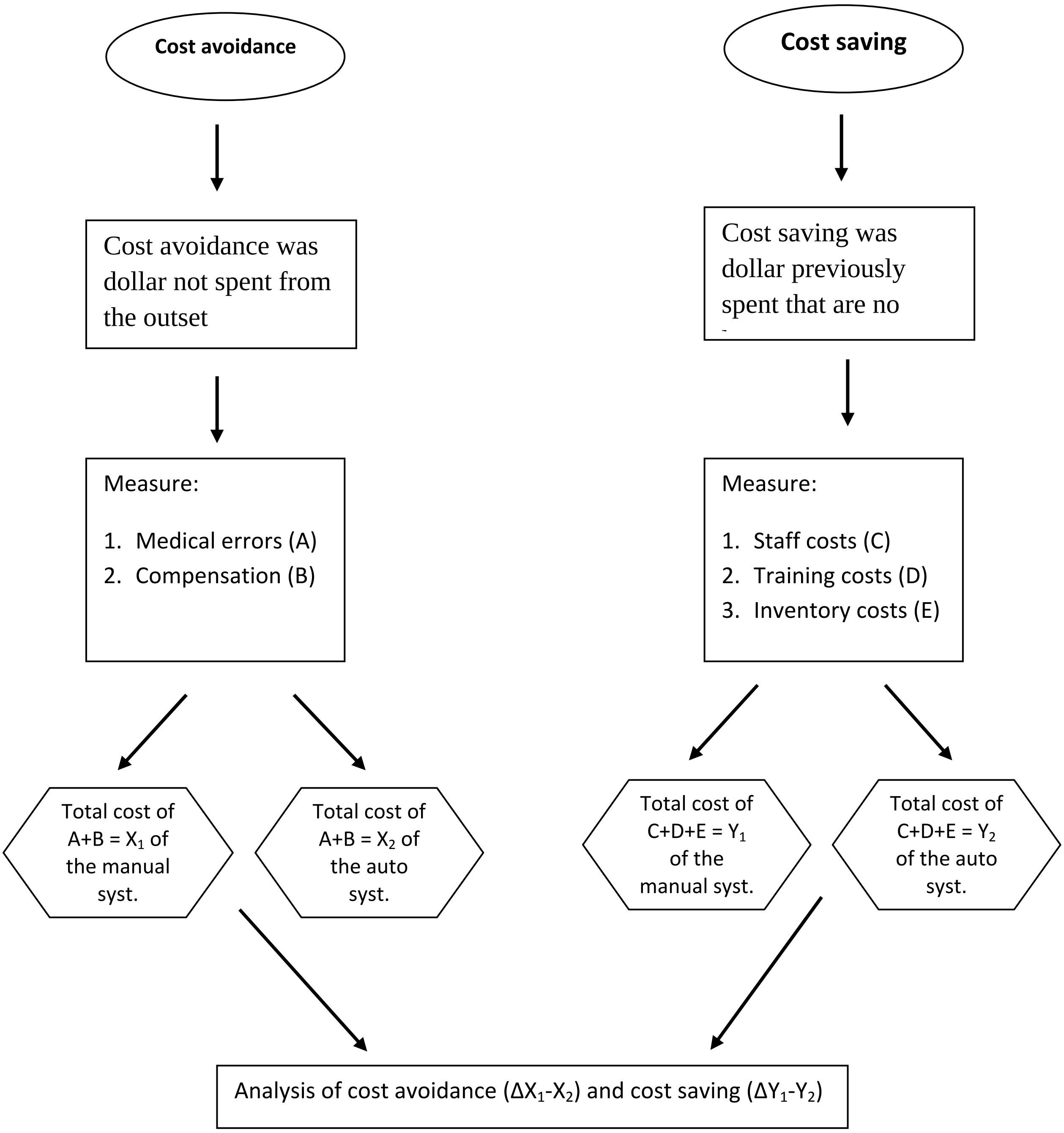
1. To provide the information of the costs of implementing the machine and its effectiveness in order to put forward to decision making on investment such the automation in Thailand.

2. To be an informative data for improving patient safety and resource allocation for health investors.

3. To be an informative data for the effectiveness of the pharmacy automation system in term of cost saving and cost avoidance.

Conceptual Framework:

Figure 1: Conceptual framework of cost analysis of the pharmacy automation system.



1st period (the traditional dispensing system): to collect information of the traditional dispensing system since 1st July till 31st December 2007.

2nd period (the dispensing system with robot implementation): to collect information of the pharmacy automation system since 1st July till 31st December 2008.

CHAPTER II

LITERATURE REVIEW

Medication errors reported as a significant health problem. Many evidences supported this threat which was also apparently contributed to serious adverse drug events and to the high costs of health care. These concerns would challenge health care providers who aimed at minimizing the risk of trouble at the lowest level as much as possible. To be more understood of these points, many of published journals, books, reports and others were critically reviewed. From the literatures presenting in this chapter indicated the facts about medication errors, relevant to health problems, financial issues and the cause built by human. Plus, in order to reduce errors, several technological attempts were mentioned with the more focus on dispensing process. Finally, best suitable hi-tech devices to the organization need the clearer view of economics. It can help the investors to draw up financial costs resulting from such errors and what should be decided to diminish the significant health problem. So, the last part of this section pointed up to cost measurement.

Part 1: Medication Errors

Medication errors are a well-known problem in hospital. Actually, they occurred not only in hospitals but also be found in other health care settings, such as physician's offices, nursing homes or care delivered at home. Unfortunately, very little erroneous events existed outside the hospitals [2]. In most instances they were likely to be caught by the system and caused minor effects to the patient. However, numerous evidences had shown that medication errors and adverse drug events were leading to a significant number of disabilities and death of hospital admissions [1, 3, 5, 16, 21, 22, 47, 48]**.** Medication error occurs as a result of multiple, compounding events rather than from a single act by a single individual. Several studies had attempted to investigate how and why errors were likely to occur. Errors can be classified as either active or latent. Active errors have an effect that is immediate, while latent errors, on the other word, have delayed effects or results, accidents waiting to happen or impact of medical equipments misused. Most medication errors were considered as latent effect, such as when a prescription was filled with a wrong medication, patient realized this mistake once returning home and had took the drug

[49]. Processes and causes of errors are possible to identify and can be corrected before the error persists.

A. Definitions of Medication Errors

Medication errors can occur at any points in the medication use process of prescribing error, transcribing error, dispensing error, and administrating error [2, 50]. A number of research groups had indicated definitions of medication errors which were interested to be first addressed and further developed a study.

National Coordinating Council for Medication Error Report and Prevention (NCC MERP) stated "a medication error is any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of health care professional, patient, or consumer. Such an event may be related to professional practice, healthcare products, procedures, and systems, including prescribing, order communication; product labeling, packaging, and nomenclature; compounding; dispensing; distribution; administration; education; monitoring; and use" [19].

A definition of medication error was given by Resar, Rozich and Classen as "a medication error includes the failure of a planned action to be completed as intended or the use of a wrong plan to achieve an aim". It is a process focused and ends up exclusively examining an individual's role [51]**.**

American Society of Hospital Pharmacists (ASHP) defined a potential error as "a mistake in prescribing, dispensing, or planned medication administration that is detected and corrected through intervention (by another-care provider or patient) before actual medication administration". Hospital's routine quality improvement process was recommended in order to detect of potential errors [50].

Allan and Barker defined medication errors as "a deviation from the physician's medication order as written on the patient's chart. Medication errors are typically viewed as being related to drug administration, whereas dispensing errors are mistakes made by pharmacy staff when distributing medications to nursing units or directly to patients in an ambulatory-care pharmacy" [52].

In general, ASHP also indicated medication errors can breakdowns according to process or subsystems involved with; Prescribing, transcribing, dispensing and administrating errors. However, errors may involve more than one aspect of the system. Overall, many studies subdivided types of medication errors by the following definitions and sub-definitions within the system. Types defined used in different studies had variations in categorical definitions because of study purposes, setting, methodologies, variables being concerned or available database [2, 3, 26, 31, 49, 53, 54]. Moreover, error categorization logically required consideration of hospital policy and other factors that appropriately prevent the correct dose to patient.

1) Prescribing errors can be defined as an incorrect drug selection for patient, including omission of drug name, drug formulation, route, dose, dosing regimen, date signature, treatment time for antibiotics. Transcribing errors were depicted as errors in which incorrect duplicated prescription from the original transcription.

2) Dispensing errors were errors that occur at any stages during the dispensing process from the receipt of a prescription in the pharmacy through to the supply of a dispensed product to the specific patient.

Dispensing errors studied by Beso had cited this kind of error as "a deviation from an interpretable written prescription or medication order, including written modifications to the prescription made by a pharmacists following contact with the prescriber or in compliance with pharmacy policy. Any deviation from professional or regulatory references, or guidelines affecting dispensing procedures, was also considered a dispensing error" [2].

Poon et al. defined dispensing errors as "any discrepancy between dispensing medication and physician orders or replenishment requests or any deviation from standard pharmacy policy" [31].

Most dispensing studies included these following variables as determining such errors: incorrect drug, strength, dosage form, dose added, miss doses, omission, expired drug, drug in appropriate container; incorrect labeling of patient name, drug name, drug strength, drug quantity, dosage form, date, instruction, additional warning and pharmacy address; documentation errors of incorrect controlled drug documentation, and other documentation errors [2, 3, 26, 31, 52].

Over than above, Betz and Levy included other pharmacist's skill, knowledge and practices in to the definition of dispensing errors. These were "dispensing a medication without sufficient education of the patient on its proper use and effects, dispensing a medication with an inappropriate dose or dosage schedule, dispensing a medication that has no indication or a contraindication for the patient's diagnosis, dispensing a medication without altering the prescriber when the patient has a known idiosyncrasy, dispensing a medication that has the same pharmacologic intent as other drugs the patient is receiving, incorrect transcription, establishment of an inappropriate therapeutic regimen, and providing incorrect drug information" [54].

Allen and Barker, as mentioned earlier, also reviewed most error categories that had been used in studies of pharmacy dispensing errors included selection (picking) error which was a broad term encompassing incorrect medications, dosages, and dosage forms, omission, and extra doses; missing doses (or omission errors) which was absence of an ordered drugs; drugs not in light-protective packaging; incorrect reconstitution or preparation [52].

More to the point, pharmacists and pharmacy technicians are taking high responsibility at the point of dispensing. As variety delivery pharmacy services, the role of pharmacists have expanded, they have delegated more of their routine responsibilities to the technicians. A study from Cowley found that only 38% of technician's medication errors were intercepted before reaching patients. Although the majority of error reaching the patients did not cause serious harm but some were resulted in temporary injured that required an initial or prolonged hospitalization, a near-death events or even death. The most frequency type of error by the technicians was an unauthorized drug. The second common type was product errors such as improper drug dose or quantity and confusion between similar labeling or packaging. Consequently, these mechanical errors are the leading cause of the claims against pharmacies [27].

Pharmacists have a significantly role in preventing medication errors. Importantly, they should have collaboration with other professions in term of drug therapy monitoring. It is also essential that pharmacists must devote careful attention to dispensing processes to ensure that errors are not presented at any points in the medication process [50]. Although, definite dispensing accuracy does not guarantee error-free medication administration, it rationally provides increase the probability of success. Besides, this presenting study proposed to highlight at this dispensing arena of medical management process. It, moreover, seeks to determine inpatient point of care in the particular [52].

3) Drug administration errors were possible to define as a discrepancy between the drug therapy received by the patient and the drug therapy intended by the prescriber, such as wrong route, wrong time, administration technique, unordered drug, unordered dose, omission of dose and lack of identify control. Drug administration is associated with one of the highest risk areas in nursing practice.

B. Common causes of Medication Errors

However, medication error itself did not cause harms to patient, only some medication errors were associated with adverse drug events which all potential ADEs were medication errors [20]. Previous studies of the association had shown that less than 1% to 2.4% of medication errors can actually caused adverse events but, however, up to 7% were assessed as potential adverse drug events [5, 16, 22-24]. ADEs rate can resulted up to 6.5% of total patient admission, but 28% of those were judged as preventable events [5, 21, 22]. The outcomes of medication errors could range from minimal or no patient risk to life-threatening risk. However, criteria in which medication errors were classified in the process were different. Common causes of medication errors given by American Society of Hospital Pharmacists (ASHP) were [50]

- Drug product nomenclature (look-alike or sound-alike names, use of lettered or numbered prefixes and suffixes in drug names)
- Equipment failure or malfunction
- Illegible handwriting
- Improper transcription
- Inaccurate dosage calculation
- Inadequately trained personnel
- Inappropriate abbreviations used in prescribing
- Labeling errors
- Excessive workload
- Lapses in individual performance
- Medication unavailable

C. Monitoring Medication Errors

It is generally recognized that ongoing quality improvement programs for assessing of types and frequency medication errors within the organization are essential. Medication errors should be identified and documented in order to develop minimizing recurrence systems or determined whether procedures need to be changed. Besides, consideration of the effectiveness or quality of a drug distribution system, the error rate is generally determined as one of the best indicators. Several efforts to identify and understand had been made and thereafter solutions based on practical and effective responses had been sought. Efforts directed solely at identifying and quantifying medication errors are likely leading to optimal the safety of care and will assist in determining appropriate technologies and setting priority. In order to improve safety, which must be a significant characteristic of the system or organization, it is important to know underlying causes and nature events that injure patients. Medication errors can be detected by several typical techniques. Existing error monitoring techniques are presenting as the follow: [19, 20, 50, 52].

1.) Anonymous self-reports

There are two main type of self-report from health professional, such as physicians, nurses, pharmacists or other health professionals who become aware of any adverse drug events or medication errors, and those generated by research assistants, nurses or patient safety officers collect and record data of any incidences at the patient care units or clinics [20].

2.) Incident reports

These reports were defined as “any happening which is not consistent with the routine operation of the hospital or the routine care of a particular patient. It may be an accident or a situation which might result in an accident” or “all unusual occurrences within the hospital or its physical plant which might result in a liability or any condition, situation, or event which might create a liability for the hospital” [55].

This kind of source can be conducted either retrospective or concurrent chart review. Incident reports have attempted to identify specific events that endanger or possible lead to injury of patients [51]. A procedure for monitoring dispensing errors was developed by Betz and Levy proposed the two situations when reports of medication dispensing incident needed to be completed

1.) If potential dispensing errors are likely to affect the patient are detected by nurses or prescribers before they have resulted in an actual error in patient's drug therapy, and

2.) if observation form reviewing patient profile are found [54].

3.) Critical incident technique which soliciting any incidents from health professional

4.) Disguised observation method

The kinds of reporting systems do provide a record of the unusual situations and to document the facts; do provide a base from which hospital staffs can further investigate to determine and evaluate of deviations from the standard of care, policies, procedure, and of corrective measures needed to prevent recurrence; do provide means of refreshing the memory of those having a direct knowledge of the incident; do alert hospital risk management staff to a possible claim situation and to respond immediately for complete investigate and documentation; it is a Joint Commission Accreditation of Hospital requirement; the document is often used for statistical analysis and computer input. They should be completed immediately after the incident is discovered by the individual who has the best knowledge of the incident. It is obvious that the longer the wait before report completion, the less clear would be the facts. As well as the concept of factual documentation should be made clear. To get all the facts, the person completing the reports must address who, what, where, why, and how of the situations. Hearsay and opinions can be valuable for further investigation but must be identified as so [55].

The most useful reports included a factual description of the event of what happened and the patient outcomes, plus explanatory information. The report should describe any additional patient monitoring or testing performed as a result of the event, additional medications administered, e.g. reversal agents, antihistamines, medication to treat symptoms, other treatment necessary to preclude harm, and actual patient harm. The factual description of such event should never include personal or professional conclusions, opinions, accusations, criticisms or admissions. Patients' name should not be included in reports submitted to external reporting systems. Moreover, causative factors are important information. It is likely that with this information the report gain much value for improving medication safety [56].

Error reports should be categorized according to the severity of patient outcome. The National Coordinating Council for Medication Error Reporting and Prevention (NCCMERP) purposed severity index which considered factors such as whether the error reached the patient and, if the patient was harmed, to what degree. NCCMERP also provided an algorithm for selecting the proper category for each error report. These categorized reports can help organization monitor patient harm and prioritize their medication safety activities. Each category was depicted below; [56]

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 not 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.

Hartwigs and friends had developed medication error severity ranking reflecting patient outcomes, based on numerical scales of 0-6 as depicts below; [57]

Level 0: Upon review of the incident report and in reference to the standard definition of a medication error, it is determined that no medication error occurred.

Level 1: An error occurred but resulted in no harm to the patient.

Level 2: An error occurred that resulted in a need for increased monitoring of the patient. There is no change in vital signs and no harm to the patient.

Level 3: An error occurred that resulted in a need for increased monitoring of the patient and a change in vital signs but ultimately no harm to the patient; or any error that requires additional blood draws for laboratory monitoring.

Level 4: An error occurred that resulted in the treatment of an adverse event with another drug, increased the length of stay, or affected the patient's participation in an investigational drug protocol.

Level 5: An error occurred that resulted in permanent harm to the patient.

Level 6: An error occurred that contributed to the death of the patient.

The validity of data obtained by various error monitoring techniques are different. Determining the best method of detection for use in specific organization requires consideration of utility, feasibility and cost. Each approach seems to be highly practical effective for detecting errors in different steps in the medical process. Interestingly that it is useful for identification of incidents in the inpatient setting by using the process self reports from health professionals. Moreover, it is an important tactic to educate healthcare providers about the purpose of the study which aim to clarify preventable factors related to medication errors because investigation of unlikely incidences always provoke concerns in relevant to liability among them and such concerns are possible to inhibit the self-reports.

Regarding to collecting practice data, the following resources had suggested particular attention in identifying errors occurred in the inpatient setting; discharge summary, procedure note, physician progress note, laboratory reports, physician orders, and multidisciplinary progress note. These data resources can be used individual or in combination to identify the likelihood of errors [20]. The goal of data collection on medication errors is to provide useful practical data to hospitals, not only considering errors themselves, but also determining methods used to reduce their incidence.

D. Common Errors Occur Nationwide

A study of errors in medication process investigating frequency, types and potential by Lisby and her colleagues by direct observation, unannounced visit and chart review detected actual medication errors occurred by 43% from the total opportunity for errors. The majority of around 50% occurred at the prescribing process, followed by administration, transcribing and dispensing. Significant and serious errors were found to be a large portion from the overall occurrences [3].

Over 30 month-period of Engum and Breckler study, they retrieved information from the pharmacy database noted 5.1 errors per 1000 orders which accounted for average 1.8 errors per an individual pediatric patient. The study result shown that the majority of medication variance found in prescribing process as the result obtained from Lisby. However, even prescribing problems had a high incidence rate, most of prescribing medication errors were rarely to reach the patient because of interception by pharmacists and nurses [53].

Observational study conducted at intensive care unit by pharmacist investigators found the meaningful medication error rate by 20% and those of which 1.5% were classified as life-threatening. It was also indicated some of adverse events were intercepted by a pharmacist. All entire identified errors were resulted from personnel's faulty [48].

Incident report-based medication error-reporting program was used to inspect errors in medication process at the Ohio State University Hospital. The reports were performed by the person who discovered the errors. The results shown that the number of medication error reports received per month range from 73 to 141 (0.026% to 0.049%), most were harmless to the patients. Up to 375 were errors of omission, other included unauthorized drug errors, wrong-time errors and wrong-dose errors. Errors most directly associated with pharmacy functions were medication unavailable, wrong medication dispensed and labeling error, constituted approximately 13% of errors. Moreover, it is noticeable that a marked increased in the number of errors reported was observed during the year [57].

One direct observation study examined adverse events related to drug in inpatients at Paholpolpayuhasena hospital, Thailand. Four medication processes were monitored; prescribing, transcribing, dispensing and administrating. It was found that 34.20% of hospitalized patients had experienced with medication errors, which is 946 of 2,766 first doses [24].

A study of medication errors in outpatient pharmacy service at Lerd-Sin Hospital was observed. Prescription errors were recorded all along steps of prescription-processing. During one year of study period, the error rate was 10.14% and 9.3% of errors were caused by pharmacy [58].

In 1993, there was a study determining pattern, causes and types of medication errors at the Srisaket Hospital. Medication process included prescribing, dispensing and administrating were evaluated by prospectively inspection. The results shown the rates of prescription, dispensing and administrating errors were 2.7%, 2.95%, and 16.74%, respectively. The three most frequently found of dispensing errors were omission, wrong doses and unordered drugs. Finally, the major causes of dispensing errors were personnel error, inappropriate system and excessive workload [59].

Although, a large number of researches had focused on prescribing and administrating errors, dispensing errors can also result in patient harms. As aforementioned, understanding frequency, type and cause of dispensing errors could help to identify strategies to reduce such errors, as well as to provide a baseline for assessing the impact of future technologies implementation.

The prescription dispensing error rates in a high-volume Army outpatient pharmacy was investigated. It was determined by direct, undisguised observation and retrospective prescription review. The overall prescription error rate, including both content and labeling errors, was 3.39%. Labeling errors of incorrect directions, incorrect refills, and incorrect quantity were most found in this study. There was a linear relationship between pharmacist's error rate and the pharmacist's corresponding daily prescription workload. In addition to dispensing errors study, the level of illumination was associated with a significantly lower error rate [60].

A study carried out in the UK by Beso and friends report within the pharmacy department found the rate of 2% of dispensed items had one or more dispensing error and outside the department in 0.02%. They prospective investigated errors occurred at the final check stage of the pharmacy dispensary and interviewed staffs involved in dispensing in order to identify causes of such errors. Details of those were miss doses, slips in picking products or mistake in making assumptions about products concerned, including contribution factors such as labeling and storage of container in the dispensary [2].

Bond and Raehl had examined the risk of dispensing errors in various types of pharmacy. They found about 34% of respondent pharmacists reported at least one patient per a week was at risk of dispensing error and interestingly the report shown the significant relationship between the risk of dispensing errors and the number of prescription orders filled/hour. In addition to this relationship, they investigated other contribution factor associated with the risk of errors, as were practice site, demographic, staffing, and pharmacist satisfaction. It can be concluded that different practice site received differently in prescription orders which was strongly related to the risk of errors. This was in the same trend of high time spending in dispensing activities. Otherwise, the more time devoted for clinical and management activity, the more pharmacists staffing, job satisfactions and the higher experiences of registered pharmacists, the risk of dispensing errors decreased [61].

There was a study of inpatient dispensing errors at the Mahasarakham, Thailand Hospital by using retrospective voluntary medication error report system and focus groups. The dispensing error rate was 22.65 errors per 100,000 items, in which wrong drug and wrong drug formulation were the majority of errors [26].

E. Human involved in Medication Errors

Despite various contributing factors has associated with the risk of errors along with medical management process, one important concern points at human errors. Generally, interfering or inappropriate physical working conditions, psychological or distorting well-being of individual workers seem to affect poor performance. Fatigue was an example of contributing factor to error. It had a negative impact on alternating mood, psychomotor and cognitive performance. All of which can be influence on patient safety. It is inevitable that in patient care required shift work, in certain circumstances, long hours and increased workloads [49].

From a study of the frequency and cause of dispensing errors in hospital pharmacy by Beso revealed most commonly reports from pharmacy staff were being busy, shortage of staff, time constraints, and unwell feeling conditions. Others were interruptions, distractions, improper product design, and lack of knowledge of medications, so that resulting most in content errors such as picking up incorrect drugs or strength, missing doses or label errors [2]. As well as, the result of inpatient dispensing errors conducted in Thailand, the results obtained similarly to Beso’s; busy work environment, inappropriate product containing, and confusing communication among disciplines [26]. Lack of medication knowledge, slips and memory lapses, and errors in medication identification were again being observed at the surgical intensive unit and evaluated as the most common system failures relating to medication errors [48]. Human contribution factor such as satisfactions had relatively associated with the risk of medication errors as were revealed by Bond and Raehl [61]. The more preferable sentiments, the more decreased of the risk of errors.

Part 2: Pharmacy Automation

As a result of occurrence of death and loss associated with medication errors, a large number of strategies had been established. These attempts included adoption of more and more advance technologies. Although, hospital pharmacy technologies had long been developing over half of the century, only during the previous decades technology played a pivotal role in drug management system. Moreover, recommendations from several institutions of the use of technology had forced many healthcare organizations have increasingly followed to do so. Main proposes were to enhance patient safety, reduce human errors, and increase efficient on clinical tasks. To entail deep to points of these statements as the follow:

The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) – recommends preventing adverse events throughout the medical management process and avoid of human errors through safety standard. With this awareness, the suggestion from JCAHO is to implement the technology to increase patient safety. Staffing effectiveness can also meet the JCAHO requirement as another indirect advantage of the automation machine [15, 62].

Agency for Healthcare Research and Quality (AHRQ) – address potential human errors which could occur all along with the medication management process. AHRQ had studied several approaches for improving healthcare delivery system and that suggest the design features of technology involved such routines to prevent errors, such as computerized intervention systems [63].

The Institute for Safe Medication Practices (ISMP) – encourages medication error report system and expands core knowledge of medication safety. Otherwise, they also were providing prevention effort and medication safety practice; proposed medical technology and automation guidelines, as well as the recommendation of bar-code administrated intervention [64].

American Society of Health-System Pharmacists (ASHP) – recommend the use of technological innovation for preventing medication errors such as, computerized pharmacy system bar coding in order to facilitate greater health care. They recommended the important role of pharmacists should have more devote for clinical interventions and incorporate with other health professionals [50].

Of several strategies, technology-based interventions have been recommended as one of a key mechanism of reducing the likelihood of medication errors. At each point where errors take place, particular type of technology is suggested, but, however, some overlaps of employed electric equipments are possible. Among these are, for example, computerized physician decision supports, computerized order entry, robot for filling prescriptions, bar-coded technology, automated dispensing devices and computerization of the medication administration record. In addition, the growing of automation has been increasingly extended. This kind of technology provides better medical pharmacy management in the product-related functions of the department, including distribute medications to and from the patient care areas, direct deliver medication to the patient, inventory control, manage controlled substances or documentation matters. The better medical processes with technology do not intend to replace human, but do strengthen information technology, such as gathering information, doing boring repetitive tasks including check for problems. Consequently, these would allow people to do best thing done by people. In order to facilitate the decision process, it is beneficial to create a list of available IT system needed and to characterize those systems according to their relationship of impact on patient safety, financial investment, implementation time, as well as their impact on facility design and operation. Moreover, the total cost of ownership, including costs of purchasing, implementation, maintenance and staff support. Prior to go in more detail of the specific machine used in this study, the following part is to be about to briefly overview some other technologies that being common employed in the everyday care practice with respect to arise an understanding aspect and to discover relevant issues that possible to be used in robot medical filling's evaluation [9, 28, 33].

To begin with prescribing process, computerized physician order entry (CPOE) is an applicable facilitate physician to order a prescription online. As a result that considerably high prescription error, so this system has probably the largest impact of any automated intervention in reducing medication errors. It promotes patient safety through structured order, availability of patient information and checking system for a number of problems in order to increase accuracy and legibility of the order. A computerized physician decision support is computerized alert system of specific drug advert reaction which is vulnerable for reducing drug adverse events. This approach perform partly by helping physicians to associated key pieces of information, which can be problematic given the overwhelming stream of data confronting them. Interestingly, computerized physician decision support is a key intervention for preventing errors that actually result in injury, though computerization of ordering dramatically decreases the overall of medication errors. However, these two supportive systems might not connect to each other, although most of which clinical decision support involves multiple individual technology such as including CPOE and alert system. So, much of attentions aim to focus on the computerized physician order entry.

Concerning on medication errors associated with traditional distribution system, provides motivation for the improvement of such the system. Several methods designed to make improvement of the process and to meet the needs of individual institutions. One of the efforts is the use of automation infrastructure supporting healthcare delivery in order to not only reduce more errors, but also reduce labor intensive, and reduce procedural product-related tasks. Advance in Information technology and electronic systems have generally known as providing the better developments in automated medication management system [33].

Automation medication management systems can be divided into three major categories. The first category is patient care unit-based medication distribution devices, such as Lionville CDModule, Access system, Meditrol, Argus, MedStation and MedStation Rx (Pyxis), Sure-Med Unit Dose Center and Sure-Med Dispensing Center, and SelecTrac-Rx. This technology is one another technology in which increasingly common used in hospitals. These machines vary in individual specification but the same aspects are designed to replace the traditional manual system of filling and delivering the unit dose cart which allows decentralized dispensing procedure, or to provide increase control over floor-stock medications and controlled substances. Quickly and conveniently access to medications is the main advantage of decentralized devices which suitable for organizations that lack an efficient system for delivering products from the central pharmacy to the patient floors. Other advantages include reducing the need for nurses to manually reconcile the controlled-substance inventory, eliminate the medication cart-filling process, increase charge capture and can be configured to provide electronic documentation of medication administration. On the other hand, negative consequences of the patient care unit-based medication distribution devices can be noticed. They seem to increase labor cost of the pharmacy department for stocking and for manually clarifying discrepancies noted during controlled-substance reconciliation and as many doses of the same product are available and easily to access at the floors, it is likely to have a high potential for product selection errors. Moreover, automated dispensing device can also linked with bar-code system for increasing the efficiency of use. In general, it makes medication availability, increases the efficiency of drug dispensing and billing and increases time for patient care. Importantly, it proposes to minimize medication errors by ensuring an electronic match between physician order and the corresponding administered medication.

Centralized medication management devices are the then introduced. Automated devices included in this category such as Automated Pharmacy Station (APS), ATC-212, Medispense, and ScripPro. This system is highlighted to be concerned of this research stud, because it has a close similarly features to the robot being studies. Centralized medication management devices are created with respect to replace or improve the manual process of filling unit dose carts. A larger floor space is required more than the decentralized instruments and is still needed a manual cart-filling system in addition to the automated system. This system is believed to be associated with lower overall inventory, of both the costs of carrying inventory and restocking, than the cost of maintaining multiple decentralized inventories. Centralized medication management system relies on an efficient distribution system for the delivery of first doses (doses of a new medication order to be dispensed individually before the next scheduled cart delivery) [32-34, 65, 66].

- Automated pharmacy station is a triaxial robot equipped with a bar coded reader to select bar code labeled unit dose medications as required. It helps the pharmacy to do cart-filling, verification, restocking of returned drugs, removal expired drugs, and inventory control. It is suggested the system help to reduce the time required to fill and verify unit dose medication carts, and ensure a high level of dispensing accuracy because the use of bar coding. APS has a high capacity to accommodate a wide variety of dosage forms with a large available online inventory. However, every dose dispensed through this system required accurately repackaged and bar-code labeled.

- ATC-212 is patient specific unit doses of oral solids packaging machine which centrally-located operation. It can reduce the amount of time required to fill and check unit dose carts but restock of return medications may be time consuming. The more important issue of ATC-212 is also the ability to reduce medical errors. However, it has a limited capability of containing only 212 oral solid products.

- Medispense is an automated cart-filling machine which accommodates a large variety of dosage forms and no additional packaging is needed. It can be used either centrally or decentralized on the patient unit cares.

- ScripPro is the robotic prescription-filling system with pouring and labeling functions. This automatic tablet and capsule machine has a robotic arm, for obtaining the appropriate size vial, collecting medication, and labeling vials, and as well as bar-coded scanning to ensure that the correct medication goes from the container to the vial to the patient. It also uses a conveyer belt to transport the labeled vial to the inspection area. Bar-coded information can be able to display an image of the tablet or capsule as an additional feature. This system proposes to free pharmacists from involvement in boring technical prescription-filling tasks, reduce the risk of dispensing errors, and increase the productivity of filling prescriptions [32].

The last automation medical management system focuses on point of care information systems. They enable healthcare providers to enter and retrieve electric format of patient-specific information. Data is integrated of all hospital information systems providing rapid access to patient data and facilitates electronic documentation of care. This system includes the use of bar-code technology. Bar coding can be applied or integrated to many applicable practices such as quality assurance programs for unit dose dispensing, inventory control, documentation, clinical information supports, or medical administration. This technology is believed to increase both efficiency and the accuracy of the traditional system. More to the point, the robot in this research study also has this prominent feature. Bar coding can ensure that the right drugs are being dispensed and administered with the high potential to improve patient safety. The system is generally recognized as correcting medication use, providing accurate patient and drugs identification, and improving documentation keeping. It has been suggest that bar-coded technology has implemented with a wide range of use, such as for medication, blood products, devices and patients. Bar coding has successfully integrated with other kinds of technology. One of which is the robot filling prescription. With this bar code, it contains information relevant to a specific drug, lot number, expiration date and etc, available for identification and tracking system. Moreover, implementation of drug individual bar code facilitates further safe care intervention of the administration procedure. So that right drug can be given to the right patient, leading to safety and ease of use.

Regarding to the technology intervention being evaluated in this research study, interesting aspect pursues the dispensing process. As a result of increased public awareness of medication errors, automated packaging and dispensing systems for filling patient orders are becoming more and more bring in among US hospitals. This system could help the organization to reduce unintended erroneous events occur during dispensing and administrating processes. Such technology comprises of unit dose dispensing, bar-coded and automation in which to obtain advantages of their characteristics. More to the point, bar codes could ensure professionals to dispense and administer the right drugs to the right patients, unit dose medications provide simplicity onto the system, and automation help to reduce workload, minimize potential for human errors, doing such repetitive tasks instead of human which pharmacists could facilitate more clinical works. Overall aim of the automation is a subject to increase safety along with working procedure. In this presenting study, the pharmacy automation system called “Swisslog” is going to be examined.

Swisslog is a fully centralized automated unit dose packaging, storage, and dispensing system. It is believed to increase pharmacy productivity and enhance patient safety. The system enable customers to choose a feature set appropriate to their pharmacy operation. This following section is to introduce to general characteristics of Swisslog and its operation [67].

A. Robot’s characteristics

It consists of five main parts BoxStation, AutoBox, AutoPhial, DrugNest and PillPicker.

1.) BoxStation where the system is to be controlled by software. It controls all PillPick system components. User identification always required and recorded and maintenance database for all actions. Concerning inventory control, it monitors the inventory throughout PillBoxes, PhialBoxes, DrugNest and return. As well as expiration date and lot number are automatically checked by PillPick manager. It is integrated with pharmacy information system.

2.) AutoBox is a buffer module that automatically connects with the packaging component (PillPicker) to load of canisters and stock replenishment orders are automatically fullfilled.

3.) AutoPhial are the system components responsibility for medication bar-coded, over-wrap of vials, cups, syringes, ampoules and blisters. It retrieves product one at a time from a canister placed onto the AutoPhial and index into the PillPicker. Other option is BlisterCutter cuts blister sheets into individual doses for further over-wrapping in the PillPicker. Cutting is customizable for various configurations of blister sheets. Moreover, it also provides manual packaging in which a staff places the individual dose into a buffer cup and the packaging in the PillPick.

4.) PillPicker is the central packaging component of the system. It packages, bar-codes and labels bulk drug items into unit doses with unique serial number ready for automated dispensing. Unit doses medication can be dispensed from the PillPicker or stored in the DrugNest for future dispensing. These serialized bags enable drug tracking system and facilitates automatic drug returns.

5.) DrugNest is a high-density robotic warehouse. It stores bar-coded unit doses which loaded from the PillPicker automatically. At each end, the DrugNest has two independent robots, and can store and dispense simultaneously. In addition, drugs return from the wards can be restocked into the DrugNest automatically.

This pharmacy automation system has the capability if holding up to 44,000 unit doses and as many as 4,400 line items. The following items are possible to be stored in the machine: oral solids, ampoules, vials, syringes and other items. For items that are too large, bulky to fit inside the PillPick system, refrigerated drugs or drugs that are very sensitive to light or humidity, are typically dispensed by hand. The robot also provides multi-tasking activity such as packaging, medication filling, cabinet restocking, first doses, stats, returns, IV prep, etc. It is able to perform up to three tasks simultaneously. However, the majority of tasks can be scheduled, while many are completed on demand.

B. General work flow

To begin with, each drug is filled in a canister, key in information of drug name, lot number expiration date into the system by a technician and verified twice by a pharmacist. With the canister verification of up to 1500 oral solids, this result in as a replacement for checking each single unit dose but allow the system performs automatically After that, it is not touched by human hands until it is dispensed on a ring. Bulk pharmaceutical items are packaged, bar-coded and labeled into individual unit dose. Then, those are automatically put into buffer storage for future retrieval and dispensing to nursing units. The focal point of action is to generate medication for individual patient administration. Once a physician has ordered a drug for a patient, the order has scanned by nurses and sends directly through the pharmacy system. Then, the doctor order sheet is verified by a pharmacist before the dispensing process begins. After verification, two groups of order filling are separated; one is filled manually by pharmacy staffs and another is automatic dispensed by the machine. The automation software (called the PillPick Manager Software) receives the electronic patient orders, sort and retrieve medications by priority. The automated system automatically prepared a patient specific, 24 hours supply of unit doses grouped together, orderly according to administration time, on a flexible plastic ring (PickRing^{TM}). The PickRing itself has a label attached with patient information, a list of drugs for 24 hours supply, and administration time. Thereafter, all patient drugs are loaded into carts or individually delivered to the patient floors which no need of re-inspection again for correctness by a pharmacist. Furthermore, the robot has provided an additional function which is automatically restocked medications that returned from the wards and credits to patient account into PillPick system. Returning process is operated with simplicity as unit doses placed onto the return conveyor via the return window, and then the robot completes the return process by scanning medication bag individually. At this step, the system would check for serial number, which contains lot codes for drug recalled and expiry date on every unit doses, to determine whether or not each drug should be re-stored or discarded. This serial number provided tracking though the entire pharmacy supply chain (downstream of the packaging).

C. Relevant Studies

Although research study about automation is relatively limited, among those of available studies provide useful informative knowledge on evaluation. Most of which, assessment of the automation had mentioned about the efficacy as the primarily main outcome. Most published studies of those technologies mentioned early had besides evaluated patient outcomes associated with the use of the technologies. These included medication errors and ADEs, in which some of them also assessed costs, work efficiencies and other measures. They designed to collection information at sites by comparing before and after implementation of the automated systems. The studies would delayed post examination time approximately 3-6 months in order to unfamiliarity bias on the new employed devices.

From review of literatures, appraisal of the automation-management system, such as the central pharmacy robot (Automated Pharmacy Station) at the University of Wisconsin Hospital [34], the study of comparison of automated medication-management systems [33], ATC-212 operated at the tertiary, university teaching hospital, a new type of automated dispensing system (Consis) in a hospital pharmacy [25], ATC-212 operated at the tertiary, university teaching hospital, a new type of automated dispensing system (Consis) in a hospital pharmacy [68], another Medstation Rx machine employed in cardiovascular surgery unit and an 8-bed cardiovascular intensive care unit [29], and the Auto Tablet Counting (ATC) machine at the Makaruk hospital, Thailand [35], had emphasized both time spend in dispensing process and medication errors (or dispensing errors).

Time required for cart-filling, verification and restocking of medications were the focal points of such efficiency evaluation. In addition, labor time refer to the studies had examined separately between pharmacists and pharmacist assistances dimensions. Only the study of a robotic prescription-filling “ScripPro” at a pharmacy measured prescription-filling time alone dividing into direct and indirect prescription-filling times [32].

Medication errors were all stressed on internal dispensing errors of cart-filling by technicians' accuracy or the risk of product selection errors. One study of bar code technology implementation in pharmacy, at a large tertiary academic medical center hospital assessed potential adverse drug events in addition to dispensing errors [31].

Cost saving of implementation of the automations was seemly to be assessed. Due to high cost of implementation, the most possible balance returns beneficial outcomes greatly more important. Economic evaluation of the technology had carried out such as basic cost appraisal of implementing the Auto Tablet Counting (ATC) machine to the exits manual dispensing system at the Makaruk hospital, Thailand [35]. Cost-benefit analysis of bar code technology evaluated cost of adverse drug events compared to cost of the device's implementation [12]. Plus, cost analysis of implementation of an automated drug dispensing systems in intensive care unit and accident and emergency departments, Albacete General Teaching Hospital. Cost and valuation of capital investments required for the installation and maintenance of the machine, staff costs, drug inventory costs, and drug-use policy costs were important determinations [69]. The study of ATC-212 at the Erie County Medical Center (ECDC) determined several dimensions of costs; drug acquisition dispensing costs dispensing costs and the costs of personnel time were also compared [66]. A patient charge capture rate was examined at a large tertiary-care referral hospital in order to estimate additional annual billable patient charges [30]. Implementation of the unit-based automated medication dispensing devices in four satellite pharmacies at Wausau Hospital, Wisconsin was considered cost of pharmacists' and nurses' salary and benefits, and the financial benefit of the drug costs per patient day [10]. Moreover, studies of time required for dispensing process as cited previously were additional subjects to figure cost consideration as well [25, 29, 30, 32-34, 66].

Whilst some of which had further concerned on other aspects. A published study of the ATC 212 system at the decentralized pharmacy services of the Presbyterian Hospital, Dallas, had drawn attention to personnel involved in the use of such the system. The main measurements were staff time saved, and job satisfaction on operating the new automated system [65]. As well as the study conducted at a large tertiary-care referral hospital assessed attitudes of nursing personnel and pharmacy technicians toward the automated system [30]. The evaluation of Consis also measured impact of automation on storage space occupied and speed of turnaround time of prescriptions [25]. Moreover, robotic removal of out of date medications and inventory control were also inspected [33].

Part 3: Cost Analysis

Medical errors carry a significantly high financial cost. It is estimated that the U.S. nation loss due to medication errors was approximately $37.6 billion and about $17 billion of those cost were associated with preventable errors. Direct health care costs were accounted for major expenditure for preventable medical errors [1]. Costs may include extended length of stay, or any extra intervention costs in order to further treating those conditions.

There were several studies examined costs associated errors in hospitalized patients. Classen and his colleagues exposed that $2262 more cost of hospitalization needed to spend in the relation to an ADE [5]. Bates and et.al estimated an ADE was associated with additional cost of $2595, and around twice higher for preventable ADEs. With this figure, annual costs of ADEs for a large teaching hospital were $5.6 million and $2.8 million for preventable ADEs [4]. Another example of cost of medication-related problems, including both adverse drug reactions and medication errors, at a university hospital estimated total cost almost $1.5 million per year [6]. In Thailand, exceed direct costs of hospitalized patients toward adverse drug reactions had examined. The average cost was around 1,900 baht for a reaction [7]. Different amount of obtained costs may possible from the extent to which costs were identified and details included.

It is recognized that not only information about automation in Thailand is rarely available but also research on costs relevant to such implementation are limited. Knowledge on nature of problems seems to be useful information with respect to creating mechanism onto overcoming them as well. Costs of medication errors and, also, in association with cost containment are not widely formally established in this country. Useful facts of errors can help healthcare investors figure out of what should be done for improving healthcare quality together with impressive return. Study on cost analysis leads to the more understanding of various cost calculating elements. The very beginning of this part generally introduces to outcomes assessment in order to developing indicators evaluated the machine and those are essentially possible to link with cost analysis later on.

A. Evaluating of effectiveness

With respect to facilitating the better the health of individuals in the population, purchasers would make an investment in the health care system. Providers in this sector are responsible for making appropriate health intervention by several applications such as applying knowledge of exiting preventive, diagnosis, therapeutic or health promotional strategies. Usually, interventions involve in term of the use of drugs, devices, equipments and other health supplies. A number of technologies are aimed at reducing the risk of diseases. The choice of whether to use a particular medical intervention over others alternatives depend on numerous factors e.g. comparative efficacy, effectiveness, preferences, and cost. Medical decision making process and critical to obtaining the decision health outcomes assist to in determining of those relevant factors. Health outcomes for a particular individual can be defined and monitored in terms of health status indicators and are often measured using birth and death rate, quality of life, morbidity from specific diseases, and presence of risk factors. In addition, those of influencing the supply and demand for health services in the community, including use of ambulatory care and inpatient care accessibility of health personnel and facilities, financing of health care, and health insurance coverage are other important determinants of health outcomes are those factors [70].

It is useful to review the types of health care technologies under consideration in order to understand the nature of the evidence supporting the effectiveness of new health care technologies. Such a technology includes all intervention that requires the use of both labor (e.g. pharmaceutical products or equipments) resources. Demonstration on the new technology that provides better effectiveness than harm in comparison to the older one is a simply understandable measurement. Plus, the process regularly measures the clinical course for a group of subjects treated with and without the new technology.

- Outcomes measurement

Many of researches have focused on and performed outcomes assessment. The measurement of outcomes can be viewed as an organized approach that is rooted in the traditional practices of many health care professional, e.g. physicians, pharmacists and others. In addition, final improved patient outcomes do not only affect patients themselves but also to experience pharmacists in achieving greater professional satisfaction from providing services. The use of this term can also be applied in the health care intervention evaluation or managed care financing. Formal recording of outcomes measures provide the first step needed to move from decision making at the individual level toward the more structured decision making in relation to a population. Mullins and his friends had noted about outcomes in an article as [37]

"A health care outcome is a change in a patient's health status resulting from health care service. Outcomes measures include morbidity and mortality, functional status and quality of life".

"Any evaluation of pharmaceutical care services should include: measures of structure (pharmacy, drug inventory, patient profiles) and process (taking medication history, monitoring drug regimen, counseling on medication use), as well as outcomes (relief of symptoms, adverse drug reactions, improvement in quality of life)".

"Ideally, pharmacists are committed to ensuring optimal outcomes of drug therapy and pharmaceutical care for their patients".

Outcomes assessment can be used for several purposes, for instances to evaluate effectiveness of health care interventions, to support and understand research conclusions, to measure health care system accountability, and to provide an information basis on which improvements in health care treatment can be assessed. Moreover, it can help in rationale for purchasing decision. To rising concerns on medical costs, outcomes information has been requested the payers for the interventions who receive them to justify purchasing decisions. Assessments of value include determination of quality (how well the product actually performed), and outcomes (whether the effects produced) are useful to the patient, payer, or provider of care [70, 71].

The following paragraphs are to elucidate the essences of outcomes measured elements of structure, process, and outcomes for the more understand of outcomes evaluation which, say, can use pharmacoeconomic tool for performing the appraisal. Evaluation of a managed care service is multidimensional by which all three elements; structure, process, and outcome must be incorporated into any evaluation of the services. The assessment monitors and records of the change in patients' health status related to specific intervention [37].

1.) Structure

This first term refers to "the material and social instrumentalities used to provide care or incorporate the resources and personnel available for the provision of care as well as the related set of policies and procedures that govern the use of resources and guide health care workers in decision making". Resources include all items related to the provision of care, such as medical equipments, or computer system, while personnel include medical professionals as well as support staff. Moreover, structure may cover social instrumentalities which are the relationships among the multiple practitioners, regulations and policies or links between the various subcomponents of care. In the hospital setting, the numbers and qualifications of physicians on staff or the type of equipment on hand can be used in the measurement of structure. To be more specific in the hospital pharmacy department, for example, material structural measures of quality include such as number and qualification for transmitting prescription orders, dispensing, monitoring drug use and controlling inventory. In determining structural social instrumentalities in a hospital pharmacy setting, it may include the location of the pharmacy within the facility, the existence of drug formulary, or the use of computer-assisted scheduling.

2.) Process

Process of care refers as set of activities that go on within and between practitioners and patients. It encompasses both the technical competence of provider (science) the interpersonal or humanistic aspects of the patient-provider relationship (art). Technical competence involves the skills, knowledge and judgment of the provider. Process measures of care are indicators of how well the structural measures are used in the provision of care. Generally, these indicators include most activities of monitoring and providing service such as the routine monitoring and recording of inpatient vital signs by nurses or aides. For pharmacy process activities include dispensing prescriptions, counseling patients to improve compliance or monitoring patient profiles for potential drug interactions. A numerical count or rate that indicated how often or how well these services have been performed is the process of measuring.

3.) Outcomes

This indicator defines as a change in patient health status resulting from health care service. It can be say as patient oriented of declines or improvements in health status, and not focused on the provider or facility. Traditionally mortality and morbidity have served as readily available outcome measures. Moreover, these measurements capture relevant aspects of both quantity and quality of life including physical, mental, social and perceptual health measures. Measures for evaluating patient outcomes are resulting from pharmaceutical therapy, including both drug treatment and associated pharmaceutical care.

Otherwise, types of outcomes can be grouped into different way from above which is divided into three categories [70, 71]

A.) System-centered clinical outcomes

All factors reflecting the physiological results and performance of therapeutic, interventions, services and product provided by health care professional and the process or system for delivering the care has on the patients. This type of outcomes represents to reflex numerous factors of care, for example.

- Performance of individual health care providers
- Process of care within the health care system
- Ability of treatments to achieve clinically desirable therapeutic ends or to avoid undesirable consequences.

It must be concerned that those of traditional commonly used medical measurements such as lower cholesterol, blood glucose or blood pressure are deemed to be surrogate endpoints that simply represent that immediate pharmacological effects. Whereas, changes in rate of morbidity, mortality or complication known as measuring a long term clinical outcomes. Other evidences of the quality, outcomes of clinical care, and as well as the effects of an intervention or process of care has on the organization can be considered

- Unanticipated return to surgery to correct results of an unsatisfactory intervention
- Nosocomial infections due to in adequate infection control procedures
- Iatrogenic complications introduced by the provider during the course of treatment

- Adverse effects from drugs or devices
- Management of disabling clinical symptoms such as pain or psychological distress
- Rates of rehospitalization, outpatient visits, or emergency procedures according to medical treatment.

B.) Patient-centered outcomes

This category includes factors that reflect the effect a therapeutic product or service has on how patients perceive their health status and satisfaction with care. It generally focuses on quality of life parameters. Patient outcomes include measures such as;

- Impact of asthma in patient QoL
- Post-surgical pain assessment
- Patient preference for oral compared to intravenous therapy
- Satisfaction with amount of information provided
- Functional status following myocardial infraction
- Impact of Parkinson’s disease on activities of daily living

C.) Cost outcomes

This economic outcome encompasses the use of resources e.g. financial, human, material, or support associated with application of a product or service in health care system and product to patients. There resourcs include prescription medications, physician visits, pharmacist and nursing time to prepare and administered medication, laboratory tests, hospital stays, surgical procedures, and so on. Moreover, cost associated with adverse events and treatment failures are considered economic outcomes. These following item are examples of economic outcomes.

- Decreased length of hospital stay
- Reduction in visit to emergency room
- Decreased nursing time to administer medications
- Reduction in adverse drug effects requiring additional treatment

Particularly, this type of outcome is most useful in evaluating the cost-benefit relationship of health care technologies, procedures and products. The assessment of cost outcomes in the relationship to other outcomes such as clinical outcomes can be made using the tools of pharmacoeconomics. By linking together the outcomes produced with the costs required to produce those outcomes. Cost outcomes can be obtained from a number of sources. Pharmacoeconomics helps to define the relationship between the cost of a product or service and the consequence produced. Consideration in assessing cost outcomes include the following

- What are the costs of an intervention across all the various components of an integrated health care system? Cost outcomes should measure the total cost of care, not just the costs for one component such as pharmaceutical costs.
- What are the unit costs, or resources, associated with producing a successful clinical or patient outcome for a service or product?
- What are the incremental or additional costs of delivering a particular product or service, compared with other products or services?

B. Cost Evaluation

Concerning to pharmacoeconomics, evaluating a specific disease or treatment intervention and treatment alternatives by using economic information and its effectiveness are seemly to be incorporated into the medical decision making means. It seems that pharmacists have a responsibility to ensure positive patient outcomes and, plus, pressures from managed care is continuing to attach the hospital pharmacy which is faced with difficult decisions on achieving cost saving or avoiding cost incurred to offset the expense of providing service. Moreover, the trend of health care has become market driven and the more competition in the private sector who demands for cost accountability and focus on high quality affordable care. Investors are looking for demonstrating evidence that the service add value. Costs may be performed in an integral part of the outcomes study as well in which they are used to assign value to the outcomes of the interest in a research study. Besides, outcomes research becomes the focus of medical evaluation because of the costly variations in resources utilization and a discipline of health economics require models developed to assist evaluation the outcomes of selecting an intervention. Outcomes have been broadened beyond the traditional clinical measures to include those that are financial, encompassing resource utilization and cost of care. However, a relevant consideration is how much more the organization decides to pay for an intervention that produces better results consist of several factors. Economic assessment incorporates with patient’s outcomes study from a given intervention provide a best choice for managed care organization in investment of such intervention improving patient safety [70].

- Identification of outcomes assessment parameters [70-73]

Several factors are suggested to e concerned when performing patient outcomes evaluations. Further, information can be derived from a wide variety of sources, the selection of which depends on need for, and availability of the data. The following determinations are proposed with respect to facilitating plan of research study. Specifying the outcomes can be use retrospective approach in addressing possible benefits. Using information from clinical studies, medical literatures and/or expert panels are optional. The appropriate outcomes depend on the results of intervention. For relevant to pharmaceutical products, common measures include efficacy rate and incidence of adverse drug effects.

From literature review, implementation of the new dispensing system is potential to result in three main benefits, decreasing of medication errors and staff efficiency and good inventory control.

1. Defining the pharmacoeconomic problem. This can help to focus the study as a clear description of the problem takes into account. For instance, incidences of medication errors are highly concern for the hospital, so any intervention with respect to overcome such problem is likely to be introduced. Consequently, cost of investment of newly technology and obtained outcomes are interested to be assessed.

2. Time course of an illness: whether is the condition acute or chronic? This can help in specify study period.

3. Length of disease episode: In this instance research study, it is the time from onset to cure.

4. Perspective of the study: To whom is the outcomes measurement important, payer, provider or patient? This is a prior step incorporating pharmacoeconomic evaluation in any clinical studies. Determining the study’s perspective depends on the view point of an investigator takes and relatively associated with methodology being conducted. Besides, the perspective of the study affects the resources that are included, so obvious define the perspective is recognized to avert from confusing. Some same resources are possible to be concerned for one party but not for the others.

This technology intervention research study focuses on from the health care organization’s (provider) view point.

5. Concerning on treatment alternatives. The alternatives in the evaluation includes those should be actually available to the decision maker or to be set as a reference for assessing the intervention.

For example, this study is being used two alternatives dispensing process. The first one is the conventional procedure in which there was no technology involved and another choice is the use of the pharmacy automation system occupied some part of the process.

6. Method of data collection:

- Retrospective chart review raises questions of completeness, accuracy, validity, and may include other records as necessary, such as inpatient chart, or outpatient records.

- Prospective studies must consider variables that empower the statistics means, such as size, duration, calculation of statistical power. Likewise, an ongoing clinical trial, ability to conduct longitudinal research, and inclusion of protocol-driven costs must not be over look.

7. Data sources:

- Large databases include billing or claims sources, electronic medical record. Also, these should be concerned of costs or charges information availability. Concerning on economic outcomes can be measured in several ways. Unit of resources use may be collected and assigned a monetary value based on costs or changes of a specific institution of from national average. Medical resource use can be determined via patient self report, prospective physician reports, medical charts, or billing records. Chat review is typically more accurate than self-report due to recall bias, even though more labor intensive. Prospective data collection is desirable but time consuming than a retrospective assessment of resource utilization. Medical chart review is very effective when dealing with a single provider or medical system. Computerized records simplify the chart extraction process but required computer programming support and labor intensive depending on the data structure and format. Proper collection and costing of medical resource data needed careful and thoughtful consideration [70].

- Minor sources of information can be obtained from provider interviewing.

8. Data linkages: This step covers methods to identify patients through illness occurrences and create linkages to clinical records. In this research study, for example, it focused on patients who experienced with adverse drug events resulting from pharmacy practice, therefore those can be identified through records of these events from pre-dispensing errors records and incidences reports. Once patients are identified, they may be linked through their medical record number to the hospital information system for additional cost and resource utilization information.

9. Availability of funds to support the study: Retrospective chart review and linkage studies are generally least expensive and fast to perform. They are useful in building decision models provide the basis for designing prospective study. Then, the evaluation of a large databases and patient interviews may be ranked on an intermediate level of expense and difficulty. The most expensive and difficult studies to perform are large-scale prospective studies.

C. <u>Cost calculation</u> [74-76]

It is essential to identify resources necessary to carry out the study. Cost, in economics, means the value of the raw materials used in creating goods and services. Identifying costs, in general, can be done by characteristics of each job, e.g.

6.1 Function or activity

6.2 Resources consumed or input which include

- 6.2.1 Capital cost
- 6.2.2 Operating or Recurring cost that vary according to volume of production which consists of
  - (a) Labor cost
  - (b) Material cost

6.3 Relationship to medical approach

- 6.3.1 Medical cost
- 6.3.2 Non medical cost

6.4 Relationship to cost object or cost product

- 6.4.1 Direct cost
- 6.4.2 Indirect cost

6.5 Characteristics of costs

6.5.1 Tangible cost represents expenses arising from such things as purchasing materials, paying employees or renting equipment.

6.5.2 Intangible cost consists of a subjective value placed on a circumstance or event in an attempt to quantify its impact.

6.6 Production based in short run

6.6.1 Fixed cost is expenses that do not change in proportion to the activity of a business, within the relevant period or scale of production.

6.6.2 Semi fixed cost such as salary of staffs

6.6.3 Variable cost changes in relation to the activity of a business such as sales or production volume.

This study determines costs according to resources consumed at a certain institution in which they could be relevant to cost avoidance and savings as a result from dispensing automation system. For instance, operating costs expensed consequential from medical errors calculated from all recording the inputs of each drug product, material supply, labor supply incurred during the study period. The information includes volumes used in a certain time frame, prices and the total cost of that particular material estimation can be done by using, drugs and material requisition record [75, 76].

Labor cost means the cost that paid to the staffs in exchange of their work. It consists of salary payment, overtime wages, additional expenditure in training, official off-site working, fringe benefit (e.g. housing, health insurance, sick leave, vacation or funding of education), and other expenditure in performing their duty. Labor productivity measurements can be conducted by several methods such as [71]

1) Self-estimating
2) Direct time study or Stop watch
3) Work sampling
4) Expert opinion

Information can obtain from time usage might come from record of work schedules or creating a form for each employee to self-record, which the sample time could be 1 month long. The convenient and popular method is the self-estimation for each employee. Each employee will estimate how much time he/she uses in the production process per day.

Base Information comes from two sources. The personnel department cans identify an employee's department and salary information. The payroll accounting department cans identify the time, salary and overall payment [76].

Inventory cost can be measured through several outcomes. Effects of the system most are simply divided into two types; workload and quantities in drug inventory. Amount of time spent processing inventory management can be assessed by using time notion study method or surveying working records of pharmacy employees on operation, for example [29, 33, 77-79].

On the other hand, the number of inventory items can be counted to assess stock supply [33, 79]. Quantities in drug inventory management can be observed from the record stored in the main computer database [78] or missing doses delivered by the pharmacy department were inspected and then recorded by nurses [29]. In addition, many were also concerned in collecting data on outdate medication in term of frequency, and types [33, 80]

Some other studies determining cost of drug acquisition cost in which the data can be collected from drug used in the dispensing system during a certain period [66]. Cost savings with respect to stock holding, ordering efficiency and out of hours supply were one alternative inventory cost evaluation method suggested by Whittlesea and the colleagues [81].

Assigning monetary value to each resource consumed. In this research study, direct costs require special attention because of their relative magnitude; they are the easiest to measure, are the costs best understood by most health care organization, and have a direct financial impact on health care organization. As well as, some other indirect costs necessary to be focused carefully because it is the subject of data availability.

Essential resources are where required information possible to be achieved. For example, these include accessing to medication errors record, productivity record, cost data within the organization, purchase agreement, labor costs, material usages and their costs. This also involves staff support to suggestion, review literature, or retrieved data from database.

D. Relevant studies

Much of concerns in everyday practices have long been highlighted on developing patient safety strategies. Another factor impacts the selection of effectiveness intervention is advantages on costs of either, for example, minor expense on funding interventions or money saving obtained from the interventions. The use of cost analysis is an efficient method to improve the decision making process by enabling the health investors to quantify costs and obtained benefits rather than relying on qualitative judgments alone. Also, several institutions had implied these two dimensions of improving patient's outcomes and costing. So, that a number of researches had conducted with the main focal points in term of cost saving and cost avoidance on health care interventions.

Definition of money saved and avoided by health care interventions have seemly slightly different in meanings and are sometimes used interchangeably. However, many of studies have clearly defined cost savings a specific pharmacy intervention as which “dollar previously spent that are no longer spent”. The calculation can be derived from the different of cost associated with interventions of before applying intervention, original therapy, and after the intervention, new recommended therapy. Whereas, cost avoidance was described as “dollar not spent from the outset”. Cost avoidance can be determined by the different of relevant intervention cost, such as drug therapy or lab test, that would have been initiated without intervention and the actual cost of intervention administered to the patient after the pharmacy intervention [39-46, 82]. Some other literatures were determined cost saving by using cost avoidance, in which subtracting the cost required for performing the interventions or medical program and equipments [44, 83].

Cost savings and cost avoidance can be further applied in determination of economic analysis. They are referred to benefits obtained from implemented intervention and then would be weighed against costs of performing such interventions. For example, a study conducted by Schumock and his colleagues evaluated the new pharmacy practice and the use of automation by using economic view point. Clinical outcomes or benefits of this program were prevention of adverse drug reaction and other drug-related problems that resulted in additional economic benefits of drug cost avoided. These economic outcomes were then be compared to associated costs with new interventions; pharmacists and nurses' salaries and benefits, indirect costs associated with purchasing drug information resources and other material consumed in providing the service. This evaluation provided an opportunity to justify additional staff, redeployment and to assess an aspect of purchasing the machine [10].

Calculation cost savings and cost avoidance are focused on all financial outcomes associated with interventions in patient care. Cost captures most are relevant to the drug acquisition and lab tests, the cost of a change in therapy and personnel costs such as physicians, nurses and pharmacists. Other includes costs of hospital, physician visits, discontinued or avoided prescriptions, costs for special clinics, additional therapy, laboratory, contacts with health care professionals, staff productivity loss, and personnel costs.

CHAPTER III
METHODOLOGY

The preceding chapter was mentioned about literatures reviewed. It revealed toward medication errors and related ADEs resulted from human errors caused individual suffering and financial loss. Noticeable, several strategies has been being put into practice in order to overcome such problems. Technology, especially in term of automation, is one of the plans of minimizing unintended erroneous events, increasing handling work capacity and providing other more creative tasks to human. Interestingly, many kinds of technology have long been implemented in healthcare arenas of the western countries. In Thailand, healthcare strategies and technology have increasingly more and more bring in. One concern on implementing such a new system is to look for the impacts of the technology on several aspects. According to medical errors producing devastated expenditure to health care institutions and technology tries to solve this problem. Study on cost of occurred problems and the effects of implemented strategy were interested to be proceeded. Besides, studies of this area were rarely available in Thailand. Therefore, it is deemed that relative advantages of this information could help health care investors who concerned on cost incurred as a result of medical errors and planed to apply this technology into practice and to be a study model for enabling other health care organizations decision makers to quantify costs of obtained benefits rather than relying on qualitative judgments alone. Decide on the right technology in the right place has been more and more important concerned emphasizing a resource containment approach in this day and age. The aim of this study was to better understand of economics' impact of the pharmacy robot implementation, to examine its performances in relation to reducing adverse events, and to investigate associated costs of medication errors and the performances of minimizing such errors.

Study Design:

This study was a one group pre and post test design with technology intervention and had carried out on a single centre. It investigated the objective data relevant to the traditional dispensing procedure and the new pharmacy system with the robot drugs dispensing. Medication errors and adverse events had been occurred in relation to the intervention were observed before and after implementation of the machine. Moreover, costs associated with those incidences, including other expenditure related to revising the system had examined in term of cost saving and cost avoidance. All data in this study had carried out by retrospective approach.

Study Period:

According to the intervention, study period was then divided into two separated time frames; 1st July – 31st December 2007 (the manual dispensing system) and 1st July till 31 December 2008 (the pharmacy automation system). Exception to inventory data, it was collected during 1st October – 31st March 2007 (the manual dispensing system) and 1st October – 31st March 2008 (the pharmacy automation system).

Study Perspective:

This economic evaluation study had been performed from the hospital's point of view. This perspective was proposed because impact on costs if malpractice and technology intervention needs a special consideration especially for the healthcare investors. Thus, this study was likely to provide useful information in order to better understanding on cost of error occurred within the system and to evaluate cost saving and cost avoidance from implementing the new pharmacy automation system.

Study Process:

Step 1: Planning and preparing of research study

Step 2: Data collection methods

Step 3: Data analysis and conclusion of study results

Step 1: Planning and Preparing of Research Study

1.1 Reviewed of literatures relevant to the study

It aimed to contribute to information and knowledge about the pharmacy automation system and some other similar kinds of technology, problem occurrences along with medical management process, strategies to overcome such problems, and the use of economics and methodology issues in evaluating a new technology.

1.2 In-depth study of the pharmacy automation system

This step was to contact the selected study setting, observed in patient work flow and the pharmacy automation system at its site during operation. Additionally, study investigator was to give emphasis on consulting and interviewing with experts and pharmacy staffs. It supported the more understanding of what the robot looked like and how it proceeded work likely in a real situation.

1.3 Planning and designing the study process

After obtaining sufficient primarily data, the next step was to assemble them together, designed and planned the research to be performed. The possible direction would be drawn up based on previous studies, likely procedures, suggestion from experts and available information at the research site.

1.4 Examining cost savings and cost avoidance from implementing the dispensing medication machine.

Costs examined focus on the main benefits that were likely to gain from the drugs filling machine; medication errors, inventory control, and staff efficiency. Thus, those benefits were set as main outcomes to be assessed from economic view point. Outcomes consisted of clinical and financial outcomes. By standing this view point, clinical outcome such as medication errors needed to be transformed to monetary unit.

All information and other associated costs information had been observed retrospectively from specific resource information provided by the in-patient pharmacy department Bumrungrad international hospital.

Cost avoidance defined as money that would have to be spent by the pharmacy department but do not spent because of the use of pharmacy dispensing machine. This can be obviously classified as costs of medication errors in the relation to the drug dispensing system, including costs of accusation as a result of dispensing deviations.

Cost savings referred to money that previously was spent but no longer spent due to implementation of the pharmacy dispensing robot. Cost savings included money saved from cost of labor who works for dispensing in the in-patient pharmacy, pharmacy staff training cost, and inventory cost.

Tools:

Tools for data collections were designed by the investigator

- Medication filling error record
- Incident report recording form
- Form for collecting data used to calculate in medical costs resulting from filling errors
- IPD staff payment record
- Monthly usage of IPD staff record
- Drug IPD inventory acquisition record

The Research Setting:

This study conducted at the Bumrungrad International Hospital, 480-bed general hospital. Bumrungrad International is recognized as the tertiary care level, an internationally accredited, multi-specialty and is the largest private hospital in Southeast Asia. It has a potential to provide the high quality of one-stop medical care for the population. It is located at the center of Bangkok, Thailand. Bumrungrad International Hospital served services approximately 32,000 admissions annually with a large number of internationals. For in patients, around 7000 doses were administered per day. Approximately, thirty pharmacists and fifty pharmacist assistances were taking responsibility of the in-patients medical dispensing. The first pharmacy automation system has been implemented at Bumrungrad, specifically for refurbishing inpatients dispensing procedure. The robot was put into practice in phases since April 2008 and entirely implementation was on July 2008.

1.8 Study population

This study had targeted toward only all in-patients who had admitted during both study periods. Patients care units in this research included the general care units 6-11, the intensive care units (ICU) 1-3, and the critical care unit (CCU).

Step 2: Data Collection Methods

There were two main parts of data collection; the first one was cost avoidance which largely obtained from medication errors and associated costs, and another part was information and costs related to expenditures used for IPD dispensing that could be saved, including cost of labor who worked for dispensing in in-patient pharmacy, pharmacy staff training cost, and inventory cost. All data was provided by the department of pharmacy, Bumrungrad International Hospital. Data had been collected from two separated periods which were the time of being used each dispensing system. Time between the two periods was available for member of staffs involved in dispensing to be familiar with the new pharmacy automation system. Moreover, methods of collecting the information from both periods were exactly the same.

1st period (the traditional dispensing system): to collect information of the traditional dispensing system since 1st July till 31st December 2007.

2nd period (the dispensing system with robot implementation): to collect information of the pharmacy automation system since 1st July till 31st December 2008.

Before instillation of the robot, drugs were supplied manually with multiple doses. Pharmacists' assistances were responsible for filling prescriptions and then rechecked by a pharmacist before sending to the nursing units. When the pharmacy automation system implemented, the dispensing process had been changed. Medications were dispensed with unit doses supply. Drugs were separated into two groups. The first group was stored in and automatically dispensed by the robot and another was on the medication shelves which dispensed manually as the same. By doing so, only drugs filled by the robot had no need to re-inspect again by a pharmacist but the other remained doing the same. Returning medications from the wards kept according to where they were from and put them in places; drugs dispensed by the machine can be automatically return by the system, and the manual filled medications were returned by hand. Otherwise, all other steps in the dispensing process were still the same.

2.1 Cost avoidance

A. <u>Medication errors</u>

Data was retrieved from the IPD pre-dispensing errors record system. It was a report system set up by the department of pharmacy for recording any errors occurred along with the in-patient medical dispensing process. When errors occurred, information was given by staffs who discovered the erroneous events. Then, this data was transferred and recorded into the computer system. Information included types of errors, types of medications, medication name and individuals who made errors. Although, these records consisted of several types of error but only filling errors were selected because they had merely relationship with the change of dispensing process. In addition, as a result that some filling faulty had a potential to be found at the patient care units, especially after dispensing medications by the machine had no pharmacist to recheck once more. Thus, medication filling error data collection also concerned related information from the incidence reports by nurses. As the same as pre-dispensing errors record, only incidence reports that had a result from filling mistakes were counted.

After obtaining filling errors, all errors were then classified into level of severity, graded from 0 to 6 according to hospital's medication errors level of severity. Seven medication error severity levels (outcome) were classified as

Level 0: Non medication error occurred (potential errors would be classified here)

Level 1: An error occurred that did not result in patient harm.

Level 2: An error occurred that result in the need for increased patient monitoring but no change in vital signs and no patient harm.

Level 3: An error that resulted in the need for increased patient monitoring with a change in vital signs but no ultimate patient harm or any error that resulted in the need for increased laboratory monitoring.

Level 4: An error occurred that resulted in need for treatment with another drug or an increased length of stay or that affected patient participation in an investigational drug study.

Level 5: An error occurred that resulted in permanent patient harm.

Level 6: An error occurred that resulted in patient death.

Data collection included descriptions, and level of severity of each error. Others information required for the higher levels (1-6) of the filling errors including;

- Drugs that already administered to the patients
- Additional medications required for treating patient's conditions resulting from given wrong drugs.
- Descriptions of additional therapy required for treating patient's conditions resulting from given wrong drugs.
- Number of hospitalization prolonged day resulting from given wrong drugs.
- Additional lab tests or x-rays
- Vital signs monitoring

- Others if specified in the incident reports

Other data included damages and compensation claims from wrongful acts as a result from IPD dispensing providing by the pharmacy director. Data was then filled in the medication filling error form. Data had been collected over six months of the two separated time frames; July-December 2007 and July-December 2008. Six months data collections performed, instead of one single month, because some of outlandish data possible to somehow occurred as result of unusual conditions.

B. Costs information

This information determined associated costs with filling erroneous incidences and other related costs that could be saved or avoided by the introduction of this robot filling machine. Only the direct costs were determined. Costs were recorded in separated sheets of the two periods and were filled in costs information form. All costs were obtained from the pharmacy department. Details of each cost were given below;

- The unit cost of drug filling which was an average cost of a medication dispensed by inpatient pharmacy department only. This cost estimated from IPD labor payment each month (salary and wages, included benefits) per a medication dispensed. To obtain more accurate cost of filling a drug, the estimated medications filling time that was spent per one prescription, out of the entire dispensing process, had took into account and then weight on cost of drug filling.
- In-patient nurse labor cost
- Drug acquisition costs that already administered to patients (wrong drug dispensed cost)
- Drug acquisition costs of additional medications for treating the consequences of errors.
- Additional therapy costs required for treating patient's conditions resulting from given wrong drugs.
- Room fees for prolonged hospital stay as a result from given wrong drugs.
- Physicians or specialists fees only required for treating patient's conditions resulting from given wrong drugs.
- Costs of additional lab tests

- Costs of vital signs monitoring
- Other costs were included if specified in the incident reports.

Moreover, cost information also considered cost of claims or compensations associated with pharmacy dispensing. This information referred from actual claims and estimated cost of suing provided by the pharmacy director.

All above costs are finally filled in the form for collecting data used to calculate in medical costs resulting from filling errors.

2.2 Cost savings

Information used in determination cost savings were following defined as;

A. Dispensing labor costs concerned actual time spent in dispensing process divided by staffs' positions, and average pharmacists' salary and average pharmacist technicians' salary. Cost of salaries, wages and overtimes in 2008 were adjusted percentage of salaries increased based on the Bumrungrad International Hospital standard. This could lead to the more reasonable values in comparison costs of the two years.

B. Pharmacy training cost can be assumed from data of training costs available at the pharmacy department and number of staff worked for IPD dispensing each study period. Additionally, it is necessary to determine cost of productivity loss incurred as a result from new staff. It was a cost of individual teaching for new staff which required one experienced staff trained for each new comer. That staffs had to devote themselves taking care of new employees though partially relinquishing foregoes duties. Only new employments starting during each study period were determined. To calculate this cost, it required new staffs' salaries as a cost determinant. Overall, these were basically considered as essential costs must be spent for all workers ensuring workers do have enough abilities to proceed works.

C. Due to continuing adjustment of drugs supplied for IPD pharmacy and the PillPick, stock volume of the new dispensing system had extended unsteady end-point. Consensus was made to expand study time frames only for inspection of inventory cost changing. Thus, the periods were between October-March which had 6 months long as the same as other cost elements. It was assumed that at this point, whether proper inventory controlled of drugs stock volume available at the in-patient pharmacy inventory can be inspected. Good inventory management might impact balancing between stock supply and sale demand in which no need to stock high quantity medications. Only drugs store and supply for IPD took into account. It was believed that the new system could save money from drug inventory as providing better control of drug uses.

All data are collected for two separated periods and filled in the cost savings data sheet.

Step 3: Data Analysis and Conclusion

Subsequent to data collection, costs that can be avoided and the money saved were separately assembled. Cost savings from implemented robot intervention clearly presented in financial value, only additional calculations were required. Whereas, cost that expected to be avoided after applying the new system consisted of both clinical and economic outcomes, thus patient clinical outcome needed to attach monetary value and later added together with all other financial outcomes.

Overall cost saving of the dispensing system was the sum of costs of staff, pharmacy training, and inventory of the traditional dispensing system, during July-December 2007, compared to the sum of those costs of the new dispensing system, during July-December 2008. Total cost avoidance was the sum of costs relevant to medical filling errors during the first period subtracted by any costs of those occurred during the afterward time frame.

3.1 Data analysis

3.1.1 Cost avoidance

Medication filling errors, one of the outcome indicators of this study, was a cumulative data over six month periods and needed to be converted to the monetary value. Only filling errors from those of pre-dispensing errors and incidences report were retrieved. Information was dividing into the former system and the new system. Each error was classified into level of severity. It was assumed that all pre-dispensing filling errors considered as level 0, though other incidence cases detected at the nursing units were clearly classified in the report system. All pre-dispensing errors were filled in level 0 because these mistakes first found and re-corrected by the pharmacy personnel before sending to the patient care unit and reaching the patients.

Determination of cost avoidance used medical error data incorporated with costs data described previously. This step of calculation can be depicted by level of significance as;

Level 0: 1.) Each filling error at this level, either from all pre-dispensing errors or harmless incidences detected at nursing units, multiplied by unit cost of medication filling to obtain cost per one error at level 0. Then, all were summed to get the total amount of money lost from filling errors.

Cost of drug filling at level 0 = (no. of errors) x (unit cost of medication filling)

2.) Moreover, because of wasting time returned wrong medications and getting the right ones, incident cases level 0 at nursing units included nurse cost per patient day. This labor cost considered only one shift of nurse per one patient. It was calculated by using average nurse' salary and number of patients in charge. Subsequently, each nurse cost of each case was summed.

$$\text{Nurse cost at level 0} = \frac{\text{Nurse labor cost per shift}}{\text{No. of patients}}$$

Total cost of errors at level 0 can be computed from costs of these two parts.

Level 1: Each incidence needed to be figured out from the total cost per case, as the following determination;

1.) First calculation was the same as conducted in level 0, cost of drug filled (money loss within pharmacy department) and nurse labor costs.

2.) Then, calculated costs of drug that already administered to the patient by multiplying quantity of drugs that already taken with its price.

$$\text{Cost of wrong drugs} = \sum [(\text{quantity of drugs}) \times (\text{drug price})]$$

3.) Labor cost considered only one shift of nurse per one patient which can be calculated from nurse labor cost per day and number of patients in charge of the nurse, as the same as nurse labor cost at level 0.

Costs of all cases at this level were subsequently toted up to obtain the total level 1 error expenditure.

Level 2: Each incidence needed to be figured out from the total cost per case, as the following determination;

1.) Calculation, as the same as level 0 and 1 error, of filling a drug (money loss within pharmacy department).

2.) However, this level of seriousness generated more workload to nurses in term of monitoring vital sign and taking the more special care of the patients. So, nurse cost was supposed to be one full day labor cost.

$$\text{Nurse cost at level 2} = \frac{\text{Nurse labor cost per day}}{\text{No. of patients}}$$

3.) Calculated costs of drug that already administered to the patient by multiplying quantity of drugs that already taken with its price.

4.) At this level some additional medications might prescribed in order to treat patient's condition as a result of wrong drug administered. Thus, amount of those additional drugs multiplied by their prices take into account of cost of additional drugs. Prices considered charge prices of drugs to patients.

$$\text{Cost of additional drugs} = \sum [(\text{quantity of drugs}) \times (\text{drug price})]$$

Overall costs of all cases at this level were then toted up to obtain the total level 2 error cost.

<u>Level 3</u>: Each incidence needed to be figured out from the total cost per case, as the following determination;

1.) Calculated, as the same as level 0, 1 and 2 errors of a drug filling cost (money lost within pharmacy department).

2.) Calculated costs of drug that already administered to the patient by multiplying quantity of drugs that already taken with its price.

3.) Nurse cost was calculated by using double nurse labor cost per day due to this stage would result much more workload and busy work environment to nurse staffs at the patient care units. This cost was multiplied by number of days of giving care under extra conditions.

Nurse cost at level 3 = 2 (Nurse labor cost per day) x (no. of days since ADEs occur)

4.) At this level some additional medications might prescribed in order to treat patient's condition as a result of wrong drug administered. Thus, amount of those additional drugs multiplied by their prices took into account of cost of additional drugs. Prices considered charge prices of drugs to patients.

$$\text{Cost of additional drugs} = \sum [(\text{quantity of drugs}) \times (\text{drug price})]$$

5.) Additional physician fees that required for treating ADEs multiplied by number of days treating the conditions

Cost of additional doctor fee = (physician fee) x (no. of visit treating ADEs)

6.) Additional laboratory test that required for monitoring patients' conditions

Cost of laboratory test = ∑ [(no. of test) x (test price)]

7.) Other costs would be included if specified in the incident reports and calculated from actual consumptions.

Overall costs of all cases at this level were toted up to obtain the total level 3 error cost.

Level 4: At this level, costs of errors were computed as the same as costs of errors at level 3. However, costs were estimated since patients received therapy of adverse conditions resulting from pharmacy dispensing deviations, including prolonged hospital stay days from those incidences. Further, all costs then be summed to get the total level 4 error cost.

Level 5-6: These two most harm stages were not included in the cost consideration because there had been no error occurred at these levels ever since. However, if such an error took place, costs would determine according to details specified in the incident reports.

Another cost avoidance determinant was accusation charges. This amount of cost was estimated by actual sue cases due to malpractice pharmacy dispensing. It was likely that this kind of cost comprised of compensation for wrongful act, lawyer's fee, and court's fee. Costs were provided by the pharmacy director.

Consequently, all costs of filling errors and accusation charges during each six months period were then summed in order to achieve the grand total cost lost due to pharmacy drug filling errors. To obtain cost avoidance from implementing the pharmacy filling machine, costs of error occurrences of the two pharmacy systems were compared.

Cost avoidance = (Cost of errors from the traditional Rx syst.) – (Cost of errors from the new Rx syst. with the robot)

3.1.2 Cost savings

Cost saving determined the different costs of pharmacy workers, pharmacy staff training, and inventory between the traditional IPD dispensing system and the new system with the drugs filling robot .

1.) Cost of pharmacy dispensing labor

This cost determined the different of total pharmacists' and pharmacist assistances' salaries, who have been worked for in-patient pharmacy of the two study time frames.

2.) Pharmacy staff training cost

Training cost can be assumed from data of training costs available at the pharmacy department. This cost was then be multiplied by the number of staff worked for IPD dispensing of each study period. Additionally, it is necessary to determine cost of personal teaching for new staff which can be calculated by referring double costs of new staff salary, excluded benefits, and only new employments starting during each study period take into account. The different of the sum training and individual teaching costs of the two research time frames was regarded as cost saving.

3.) Inventory cost

Overall costs were summed of IPD inventory medications' stock costs at the end points. The different of the two inpatient drug inventory costs, at the end of the study period (March 2008), and at some point in March 2009, was compared to obtain the inventory cost that can be saved.

Afterward, these three sources; pharmacy dispensing labor, new pharmacy staff training, and inventory costs, were pooled together in order to achieve money that can be saved because of revising the new dispensing system.

Finally, these three costs during each six months period were then summed and compared to obtain the grand total cost saving from filling errors technological prevention.

Cost saving = (Cost of the traditional Rx syst.) – (Cost of the new Rx syst. With the robot)

3.2 Conclusion of study results

Regarding to all obtained information, study results can be concluded as the following.

3.2.1 Cost saving from implementing the pharmacy automation system was computed by the different of the sum of labor cost, training expenditure and inventory cost between the two dispensing systems.

3.2.2 Cost avoidance from implementing the pharmacy automation system can be concluded from the different medication errors costs between the two study periods.

3.2.3 Effectiveness of the pharmacy automation system can be evaluated from the number of reduction in medication filling errors in comparison to the former dispensing system.

3.2.4 From above information, a model of cost saving and cost avoidance can be suggested in this paper in order to put forward patient safety concerns in relation to technology intervention.

CHAPTER IV

RESULTS AND DISCUSSION

As early mentioned, medication errors are recognized to have enormous potential influencing on health care service by several researchers and presenting in a number literatures on chapter II. Many attempts had devoted to figure out the reasons of what underlining such situations, including costs of troubles. Moreover, improving health cares were also being a target of health economic study in term of balancing worthiness on investment and gained benefits. With these disclosures, healthcare providers are possible to create avoiding risks and loss, resulting from deviated cares, strategies. The majority cost analysis study previously were mainly focused on cost of adverse drug reactions which were clearly notice and caused significantly failure of providing cares. However, there were rarely aimed at exploring others aspect of medical care malfunction. This study had seek to fulfill this gap with respect to calculating costs of pharmacy malpracticing in term of cost saving and cost avoidance from the use of pharmacy drugs filling machine. Pre and post Swisslog study were conducted by the investigator establish a baseline and measure impact of the system. In this presenting chapter, it described obtained end results of this study in which methods were detailed in preceding chapters. Overall, it was generally divided into two parts of cost saving and cost avoidance from the use of pharmacy drugs filling robot, by the comparison of two separated time frames which were before and after using the automation.

General Information:

Bumrungrad International Hospital provided health care services to Thai and non-Thai patients at almost equally number. Numbers of patients under the two study periods, of ICU 1-3, CCU, and patient care units 6-11, were approximately 10,000 patient-days per month, and percentages of occupied bed were around 60%-80%, as shown in Table 1. Although, during the second study period had a slightly lower number of patient days than the first period (8%), overall items dispensed in 2008 had moved toward to higher amounts. Total dispensed drugs in 2007 were 808,594 items, while the total of 914,136 items dispensed in the later year. Fluctuation in numbers of patient-days admitted in 2008 was reasoned as some parts of patient care units were closed because of renovation. It was likely that patients admitted to the hospital were in the same trend of both study phases and had small figures during the end of the years all the same.

Table 1 Number of in-patients, bed occupation percentages and number of dispensed items of the Bumrungrad Hospital under study periods.

Lists	Month						
	July 2007	August 2007	September 2007	October 2007	November 2007	December 2007	**Total patient days in Jul-Dec 2007**
No. of patients (patient days)	11,376	10,820	8,512	9,883	9,626	9,990	60,207
% occupied (%)	80.48	78.61	64.93	72.46	72.93	73.24	
Dispensed medication (items)	144,557	141,984	134,366	128,209	129,218	130,260	808,594
	July 2008	August 2008	September 2008	October 2008	November 2008	December 2008	**Total patient days in Jul-Dec 2008**
No. of patients (patient days)	10,112	9,976	8,318	9,194	9,240	8,624	55,464
% occupied (%)	76.58	72.48	66.18	69.95	74.76	67.53	
Dispensed medication (items)	165,390	163,845	136,129	149,889	154,065	144,818	914,136

Cost Avoidance from the Use of Pharmacy Automation System:

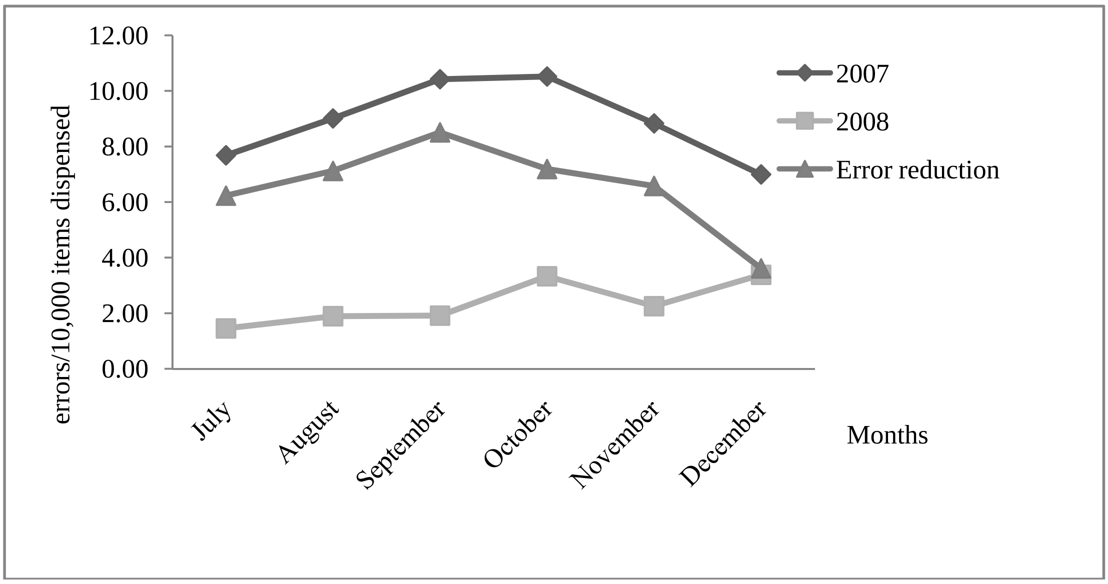
Cost avoidance from automation system can be reflected from the reduction of medication filling error. This part of cost analysis was calculated from related-costs of IPD medication filling errors. All filling mistaken events within in-patient pharmacy department and patients with suspected medical filling errors occurred in nursing care units had been detected and recorded as described in Chapter III.

A. The incidence of medication filling errors of both study time frames, categorized by levels of severity was summarized in Table 2.

Manually drugs filling error rate during 6 months in 2007 was inspected and compared to the post automation phase performance. It was measured errors from

Swisslog dispensed items and those still dispensed manually, but did not discriminate between them. In an overview, the incidence medication filling errors occurred at 1.19% or 119 cases from 10,000 patient-days before implementing the automation drugs filling. When putting the machine in to practice, the error rate reduced remarkably to 0.39% or 39 cases of 10,000 patient-days afterward. On the other way, the incidences could be simply shown in term of items dispensed. Presenting results indicated that medical filling errors had the rates (errors/10,000 items dispensed) of 7.68, 9.01, 10.42, 10.52, 8.83, and 6.99 (average 8.91) from July to December 2007, respectively. The last 6 month intervals filling error rates in 2008 were 1.45, 1.89, 1.91, 3.33, 2.25, and 3.38 (average 2.37). It is interesting that around 70% of errors had been reduced as the introduction of the automation. Error rates of each study period and the rate of reduction were simply illustrated in Figure 2.

Figure 2 Rates of errors per 10,000 items dispensed during 6 months in 2007, 2008 and rates of error reduction



In addition, a number of studies had been conferred about this issue.

- Comparison of traditional and unit dose systems in Srisaket hospital by Moolasarn found no different in dispensing errors frequency (around 2.5%-3.0%), in which wrong products were most frequently found. This could suggest that even developing new drug distribution system, medication errors still greatly existed [59]. This had a similar result to a study in inpatient dispensing errors conducted by Beso that obtained the rate of 2.3% [2]. As well as, inpatient dispensing errors at

Mahasarakham hospital found the incidence of 2.65 errors per 10,000 items [26]. Also, decentralized pharmacists program could decrease medication errors by 45% of 1116 U.S. hospital [84]. Thus, the more usefulness of automation was possible contribute to obvious medication errors reduction.

- When concerning effectiveness of automation in comparison to the manual systems, several researchers had reported interesting results. An automatic tablet counting machine operated at Makaruk hospital had reduced dispensing errors to 0.65%, while the existing manual unit dose system was 1.93% (33.68% error reduction) [35].
- Consis system, channel storage-based automated dispensing machine, was inspected the changes in drug picking errors in which only 16% reduction in dispensing errors, 10.4 errors/10,000 items, it had smaller figure than the presenting study [25].
- Klein and the colleagues studied the accuracy of unit dose cart filling with the ATC-212 dispensing system in comparison with manual filling. They found that the automated system was 99.35% accurate, compared with an accuracy rate of 99.16% when the technicians filled drugs manually. However, doses inspected were just about 7,000 doses [66].
- A bar code-assisted dispensing system implemented at tertiary care academic medical center could highly reduce approximately 95% dispensing errors and the rate of potential ADEs decreased by 63%, in comparison to the pre-implementation period. The observation dispensed medication doses had comparable amount to the presenting study, as well as the length of study time frames. Nevertheless, error rates had relatively low at baseline as the same [31].
- The most likely automation to Swisslog called Automated Pharmacy Station (APS) was examined of its effectiveness after introducing to University of Wisconsin Hospital studied by Landis. The use of the automated system could greatly diminished errors of patient cassettes filling by technicians up to 88%. This machine handled around 87% of medications dispensed by the hospital’s pharmacy, while Swisslog is responsible just about 35% of IPD drug dispensing [34].

Most of filling errors occurred at level 0 of either within in-patient pharmacy department or on patient floors, and no errors presented at any higher stages other than level 0 and 1. This had a consistence to the study of Dr. Cowley that a majority of technician medication errors were intercepted before reaching the patients and most were harmless. However, this 5-year study found up to 31% of temporary harm and 7% of a near death event in which these serious levels had not been happened at the Bumrungrad Hospital [27]. Also, Hartwig had reported the majority of error did not affect patient outcome, in which 76.3% presented in severity level 1 [57]. Up to 95.8% of total inpatient dispensing errors occurred at Mahasarakham hospital was classified in level 0, according to Hartwig’s severity ranking, and there was no error found over than level 3. However, this study found only 47 cases in 3 months study period [26]. On the other hand, Detdechasunan pointed toward the different results that most occurred events had presented in the higher level of medication errors severity, while the most harmless level found only 6.67% [24].

It was likely that potential adverse drug event could be estimated from incidences reaching the patient. Out of total 719 filling errors occurred during the first study period, the rate 0.33 error/10,000 patient-day was considered potential to harm the patients, while 0.18 error/10,000 patient-day had found in the latter period. Others also investigated medication errors in a relationship to adverse events in patient floors.

- An observational study by Detdechasunan at Paholpolpayuhasena hospital found 0.98% of medication errors occurred after dispensing medications had related to adverse drugs events [24].
- As well as, dispensing errors at the Mahasarakham hospital found 2.1% reaching patients and required further monitoring of the patients [26].

In general, dispensing incorrect drugs and incorrect quantity were the most frequency type of errors of the two periods, take into account of around 40% and 30% of total filling errors, followed by wrong strength, wrong formulation, wrong label and omission, respectively. Table 2 showed details of percentages of error changed or reduction according to types of error and dispensing processes. Most of which were highly reduced from just about 30% up to 100%. However, some of dispensing errors were increased such as a major changed in dispensing wrong amount of drugs.

Table 2: Percentages of errors changes comparison monthly of the two study periods dividing according to types of errors.

Types of error		Errors changed (%)					
		July	August	September	October	November	December
Wrong Strength	Pre-dispensing	86.36	60.87	79.31	72.41	47.06	68.75
	Dispensing	100	-100	0	-50	100	-300
Wrong quantity	Pre-dispensing	65.22	89.47	85.37	77.78	83.87	73.08
	Dispensing	-300	100	0	-200	-400	-400
Wrong drug	Pre-dispensing	84.10	85.42	85.71	57.58	72.92	31.25
	Dispensing	100	25	0	-150	33.33	60
Wrong label	Pre-dispensing	0	100	66.67	100	0	0
	Dispensing	0	0	50	0	0	0
Wrong formulation	Pre-dispensing	85.71	63.64	83.33	81.81	100	54.55
	Dispensing	-100	-100	0	100	100	-100
Omission	Pre-dispensing	100	100	100	-100	0	0
	Dispensing	100	0	0	-200	0	100

Obtained results varied and were different from others. Possible explanations were identified definitions, populations, observation methods, as well as differences in drug distribution systems. It was obvious that on the whole dispensing process had widely studied but specific internal steps quit rare discovered. However, wrong products were likely to be prior types of dispensing errors overall such as;

- Hartwig's observation of highest rate of recurrence of errors that were directly caused by pharmacy functions were wrong drugs dispensed and labeling error constituted approximately 13% [57].
- Obtained frequency type of errors were similar to the others studies, such as product errors of improper drug dose or quantity second most found from the technicians' medication errors by Cowley in which unauthorized drugs were the highest frequency in her study [27].
- A similar errors investigation methodological study conducted by Beso and friends had a very likely result to this presenting study that wrong drugs, wrong strength, and labeling errors had the highest occurrences [2].

- Inpatient dispensing error studied in Mahasarakham, Thailand presented similar results to this study. Wrong drugs and wrong forms most happened [26].
- A change in internal dispensing error after introduction of Consis automation was greater in drug omission (68%), wrong strength (45%) and wrong drugs (21%), but, however, error label instructions had increased up to 35% [25].
- The use of bar code technology in dispensing was possible to totally eliminate expired medications, included 90% reduced wrong formulation, 71% and 56% reduced wrong strength and wrong drugs, correspondingly, reported by Poon and the colleagues [31].

Before implementing the machine, the majority of errors found in September and October, while the succeeding study period they were most found during October and December. These occurring of errors did not consistent with the number of patients in the months. Negative values presented in Table 2 indicated the higher number of errors occurred from the baseline. Regarding to percentages changed, incorrect dispensing medications were mainly found after delivering drugs to nursing units. Focused deeply on causes underling the problems found that several errors turned out as a result of overload dispensed items in a hour. This reason could be supported by a study of Bond and Raehl that indicated a significant relationship between the risk of dispensing errors and the number of prescription orders filled per hour [61]. Obtained data revealed that the robot largely reduced both pre-dispensing and errors occurred in the nursing care units, although some types of errors found on the nursing care units had increased.

Many of occurred incidences resulted from robot errors, such as over filled drugs, filled more than one drugs in a bag, no drug in a bag or drug deterioration. These incidences were likely to happen because drugs dispensed by the robot have no re-checked routine before sending out from pharmacy. As well as, the robot implemented during initiation phase, it was resulted in several defects occurred. Thus, continuing improvement is required in term of eliminate both mechanical and technical deficiency or adjust to most suitable environment. This was seemly consistent result with Klein and friend’s study in which automated dispensing defects were consequence to incorrect number of doses or incorrect drugs dispensed [66]. Moreover, down-time of the robot system has also experienced and partly believed to be one of the causes of errors occurred at the patient floors. When the down-time arisen, the manual drug filling is extended, the dispensing system has increasing the extent of busy, obviously, to higher potential of errors.

However, there was a possibility to had a underreporting of errors but even so, the incident of errors were still high and the largely reducing occurrences can obviously be seen.

B. Costs of medication filling errors

As described in Chapter III, it was presenting the method of calculation of medication filling error costs among hospitalized patients. Correcting the actual additional costs related to medical errors had used to be a cost estimation method in this present study. Severity of errors was concerned on the analysis because each of those required different supplies to re-correct the mistakes. There was no such technique developed in order to calculate cost of medication error. Calculating error costs were given details in Table 3 and 4 of each study phase respectively.

Table 3 Calculating error costs before robot implementation

Months	Levels of severity			Cost of drug filling (baht)	Total cost of filling error (baht)		Cost of drugs (baht)	Monthly nurse labor costs (baht)	
	Level 0		Level 1						
	Within Rx	On Wards			Level 0	Level 1		Level 0	Level 1
July-07	104	7	0	3.27	363			467	
Aug-07	123	4	1	3.42	434	3	100	267	67
Sep-07	135	5	0	3.48	487			333	
Oct-07	130	5	0	3.58	483			333	
Nov-07	108	6	0	3.78	431			400	
Dec-07	85	5	1	4.00	360	4	8	333	67
Total	685	32	2		2,558	7	108	2,133	134
Grand Total	Drug and filling cost + Nurse cost = 2,673 + 2,267 = 4,940 baht								

Rx = Pharmacy department

In Table 3, it illustrated medication filling errors cost of before the robot implementation period (July-December 2007) by dividing into the records from pre-dispensing filling errors and harmless incidences detected at nursing units, and calculation of relevant costs. Two stages of errors found can be computed as presenting below

Level 0: Total amount of money loss from medications filling errors at level 0 can be derived from;

1. Cost of filling errors at level 0 = (no. of errors) x (cost of a drug filling). This cost was 2,558 baht

2. Cost of nurse labor, costs of incident cases at patient care units. This labor cost can be calculated from estimated nurse monthly payment, included benefits, (26,400 baht). It was considered only 1 shift out of 3 shifts of daily nursing, working days were 22 days, and the average nursing was given care to 6 patients per one nurse. Then, nurse labor costs can be obtained as 66.67 baht per patient day. Subsequently, each nurse cost of cases was summed to be 2,133 baht.

Overall, total cost of errors at level 0 can be computed from costs of these two parts, which was 2,558 + 2,133 = 4,691 baht.

Level 1: There were 2 cases during the period. Total amount of money loss as a result from drugs filling errors at level 1 can be figured from;

1. Cost of money loss within pharmacy department = (no. of errors) x (unit cost of prescription). So, this cost was 7 baht

2. Cost of nurse labor costs of incident cases at patient care units calculating as the same as conducted in level 0. Then, total nurse labor cost was 133 baht.

3. Calculated costs of drug that already administered to the patient by multiplying quantity of drugs that already taken with its price. Thus, total cost of drugs was 108 baht.

Therefore, cost of the two cases at this level was 7 + 133 + 108 = 248 baht.

On the whole, costs of medical errors of these two levels were toted up to obtained the entire costs of medication filling errors occurred during July-December 2007 (before implementing the drugs filling robot). The cost was 4,940 baht. This cost can be simply figured out to relevant to pharmacy filling process in which 2,673 baht was drugs and filling costs and left was nurse labor costs.

Table 4 explained medication filling errors cost calculation during 6 months after implementing the automation. Estimation procedure of this cost had identical to the earlier period. Therefore, obtained cost of medication filling error at level 0 was 3,676 baht and at level 1 was 377 baht. Following, total cost of medication errors during July-December 2008 was 4,053 baht. Also, 986 baht was extended to drugs and filling costs, while 3,067 was nursing care costs

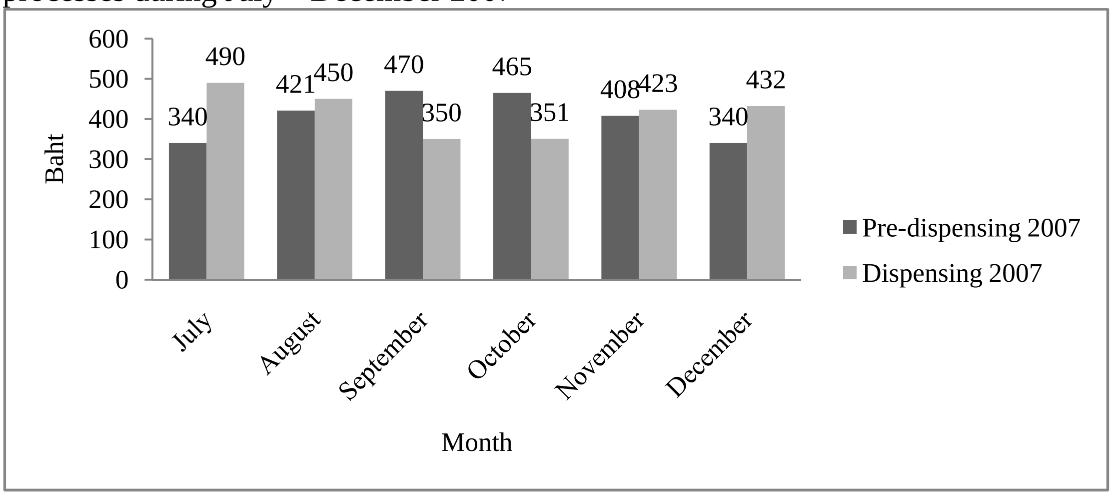
Table 4 Calculating error costs after robot implementation

Months	Levels of severity			Cost of drug filling (baht)	Total cost of filling error (baht)		Cost of drugs (baht)	Monthly nurse labor costs (baht)	
	Level 0		Level 1						
	Within Rx	On Wards			Level 0	Level 1		Level 0	Level 1
July-08	20	4	0	3.06	73			267	
Aug-08	24	7	0	3.12	97			467	
Sep-08	22	4	0	3.49	91			267	
Oct-08	36	13	1	3.15	154	3	307	867	67
Nov-08	28	7	0	3.27	115			467	
Dec-08	39	10	0	2.97	146			667	
Total	169	45	1		676	3	307	3,000	67
Grand Total	Drug and filling cost + Nurse cost = 986 + 3,067 = 4,053 baht								

Rx = Pharmacy department

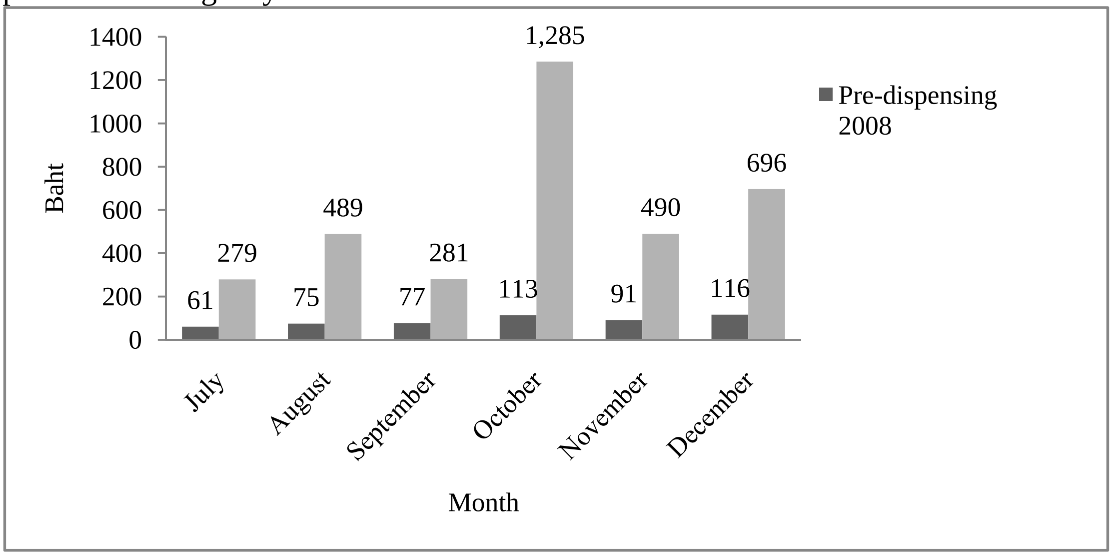
Therefore, cost of medication errors reduction from using the pharmacy automation at the Bumrungrad Hospital was 4,940 - 4,053 = 887 baht. It is obvious that when errors occurred at the patient care floors, high expenditure was inevitable in which, the robot had not reduced nurse cost but reduced cost of medications and cost of drug filling. The reduced cost of drug and filling error was 1,687 baht.

Figure 3: Costs of medication filling errors classified into medication management processes during July – December 2007



In addition, medication errors cost calculation can be shown according to processes of medical management. To be specific to the study, relevant processes were classified as pre-dispensing and dispensing processes. A chart of costs of medication filling errors classified into medication management processes during July to December 2007 was shown in Figure 3, and Figure 4 was illustrated filling error costs over 6 months in 2008. When compared costs from the two dispensing steps in 2007, it was found that costs were slight similar. Cost tendency was changed after using the robot as pre-dispensing filling error costs had very much lower and had large differences in comparison to the year before, while dispensing costs were not remarkable changed and extremely high cost was seen in October.

Figure 4: Costs of medication filling errors classified into medication management processes during July – December 2008



C. <u>Cost of compensation resulting from medication filling wrongful acts</u>

Over the investigations, there were reports of claims and compensations consequent to drugs and drugs used by which 4.79 million baht incurred in 2007, while 5.63 million baht lost throughout in the later year. However, these extra expenditures could not clarify of fundamental causes of which specific details, background basis, or department's responsibility. So, claim costs data were unable to generate to accurate amounts and would not, in case, included into cost avoidance here. Nevertheless, this cost aspect is likely relevant to extra expenditure of wrong filling drugs and important to comprise in the cost avoidance calculation in general.

D. <u>Cost avoidance from pharmacy automation system</u>

In comparison of the two study time frames (six months each), the results revealed a gradually reduced in expenses when errors occurred. This could present in term of cost avoidance, money should not spent from the outset. From above obtained information, the related cost of medical error of the traditional pharmacy system (4,940 baht) weighted against the related cost of medical error of the new pharmacy dispensing system with the drugs filling robot (4,053 baht), it shown that the use of inpatient pharmacy automation could avoided 887 baht or reduced cost of medications and drugs filling 1,687 baht along 6 months in practice. Calculation of cost avoidance as a result from the pharmacy automation system was shown in Table 5. Obtained result indicated a small amount of money that can be avoided from medication filling errors because after using the robot considerable number of mistaken events found outside the pharmacy department, even total numbers of errors had been reduced. So, there were needs of extra expenditures to collect such errors.

Table 5 Calculation cost avoidance of the pharmacy automation system

Cost elements	Tradition dispensing system (baht)	New system with filling robot (baht)
Medication filling errors	4,940	4,053
Claims and compensation	-	-
Total	4,940	4,053
Cost avoidance	4,940 – 4,053 = 887 baht	

As aforementioned, published reports about costs of medication error were rarely available. Many had focused on the value of the health lost as a result of adverse drug events (ADEs) or adverse drug reactions (ADRs). In comparison to previous studies, costs of medication error might approximate from costs for potential ADEs in which producing the most likely economic outcome possibility.

- A case-control study at 2 large tertiary care hospitals over 6-month period experienced 190 ADEs. Data was collected from actual resource utilization and length of stay. They projected $2595 for individual events [4].
- Scineider and the colleagues conducted a retrospective chart review of patients whom suspected of having clinical consequences from ADRs or medication errors. All given interventions resulting from the problems were assigned financial

values without considering patient's severity. Of 1911 medication-related problem reported throughout 24 months investigation, the estimated total cost was $1,497,148 in which transferring to ICU and prolonging length of stay were corresponding the highest costs. It was believing that patients with developed ADRs might experienced high outcome seriousness and lead to high expenses lost of ADRs management, thus caused the total costs of resolving medical problems at this amount [6].

- From Schumock study, comparison of drug costs was calculated according to re-engineering program at Wausau Hospital. $7.33 per patient day could reduce and gross costs avoided increased to $374,168. However, this study had focused from on patient's charges lost from medical errors over the two 12-month intervals, pre and post implementation [10].

- Karnon, et al. undertook modeling prediction of the potential costs and benefits of bar coding regarding to reduce medication error in 400-bed hospital. Cost ranges were estimated from published literature divided according to error severity. Annual health service treatment cost of £138,000 was avoided from baseline with the incidence of adverse events of 362 cases [13].

Cost Saving from the Use of Pharmacy Automation System:

This section was to illustrate the three dimensions determining money that can be saved from the introduction of the drugs filling machine; cost of pharmacy staffs, training, and inventory.

A. Cost of pharmacy dispensing labor

Table 6 Monthly usages of IPD staff

Lists	Months											
	Jul 07	Jul 08	Aug 07	Aug 08	Sep 07	Sep 08	Oct 07	Oct 08	Nov 07	Nov 08	Dec 07	Dec 08
No. of PH	34	35	34	35	34	35	34	34	35	34	35	33
No. of PHA	56	52	56	51	56	49	56	49	55	49	55	49
No. of PH+PHA overtime (hrs.)	2,841	3,988	2,830	3,074	2,996	2,052	2,997	2,768	3,164	2,277.5	4,229	2,652.5

PH = Pharmacist
PHA = Pharmacist assistance

According to information in Table 6, it pointed up to number of staffs worked for IPD dispensing compared monthly throughout the six months. In general, there were approximately 35 IPD pharmacists and 53 IPD pharmacist assistances. As can be seen in the table, there was a small change of the number of pharmacists worked for IPD after applied the automation system, meanwhile the numbers of pharmacist assistances had obvious lower than in the year 2007. Some change within the department was about transferring staff to other section such as outpatient pharmacy, or changing job positions. Other studies had also observed the impact of the automation systems revealed same tendentious outcomes.

- The ATC 212 dispensing system operated at Presbyterian Hospital of Dallas has allowed the department to reduce 1 cart-fill technicians. This technician was used to support other areas of the department, such as clinical data collection, computer data functions, and production areas. Besides, pharmacists gained benefits from the machine by which decreased the amount of time spent checking medication of 31% and then reallocated to perform other clinical activities [65].
- Landis had suggested that the robotic arm reading, tracking, picking and placing medications implemented at University of Wisconsin Hospital was able to do tedious filling works of technicians. It held more than 80% of all medication dispensed by the pharmacy department. Just over 30% of technician staff had been reassigned to other work positions, as well as pharmacists had more time for clinical professions [34].

It was being the same tendency of IPD overtime working hours in which declining right through the new system. However, at the early stages of implementing the robot IPD overtime working hours had a large increased, of about thousand hours added. This could happen because major changes of working environment from the traditional system to the new dispensing system with the robot, so there was a possibility of requiring the more workloads remodeling the system.

Table 7 indicated IPD dispensing labor expenditures during the study periods. Total IPD dispensing payments were calculated from the actual time that was spent in dispensing jobs by pharmacists and technicians timed by payment per working hour. In the last half year of 2007, the total cost was 7,831,742 baht and 7,527,746 baht in the same period of 2008, so that 303,996 baht could be saved. During the 6 months, cost of dispensing was decreased as according to lower number of staffs, decreased human workloads and some were shifted to robot dispensed. Even, this study did not extrapolate costs to the next subsequent years on operation, so remarkable reduction in expenditure cannot be seen.

Table 7 Expenditures of the inpatient pharmacy dispensing

Month	Pharmacists' dispensing hour (hours)	Total pharmacist payment (baht)	Pharmacist assistances' dispensing hour (hours)	Total pharmacist assistance payment (baht)
July 2007	4,466	687,764	9,967	637,248
August 2007	4,455	686,070	10,053	643,392
September 2007	4,429	651,266	9,842	629,888
October 2007	4,356	670,824	10,146	649,344
November 2007	4,326	666,204	9,736	623,104
December 2007	4,275	658,350	9,817	628,288
Total	26,107	4,020,478	59,551	3,811,264
Grand Total	4,020,478 + 3,811,264 = 7,831,742			
July 2008	4,590	706,860	9,761	624,704
August 2008	4,649	715,946	8,927	571,328
September 2008	4,357	670,978	8,502	544,128
October 2008	4,565	703,010	8,843	565,952
November 2008	4,373	673,442	8,528	545,792
December 2008	4,223	650,342	8,676	555,264
Total	26,757	4,120,578	53,237	3,407,168
Grand Total	4,120,578 + 3,407,168 = 7,527,746			

However, costs of time spent in all activities involved medication errors were obtained from the estimation by the investigator and experts. No activities were truly timed as limited data collection procedure. Several researchers studied impacts of the filling automation by using work sampling, time study or log activities. The more accurate costs incurred could be generated. Such as, time study by Lin and friends in order to investigate filling time spent saved after implementation of ScriptPro SP-200, in which 0.56 minute per one prescription could save. Time spent by pharmacists estimated 776 minutes were saved each month, while time spent by technicians increased about 4,080 minutes per month [32]. Dispensing activities time spent as a result from using Consis machine were logged. It was found that the machine reduced 348 hours per month of drugs dispensing [25]. These figures had built to labor financial saved as an introduction of the automation by applying staff labor costs. By estimation of annual cost saving from using ACT-212, a study of Klein, suggested just about $7,000 believed to be contained each year. The cost effected from 0.36 technicians FTE and 0.07 pharmacists FTE time reduction, but did not include employee benefits [66].

B. Pharmacy staff training cost

There was no formal training course for a new staff of pharmacy department at the Bumrungrad hospital. The only training of a new staff was individual teaching by an experienced staff. Table 8, 9 presented number of new and resigned inpatient pharmacy employees during study periods of the traditional dispensing system and the new system with the use of the robot, correspondingly.

Table 8 IPD Staff turnover during July-December 2007

Positions	Turn over rate (%)	No. of staff	July	August	September	October	November	December	**Total**
PH	3	36	0	0	0	0	+1	0	+1
PHA	4	55	-1	0	0	0	-1	0	-2
Total		91							

+ represents new employee
- represents resigned employee

There was one new pharmacist employed and two pharmacist assistances had resigned during the six months in 2007. Total staff worked for inpatient pharmacy section was 91. Pharmacists' turnover rate was 3% and 4% for pharmacist assistances. Hence, personnel teaching cost equaled to 22,000 x 2 x 4 = 176,000 baht (double cost of a new employee and the coaching would extended for 4 months)

Table 9 IPD Staff turnover during July-December 2008

Position	Turn over rate (%)	No. of staff	July	August	September	October	November	December	**Total**
PH	3	33	0	0	0	0	0	-1	-1
PHA	2	49	0	0	-1	0	0	0	-1
Total		82							

+ represents new employee
- represents resigned employee

Staff turnover data since July till December 2008 was stated in Table 9. There was one pharmacist and one pharmacist assistant had leaved the jobs through the period and no new employee had recruited. Moreover, pharmacists' and pharmacist assistant' turnover rate were lower than the previous year, which had 3% and 2% of the overall staff available respectively. As a result of this, there was no such of cost incurred in this study phase. In addition, after introducing the robot, some of staffs had been reallocated to other work areas such as out-patient pharmacy or even shifting within the department but different positions. This result was benefit to the organization because since there was no new coming staff employed, the existing workers could devote more attention to the works.

C. Inventory cost

Drug inventory cost at the end of each study period was inspected to examine stock volume controlling capability of the automation. Drug inventory cost of IPD store of the first study duration (October 2007-March 2008) was ended at 14,596,703 baht. Whilst, the later six months (October 2008-March 2009), final stock volume of drugs for in-patient was 13,547,395 baht (Table 10). Thus, the machine could produce cost saving 1,529,304 baht over 6 month-interval.

Table 10 Drug inventory costs during the two study periods

Months (The manual system)	Drug inventory costs (Baht)	Months (The new system with automation)	Drug inventory costs (Baht)		
			Pharmacy IPD store	Pharmacy PillPick store	Total inventory cost
October 2007	12,221,057.60	October 2008	13,206,221.96	2,081,390.81	15,287,612.87
November 2007	12,296,317.67	November 2008	15,047,680.60	2,271,426.56	17,319,107.16
December 2007	14,056,182.63	December 2008	14,427,858.99	1,877,624.72	16,305,483.71
January 2008	15,606,490.73	January 2009	12,989,901.91	1,748,416.68	14,738,318.59
February 2008	12,465,633.87	February 2009	12,739,027.50	1,995,647.44	14,734,674.94
March 2008	14,596,702.89	March 2009	11,589,757.33	1,957,638.10	13,547,395.43

Many factors may involve in drugs expenditure. For instance, costs of drugs typically vary across institutions, classes of drugs used in the hospital are usually changing, as well as the amounts of drug in term of money are increasing each year. Several new expensive drugs have been introduced to the hospital in 2008. It is interesting that even implementing the robot, which had to divide inventory into 2 stores, the robot did not cause extra expenditure in order to managing drugs. In addition, since implementation of the Swisslog, inventory system is still requiring system adjustment and improvement. These included, the amounts of drugs supply to the machine or recurring materials used for operation.

There was a study of inventory control system which produced an impressive return after 10 years implementation. This drug inventory management system named Artima allowed inventory functions such as real time retrieving data, and searching the lot number and expiration date of drugs in purchase and delivery records. After surveying of drug cost containment, in a 600 beds hospital, over a decade by Awaya and friends, Inventory decreased by 70% along with the continuous improvement of the system. Though, no detail was shown about inventory costs of the very beginning years after implementation [78]. This system could reflect the presenting study in which anticipated to increased hospital revenue by reducing drug inventory acquisition expense soon after settle system stability.

D. Cost Saving from the Pharmacy Automation System

Table 11 Calculation cost saving of the pharmacy automation system

Cost elements	Tradition dispensing system (baht)	New system with filling robot (baht)
Cost of Rx staff	7,831,742	7,527,746
Rx training cost	176,000	-
Inventory cost	14,596,703	13,547,395
Total	22,604,445	21,075,141
Cost saving	22,604,445 - 21,075,141 = 1,529,304 baht	

Table 11 explained overall costs referred to cost saving. It can be seen that since July to December 2007 cost from the three dimensions was 22,604,445 baht, while the later half year in 2008 was 21,075,141 baht. When compared these values, the cost would saved 1,529,304 baht. This can be said that the robot produced positive outcomes from expectation. However, as a result that this study evaluated the machine in the very beginning years, costs discrepancy might impact from many factors. It is believed that the robot is likely to be able to produce cost saved when it has fully operation to other automated system or take into account of other advantages in the next operating years, such as more staff benefits of growing clinical works or other benefits best gain from people.

A Model of Cost Saving and Cost Avoidance from Having the Pharmacy Automation System:

Data presenting above had a clear direction to exemplify costs averting from the hand help machine observed at the Bumrungrad International Hospital, Bangkok, Thailand. Moreover, supplementary advantage from cost analysis study was to suggest a model of cost saving and cost avoidance from having the pharmacy automation. Each of cost averted was demonstrated below;

Cost avoidance = costs of traditional dispensing system – costs of pharmacy automation system

While:

Cost of traditional dispensing system = (cost of medication errors$_T$) + (cost of compensation $_T$+ lawyer's fee$_T$ + court's fee$_T$)

Cost of pharmacy automation system = (cost of medication errors$_A$) + (cost of compensation $_A$+ lawyer's fee$_A$ + court's fee$_A$)

Cost of medication errors can be analyzed as illustrated in the Table 12

Cost saving = costs traditional dispensing system – costs of pharmacy automation system

While:

Cost traditional dispensing system = (dispensing labor costs$_T$) + (training cost$_T$) + (drug inventory acquisition costs$_T$)

Cost of pharmacy automation system = (dispensing labor costs$_A$) + (training cost$_A$) + (drug inventory acquisition costs$_A$)

The model was established as a following of the investigator and experts' consideration mutually with corresponding evidence bases of cost analysis. Nonetheless, such a model of cost study had never been publicly proposed. With the data available, it cannot bring the model into discussion or comparison to the others.

Table 12: Cost components for calculating medication error costs divided according to error stages

Error stages	Cost elements
Dispensing errors within the pharmacy dept.	1. Cost of filling medication
Dispensing errors outside the pharmacy dept. (Classified into 6 levels)	
Level 0:	1. Cost of filling medication 2. Nurse labor cost (one shift-work = 8 hours)
Level 1:	1. Cost of filling medication 2. Nurse labor cost (one shift) 3. Cost of administered drugs
Level 2:	1. Cost of filling medication 2. Nurse labor cost (one working day = 24 hours) 3. Cost of administered drugs 4. Cost of additional drugs
Level 3:	1. Cost of filling medication 2. Nurse labor cost (one working day) 3. Cost of administered drugs 4. Cost of additional drugs 5. Cost of additional laboratory test 5. Additional physician /specialist fee
Level 4:	Same as level 3, costs are estimated since patients received therapy of adverse conditions resulting from pharmacy dispensing deviations, including prolonged hospital stay days from those incidences.
Level 5-6:	These two most harm stages are not included in the cost consideration because there has been no error occurred at these levels ever since. However, if such an error takes place, costs would determine according to details specified in the incident report.

CHAPTER V
CONCLUSION

As following the world quality standard, seeking the best and appropriate advanced equipments, or standing at the highest point of customer expectation, all medical institutions are willing to accomplish. So, do the Bumrungrad International Hospital which is targeting toward middle to high-end Thai and non-Thai customers and is well-known of providing the high standard of care in Thailand. Best choices of medical technologies have been bring in. The pharmacy automation was an example of widely interesting subject matter to the public due to the innovative technology, unique features or even remarkable expense. With the questioning of its effectiveness and worthiness of investment, it was leading to the study of cost analysis of this pharmacy drug filling machinery. After reviewing literatures, consulting with experts, and real observation of the robot system operation, the study procedure had developed. Cost analysis was divided into 2 parts, cost saving and cost avoidance from the use of pharmacy automation system. Moreover, this presenting study had been investigated the effectiveness of the system by concerning medication filling errors and had proposed a model for medication errors calculation. Those were compared to the conventional manual system with the same investigation method. The sum up section then began with general information, results of cost avoidance together with effectiveness analysis of the system, cost saving, the proposed model of medication errors calculation, and further recommendation and suggestions.

Conclusion:

A. General information: During July – December 2007, the numbers of patient were around 10,000 patient-days per month, percentages of occupied bed were around 60%-80%, and total dispensed drugs in 2007 were 808,594 items. During the same period in 2008, the amount of patient-day was slightly lower by 8% but dispensed items were higher (914,136 items).

Medication filling errors were set as an indicator for assessing the impact from using the robot and measured for generating related cost avoidance. The incidence medication filling errors occurred at 1.19% or 119 cases from 10,000 patient-days during the time in 2007. The pharmacy automation reduced the rate to 0.39% or 39 cases of 10,000 patient-days. It is also presented in term of items dispensed in which medical filling errors had the average rates of 8.91 errors/10,000 items dispensed in 2007, while the 6 months interval in 2008 the rate was 2.37 errors/10,000 items dispensed. The incidence occurred did not consistent with the number of patients in the months, other factors might involve with a likely possibility. Overall, the drugs filling errors have been reduced up to 70% since an introduction of the pharmacy automation system. Many errors were caused by the robot, for instance, drugs filling deviations, or down-time circumstances. Almost all filling errors occurred at level 0 (99%), the very few errors were within level 1 (2 errors in 2007 and 1 error in 2008), and no errors presented at any higher stages other than level 0 and 1. Incorrect drugs and incorrect quantity were the most frequency type of errors of the two periods, take into account of around 40% and 30% of total filling errors.

B. Cost avoidance: Regarding to costs of medication filling errors, these were calculated according to levels of severity and concerning all relevant resource utilizations and human labor expenditures. On the whole, the entire costs of medication filling errors occurred during July-December 2007 (before implementing the drugs filling robot) was 4,940 baht, which 4,691 baht and 249 baht were the cost of errors in level 0 and 1 respectively. In the later year, the total cost was reduced to 4,053 baht in which consisted of cost of medication filling error at level 0 was 3,676 baht and at level 1 was 377 baht. Therefore, cost of medications and filling cost reduction from using the pharmacy automation at the Bumrungrad Hospital was 1,678 baht. Besides, other medication error costs were cost of claim or compensation resulting from medication filling practice deviations. However, there costs incurred during both two study time frames but did not include in the calculation because of unable to clarify direct and specific amounts to medication filling errors. In conclusion, the results revealed a gradually reduced in expenses when errors occurred. The data showed the use of inpatient pharmacy automation could avoid 1,678 baht along 6 months in practice.

C. Cost saving: With respect to cost saving from the use of in-patient pharmacy automation system, it was summed up from 3 aspects; cost of pharmacy staff, training, and inventory costs. First of all, the average staff worked for inpatient pharmacy section was eighty-five, 35 pharmacists, and 50 pharmacist assistances. In

2007, Pharmacists' turnover rate was 3% and 4% for pharmacist assistances. In 2008, the turnover rates were lower than the preceding year, which had 3% and 2% of the overall staff available respectively. Over the first study time frame, 1 new pharmacist staff was employed but two technicians had resigned. On the other hand, throughout the study periods in 2008, 1 pharmacist and 1 pharmacist assistances had resigned with no new coming staff. When comparing the monthly staff usage with the earlier year, 2 pharmacist staffs and 6 technician staffs decreased. The changes were due to resignation, transferring staff to other sections and changing job positions. Moreover, IPD overtime working hours were declining each month right through the new system investigation. Total pharmacy labor expenditure was concerned dispensing times that were spent by IPD staff during the study periods. Cost of pharmacy dispensing labor in 2007 was 7,831,742 baht, while the subsequent year the cost saved 303,996 baht which was 7,527,746 baht in an overall. Then, there was no formal training course for a new staff of pharmacy department at the Bumrungrad hospital. Only personal trainers were responsible for new employees' jobs learning. Two new pharmacists were employed during the second half of 2007. So, training cost was 176,000 baht. Otherwise, there was no new employee during the study period in 2008.Thus, there was no such of cost incurred in this study phase. Finally, due to inventory management variability of continuing adjustment to steady amount of stock supply, the study time frames were allowed to extend a few more months, with respect to generating the more accurate costs. Drug cost of IPD store at the end of first study period was 14,596,703 baht. Whilst, the later period cost of stock volume of drugs for in-patient was 13,547,395 baht. Thus, when included all of these 3 costs, cost saving over the study period was 1,529,304 baht.

D. A model for calculating cost saving and cost avoidance: A model of cost saving and cost avoidance from having the pharmacy automation was suggested in this study. The model was developed based on literature study incorporated with expert suggestions. Cost analysis calculation illustrated as the following;

Cost avoidance = the traditional dispensing system [(cost of medication errors$_T$) + (related costs of compensation$_T$)] –
the pharmacy automation system [(cost of medication errors$_A$) + (related costs of compensation$_A$)]

Each level of seriousness of medication errors can be computed costs as indicated in Table 12.

Cost saving = the traditional dispensing system [(dispensing labor $costs_T$) + (training $cost_T$) + (drug inventory acquisition $costs_T$)] – the pharmacy automation system [(dispensing labor $costs_A$) + (training $cost_A$) + (drug inventory acquisition $costs_A$)]

Limitations of the Study:

1. This study was conducted retrospectively. It might lead to limited on data availability, difficulty of in depth analysis, restricted further discussion, and accuracy of obtained outcomes.

2. It had inappropriate study time-frames because all aspects were not in the same duration. As well as, limitation on research periods, the investigator could not collect all data in the same months. With a well proper time-frame, it seems direct to better study methods can be proceeded, such as real-time study.

3. As aforementioned, the Swisslog was being in the initiation phase of implementation, so there were some problems resulted from system instabilities impacted study's outcomes. Thus, a study of changing or improving a system needed an adequate time leaves for the new system to run smoothly and suitably.

4. There were limited on likely previous studies available. So, it was unable to widely compare and generate better discussion.

5. There were possibilities of underreporting of medication error occurrences. However, it is generally that the more incidence determinations, the more necessary costs would be detected.

6. Because of high-end private hospital, the findings in this setting were difficult to widely imply to general hospitals. Different results could be achieved at other institutions, depending upon the variation in cost rates.

Then, recommendation and suggestions were developed according to pros and cons of this study. The data from this study reflected the importance of better patient's care from using technology, and suggested the better system of cost estimation from medication errors. The model of pharmaceutical care in this study may serve as the pilot or the fundamental initiation for further development in other hospitals. The values of cost avoidance and cost saving from using the new pharmacy automation system significantly showed the impact to the hospital.

Recommendation and Suggestions to the Study Setting:

1. With respect to implementing the automated system, proper plan should be arranged. It is important to emphasize collaboration of all health care personals who involve with the system. There should be a precise plan on how to convey the users to comply with the new system such as developing a questionnaire asking about opinions of the new system, or establishing a multidisciplinary team-work responsible for arranging anti-failure strategies, as well as pharmacists and system engineer should develop the system jointly.

2. Obtained findings reveals a number of doses dispensed by the robot were deficient in which these failures were detected after drugs delivery process. It is likely to produce high loss of cost. As a result of this, re-inspection points of prepared drugs should exist.

3. Interesting outcomes of this study are recommended to present to relevant users with respect to providing information of the new system's successfulness, errors reduction, cost reduction, better dispensing performance, or workforce improvement. These advantages are probable leading to higher staffs' cooperation.

4. It is possible that the number of medication errors was rather smaller and might be underreported. More incidence determination and necessary costs would be detected if all health professionals are working as a team, and receive appropriate force of medication errors monitoring.

Recommendation and Suggestions for the Usefulness of the Study:

1. This cost calculation model is simple applied to other settings with better cases serious categorized. It would be more beneficial if the area of study is conducted in different kinds of hospitals, even or located in different geographic areas. Different results could be achieved at other institutions, depending upon the variation in cost rates.

2. A predominant advantage of this cost analysis research was simply presenting in monetary values descriptions. It generally provided a straightforward

direction to decision making on investment such a robot hand-help in Thailand, especially, in the situations of facing with economic crisis. Projecting on investment should be more carefully concerned of least acceptable costs with high possible benefits.

Recommendation and Suggestions for Further Study:

1. More in-depth analysis of cost estimation should be explored and the real time-study system of medication error and estimation should be developed which was unable to conduct in this study due to limited on data availability and narrow study time-frame. Time study should project on each step of dispensing process including returned medications, and stock management. Moving toward to prospective analysis would be appreciated expectation. As well as, various methods and assumptions for estimation should be compared to seek the most suitable approach.

2. Cost analysis and cost estimation of medication errors should be further studied in comparison to investment costs, as a result that it is leading to the better understand of cost loss and benefits gained. Several specific types of cost analysis such as cost-effectiveness analysis, cost-benefit analysis, or cost minimization are likely to apply to medication technology investments. It is increasingly clear visions to the health investors. Moreover, cost analysis would be increasingly useful in case of extrapolation covering operational years or life-time of the robot.

3. This study intensely focused on dispensing system related to the automation. The more useful of investigation should concern other aspects of human being such as interdisciplinary relationships, workers’ satisfaction, or attitudes about working with the machine. As well as, it is important to determine the impact of the new system implementation on other departments in which the most directly affected area would be nursing.

4. Moreover, study of inventory management should produce many more years after the system implemented which is possible to provide a clear picture of cost control, higher outcomes are likely to be obtained as the system has minimizing deficient.

5. Costs of claim and compensation resulting from dispensing deviation were found during the investigational periods but did not include in the analysis because of

data availability. Cost of medication errors may high above presenting in this study if adding compensated expenditures. A case of such customer’s claim may high over a million baht. Otherwise, high potential costs can incur if hazardous drugs reach patients.

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APPENDICES

Appendix A

Number of medication filling errors occurred during the two study periods

Months	Level of severity						
	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
Jul-07	111	0	0	0	0	0	0
Aug-07	127	1	0	0	0	0	0
Sep-07	140	0	0	0	0	0	0
Oct-07	135	0	0	0	0	0	0
Nov-07	114	0	0	0	0	0	0
Dec-07	90	1	0	0	0	0	0
Total	717	2	0	0	0	0	0
Jul-08	24	0	0	0	0	0	0
Aug-08	31	0	0	0	0	0	0
Sep-08	26	0	0	0	0	0	0
Oct-08	49	1	0	0	0	0	0
Nov-08	35	0	0	0	0	0	0
Dec-08	49	0	0	0	0	0	0
Total	214	1	0	0	0	0	0

Level 0: Non medication error occurred
Level 1: An error occurred that did not result in patient harm.
Level 2: An error occurred result in increased patient monitoring, no change in vital signs and no patient harm.
Level 3: An error resulted in the need for increased patient monitoring with a change in vital signs, no ultimate patient harm. Level 4: An error occurred resulted in need for treatment with another drug or an increased length of stay or that affected patient participation in an investigational drug study.
Level 5: An error occurred resulted in permanent patient harm.
Level 6: An error occurred resulted in patient death.

Total medication filling categorized by frequency of medication filling errors

Months	Frequency of medication filling errors						**Total filling errors**
	Wrong strength	Wrong quantity	Wrong drug	Wrong label	Wrong formulation	Omission	
July-07	24	23	48	0	14	2	111
Aug-07	23	39	52	1	11	2	128
Sep-07	29	42	51	5	12	1	140
Oct-07	30	54	35	3	13	0	135
Nov-07	18	31	51	1	12	1	114
Dec-07	16	26	37	0	11	1	91
Total	140	215	274	10	73	7	719
Jul-08	3	11	7	0	3	0	24
Aug-08	10	4	12	0	5	0	31
Sep-08	6	7	9	2	2	0	26
Oct-08	10	14	21	0	2	3	50
Nov-08	9	9	15	1	0	1	35
Dec-08	8	11	24	0	6	0	49
Total	46	56	88	3	18	4	215

Monthly rates of errors

Month	Types of errors						
	Wrong strength	Wrong quantity	Wrong drug	Wrong label	Wrong formulation	Omission	**Total**
Jul-07	1.66	1.59	3.32	0	0.97	0.14	7.68
Aug-07	1.62	2.75	3.66	0.07	0.77	0.14	9.01
Sep-07	2.16	3.13	3.8	0.37	0.89	0.07	10.42
Oct-07	2.34	4.21	2.73	0.23	1.01	0	10.52
Nov-07	1.39	2.4	3.95	0.08	0.93	0.08	8.83
Dec-07	1.23	2	2.84	0	0.84	0.08	6.99
Jul-08	0.18	0.67	0.42	0	0.18	0	1.45
Aug-08	0.61	0.24	0.73	0	0.31	0	1.89
Sep-08	0.44	0.51	0.66	0.15	0.15	0	1.91
Oct-08	0.67	0.93	1.4	0	0.13	0.2	3.33
Nov-08	0.58	0.58	0.97	0.06	0	0.06	2.25
Dec-08	0.55	0.76	1.66	0	0.41	0	3.38

Error rates reduction over 6 month-periods (July – December)

Month	Types of errors						
	Wrong strength	Wrong quantity	Wrong drug	Wrong label	Wrong formulation	Omission	**Total**
July	1.48	0.92	2.9	0	0.79	0.14	6.23
August	1.01	2.51	2.93	0.07	0.46	0.14	7.12
September	1.72	2.62	3.14	0.22	0.74	0.07	8.51
October	1.67	3.28	1.33	0.23	0.88	-0.2	7.19
November	0.81	1.82	2.98	0.02	0.93	0.02	6.58
December	0.68	1.24	1.18	0	0.43	0.08	3.61

Pharmacy Standard time for general prescription

Activity			Avg. Items/ prescription	Time/UOS	
				Avg. Process Time/ prescription (min)	% Allowance
No.	From	to		1	4
1	Print/open scanned prescription	Complete order creation in syst.	2	02.14	15%
2	Start review prescription	Verify prescription in system	2	01.04	15%
3	Separate MAR Label (robot&manual fill)	Medication Label printed complete	2	00.25	15%
4	Start manual fill	Finish manual fill	2	01.07	15%
5	Start checking	Finish checking	2	00.48	15%

UOS = Unit of Service (a prescription

Drug filling costs

Year	Month (baht)											
	July		August		September		October		November		December	
	Cost of Rx	Cost of filling a drug	Cost of Rx	Cost of filling a drug	Cost of Rx	Cost of filling a drug	Cost of Rx	Cost of filling a drug	Cost of Rx	Cost of filling a drug	Cost of Rx	Cost of filling a drug
2007	21.82	3.27	22.82	3.42	23.21	3.48	23.87	3.58	25.22	3.78	26.78	4.00
2008	20.42	3.06	20.81	3.12	23.27	3.49	21.00	3.15	21.83	3.27	19.78	2.97

Rx = dispensed a drug (all dispensing process)

Cost of medication filling errors classified into pre-dispensing, and dispensing process

Month	Costs of drug filling errors (baht)		Month	Costs of drug filling errors (baht)	
	Pre-dispensing	Dispensing		Pre-dispensing	Dispensing
Jul-07	340	490	Jul-08	61	279
Aug-07	421	450	Aug-08	75	489
Sep-07	470	350	Sep-08	77	281
Oct-07	465	351	Oct-08	113	1,285
Nov-07	408	423	Nov-08	91	490
Dec-07	340	432	Dec-08	116	696
Total	2444	2496	**Total**	533	3520

Appendix B

Medication errors from patient care units' data collection form

Case no. : 10xxxxx Date: ________

Case description:

____
____
____
____
____
____
____

Length of problems: _____ day

Prolonged LOS resulted from medication errors: _____ day

Severity (level): ☐ level 1 ☐ level 2 ☐ level 3 ☐ level 4 ☐ level 5 ☐ level 6

Types of errors: ☐ Wrong strength ☐ Wrong quantity ☐ Wrong drug ☐ Wrong label

☐ Wrong formulation ☐ Omission

Wrong drugs:

Drug name	Quantity

Curing drugs:

Drug name	Quantity

Lab tests: ___________________________________

X-rays: _____________________________________

Cost of Hospital stay: _______________ bath/day (ONLY extended days)

Doctor/specialists:

Doctor/specialists	No. of visit

Medical materials	Quantity

Appendix C

Form for collecting data used to calculate in medical costs resulting from filling errors

No.	Case no.	Length of problems (day)	Prolonged LOS (day)	Severity (level)	Types of errors	Cost of wrong drugs(baht)	Cost of curing drugs (baht)	Cost of Lab tests (baht)	Cost of X-rays (baht)	Hospital stay cost (baht)	Doctor/ specialists fees (baht)	Medical materials costs (baht)	Total (baht)

Appendix D

Medication filling error form (pre-dispensing)

Months	Frequency of medication filling errors						Total filling errors
	Wrong strength	Wrong quantity	Wrong drug	Wrong label	Wrong formulation	Omission	
July 2007							
August 2007							
September 2007							
October 2007							
November 2007							
December 2007							
Total							
July 2008							
August 2008							
September 2008							
October 2008							
November 2008							
December 2008							
Total							

Level of severity of medical dispensing errors

Months	Level of severity					
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
July 2007						
August 2007						
September 2007						
October 2007						
November 2007						
December 2007						
Total						
July 2008						
August 2008						
September 2008						
October 2008						
November 2008						
December 2008						
Total						

Appendix E

The inpatient pharmacy dispensing workload

Month	Pharmacists' dispensing hour (hours)	Pharmacist assistances' dispensing hour (hours)
July 2007		
August 2007		
September 2007		
October 2007		
November 2007		
December 2007		
Total		
July 2008		
August 2008		
September 2008		
October 2008		
November 2008		
December 2008		
Total		

Average Pharmacist's payment =________/hour

Average Pharmacist assistance's payment =________/hour

Percentage of salary increased =________/year

Appendix F

Drug IPD inventory costs record

Months (The manual system)	Drug inventory costs (Baht)	Months (The new system with automation)	Drug inventory costs (Baht)		
			Pharmacy IPD store	Pharmacy PillPick store	Total inventory cost
October 2007		October 2008			
November 2007		November 2008			
December 2007		December 2008			
January 2008		January 2009			
February 2008		February 2009			
March 2008		March 2009			

VITAE

The author, Miss Wanna-on Plodkratoke, was born on September 23rd 1983 in Bangkok, Thailand. She obtained the Bachelor of Pharmacy from the Faculty of Pharmacy, Srinakharinwirot University in 2006 and the Bachelor of Pharmaceutical Science with Honours (co-program), Nottingham University, England in 2005. She enrolled in this Master of Science in Social and Administrative Pharmacy, Chulalongkorn University in 2007 with full-time study after graduation the Bachelor Degrees.