IMPROVEMENT OF RE-ORDER POINT FOR DRUG INVENTORY MANAGEMENT AT RAMATHIBODI HOSPITAL

CHULEEPORN LAEIDDEE

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN PHARMACY (PHARMACY ADMINISTRATION) FACULTY OF GRADUATE STUDIES MAHIDOL UNIVERSITY 2010

COPYRIGHT OF MAHIDOL UNIVERSITY
Thesis entitled

IMPROVEMENT OF RE-ORDER POINT FOR DRUG INVENTORY MANAGEMENT AT RAMATHIBODI HOSPITAL

Miss Chuleeporn Laeiddee
Candidate

Assoc. Prof. Cha-oncin Sooksriwong,
Dr.PH. (Public Health Administration)
Major-advisor

Lect. Rawee Suwandechochai,
Ph.D. (Industrial and System Engineering)
Co-advisor

Prof. Banchong Mahaisavariya, M.D.
Dean
Faculty of Graduate Studies
Mahidol University

Assoc.Prof. Arthorn Riewpaiboone,
Ph.D. (Pharmacy)
Program Director
Master of Science in Pharmacy
Program in Pharmacy Administration
Faculty of Pharmacy
Mahidol University
Thesis
entitled
IMPROVEMENT OF RE-ORDER POINT FOR DRUG INVENTORY MANAGEMENT AT RAMATHIBODI HOSPITAL

was submitted to the Faculty of Graduate Studies, Mahidol University for the degree of Master of Science in Pharmacy (Pharmacy Administration) on March 10, 2010.

Miss Chuleeporn Laeidddee
Candidate

Lect. Kusawadee Maluangnon, Ph.D. (Pharmacy Administration) Chair

Assoc. Prof. Cha-oncin Sooksriwong, Dr.PH. (Public Health Administration) Member

Lect. Rawee Suwandeechochai, Ph.D. (Industrial and System Engineering) Member

Prof. Banchong Mahaisavariya, M.D. Dean
Faculty of Graduate Studies
Mahidol University

Assoc. Prof. Chuthamanee Suthisisang, Ph.D. (Pharmacology) Dean
Faculty of Pharmacy
Mahidol University
ACKNOWLEDGEMENTS

I would like to express my gratitude and a deep appreciation to my advisor, Associate Professor Dr. Cha-Onchun Soosriwong, for her understanding, kind supports, encouragement, helpful guidance, and continuous valuable advice throughout this study. I would like to express my respectful gratitude and deep appreciation for her supervision and continual encouragement.

My sincere and grateful appreciation is also expressed to my co-advisor, Dr. Rawee Suwanchochaisai, for her valuable suggestions, helpful discussion and continuous supervision of my study. I also would like to thank my external examiner, Dr. Kusawadee Maluangnon for her kindness in providing suggestions during thesis defense.

I am very grateful and wish to express my deepest thanks to pharmacy staffs, especially to Mrs. Patcharin Suwanakoot from Ramathibodi Hospitals for implementing this study.

I am grateful to all the lecturers and staffs at the Division of Pharmacy Administration, Faculty of Pharmacy for their valuable advice and providing suggestions for improvement and thanks also go to my friends in Pharmacy Administration class for their cheerfulness and kind support.

Finally, my special thanks go to my beloved parents for their entirely care, my sister, my brother and my dear for their encouragement, dedication, love and give continuous support throughout my life.

Chuleeporn Laeiddee
ABSTRACT

The objective of this study is to find out if a re-order point model can improve the efficiency of drug inventory management at Ramathibodi Hospital by using inventory performance data from the fiscal year 2006. Three case study drugs were used in this research: Eprex Prefilled Syringe 4000 U injection, Metformin 500 mg tablets, and Vitamin B Complex tablets. The criteria for drug selection were cost, storage space, and delivery time. The research procedure was divided into three parts. First, we analyzed activity and cost of drug purchasing and inventory management. Second, we defined the appropriate re-order point and order up to level by the (s,S) inventory control model. Lastly, we compared the inventory performance indicators of the drug inventory management base with the (s,S) model and existing method.

The results revealed that drug purchasing and inventory management has 6 activities: purchasing, dispensing, receiving, stock level checking, expensive and narcotic drug checking, and nearly expired drug checking. The average purchasing cost was 59.89 Baht per purchasing order. The carrying charge of drugs stored in a refrigerator and drugs stored at room temperature was 1.25% and 1.20% of the average inventory value, respectively. The inventory performance indicators based on the (s,S) model had a lower average inventory value, higher inventory turnover rate, and lower cost than the existing system.

The study concludes that if the (s,S) model was implemented, the efficiency of drug inventory management would increase. The study results provide basic information for pharmacist administrators to develop processes for drug purchasing and inventory management in hospitals. In addition, there was not constant optimal purchasing nor an inventory management model for all hospitals, but that may depend on the size of the hospital, work environment, whether or not it is a private or public hospital, and the purchasing and inventory management policy of each hospital. So, implementation of this model should be considered.

KEY WORDS: INVENTORY CONTROL/ RE-ORDER POINT/ ORDER UP TO LEVEL/ HOSPITAL
IMPROVEMENT OF RE-ORDER POINT FOR DRUG INVENTORY MANAGEMENT AT RAMATHIBODI HOSPITAL

ชุลีพร ละเอียดดี 4937442 PYPA/M

ภ. ม. (บริหารเภสัชกิจ)

คณะกรรมการที่ปรึกษาวิทยานิพนธ์ ประกอบด้วย สำหรับ ศุภชัย รุนภพทิพย์, Dr.PH. (Public Health Administration), ระยิว สุวรรณ ศรีไชย, Ph.D. (Industrial and System Engineering)

บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาวิเคราะห์รูปแบบการควบคุมสินค้าคงคลังด้านการกำหนดจุดสั่งซื้อใหม่เพื่อเพิ่มประสิทธิภาพการบริหารจัดการคลังยาของโรงพยาบาลรามาธิบดี ในปีงบประมาณ 2549 โดยใช้หลักการ (s,S) 3 รายการเป็นกรณีศึกษา ได้แก่ Eprex Prefilled Syring 4000 U injection, Metformin 500 mg tablet และ Vitamin B Complex tablet ผลการศึกษาจะแบ่งตามปัญหาการจัดการสินค้าคงคลัง รูปแบบการควบคุมสินค้าคงคลังแบบ (s,S) ได้ถูกนำมาใช้ในการพัฒนารูปแบบการจัดการสินค้าคงคลัง ขั้นตอนการศึกษาแบ่งเป็น 3 ส่วนคือ ขั้นตอนแรกการวิเคราะห์การจัดซื้อและดินทุนในการจัดซื้อยาของระบบและขั้นตอนที่สั่งซื้อยาให้เป็นรูปแบบ (s,S) ขั้นตอนสุดท้ายเปรียบเทียบระบบการจัดการคลังยา ขั้นตอนสุดท้ายเปรียบเทียบขั้นตอนการจัดเก็บยาคงคลังของรูปแบบ (s,S) และรูปแบบเดิม

ผลการศึกษาพบว่า งานจัดซื้อยาและจัดการสินค้าคงคลังประกอบด้วย 6 กิจกรรม คือการจัดซื้อยาต่อใบสั่งซื้อค่า 59.89 บาท และค่าการพักการเก็บรักษาที่คิดถึงในรูปแบบเดิมเท่านั้นเท่านั้นในคลังยาคงคลังต่อเดือนและค่าอื่นๆ ที่เกี่ยวกับการจัดเก็บยาในคลังยา ค่าอื่นๆ ที่เกี่ยวกับการจัดเก็บยาในคลังยา มีค่าตัวแปรที่ต่างกันและต้องการปรับปรุงในขั้นตอนต่างๆ และมีการปรับเปลี่ยนในรูปแบบ (s,S)

จากการศึกษาได้สรุปว่า ในการบริหารยาคงคลังในโรงพยาบาล จะทำให้ประสิทธิภาพในการบริหารจัดการคลังยาดีขึ้นและจะน่าจะมีการปรับปรุงระบบการจัดซื้อยาและจัดการสินค้าคงคลังในโรงพยาบาลให้ดีขึ้น อย่างไรก็ตาม ถ้าไม่มีการปรับปรุงการสั่งซื้อยาที่เหมาะสมสำหรับทุกโรงพยาบาล ขั้นตอนต่างๆ ต้องการปรับปรุง ปัจจุบันยาคงคลังของโรงพยาบาล ทั้งหมดยังคงอยู่ที่โรงพยาบาล ปัจจุบัน

จากการศึกษาได้สรุปว่า ในการบริหารยาคงคลังในโรงพยาบาล ให้มีประสิทธิภาพในการบริหารจัดการคลังยาดีขึ้นและจะน่าจะมีการปรับปรุงระบบการจัดซื้อยาและจัดการสินค้าคงคลังในโรงพยาบาลให้ดีขึ้น อย่างไรก็ตาม ถ้าไม่มีการปรับปรุงการสั่งซื้อยาที่เหมาะสมสำหรับทุกโรงพยาบาล ผลของการศึกษาจะเป็นประโยชน์ต่อการบริหารยาคงคลัง
CONTENTS

ACKNOWLEDGEMENTS iii
ABSTRACT (ENGLISH) iv
ABSTRACT (THAI) v
LIST OF TABLES viii
LIST OF FIGURES ix

CHAPTER I INTRODUCTION 1
Research question 2
General objective 2
Specific objectives 2
Expected outcomes and benefits 3
Definition of terms 3
Conceptual framework 4

CHAPTER II LITERATURE REVIEW 6
Inventory management 6
Inventory control model 13
Activity-Based Costing (ABC) 21
Rationale on selecting the study site 24

CHAPTER III METHODOLOGY 25
Study design 25
Study site 25
Study period 25
Drug selection criteria 25
Study procedure 27

CHAPTER IV RESULTS 32
Activity analysis 32
Cost analysis 34
# CONTENTS (cont.)

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inventory model</td>
<td>42</td>
</tr>
<tr>
<td>Inventory performance</td>
<td>51</td>
</tr>
<tr>
<td>Summary of major finding</td>
<td>56</td>
</tr>
<tr>
<td><strong>CHAPTER V  DISCUSSION</strong></td>
<td>58</td>
</tr>
<tr>
<td>Activity analysis</td>
<td>58</td>
</tr>
<tr>
<td>Cost analysis</td>
<td>59</td>
</tr>
<tr>
<td>Inventory model</td>
<td>61</td>
</tr>
<tr>
<td>Inventory performance</td>
<td>61</td>
</tr>
<tr>
<td>Limitation of this study</td>
<td>64</td>
</tr>
<tr>
<td><strong>CHAPTER VI  CONCLUSION AND RECOMMENDATIONS</strong></td>
<td>65</td>
</tr>
<tr>
<td>Conclusion</td>
<td>65</td>
</tr>
<tr>
<td>Recommendations</td>
<td>66</td>
</tr>
<tr>
<td><strong>REFERENCES</strong></td>
<td>67</td>
</tr>
<tr>
<td><strong>APPENDIX</strong></td>
<td>71</td>
</tr>
<tr>
<td><strong>BIOGRAPHY</strong></td>
<td>82</td>
</tr>
<tr>
<td>Table</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>1. Number and value of monthly drugs dispensing from inventory during fiscal year 2006</td>
<td>26</td>
</tr>
<tr>
<td>2. Activity dictionary of drug purchasing and inventory management process</td>
<td>33</td>
</tr>
<tr>
<td>3. Total cost and activity cost of drug purchasing</td>
<td>35</td>
</tr>
<tr>
<td>4. Total cost of drug inventory management</td>
<td>37</td>
</tr>
<tr>
<td>5. Activity cost of drug inventory management</td>
<td>40</td>
</tr>
<tr>
<td>6. Activity cost per unit of drug purchasing and inventory management</td>
<td>41</td>
</tr>
<tr>
<td>7. Comparing MSE of Eprex between forecasting methods</td>
<td>43</td>
</tr>
<tr>
<td>8. Comparing MSE of Metformin between forecasting methods</td>
<td>46</td>
</tr>
<tr>
<td>9. Comparing MSE of Vitamin B Complex between forecasting methods</td>
<td>49</td>
</tr>
<tr>
<td>10. Comparing purchasing cost and carrying cost between the existing system and (s,S) model of Eprex</td>
<td>52</td>
</tr>
<tr>
<td>11. Comparing purchasing cost and carrying cost between the existing system and (s,S) model of Eprex</td>
<td>53</td>
</tr>
<tr>
<td>12. Comparing purchasing cost and carrying cost between the existing system and (s,S) model of Metformin</td>
<td>54</td>
</tr>
<tr>
<td>13. Comparing inventory performance between the existing system and (s,S) model of Metformin</td>
<td>54</td>
</tr>
<tr>
<td>14. Comparing purchasing cost and carrying cost between the existing system and (s,S) model of Vitamin B Complex</td>
<td>55</td>
</tr>
<tr>
<td>15. Comparing inventory performance between the existing system and (s,S) model of Vitamin B Complex</td>
<td>56</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Conceptual framework of this study</td>
<td>5</td>
</tr>
<tr>
<td>2. Carrying cost is linearly related to order size</td>
<td>14</td>
</tr>
<tr>
<td>3. Ordering cost is inversely and nonlinearly related to order size</td>
<td>14</td>
</tr>
<tr>
<td>4. The total-cost curve is U-shaped</td>
<td>14</td>
</tr>
<tr>
<td>5. Order point, Order quantity (s,Q) system</td>
<td>16</td>
</tr>
<tr>
<td>6. Order point, Order up to level (s,S) system</td>
<td>17</td>
</tr>
<tr>
<td>7. Periodic review, Order up to level (R,S) system</td>
<td>18</td>
</tr>
<tr>
<td>8. The existing system inventory situation of Eprex</td>
<td>42</td>
</tr>
<tr>
<td>9. Forecasting demand of Eprex and actual demand in fiscal year 2006</td>
<td>44</td>
</tr>
<tr>
<td>10. The (s,S) model inventory simulation of Eprex</td>
<td>45</td>
</tr>
<tr>
<td>11. The existing system inventory situation of Metformin</td>
<td>45</td>
</tr>
<tr>
<td>12. Forecasting demand of Metformin and actual demand in fiscal year 2006</td>
<td>47</td>
</tr>
<tr>
<td>13. The (s,S) model inventory simulation of Metformin</td>
<td>48</td>
</tr>
<tr>
<td>14. The existing system inventory situation of Vitamin B Complex</td>
<td>48</td>
</tr>
<tr>
<td>15. Forecasting demand of Vitamin B Complex and actual demand in fiscal year 2006</td>
<td>50</td>
</tr>
<tr>
<td>16. The (s,S) model inventory simulation of Vitamin B Complex</td>
<td>51</td>
</tr>
</tbody>
</table>
CHAPTER I
INTRODUCTION

The health care service grew over the past few years and the total world spent 4.7 trillion U.S. dollars on health in 2005. At the same time, Thailand’s total expenditure on health as percentage of Gross Domestic Product (GDP) was 3.5\(^{(1)}\). Many health care organizations are expected to grow in the next few years. Hospitals are complex organizations providing a multitude of services to patients, physicians, and staff. These services include dietary, linen, housekeeping, pharmacy, laboratory, surgery, administration, and others. Each area has specific and often unique material and supply need, creating a requirement in these facilities for supply management system that can provide the necessary supplies when need. In the current climate of increasing health care costs, systems inventory must be optimized without sacrificing the level of service provided.

As a percentage of GDP, Thailand’s health expenditure rose from 5.43\(^{\%}\) in 1995 to 6.14\(^{\%}\) in 2005, the growth rising at the rate faster than that for GDP. Most of health spending was on curative care as evidenced by the fact that the proportion of pharmaceutical spending rose to 42.8\(^{\%}\) of overall health spending in 2005\(^{(2)}\). Since drug is the important factor in curative care, study on cost containment of general hospitals revealed that hospital pharmacy department had the highest proportion between 25\(^{\%}\) to 27\(^{\%}\) of the total cost in hospital\(^{(3)}\). In 1995 the value of hospital drug inventory of nationwide under the Ministry of Public Health was 1,779.5 million Baht and it was forecasted to exceed 2,121 million by 2004\(^{(4)}\).

In an attempt to decrease the amount of hospital drug inventory, the Ministry of Public Health has continually striven to develop the efficiency of drug inventory management system. Reduction of drug inventory level will eventually lower the carrying cost, but causes the purchasing frequency to arise, which in turn, purchasing cost will increase by the number of purchasing time. And when drug inventory decreases, there will be more chances of drug to be out-of-stock. In this
case, the responsible person will urgently procure those shortage drug items, thus, it may cause some problem in the service system. In order to manage the various types of inventory, attributes of items first must be analyzed in term of cost, lead time, past usage, and the nature of demand (5). In many purchasing situations, there are number of different considerations conflicting with one another that influence the final purchasing decision. Improvement of drug inventory management can significantly decrease the expenditure in great amount.

This research is begins to study with focus on order quantity and re-order point of drug purchasing in hospital. The purpose of this study is to find out the re-order point model can improve the efficiency of drug inventory management at Ramathibodi Hospital by employing inventory performance indicators. The information of drug purchasing would be beneficial for pharmacist administrators to develop drug inventory management system.

**Research question**

Will the re-order point model improve the efficiency of drug inventory management?

**Objectives**

**General objective**

The purpose of this study is to find out if re-order point model can improve the efficiency of drug inventory management at Ramathibodi Hospital by employing inventory performance data during the fiscal year 2006.

**Specific objectives**

1. Assess the activities of drug purchasing and inventory management at Pharmacy department, Ramathibodi Hospital during the fiscal year 2006.
2. Apply the re-order point model to calculate new re-order point, order quantities and simulate the new drug inventory processes.
3. Compare the inventory performance indicators of drug inventory management base on the re-order point model and existing method.
Expected benefits and applications

1. This research provides information about re-order point method to calculate drug order quantities and reorder point that can improve performance of drug inventory management.

2. It could be used as basic information for pharmacist administrators to develop processes of drug purchasing and storage.

Definition of terms

Inventory
The total stock kept on hand at any storage point to protect against uncertainty, permit bulk purchasing, minimize waiting time, increase transportation efficiency and buffer against seasonal fluctuations.

Inventory management
The branch of business management concerned with planning and controlling inventories.

Drug expenditure
Money spends for purchasing drug to dispense that occur in the hospital.

Safety stock
The buffer, cushion, or reserve stock keep on hand to protect against stock outs caused by delayed deliveries or markedly increased demand.

Service level
The percentage of items requested that are supplied, in the quantity requested, by pharmacy inventory.

Stock out
Complete absence of an item that is normally expected to be on hand.
Replenishment lead time
The time interval needed to complete the procurement cycle. It begins at the time the need for new stock is recognized and end when that stock is received and available for issue.

Re-order Point
The inventory level set to trigger an order of a specific item.

Activity-Based Costing (ABC)
A method is measuring the cost and performance of activities and cost objects. Assigns cost to activities based on their use of resources and assigns cost to cost objects based on their use of activities.

Conceptual framework
In this study, the researcher is to find out if new inventory model can improve the efficiency of drug inventory management at Ramathibodi Hospital by employing inventory performance data during the fiscal year 2006. We conducted in 2 systems of the inventory management, which are the existing system and re-order point model (s,S) model. The inventory performance is indicated by three parameters. When the inventory performances of those 2 systems were done, the comparison between 2 systems will be present. The conceptual framework of this study is shown in Figure 1.
Figure 1 Conceptual framework
CHAPTER II
LITERATURE REVIEW

The literature review is divided into four parts as the followings:

1. Inventory management
2. Inventory control model
3. Activity-Based Costing (ABC)
4. Rationale on selecting the study site

1. Inventory management

The American Production and Inventory Control Society (APICS) define inventory management as the branch of business management concerned with planning and controlling inventories (6). The role of inventory management is to maintain a desired stock level of specific products or items. The systems that plan and control inventory must be based on the product, the customer, and the process that makes the product available (7).

1.1 Type of inventory supply

Inventory supply can be classified in terms of manufacturing process into 4 categories (8)

1.1.1. Raw material refer to the primary supply that needs to be used in the process of manufacturing parts or goods

1.1.2. Components refer to the supply that does not reach the final step of the manufacturing process.

1.1.3. Work-In Process (WIP) refers to the supply kept for use in the next manufacturing step or the supply that is under the manufacturing process. In fact, the WIP Inventory level is usually used as an indicator of the efficiency of the manufacturing system
1.1.4. Finished goods inventory refers to the supply, which is ready to use for client service or for storage in the warehouse.

1.2 Inventory management process (9)

Inventory control process is composed of 5 steps as follows: 1) Purchasing, 2) Receiving, 3) Storage, 4) Issue (Distribution stock from storeroom) and 5) Report

1.2.1 Purchasing

Purchasing is the process of inventory control to acquire medications. The objective of purchasing is to obtain the right product in the right quantity at the right price at the right time from the right vendor.

1.2.2 Receiving

When the products arrive at the warehouse, staff should physically count each item in the shipment and compare it with the invoice before stock on the shelves.

1.2.3 Storage

Proper storage of inventory is vital. Improper storage can cause a product to ruin, resulting in a loss of inventory and money.

1.2.4 Issue (Distribution stock from storeroom)

Products need to be moved from the facility store to the places where they are used. The procedures are similar, whatever the size of the facility. The movement and control of stocks are more complex in large facilities. Separate stocks or storerooms may be needed.

1.2.5 Report

The computerized inventory management systems are common today in all practice setting. The computer systems can integrate the management of inventory, information, and costs. The ability to integrate inventory and cost data allows for the generation of wide array of reports and analyses. Example of inventory management reports include

- Purchase trend report
- Sales analysis report
- Item-movement report
1.3 Inventory performance indicators

Indicator is an important tool used to measure the performance. It can be used to assess and evaluate the present situation of organization (10). The objective of indicators is to reflect health care service, which relates to the cause of needed outcome (11). Indicators are composed of three important categories (12).

1. Structural indicators
They are used to evaluate the structure of system service arrangement such as number of pharmacists in the hospital pharmacy department.

2. Process indicators
They are used to assess process, activity, or step of medical care service such as indicators of drug administration and patient treatment.

3. Outcome indicators
They are used to evaluate any outcome that may occur to the patients from medical care service process, which can be divided in two outcomes as the followings:
   - Proximate outcome
     It is the imported factor to next step of health care service such as receiving correct medicine.
   - Ultimate outcome
     It is an outcome that may happen to the patients including paralysis, death, and satisfaction of the patients.

From the hospital survey experience in hospital accreditation project, experts of the institute of Hospital Quality Improvement and Accreditation (HA) suggested that good quality indicators should have five characteristics (10).

1. They focus on hospital missions and core processes of common area. They involve the evaluation of high risk and problematic processes. They display attempting of quality development and continuous quality improvement.

2. They reflect the need and the expectation of customers, providers, and administrators especially service process, customer outcome, and public health policies.

3. They are valid, reliable and sensitive to check responsive. They can cite in academic and quality standard that everyone accepts.
4. They come from the information of potential hospital that can record the correct and reliable data. They can analyze and conduct information to use. They are not the burden to collect and analyze.

5. They consist of the sets that cover structural, process, and outcome indicators of health service and medical therapy. They are used for considering overall hospital quality improvement.

1.4 Inventory costs

One goal of inventory management is to achieve a reasonable balance between carrying cost, ordering cost and shortage cost (13). There are four types of inventory cost involved in drug management (13, 14).

1.4.1 Acquisition cost is the amount the pharmacy pays for the product.

1.4.2 Inventory carrying cost includes all associated with carrying and maintaining inventory. The cost is calculated from average inventory values. The average inventory values are obtained by adding the beginning and ending inventory values for fiscal year, and dividing by two. The inventory carrying cost includes several components, many of which have both stable and incremental aspects

- Financial opportunity cost such as interest. It is obtained by multiplying the average inventory values by average interest rate.
- Losses from inventory: This is often an incremental cost, in that losses rise as inventory values increase.
- Operating cost for storage and stock management: It is a mixture of stable and incremental cost.

1.4.3 Ordering cost is cost of ordering and receiving goods. Ordering cost is usually expressed as amount per order.

1.4.4 Shortage cost is the cost associated with being out of an item a patient needs or wants. The size of shortage costs is difficult to estimate. At minimum, it is the embarrassment and frustration of explaining to a patient or prescription that that the pharmacy is out of the item needed. At maximum, it is the cost of losing all a patient’s future purchases or, in the case of life-saving emergency drugs, of causing physical harm to the patient.
1.5 Problems of inventory control

Many problems of inventory control are found in hospital under MOPH. The problems are as follow (4):

1. Human resource management problem, such as a problem of assistant knowledge and capability, number of assistant problem inadequate.
2. Expired drug.
4. Main warehouse problem, such as the space is not enough to store drug.
5. Distributor problem, such as the shortage problems from distributors due to the long distance or inconvenience of transportation.
6. Problem from the number of medicines, such as the medicine not listed in hospital formulary not being used.

1.6 Drug management in hospital

There are four main activities involved in hospital drug management including drug selection, drug purchasing, drug storage and inventory control and drug use (15).

1.6.1 Drug selection

The selection of pharmaceuticals is basic and extremely important professional function of the hospital pharmacist who is charged with making decisions regarding products, quantities, product specifications, and sources of supply. Although the pharmacist has the authority to select a brand or source of supply, he must make economic considerations subordinate to those of quality. In selecting a vendor, the pharmacist must consider price, terms, shipping times, dependability, quality of service, returned goods policy, and packaging (16).

1.6.2 Drug purchasing

According to the Prime Minister’s office regulation on procurement, 2535 B.E. purchasing process comprises five categories.

1. Price Agreement.

This is the method by which the hospital purchases from private drug manufacturer or from a distributor with the amount not to exceed 100,000 Baht per purchase. This method is quite convenient with no purchasing committee need
except the inspecting/checking supply committee, which is formed to inspect and accept the drug supply.


This is the method by which the hospital purchases drug supply from private manufacturer or distributor within a budget of more than 100,000 Baht but not exceeding 2 million Baht.

3. Price Bidding

This is the method by which the hospital purchases drug supply from private manufacturer or distributor with the amount more than 2 million Baht.

4. Special Case Method.

In this method the hospital purchases the drug from the government, privatized other organization according to the laws of the governmental district, which no limit on purchasing budget.

5. Special Method

This method used only when other purchasing methods are not practical. For instance, this method may be used if the purchase needs to be done with urgency or the supply is used for secret agent matter.

1.6.3 Drug storage and inventory control

Storage is an important aspect of the total drug control system. Proper environmental control (i.e., proper temperature, light, humidity, conditions of sanitation, ventilation and segregation) must be maintained wherever drugs and supplies are stored in the institution. Storage areas must be secure; fixtures and equipment used to store drugs should be constructed so that drugs are accessible only to designated and authorized personnel. Such personnel must be carefully selected and supervised. Safety also is an important factor, and proper consideration should be given to the safe storage of poisons and flammable compounds. Externals should be stored separately from internal medications. Medications stored in a refrigerator containing items other than drugs should be kept in a secured, separate compartment.

1.7 The related studies in the inventory management

The 1997/98 annual Lilly Hospital Pharmacy Survey of pharmacy operation in Canada (16). The average of reported total purchases for 1997/98 was
$4,023,409. This was a 15% increase from the average of $3,485,492 reported in 1996/97. Reported total purchases ranged from $312,056 to $30,349,416, total beds from 102 to 1999 and total patient days from 11,507 to 675,965. The data therefore represents responses from hospitals with a broad range of services, programs and specialties. The information and data presented here attempts to bring order to the numbers that are representative of the diversity of respondents’ hospitals. They provide valuable insight into trends and averages and allow readers to track changes in their own facilities and make rough comparisons to national averages. They allow readers to determine if their facility is keeping pace and offers some insight as to why the changes are occurring.

Suchonwanich N. studied the inventory management at Mahasarakam hospital in the fiscal year 1996 (17). Inventory values in the fiscal year 1996 were 10,093,483 Baht. The safety stocks of essential drug (3-6 months) were higher than the safety stocks of non-essential drug (2-4 months). The essential drug values were 6,470,343.60 Baht, the non-essential drug values were 3,623,139.66 Baht. She explained why safety stocks of non-essential drug were less than essential drug. Because of the out-of-date hospital drug list, then the doctor turn to order more non-essential drug. If this trend has continued, the hospital would face the over drug stock.

Kattiviriyaoinyo K. studied about assessment of drug procurement system of private hospitals in 1998 (18). The study was conducted in two parts. In first part, procurement procedures, all 422 private hospitals and clinics with beds for admission in Thailand were surveyed by mailed questionnaire. In the second part, procurement costs were collected using cost collecting from at two Bangkok and vicinity private hospitals. The results of first part revealed that the larger hospitals and hospitals in the Hospital Accreditation (HA) project had high percentages of good procurement practices. The hospital with good procurement practices would have good procurement outcomes. For the second part, labor cost was the largest proportion of both purchasing and inventory carrying cost. In the larger hospital, the unit cost of purchasing and inventory carrying cost were less. There were not constant optimal procurement costs for all hospitals, but that they depended on the hospital’s management.
Chungsiwapornpong W. studied the process of drug inventory control systems and performance among hospital pharmacy departments in Thailand (9). It was conducted in two parts. The first part was the development of major drug inventory indicators. A list of drug inventory indicators from literature review was assessed by 20 hospital pharmacists and 9 experts according to 3 criteria of good indicators. The second part was a survey of drug inventory process and performance by mail questionnaire to 720 samples of both public and private hospitals in Thailand. The first part, nine indicators were selected as major drug inventory control. For the second part, the drug inventory performance and outcomes were also different. A combination of good drug inventory system was ABC, VEN system, group purchasing, verification of quantity in drug issuing according to the real usage, drug accepted with the expiration dates more than one year, and vendor performance. Another important finding was that the level of drug inventory value (Baht/OPD visit in each size of hospital) could be used as a benchmark to improve their drug inventory process and performance.

2. Inventory control model

2.1 Economic Order Quantity (EOQ)

In 1915, F.W. Harris of General Electric developed the Economic Order Quantity formula (EOQ) to help stock keepers in determining how much product to buy (19). The objective of an inventory system is the minimization of total operating costs. The unavoidable costs of operating pure inventory systems are ordering cost, stock out cost, and carrying cost. The EOQ derives the optimal lot size for purchasing by minimizing the cost components involved (ordering cost and carrying cost). The ordering cost or purchasing cost; all costs associated with preparing a purchase order. These include the cost of preparing a purchase invoice, telephone, salaries of purchasing clerks, and stationery. The relationship between the carrying cost and ordering cost is shown in Figure 2-4.
Figure 2 Carrying cost is linearly related to order size
Source: W.C. Benton, Jr. Purchasing and supply management, 2007

Figure 3 Ordering cost is inversely and nonlinearly related to order size
Source: W.C. Benton, Jr. Purchasing and supply management, 2007

Figure 4 The total-cost curve is U-shaped
Source: W.C. Benton, Jr. Purchasing and supply management, 2007
The total cost can be described as follows:

\[
TC = \left[\left(\frac{A}{Q}\times C_p\right) + \left(\frac{Q}{2}\times C_H\right)\right]
\]  

[1]

Where

- \(A\) = Annual requirement
- \(Q\) = Order size
- \(C_p\) = Cost of an order
- \(C_H\) = Unit inventory cost per year

To derive the minimum-cost lot size (EOQ), take the first derivative with respect to \(Q\) and set it equal to zero. The calculus is used to determine the point of inflection on the total cost curve where it is no longer decreasing and beginning to increase.

\[
\frac{\delta TC}{\delta Q} = \frac{A}{Q^2}C_p + \frac{C_H}{2} = 0
\]  

[2]

The solution to Equation (2) is

\[
EOQ = \sqrt{\frac{2AC_p}{C_H}}
\]  

[3]

The classical EOQ model assumes the following (7):

1. Constant demand.
2. Constant lead time.
3. Constant unit price.
4. Fixed order cost per order.
5. Fixed holding cost per unit.
6. Instantaneous replenishment.
7. No stock outs allowed.
8. No demand uncertainty.
9. Quantity discounts are not available.

Since the above assumptions do not reflect all real situations, EOQ model must be modified in a real inventory system analysis.

2.2 Re-order point model

The logic of the reorder point is that product is to be reordered when the stock level of material will be used up during the time required to bring in additional stock. The calculate reorder point is that predetermined inventory level at which replenishment action is called for when the on-hand and on-order drops to or below that level.

The re-order point policies are following (20):
1. Order point, Order quantity (s,Q) system

This system involves continuous review. A fixed quantity Q is ordered whenever the inventory position drops to the reorder point s or lower. This system is shown in Figure 5.

![Figure 5 Order point, Order quantity (s,Q) system](http://www.inventory-management.de)

Source: http://www.inventory-management.de
2. Order point, Order up to level \((s,S)\) system

This system involves continuous review and replenishment is made whenever the inventory position drops to order point \(s\) or lower. However, in contrast to the \((s,Q)\) system, here a variable replenishment quantity is used, enough being ordered to raise the inventory position to the order up to level \(S\). The order up to level \(S\) is given by \(S = s + Q\). This system is shown in Figure 6.

![Figure 6 Order point, Order up to level \((s,S)\) system](http://www.inventory-management.de)

3. Periodic review, Order up to level \((R,S)\) system

This control procedure is that every review interval \(R\) units of time (that is, at each review instant) enough is ordered to raise the inventory position to the order up to level \(S\). This system is shown in Figure 7.
4. **(R,s,S) system**

This is a combination of (s,S) and (R,S) systems. The idea is that every review interval units of time to check the inventory position. If it is at or below the reorder point s and order enough to raise it to the order up to level S. If the position is above the reorder point, nothing is done until at least the next review instant.

2.3 **Safety stock**

When there is the uncertainty in demand, safety stock must be considered. Safety stock is extra inventory held to protect against randomness in demand or lead time. Safety stock is needed to cover the demand during the replenishment lead time in case actual demand is greater than expected demand (5).

The safety stock may be based on sophisticated statistical formulas such as measuring the standard deviation and relating that deviation to the lot size, lead time, and desired service level. On the other hand, the safety stock may be a fix number that represents an expected demand over a predetermined period of time (7).
2.4 Application of inventory control model in the inventory management

Kwak. N. K. et al studied inventory model for optimizing purchasing of intravenous fluids for hospital (21). This study determined the optimal order interval for placing IV fluid orders interval. They calculated the appropriate safety stock, the economic order quantity, and reorder point for each fluid. The optimal order calculations can be influenced by both internal and external factors to the hospital. Some of factors that influence the reorder interval are very predictable and thus can be easily compensated. The other factors are very difficult to predict. For example, the complexity of the surgery schedule or how many premature babies would be admitted on a given day.

Thawani. V. R et al studied the economic analysis of drug expenditure in the Government Medical College Hospital, Nagpur and identified the categories of drugs needing stringent management control (22). The result of annual drug expenditure was found to be only 11.59% of the total hospital budget. The division of drug inventory into two priority categories resulted in identifying the priority drugs for stringent control. The percentage cost of each drug helped in determining the economic order quantity and the schedule of placing the purchase orders for drugs of high value but low criticality. Using the cost inflation index, it was observed that the overtly seen increase in annual drug expenditure was just 2.84% when the inflation factor-based expenditure was derived.

Vincent V. and Ranton M. studied Economic order quantity model with space limitation (23). They have used a limited storage area in a hospital to study the drug items Ampicillin injection 250 mg which belongs in A group classification. This study reveals that the application of EOQ model can lower in the inventory cost control for about $ 30.12 per annum from just one item-Ampicillin injection 250 mg from more than 800 of total drug items in the hospital. Researchers conclude that EOQ model together with computer technology application can tremendously lower the inventory management cost.

A study in Arizona Health Science Center, U.S.A. has combined the ABC classification and the Economic Order Quantity purchasing model to investigate whether such application can lower the inventory cost in comparison with the
Chuleeporn Laeiddee

Literature review / 20

traditional Maximum-Minimum system. The result shows that within a year time-frame, the cost of inventory control can decrease by more than 10,000 US Dollars.

Chanchai C. studied costs of drug inventory management and drug inventory performance at Khon Kaen Hospital in the fiscal year 2000, and then compared the existing system with a simulated model using ABC classification and Economic Order Quantity model (ABC/EOQ system) (24). The findings showed a total inventory management cost of 3.34 million Baht, which was divided into purchasing cost of 1.54 million Baht and carrying cost of 1.80 million Baht. The inventory carrying fraction was 15.18% and the purchasing cost was 421.38 Baht per item. The inventory performance was indicated as inventory turnover of 7.9, a service level of 81.3%, and expense ratio of 3.6%. When the service level was increased from 81.3% of the existing system to 95% of ABC/EOQ system, the inventory management cost did not change. The costs of inventory management and inventory performance derived from a simulated model (ABC/EOQ) were compared with those of the existing system. For category A drugs, when the service level was adjusted from 82.75% to 95%, the cost of drug inventory management did not change. For category B drugs, when the service level was adjusted from 83.73% to 95%, the cost of drug inventory management increased by 15.19%. For category C drugs, when the service level was adjusted from 75.5% to 95%, the cost of drug inventory management decreased by 13.84%. The feasibility of implementing the ABC/EOQ system in real practice was determined by the Delphi technique. It is possible to implement the ABC/EOQ system in hospitals.

Jie Yang et al. considered an inventory control problem with multiple-period replenishment lead time and nonstationary stochastic demand, and provided an optimal policy for this kind of problem (25). This paper compared the expected total costs performance of a nonstationary (s, S) policy with Sox’s method and Tarim and Kingsman’s method. The expected total cost for this policy was lower than Sox’s policy. And the expected total cost Tarim and Kingsman’s method was 2418.1, while for this policy it was only 2179.2, which saves 9.88% total costs. This policy can adjust both replenishment period and order quantity based on demand realization and thus save cost.
3. Activity-Based Costing (ABC)

Activity-Based Costing (ABC) was proposed by Kapland and Cooper in 1998, the first printed in journal of cost management and Harvard business review. After that, this system was accepted and rapid popularity in England and Europe. At the first in Thailand, the private businesses interested and adopted ABC for their organization (26). At the present, ABC was widely used in other organizations. For the health care system, there is a need for ABC because competition in health care is a driving force while efficiency remains serious concerns. ABC can deliver the information to maximize resources and to relate cost to performance and outcome measure. Management decision makers can utilize ABC information to accomplish cost efficiency without negatively impacting the quality of service delivery while also assisting in continuous quality improvement (27).

3.1 Differences between Traditional and Activity-Based Costing

There are three major differences between Activity-Based Costing and traditional cost accounting method (28).

1. In traditional cost accounting it is assumed that cost objects consume resources whereas in ABC it is assumed that cost objects consume activities.
2. Traditional cost accounting mostly utilizes volume related allocation bases while ABC uses drivers at various levels.
3. Traditional cost accounting is structure-oriented whereas ABC is process-oriented.

3.2 The importance of Activity-based cost analysis

Activity cost is the value of resources which used to perform activities of enterprise. It composed of labor, material, machine, vehicle, computer system, and others. Activity-based is the administrated system to use cost information for activity management by integrated activities. The administrators can overall processes of their services and associate of each activity for further continuous process improvement (26).

Charaemmeprasert, C described that ABC is the cost management, which can help the administrators to understand the cost behavior in their organization (29).
This system emphasized on activity management by divided organization processes into activities. This system help the administrators to know what does the activities process, how much the time spent on each activity, and how many the output of activity performed.

### 3.3 Steps of activity cost analysis

Brimon, J.A. revealed the seven steps to computing activity cost are (30):

1. **Activity analysis**
   
   Activity analysis decomposes a large, complex organization into elemental activities that are understandable and easy to manage.

2. **Life-cycle analysis**
   
   Life-cycle analysis provides a framework for managing the cost and performance of a product/process over the duration of its activities.

3. **Determine of activity cost**
   
   3.1 Tracing of organizational resources to activities with an established causal relationship
   
   3.2 Determination of measure of activity by which the cost of a given an activity varies most directly (as in number of purchase order, number of hours of grinding, and so forth.

   3.3 Calculation of cost per activity

4. **Identification of performance measures**

   Performance measures are the financial and operational statistics used to gauge the performance of a company. Under activity-based performance measurement, each activity is analyzed to determine how effectively the work is being performed as gauged by key performance measure such as quality, cost, and time.

5. **Determination of the cost of business processes**

   A business process analysis determines the interdependencies among activities. Insight into these interrelationships provides visibility of event; a company can reduce or eliminate the cost of all subsequent activities.

6. **Tracing of cost to reporting objective**

   1. Technology
      
      - Order
- Customers

7. Calculation of product cost

Products cost is determined through a bill of activities that itemizes the activities and quantity of each activity.

### 3.4 Application of Activity-based costing in Health care service.

Hugh W. et al. described the application of activity-based costing (ABC) to calculate unit costs for a healthcare organization in a developing country (31). It also describes the ways in which these calculations can provide information for improving the efficiency and quality of healthcare services. Traditional costing frequently allocates overhead and other support costs on the basis of units of production, while ABC assigns these costs to direct services by tracing actual time and other costs through the organization. This provides more accurate estimates of the full unit costs of services than traditional accounting methods. ABC also highlights areas in the healthcare process where efficiency improvements are possible.

Sopanna, W. studied prevention and promotion (P&P) activities-based costing of primary care unit at salalumduan, Sakaeo Province, Thailand in 2004(32). This study was a cross-sectional study and three principles use in ABC were activity analysis, activity costing and performance measurement. The result showed that the P&P cost in 2003 was 1,186,497.59 Baht, the government funding of P&P capital cost was 927,740.93 Baht and labor cost was 636,681.59 Baht. The operation cost was 101,055.86 Baht and capital cost was 167,586.81 Baht. The non-UC budget was 22,416.67 Baht. The lowest unit cost was in the sanitation and environmental health services sub-activity.

Lazaro M. et al. studied to calculate the cost of heart transplant by applied Activity-Based Costing in 2004(33). To develop a method to calculate accurately heart transplant cost to analyze comparatively the calculated cost a variations in clinical practice and organization-economic strategy among 4 Spanish hospitals. They found that mean of cost in 4 studied hospital was 39,975 Euros. The global cost and cost of each phases varies significant among hospitals. The difference were depends on variations in clinical practice and organization strategic planning. They conclude that
ABC method is applicable to accurately the cost, detected inefficient activities and allowed to optimized costs in heart transplant process.

Methacanon, T. analyzed the activity cost of the pharmacy dispensing service in the outpatient unit in Ladyao Hospital, Nakhonsawan Province, Thailand (34). Research used an activity-based approach in the fiscal year 2005. The results revealed that there were 18 activities of the outpatient pharmacy dispensing service in Ladyao Hospital. The total cost was 12,223,331.27 Baht which was composed of recurrent costs (96.46%) and capital costs (3.54%). The largest proportion of recurrent cost was cost of drugs and medical supplies. Unit cost of dispensing service was 85.85 Baht/prescription or 19.10 Baht/drug item. If the cost of drugs and medical supplies was excluded, unit cost was 11.76 Baht/prescription or 2.62 Baht/drug item.

4. Rationale on selecting the study site

Ramathibodi Hospital is a University Hospital of Mahidol University with 903 beds. The number of outpatients was about 5,109 patients per day with in fiscal year 2006 (35). The pharmaceutical department of Ramathibodi Hospital has drug inventory 2,111 items. Those effects to the stock values are up to 130 million Baht. The criterion of drug purchasing was based on average monthly distribution from drug inventory. In addition, a new drug order point was 70 percent of the monthly sales and quantities of drug order are up to 100-150% of the monthly sales. This system has not base on actual drug usage and cost of drug inventory. The value of drug stock can affect all systems in hospital. At the same time, the adequate amount of drug supply will affect the quality of health care service. Consequently, the study of inventory management and application of theoretical re-order point model in real situation of hospital and use a result as a practice guideline in managing the drug inventory.
CHAPTER III
METHODOLOGY

The methodology of this study was consisted of 5 parts:

1. Study design
2. Study site
3. Study period
4. Drug selection criteria
5. Study procedure

1. **Study design**
   
   This study was an analytical cross-sectional study.

2. **Study site**

   This study was conducted at the drug purchasing and drug inventory control unit of the pharmacy department, Ramathibodi Hospital.

3. **Study period**

   The process activities of drug purchasing and inventory management were collected from December 2007 to February 2008. Data during fiscal year 2006 were collected for calculation new re-order point and order quantity.

4. **Drug selection criteria**

   Drugs included in this study were suggested by the principal pharmacist and the head of drug inventory unit at a teaching hospital. These drugs are representatives of each drug inventory problems mentioned at the sample hospital. The criteria for drugs selection divided by type of problems of drug inventory management
1. High value drugs and required storage in the refrigerator. Eprex Prefilled Syringe 4000 U injection was selected under this criterion. Eprex is used for the treatment of anemia in certain patients with kidney failure, HIV, or cancer. Total number of Eprex dispensed from the inventory unit was 18,008 syringes and total value was 32,630,496 Baht in the fiscal year 2006. (Table 1)

2. High utilization rate, high volume and bulkiness. Metformin 500 mg tablet was selected under this criterion. Metformin is a drug for the treatment of diabetes mellitus. Total number of Metformin dispensed from the inventory was 6,495,500 tablets and total value was 6,495,500 Baht in fiscal year 2006. (Table 1)

3. Drugs purchased from the Government Pharmaceutical Organization (GPO), with long lead time. Vitamin B Complex tablet was selected under this criterion. Total number of Vitamin B Complex dispensed from the inventory was 2,550,000 tablets and total value was 1,275,000 Baht in fiscal year 2006. (Table 1)

Table 1 Number and value of monthly drugs dispensing from inventory during fiscal year 2006.

<table>
<thead>
<tr>
<th>Date (Month)</th>
<th>Eprex (syringe)</th>
<th>Metformin (tablet)</th>
<th>Vit. B Complex (tablet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct-05</td>
<td>894</td>
<td>347,500</td>
<td>130,000</td>
</tr>
<tr>
<td>Nov-05</td>
<td>1,380</td>
<td>438,000</td>
<td>180,000</td>
</tr>
<tr>
<td>Dec-05</td>
<td>846</td>
<td>437,500</td>
<td>221,000</td>
</tr>
<tr>
<td>Jan-06</td>
<td>1,254</td>
<td>377,500</td>
<td>192,000</td>
</tr>
<tr>
<td>Feb-06</td>
<td>780</td>
<td>438,500</td>
<td>111,000</td>
</tr>
<tr>
<td>Mar-06</td>
<td>1,640</td>
<td>438,500</td>
<td>162,000</td>
</tr>
<tr>
<td>Apr-06</td>
<td>960</td>
<td>334,000</td>
<td>170,000</td>
</tr>
<tr>
<td>May-06</td>
<td>1,560</td>
<td>437,000</td>
<td>121,000</td>
</tr>
<tr>
<td>Jun-06</td>
<td>1,140</td>
<td>585,000</td>
<td>304,000</td>
</tr>
<tr>
<td>Jul-06</td>
<td>1,500</td>
<td>347,000</td>
<td>86,000</td>
</tr>
<tr>
<td>Aug-06</td>
<td>1,380</td>
<td>437,000</td>
<td>224,000</td>
</tr>
<tr>
<td>Sep-06</td>
<td>1,026</td>
<td>481,500</td>
<td>90,000</td>
</tr>
<tr>
<td>Oct-06</td>
<td>1,314</td>
<td>384,500</td>
<td>200,000</td>
</tr>
<tr>
<td>Nov-06</td>
<td>1,158</td>
<td>559,000</td>
<td>119,000</td>
</tr>
<tr>
<td>Dec-06</td>
<td>1,176</td>
<td>453,000</td>
<td>240,000</td>
</tr>
<tr>
<td><strong>Total (unit)</strong></td>
<td><strong>18,008</strong></td>
<td><strong>6,495,500</strong></td>
<td><strong>2,550,000</strong></td>
</tr>
<tr>
<td><strong>Total value (Baht)</strong></td>
<td><strong>32,630,496</strong></td>
<td><strong>6,495,500</strong></td>
<td><strong>1,275,000</strong></td>
</tr>
</tbody>
</table>
5. Study procedure

This study procedure was divided into 4 phases: 1) Activity analysis, 2) Cost analysis, 3) Inventory model and 4) Inventory performance.

Phase1. Activity analysis

First, the activities of drug purchasing and inventory management processes were collected from interviewing staffs and observation. Then the functional flow diagram to show the relationship between processes and the departments responsible for that processes was constructed. The data from functional flow diagram were summarized to document an activity dictionary.

Phase2. Cost analysis

This study determined the direct costs of drug purchasing and inventory management activities base on activity-based costing (ABC). Total direct costs were acquired from the total of labor costs, material costs and capital costs.

1. Labor cost
   - The labor cost; total salaries of personnel in the pharmacy department related to drug purchasing and inventory management. Data were collected from financial and accounting department.
   - The proportion of time spent in each activity collected by interviews and observation of actual operations.
   - The labor cost per activity was calculated as follow.
   \[
   \text{Labor cost per activity} = \text{Total labor cost} \times \text{Proportion of time spent in each activity}
   \]

2. Material costs
   - Costs of material office supply used in drug purchasing unit and drug inventory unit were recorded and allocated to activities by estimation of material used in each activity.
   - Public utilities included electricity and telephone charges were collected from the financial and accounting department. The water supply has not been charged as a direct relationship with drug purchasing and drug inventory management. Ramathibodi Hospital did not have separate electricity meter in each department. In this study, electricity cost of drug purchasing unit and drug inventory unit was
calculated by multiplying the electric power with working time used and was computed by using government non-profit rate. The telephone cost allocated to purchasing unit and drug inventory control unit by the number of personnel. The electricity and telephone costs were allocated to activities by proportion of working time and proportion of telephone used in each activity, respectively.

3. Capital cost
- Capital cost included depreciation value of buildings and long-lasting equipments. The data collected from central supply unit. Useful life of buildings and equipments criteria based on central supply unit. Cost accounting system was used to calculate the depreciation cost based on straight-line method under the following formula:

\[
\text{Annual depreciation cost} = \frac{\text{Cost of purchasing}}{\text{Useful life}}
\]

- Capital cost was allocated to activities by proportion of working time.

4. Unit cost calculation.
This present study estimated three unit cost, activity cost, purchasing cost and carrying charge.

Activity cost per unit calculation:

\[
\text{Activity cost per unit} = \frac{\text{Total activity cost}}{\text{Output unit}}
\]

Purchasing cost per purchasing,

\[
\text{Purchasing cost/purchasing} = \frac{\text{Total cost of purchasing}}{\text{Number of total purchasing orders}}
\]
Carrying charge, the cost in one Baht of carrying one Baht of inventory for one year.

\[
\text{Carrying charge} = \frac{\text{Total cost of carrying}}{\text{Average inventory value}}
\]

**Phase 3. Inventory model**

1. Number of drugs dispensing per week during fiscal year 2005-2007 was collected. Kolmogorov-Smirnov goodness of fit test were using normal and other distribution test.

2. The demand forecasting of drugs dispensing per week in fiscal year 2006 forecasting used four exponential smoothing methods for analyses the data following (36):
   - Simple Exponential Smoothing method
   - Holt’s linear trend method
   - Brown’s linear trend method
   - Damp trend method.

Data divided into 2 parts; initialization set (44 weeks) and test set (8 weeks). Selection the best forecasting method for data used to find at least Mean Square Error; MSE following formula (36):

\[
MSE = \frac{1}{n} \sum_{i=1}^{n} e_i^2
\]

Where

\[
e = \text{Actual value} - \text{forecast value}
\]
\[
n = \text{number of data}
\]

Drugs dispensing per week in fiscal year 2006 was forecasted from number of drug dispensing per week in fiscal year 2005.

3. Data forecasting was used to calculate Economic Order Quantity (EOQ) following formula (20):
\[ Q = \sqrt{\frac{2AD}{wr}} \]

Where

- \( Q \) = Economic Order Quantity (units)
- \( A \) = Purchasing cost (Baht/purchasing)
- \( D \) = Annual demand (units)
- \( r \) = Carrying charge (Baht/Baht/ year)
- \( w \) = Unit price (Baht)

4. Calculation reorder point and safety stock as following (20):

\[ \text{Reorder Point} (s) = \int_{0}^{s} f_x(x) \, dx \]

\[ \text{Safety Stock} (SS) = \int_{0}^{\infty} (s - x) f_x(x) \, dx \]

Where

- \( x \) = demand in lead time

\[ f_x(x) \, dx = \text{Prob} \{ \text{total demand in the lead time lie between } x_0 \text{ and } x_0 + d_x, \} \]

5. Inventory model uses a \((s, S)\)

Whenever inventory position (on hand plus order) drops to reorder point \(s\) or lower, an order is placed to raise the position to the order up to level \(S\). Calculation the value \(S\) following formula (20):

\[ S = s + Q \]

6. Purchasing is determined as follows.
   - When inventory position equal to reorder point, order quantity equal to Economic Order Quantity.
- When inventory position lower than reorder point, order quantity are equal to Economic Order Quantity plus the difference between inventory position and reorder point.

The actual order quantity is round number to packing size.

Phase 4. Inventory performance

Comparison of inventory performances between the existing system and (s,S) model. Drug inventory performance was indicated by three parameters. (37)

1. Average inventory values (Baht) = Total inventory value/365 (day)
2. Inventory turnover = value of drug use/Average inventory value
3. Inventory cost (Baht) = Purchasing Cost + Inventory Carrying Cost
   
   Purchasing cost = Number of times purchasing x Purchasing cost per purchasing
   Carrying cost = Average inventory values x Unit price x Carrying charge

The data in this study were analyzed by using the Microsoft Excel 2003, XLSTAT 2008 and SPSS software version 16.
CHAPTER IV
RESULTS

The results of this study were divided into three parts as follows:

Part 1. Activity analysis
Part 2. Cost analysis
Part 3. Inventory model
Part 3. Inventory performance

Part 1. Activity analysis

This part described drug purchasing and drug inventory management processes and activity dictionary.

The Activity pools of drug purchasing and inventory management process are divided following:

1. Drug purchasing
2. Drug inventory dispensing
3. Drug receiving
4. Stock level checking
5. Expensive and narcotic drug checking
6. Nearly expired drug checking

The functional flow diagram in appendix A to show the relationship between processes and the departments responsible for drug purchasing and inventory management processes.

The activity processes of drug purchasing and inventory management were summarized to document an activity dictionary (Table 2). Drug purchasing process has 1 activity and 4 sub activities. Total time spent on drug purchasing activity in fiscal year 2006 was 6,174 hours or accounted to 36.18% of total working time. Drug inventory management process has 5 activities as follows:

1. Drug inventory dispensing was composed of 6 sub activities.
2. Drug receiving was composed of 8 sub activities.
3. Stock level checking was composed of 2 sub activities.
4. Expensive and narcotic drug checking was composed of 2 sub activities.
5. Nearly expired drug checking had 1 sub activity.

The total time spent on drug inventory management in fiscal year 2006 was 32,151.12 hours. The drug inventory dispensing activity had spent the highest proportion time of working time (65.20%) followed by drug receiving (26.81%), nearly expired drug checking (6.38%), stock level checking (1.5%) and expensive and narcotic drug checking (0.11%), respectively.

Table 2 Activity dictionary of drug purchasing and inventory management process

<table>
<thead>
<tr>
<th>Activity</th>
<th>Sub activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drug purchasing</td>
<td>1. Update stock and arrange drug list for purchasing</td>
</tr>
<tr>
<td></td>
<td>2. Record and print out purchasing order and sign to authorize by pharmacist and head of pharmacy department</td>
</tr>
<tr>
<td></td>
<td>3. Arrange document and record data after purchasing order permit by director of hospital</td>
</tr>
<tr>
<td></td>
<td>4. Arrange document sign to authorize by pharmacist after drug receiving</td>
</tr>
<tr>
<td>Drug inventory dispensing</td>
<td>1. Receive drug requisition and arrange drug requisition</td>
</tr>
<tr>
<td></td>
<td>2. Check and deliver drug</td>
</tr>
<tr>
<td></td>
<td>3. Record data in stock card</td>
</tr>
<tr>
<td></td>
<td>4. Record data in computer and print reports</td>
</tr>
<tr>
<td></td>
<td>5. Check correction of record and drug cannot dispensing list by pharmacist</td>
</tr>
<tr>
<td></td>
<td>6. Sign record report by pharmacist</td>
</tr>
</tbody>
</table>
Table 2 Activity dictionary of drug purchasing and inventory management process (continue).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Sub activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drug receiving</td>
<td>1. Check and arrange document and record with print document for committee</td>
</tr>
<tr>
<td></td>
<td>2. Check drug and record data in receiving book by committee</td>
</tr>
<tr>
<td></td>
<td>3. Check drug by inventory staff</td>
</tr>
<tr>
<td></td>
<td>4. Place drugs on shelf</td>
</tr>
<tr>
<td></td>
<td>5. Record data in stock card</td>
</tr>
<tr>
<td></td>
<td>6. Record data in computer, print</td>
</tr>
<tr>
<td></td>
<td>7. Check and arrange drug receiving document</td>
</tr>
<tr>
<td></td>
<td>8. Sign drug receiving document by chief of inventory control unit</td>
</tr>
<tr>
<td>Stock level checking</td>
<td>1. Print out inventory level report</td>
</tr>
<tr>
<td></td>
<td>2. Check drug quantity on shelf and stock card compare with report</td>
</tr>
<tr>
<td>Expensive and narcotic</td>
<td>1. Print out inventory level report</td>
</tr>
<tr>
<td>drug checking</td>
<td>2. Check drug quantity in stock card compare with report</td>
</tr>
<tr>
<td>Nearly expired drug</td>
<td>Check drug expiration date and record in report</td>
</tr>
<tr>
<td>checking</td>
<td></td>
</tr>
</tbody>
</table>

Part 2. Cost analysis

This study determined the total direct costs of drug purchasing and inventory management activities based on existing method during fiscal year 2006. Total direct costs were acquired from the total of labor costs, material costs and capital costs. In this part was divided 2 parts: 1) Total cost and activity cost 2) Unit Cost of drug purchasing and inventory management.

1. Total cost and activity cost

Total cost of drug purchasing was 821,692.90 Baht. Labor cost, material cost and capital cost were 668,452.93 Baht, 152,940.02 Bath and 299.95 Bath, respectively. The record and print out purchasing order and sign to authorize by pharmacist and head of pharmacy department sub activity cost was highest (489,004.32 Baht), which accounted for 59.51% of total cost (Table 3).
### Table 3 Total cost and activity cost of drug purchasing.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Sub activities</th>
<th>Labor cost</th>
<th>Material cost</th>
<th>Capital cost</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Baht</td>
<td>Baht</td>
<td>Baht</td>
<td>Baht</td>
</tr>
<tr>
<td>Drug purchasing</td>
<td>1. Update stock and arrange drug list for purchasing</td>
<td>49,515.03</td>
<td>14,776.74</td>
<td>22.22</td>
<td>64,313.99</td>
</tr>
<tr>
<td></td>
<td>2. Record and print out purchasing order and sign to be authorized by pharmacist and head of pharmacy</td>
<td>371,362.74</td>
<td>117,474.94</td>
<td>166.64</td>
<td>489,004.32</td>
</tr>
<tr>
<td></td>
<td>3. Arrange document and record data after purchasing order permit by director of hospital</td>
<td>123,787.58</td>
<td>10,344.17</td>
<td>55.55</td>
<td>134,187.30</td>
</tr>
<tr>
<td></td>
<td>Total (Baht)</td>
<td>668,452.93</td>
<td>152,940.02</td>
<td>299.95</td>
<td>821,692.90</td>
</tr>
</tbody>
</table>
Total cost of drug inventory management was 2,566,851.52 Baht. Labor cost, material cost and capital cost were 2,029,186.00 Baht, 378,301.76 Baht and 159,363.76 Baht, respectively (Table 5). The drug inventory dispensing activity cost was the highest (1,651,461.84 Baht), which accounted for 64.34% of total cost. Record data in stock card sub activity cost was the highest (728,061.18 Baht), which accounted for 28.36% of total cost. The drug receiving activity cost was 706,277.12 Baht, which accounted for 27.52% of total cost. Check drug and record data in receiving book by committee sub activity cost was highest (230,662.71 Baht), which accounted for 8.99% of total cost. The nearly expired drug checking was 166,799.75 Baht, which accounted for 6.50% of total cost. The stock level checking activity cost was 38,473.01 Baht, which accounted for 1.50% of total cost. Check drug quantity on shelf and stock card compare with report sub activity cost was highest (37,561.47 Baht), which accounted for 1.46% of total cost. The expensive and narcotic drug checking was the lowest (3,839.80 Baht), which accounted for 0.15% of total cost. Check drug quantity in stock card compare with report sub activity cost was highest (2,016.72 Baht), which accounted for 0.08% of total cost. Total cost, activity cost and sub activity cost was presented in Table 4-5.
## Table 4: Total cost of drug inventory management

<table>
<thead>
<tr>
<th>Activity</th>
<th>Sub-activities</th>
<th>Labor cost Baht</th>
<th>Material cost Baht</th>
<th>Capital cost Baht</th>
<th>Total cost Baht</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>1. Receive drug requisition and Arrange drug requisition</td>
<td>432,622,466.90</td>
<td>21.32</td>
<td>70,857.92</td>
<td>21.32</td>
</tr>
<tr>
<td></td>
<td>2. Check and deliver drug</td>
<td>257,097,871.28</td>
<td>12.67</td>
<td>42,109,28</td>
<td>12.67</td>
</tr>
<tr>
<td></td>
<td>3. Record data in stock card</td>
<td>584,608,49</td>
<td>28.81</td>
<td>97,540,00</td>
<td>28.81</td>
</tr>
<tr>
<td></td>
<td>4. Record data in computer and print reports</td>
<td>19,480,19</td>
<td>0.96</td>
<td>4859,22</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>5. Check correction of record and drug cannot dispensing list by pharmacist</td>
<td>19,480,19</td>
<td>0.96</td>
<td>7,585,69</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>6. Sign record report by pharmacist</td>
<td>9,740,09</td>
<td>0.48</td>
<td>1,595,30</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>7. Sign record report by pharmacist</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Copyright by Mahidol University
Table 4 Total cost of drug inventory management (continue).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Sub-activities</th>
<th>Labor cost</th>
<th>Material cost</th>
<th>Capital cost</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Baht</td>
<td>Baht</td>
<td>Baht</td>
<td>Baht</td>
</tr>
<tr>
<td>2. Check drug and record data in receiving</td>
<td>book by committee</td>
<td>172,683.73</td>
<td>28,283.34</td>
<td>14,561.86</td>
<td>214,528.93</td>
</tr>
<tr>
<td>3. Check drug by inventory staff</td>
<td></td>
<td>172,683.73</td>
<td>28,283.34</td>
<td>14,561.86</td>
<td>214,528.93</td>
</tr>
<tr>
<td>4. Place drugs on shelf</td>
<td></td>
<td>72,036.10</td>
<td>11,798.57</td>
<td>5,657.41</td>
<td>89,492.09</td>
</tr>
<tr>
<td>5. Record data in stock card</td>
<td></td>
<td>28,814.44</td>
<td>4,918.18</td>
<td>2,262.97</td>
<td>35,995.59</td>
</tr>
<tr>
<td>6. Record data in computer, print report and transfer data to purchasing unit</td>
<td></td>
<td>14,407.22</td>
<td>4,008.33</td>
<td>1,131.48</td>
<td>19,547.03</td>
</tr>
<tr>
<td>7. Check and arrange drug receiving document</td>
<td></td>
<td>21,509.37</td>
<td>5,720.96</td>
<td>1,689.26</td>
<td>28,919.58</td>
</tr>
<tr>
<td>8. Sign drug receiving document by chief of inventory control unit</td>
<td></td>
<td>5,681.72</td>
<td>930.59</td>
<td>446.22</td>
<td>7,058.53</td>
</tr>
</tbody>
</table>
## Table 4: Total cost of drug inventory management (continue).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Sub-activities</th>
<th>Labor cost</th>
<th>Material cost</th>
<th>Capital cost</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Baht</td>
<td>Baht</td>
<td>Baht</td>
<td>Baht</td>
</tr>
<tr>
<td>Stock level checking</td>
<td>1. Print out inventory level report</td>
<td>202.92</td>
<td>692.68</td>
<td>15.94</td>
<td>911.54</td>
</tr>
<tr>
<td></td>
<td>2. Check drug quantity on shelf and stock card compare with report</td>
<td>30,234.87</td>
<td>4,952.08</td>
<td>2,374.52</td>
<td>37,561.47</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expensive and narcotic</td>
<td>1. Print out inventory level report</td>
<td>405.84</td>
<td>1,385.36</td>
<td>51.87</td>
<td>1,823.07</td>
</tr>
<tr>
<td>drug checking</td>
<td>2. Check drug quantity in stock card compare with report</td>
<td>1,623.35</td>
<td>265.88</td>
<td>127.49</td>
<td>2,016.72</td>
</tr>
<tr>
<td>Nearly expired drug</td>
<td>Check drug expiration date and record in report</td>
<td>129,664.99</td>
<td>26,951.42</td>
<td>10,183.34</td>
<td>166,799.75</td>
</tr>
<tr>
<td>checking</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2,029,186.00</td>
<td>378,301.76</td>
<td>159,363.76</td>
<td>2,566,851.52</td>
</tr>
<tr>
<td>Activity</td>
<td>Labor cost</td>
<td>Material cost</td>
<td>Capital cost</td>
<td>Total cost</td>
<td></td>
</tr>
<tr>
<td>----------------------------------</td>
<td>------------</td>
<td>---------------</td>
<td>--------------</td>
<td>------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Baht</td>
<td>Baht</td>
<td>Baht</td>
<td>Baht</td>
<td></td>
</tr>
<tr>
<td>Drug inventory dispensing</td>
<td>1,323,029.27</td>
<td>224,527.40</td>
<td>103,905.17</td>
<td>1,651,461.84</td>
<td></td>
</tr>
<tr>
<td></td>
<td>65.20</td>
<td>59.35</td>
<td>65.20</td>
<td>64.34</td>
<td></td>
</tr>
<tr>
<td>Drug receiving</td>
<td>544,024.77</td>
<td>119,526.93</td>
<td>42,725.42</td>
<td>706,277.12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>26.81</td>
<td>31.60</td>
<td>26.81</td>
<td>27.52</td>
<td></td>
</tr>
<tr>
<td>Stock level checking</td>
<td>30,437.79</td>
<td>5,644.76</td>
<td>2,390.46</td>
<td>38,473.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.50</td>
<td>1.49</td>
<td>1.50</td>
<td>1.50</td>
<td></td>
</tr>
<tr>
<td>Expensive and narcotic drug checking</td>
<td>2,029.19</td>
<td>1,651.25</td>
<td>159.36</td>
<td>3,839.80</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.10</td>
<td>0.44</td>
<td>0.10</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>Nearly expired drug checking</td>
<td>129,664.99</td>
<td>26,951.42</td>
<td>10,183.34</td>
<td>166,799.75</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.39</td>
<td>7.12</td>
<td>6.39</td>
<td>6.50</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2,029,186.00</td>
<td>378,301.76</td>
<td>159,363.76</td>
<td>2,566,851.52</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td></td>
</tr>
</tbody>
</table>
2. Unit Cost of drug purchasing and inventory management.

This present study estimated three unit costs; 2.1 Activity cost, 2.2 Purchasing cost, 2.3 Carrying charge.

2.1 Activity cost

The unit cost of each activity in drug purchasing and inventory management was presented in Table 6. The inventory management activities included drug inventory dispensing, drug receiving, stock level checking, expensive and narcotic drug checking and nearly expired drug checking.

2.2 Purchasing cost

The purchasing cost was equivalent to 59.89 Baht per purchasing. This value was used to compute purchasing cost for each drug.

2.3 Carrying charge

Carrying charge, the cost in one Baht of carrying one Baht of inventory for one year. The carrying charge of drugs stored in refrigerator and drugs stored at room temperature were 0.0125 and 0.0120 (Baht/Baht/Year) on average. The carrying cost for each drug could be obtained by multiplying the average inventory value for each drug with carry charge constant.

Table 6 Activity cost per unit of drug purchasing and inventory management.

<table>
<thead>
<tr>
<th>Activities</th>
<th>Total cost (Baht)</th>
<th>Amount</th>
<th>Output</th>
<th>Unit cost (Baht)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Drug purchasing</td>
<td>821,692.90</td>
<td>13,720</td>
<td>Purchasing order</td>
<td>59.89</td>
</tr>
<tr>
<td>2. Drug inventory dispensing</td>
<td>1,651,461.84</td>
<td>18,569</td>
<td>Requisition order</td>
<td>88.94</td>
</tr>
<tr>
<td>3. Drug receiving</td>
<td>706,277.12</td>
<td>13,720</td>
<td>Invoice</td>
<td>51.48</td>
</tr>
<tr>
<td>4. Stock level checking</td>
<td>38,473.01</td>
<td>4</td>
<td>Time</td>
<td>9,618.25</td>
</tr>
<tr>
<td>5. Expensive and narcotic drug checking</td>
<td>3,839.80</td>
<td>1,440</td>
<td>Drug item</td>
<td>2.67</td>
</tr>
<tr>
<td>6. Nearly expired drug checking</td>
<td>166,799.75</td>
<td>132</td>
<td>report</td>
<td>1,263.63</td>
</tr>
</tbody>
</table>
Part 3. Inventory model

The Existing system; the criterion of drug purchasing was based on average monthly distribution from central drug inventory. In addition, a new drug order point was 70 percent of the monthly sales and quantities of drug order are up to 100-150% of the monthly sales. This system has not base on actual drug usage.

This part presented to apply the (s,S) inventory model for drug purchasing and inventory management. It comprises 3 parts for each drug; 1) Distribution test, 2) Forecasting, 3) Set inventory model

Eprex Prefilled Syringe 4000 U injection

During fiscal year 2006, Eprex was classified in group A of ABC inventory analysis and purchased by special case method. The characteristic of this drug is high value drug. The total value of Eprex dispensing from inventory during fiscal year 2006 was 32,630,496 Baht and the average inventory value was 2,012,024.94 Baht. Eprex required storage in the refrigerator that increase carrying cost. Thus, this drug should require tight inventory controls. The inventory situation of Eprex base on existing system was presented in figure8.
1. Distribution test

Kolmogorov-Smirnov goodness of fit test for number of Eprex dispensing per week during fiscal year 2005-2007 were used. The null hypothesis was that the number of Eprex dispensing was similar to the normal distribution. A statistical significance level set at 0.05. The statistical significance was 0.2000 that greater than 0.05. So the number of Eprex dispensing was normal distribution.

2. Forecasting

The forecast method that yielded the least Mean Square Error (MSE) was selected. The comparing MSE between forecasting methods was presented in Table 7.

Table 7 Comparing MSE of Eprex between forecasting methods.

<table>
<thead>
<tr>
<th>Method</th>
<th>MSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple</td>
<td>8,267.43</td>
</tr>
<tr>
<td>Holt’s</td>
<td>8,792.89</td>
</tr>
<tr>
<td>Brown’s</td>
<td>8,375.72</td>
</tr>
<tr>
<td>Damp</td>
<td>8,417.54</td>
</tr>
</tbody>
</table>

From Table 7, the best forecasting method for forecast the number of Eprex dispensing per week in fiscal year 2006 was simple exponential smoothing method. The value Mean Square Error (MSE) was 8,267.43.

Number of Eprex dispensing per week in fiscal year 2006 was forecasted from number of Eprex dispensing per week in fiscal year 2005 by using simple exponential smoothing method. Figure 9 presents forecasting demand of Eprex and actual demand in fiscal year 2006. The MSE was 6,906.97.
3. Set inventory model

In fiscal year 2006 the average replenishment lead time of Eprex was 11 days. Average forecast demand over a replenishment lead time was 407.09 syringes. Standard deviation and variance for forecast over a replenishment lead time were 104.18 and 10,853.82, respectively. The result of the demand forecasting that can determine inventory policy as follows: Safety Stock (SS) was 322 syringes, Reorder point (s) was 729 syringes, Economic Order Quantity (EOQ) was 267 syringes and Order up to level (S) was 996 syringes. In this study a cycle service level was set at 99.9 percent.

From the (s,S) model purchasing determine as follows:

- When inventory position equal to 729 syringes, order quantity equal to 267 syringes.
- When inventory position lower than 729, order quantity are equal to 267 syringes plus the difference between inventory position and 729 syringes.

The actual order quantity is round number to packing size 6 syringes. From the model above the inventory number of purchasing times increased from 12 to 43 times. The maximum order quantity was 372 syringes or 62 boxes. And minimum order quantity was 270 syringes or 45 boxes. The (s,S) model inventory simulation of Eprex was shown in Figure 10.
During fiscal year 2006, Metformin was classified in group A of ABC inventory analysis and purchased by price enquiry method. The characteristic of this drug is high utilization rate; the total number of Metformin dispensing from inventory during fiscal year 2006 was 6,495,500 tablets. Metformin is high volume and bulkiness that cause not enough storage space and stock out problems. The inventory situation of Metformin base on existing system was presented in figure 11.
1. Distribution test

Kolmogorov-Smirnov goodness of fit test for number of Metformin dispensing per week during fiscal year 2005-2007 were used. The null hypothesis was that the number of Metformin dispensing was similar to the normal distribution. The statistical significance of normality test was 0.0539 that greater than 0.05 so number of Metformin dispensing was normal distribution.

2. Forecasting

The forecast method that yielded the least Mean Square Error (MSE) was selected. The comparing MSE between forecasting methods was presented in Table 8.

<table>
<thead>
<tr>
<th>Method</th>
<th>MSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple</td>
<td>189,191,066.88</td>
</tr>
<tr>
<td>Holt’s</td>
<td>172,438,983.73</td>
</tr>
<tr>
<td>Brown’s</td>
<td>184,705,187.60</td>
</tr>
<tr>
<td>Damp</td>
<td>178,772,211.15</td>
</tr>
</tbody>
</table>

From Table 8, the best forecasting method for forecast the number of Metformin dispensing per week in fiscal year 2006 was Holt’s linear trend method. The value Mean Square Error (MSE) was 172,438,983.73.

Number of Metformin dispensing per week in fiscal year 2006 was forecasted from number of Metformin dispensing per week in fiscal year 2005 by using Holt’s linear trend method. Figure 12 presents forecasting demand of Metformin and actual demand in fiscal year 2006. The MSE was 393,281,729.22.
3. **Set inventory model**

In fiscal year 2006 the average replenishment lead time of Metformin was 11 days. Average forecast demand over a replenishment lead time was 150,102.76 tabs. Standard deviation and variance for forecasts over a replenishment lead time were 24,859.89 and 618,014,145.91, respectively. The result of the demand forecasting that can determine inventory policy as follows: Safety Stock (SS) was 76,823 tablets, Reorder point (s) was 226,926 tablets, Economic Order Quantity (EOQ) was 224,649 tablets, and Order up to level (S) was 451,575 tablets. In this study a cycle service level was set at 99.9 percent.

From the (s,S) model purchasing determine as follows:

- When inventory position equal to 226,926 tablets, order quantity equal to 224,649 tablets.

- When inventory position lower than 226,926 tablets, order quantity are equal to 224,649 tablets plus the difference between inventory position and 226,926 tablets.

The actual order quantity is round number to packing size 500 tablets. From the model above the inventory number of purchasing times increased from 17 to 21 times. The maximum order quantity was 243,000 tablets or 486 boxes. And minimum order quantity was 225,000 tablets or 450 boxes. The (s,S) model inventory simulation of Metformin was shown in Figure 13.
During fiscal year 2006, Vitamin B Complex tablet was classified in group B and purchased by price enquiry method. Drugs purchased from the Government Pharmaceutical Organization (GPO). The process of purchasing drug from GPO is more complicate than supplier. The lead time delivery is set for 30 days that the longest time for drug delivery. The inventory situation of Vitamin B Complex base on existing system was presented in figure 14.
1. Distribution test

Kolmogorov-Smirnov goodness of fit test for distribution was used. The null hypothesis was that the number of Vitamin B complex dispensing was similar to the normal distribution. The statistical significance of normality test was 0.0001 that less than 0.05 so number of Vitamin B Complex dispensing was non-normal distribution. Thus, other distributions consider to fitting the data. The weibull distribution befitted data; the statistical significance was 0.26241 that greater than 0.05.

2. Forecasting

The forecast method that yielded the least Mean Square Error (MSE) was selected. The comparing MSE between forecasting methods was presented in Table9.

Table9 Comparing MSE of Vitamin B Complex between forecasting methods.

<table>
<thead>
<tr>
<th>Method</th>
<th>MSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple</td>
<td>25,540,972.07</td>
</tr>
<tr>
<td>Holt’s</td>
<td>27,353,124.33</td>
</tr>
<tr>
<td>Brown’s</td>
<td>24,544,837.09</td>
</tr>
<tr>
<td>Damp</td>
<td>29,454,727.34</td>
</tr>
</tbody>
</table>

From Table9, the best forecasting method for forecast the number of Vitamin B Complex dispensing per week in fiscal year 2006 was Brown’s linear trend method. The value Mean Square Error (MSE) was 24,544,837.09.

Number of Vitamin B Complex dispensing per week in fiscal year 2006 was forecasted from number of Vitamin B Complex dispensing per week in fiscal year 2005 by using Brown’s linear trend method. Figure15 presents forecasting demand of Vitamin B Complex and actual demand in fiscal year 2006. The MSE was 54,961,688.22.
3. Set inventory model

In fiscal year 2006 the average replenishment lead time of Vitamin B Complex was 18 days. Average forecast demand over a replenishment lead time was 101,780.56 tablets. Standard deviation and variance for forecasts over a replenishment lead time were 11,888.23 and 141,330,055.43, respectively. The result of the demand forecasting that can determine inventory policy as follows: Safety Stock (SS) was 26,695 tablets, Reorder point (s) was 128,475 tablets, Economic Order Quantity (EOQ) was 262,103 tablets, and Order up to level (S) was 390,578 tablets. In this study a cycle service level was set at 99.9 percent.

From the (s,S) model purchasing determine as follows:

- When inventory position equal to 128,475 tablets, order quantity equal to 262,103 tablets.
- When inventory position lower than 128,475 tablets, order quantity are equal to 262,103 tablets plus the difference between inventory position and 128,475 tablets.

The actual order quantity is round number to packing size 1000 tablets. From the model above the number of purchasing times increased from 6 to 8 times. The maximum order quantity was 267,000 tablets or 267 boxes. And minimum order quantity was 261,000 tablets or 261 boxes. The (s,S) model inventory simulation of Vitamin B Complex was shown in Figure 16.
Part 3. Inventory performance

Drug inventory performance was indicated by three parameters as follows:

1. Average inventory values was calculated by total inventory value in fiscal year 2006 divided by 365 (day).

2. Inventory turnover equals the ratio of the total number of items used per year to the average daily inventory.

3. Inventory cost was composed of purchasing cost and carrying cost.

It is widely accepted that good inventory management could be shown by the low inventory value, high turnover rate and low cost. Inventory performances of the (s,S) model were compared with the existing system.

Eprex Prefilled Syringe 4000 U injection

1. Average inventory values

The average inventory level was 1,110.39 syringes. The unit value was 1,812.00 Baht. Thus, the average inventory value in fiscal year 2006 was 2,012,024.94 Baht (base on existing system). The (s,S) model; average inventory level was 581.65
syringes. Thus, the average inventory value was 1,053,953.52 Baht. For comparison of the average inventory value between 2 system, the (s,S) model decreased average inventory values was 958,071.42 Baht (47.62 %).

2. Inventory turnover

In the fiscal year 2006, Pharmacy department provided Eprex Prefilled Syringe 4000 U injection at total annual value was 25,512,960.00 Baht. The average inventory values base on existing system and (s,S) model from above. Thus, the inventory turnover increased from 12.68 to 24.21 (90.90%).

3. Inventory costs

The existing system; the total drug inventory management costs of Eprex Prefilled Syringe 4000 U injection in fiscal year 2006 were 25,796.30 Baht. These included 718.68 Baht for purchasing cost and 25,077.62 Baht for carrying cost. The (s,S) model; the total drug inventory management costs of Eprex Prefilled Syringe 4000 U injection tablet in fiscal year 2006 were 15,711.62 Baht. These included 2,575.28 Baht for purchasing cost and 13,136.34 Baht for carrying cost (Table 10).

Table 10 Comparing purchasing cost and carrying cost between the existing system and (s,S) model of Eprex

<table>
<thead>
<tr>
<th>Cost</th>
<th>Existing system (Baht)</th>
<th>(s,S) model (Baht)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchasing cost</td>
<td>718.68</td>
<td>2,575.28</td>
</tr>
<tr>
<td>Carrying cost</td>
<td>25,077.62</td>
<td>13,136.34</td>
</tr>
<tr>
<td>Total inventory cost</td>
<td>25,796.30</td>
<td>15,711.62</td>
</tr>
</tbody>
</table>

The existing system incurred the purchasing cost lower than the (s,S) model. In the opposite, (s,S) model had the carrying cost and the total costs of drug inventory management lower than the existing system. Thus, the total costs of drug inventory management were decrease 39.09%.

The result of comparing inventory performance between the existing system and (s,S) model of Eprex Prefilled Syringe 4000 U injection was presented in Table 11.
Table 11 Comparing purchasing cost and carrying cost between the existing system and (s,S) model of Eprex

<table>
<thead>
<tr>
<th>Performance indicator</th>
<th>Existing system</th>
<th>(s,S) model</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average inventory values</td>
<td>2,012,024.94</td>
<td>1,053,953.52</td>
<td>-47.62</td>
</tr>
<tr>
<td>Inventory turnover</td>
<td>12.68</td>
<td>24.21</td>
<td>+90.90</td>
</tr>
<tr>
<td>Inventory cost (Baht)</td>
<td>25,796.30</td>
<td>15,711.62</td>
<td>-39.09</td>
</tr>
</tbody>
</table>

**Metformin 500 mg tablet**

1. **Average inventory values**

The average inventory level of Metformin 500 mg tablet in fiscal year 2006 was 297,591.78 tablets. The unit value was 1 Baht. Thus, the average inventory value was 297,591.78 Baht (based on existing system). The (s,S) model; average inventory level was 216,027.10 tablets. Thus, the average inventory value was 216,027.10 Baht. For comparison of the average inventory value between two systems, the (s,S) model decreased average inventory values by 81,564.68 Baht (27.41%).

2. **Inventory turnover**

In the fiscal year 2006, Pharmacy department provided Metformin 500 mg tablet at total annual value was 5,041,197.00 Baht. The average inventory values based on existing system and (s,S) model from above. Thus the inventory turnover increased from 16.94 to 23.34 (37.76%).

3. **Inventory cost**

The existing system; the total drug inventory management costs of Metformin 500 mg tablet in fiscal year 2006 were 4,578.79 Baht. These included 1,018.13 Baht for purchasing cost and 3,560.65 Baht for carrying cost. The (s,S) model; the total drug inventory management costs of Metformin 500 mg tablet in fiscal year 2006 were 3,842.43 Baht. These included 1,257.69 Baht for purchasing cost and 2,584.74 Baht for carrying cost (Table 12).
Table 12 Comparing purchasing cost and carrying cost between the existing system and (s,S) model of Metformin

<table>
<thead>
<tr>
<th>Cost</th>
<th>Existing system (Baht)</th>
<th>(s,S) model (Baht)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchasing cost</td>
<td>1,018.13</td>
<td>1,257.69</td>
</tr>
<tr>
<td>Carrying cost</td>
<td>3,560.65</td>
<td>2,584.74</td>
</tr>
<tr>
<td>Total inventory cost</td>
<td>4,578.79</td>
<td>3,842.43</td>
</tr>
</tbody>
</table>

The existing system incurred the purchasing cost lower than the (s,S) model. In the opposite, (s,S) model had the carrying cost and the total costs of drug inventory management lower than the existing system. Thus, the total costs of drug inventory management were decrease 16.08%.

The result of comparing inventory performance between the existing system and (s,S) model of provided Metformin 500 mg tablet was presented in Table 13.

Table 13 Comparing inventory performance between the existing system and (s,S) model of Metformin

<table>
<thead>
<tr>
<th>Performance indicator</th>
<th>Existing system (Baht)</th>
<th>(s,S) model (Baht)</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average inventory values</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Baht)</td>
<td>297,591.78</td>
<td>216,027.10</td>
<td>-27.41</td>
</tr>
<tr>
<td>Inventory turnover</td>
<td>16.94</td>
<td>23.34</td>
<td>+37.76</td>
</tr>
<tr>
<td>Inventory cost (Baht)</td>
<td>4,578.79</td>
<td>3,842.43</td>
<td>-16.08</td>
</tr>
</tbody>
</table>

Vitamin B Complex tablet

1. Average inventory values

The average inventory level of Vitamin B Complex in fiscal year 2006 was 385,662.09 tablets. The unit value was 0.3 Baht. Thus, the average inventory value was 115,698.63 Baht (base on existing system). The (s,S) model; average inventory level was 49,690.15 tablets. Thus, the average inventory value was 49,690.15 Baht.
For comparison of the average inventory value between 2 system, the (s,S) model decreased average inventory values was 66,008.47 Baht (57.05%).

2. Inventory turnover
In the fiscal year, Pharmacy department provided Vitamin B Complex tablet at total annual value was 599,461.20 Baht. The average inventory values base on existing system and (s,S) model from above. Thus the inventory turnover increased from 5.18 to 12.06 (132.84 %).

3. Inventory cost
The existing system; the total drug inventory management costs of Vitamin B Complex in fiscal year 2006 were 1,743.66 Baht. These included 359.34 Baht for purchasing cost and 1,384.32 Baht for carrying cost. The (s,S) model; total drug inventory management costs of Vitamin B Complex in fiscal year 2006 were 1,073.66 Baht. These included 479.12 Baht for purchasing cost and 594.54 Baht for carrying cost (Table 14).

Table 14 Comparing purchasing cost and carrying cost between the existing system and (s,S) model of Vitamin B Complex

<table>
<thead>
<tr>
<th>Cost</th>
<th>Existing system (Baht)</th>
<th>(s,S) model (Baht)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchasing cost</td>
<td>359.34</td>
<td>479.12</td>
</tr>
<tr>
<td>Carrying cost</td>
<td>1,384.32</td>
<td>594.54</td>
</tr>
<tr>
<td>Total inventory cost</td>
<td>1,743.66</td>
<td>1,073.66</td>
</tr>
</tbody>
</table>

The existing system incurred the purchasing cost lower than the (s,S) model. In the opposite, (s,S) model had the carrying cost and the total costs of drug inventory management  lower than the existing system. Thus, total drug inventory management costs of Vitamin B Complex were decrease 38.43 %.

The result of comparing inventory performance between the existing system and (s,S) model of provided Vitamin B Complex tablet was presented in Table15
Table 15 Comparing inventory performance between the existing system and (s,S) model of Vitamin B Complex

<table>
<thead>
<tr>
<th>Performance indicator</th>
<th>Existing system</th>
<th>(s,S) model</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average inventory values (Baht)</td>
<td>115,698.63</td>
<td>49,690.15</td>
<td>-57.05</td>
</tr>
<tr>
<td>Inventory turnover</td>
<td>5.18</td>
<td>12.06</td>
<td>+132.84</td>
</tr>
<tr>
<td>Inventory cost (Baht)</td>
<td>1,743.66</td>
<td>1,073.66</td>
<td>-38.43</td>
</tr>
</tbody>
</table>

Summary of major finding

1. Activity analysis

Drug purchasing activity has 4 sub activities. Total time spent on drug purchasing activity in fiscal year 2006 was 6,174 hours or accounted to 36.18% of total working time.

Drug inventory management has 5 activities and 19 sub activities. The total time spent on drug inventory management in fiscal year 2006 was 32,151.12 hours. The drug inventory dispensing activity had spent the highest proportion time of working time (65.20%).

2. Cost analysis

Total cost of drug dispensing was 821,692.90 Baht. Labor cost, material cost and capital cost were 668,452.93 Baht, 152,940.02 Baht and 299.95 Baht, respectively. The purchasing cost was equivalent to 59.89 Baht per purchasing.

Total cost of drug inventory management was 2,566,851.52 Bath. Labor cost, material cost and capital cost were 2,029,186.00 Baht, 378,301.76 Baht and 159,363.76 Baht, respectively. The carrying charge of drugs stored in refrigerator and drugs stored at room temperature were 0.0125 and 0.0120 (Baht/Baht/Year) on average.

3. Inventory model

Epren Prefilled Syringe 4000 U injection; when the inventory position equal to 729 syringes or lower, order to raise the inventory position to 996 syringes. The actual order quantity is round number to packing size is 6 syringes.
Metformin 500 mg tablet; when the inventory position equal to 226,926 tablets or lower, order to raise the inventory position to 451,575 tablets. The actual order quantity is round number to packing size is 500 tablets.

Vitamin B Complex tablet; when the inventory position equal to 128,475 tablets or lower, order to raise the inventory position to 390,578 tablets. The actual order quantity is round number to packing size is 1000 tablets.

4. Inventory performance

Average inventory values

The (s,S) model decrease the average inventory value of Vitamin B Complex was the highest (57.05%), Eprex was lower (47.62 %) and Metformin was lowest (27.41%).

Inventory turnover

The (s,S) model increase the inventory turnover of Vitamin B Complex was the highest (132.84 %), Eprex was lower (90.90%) and Metformin was lowest (37.76%).

Inventory cost

The (s,S) model decrease total costs of drug inventory management of Eprex was the highest (39.09%), Vitamin B Complex was lower (38.43 %) and Metformin was lowest (16.08%).

From the result of this study, The application of (s,S) model can improve the efficiency of drug purchasing and inventory management at Ramathibodi Hospital in fiscal year 2006.
The purpose of this study is to find out if re-order point model can improve the efficiency of drug inventory management at Ramathibodi Hospital. The re-order point model used in this study is (s,S) model.

The discussion presented in five parts as follows:

Part 1 Activity analysis
Part 2 Cost analysis
Part 3 Inventory model
Part 4 Inventory performance
Part 5 Limitation of this study

Part 1. Activity analysis

One way to understand processes and activities more clearly is using functional flow diagram, it is used for showing departmental or individual responsibilities in a process flow. This tool can provide a quickly understood picture of the activities involved, and who does them. The creation with documenting the material flows provides useful knowledge for identifying activities and resources. In this study, the functional flow diagrams of drug purchasing and inventory management process were constructed.

The functional flow diagram of drug purchasing process was showed that purchasing document was sent and approved in many divisions. The process has long waiting period such as waiting for documents approval. The complexity of drug purchasing issue is complexity may due to the regulation. The drug purchasing issue follows by the Prime Minister Office Regulation on Procurement, 2535 B.E; the purchasing issue must approved by purchasing committee. However every hospital
under supervised by the Ministry of Public Health used the same present regulation in purchasing but methods and details of purchasing may be different. It happened because of the different explanations. In some hospitals, executives created their own systems to support regulation on procurement. This made the details of purchasing was different.

The inventory management process comprises 5 activities following; drug inventory dispensing, drug receiving, stock level checking, expensive and narcotic drug checking, and nearly expired drug checking. Drug inventory dispensing activity and drug receiving activity are main activities because of both activities are daily routine. The average time spent of inventory dispensing activity and drug receiving activity was 65.20% and 26.81% of total working time, respectively. The functional flow diagrams of both activities were showed that the data of drug dispensing and receiving was recorded in both stock card and computer. They were redundant work that needed for considering. The activity time spent of drug purchasing and inventory unit was the same way of the survey inventory activity time among public and private hospitals (38). It found that they had spent the most time for receiving drug, ordering drug, drug requisitioned order and checking inventory.

**Part 2. Cost analysis**

In this study determined the direct costs of drug purchasing and inventory management activities base on activity-based costing (ABC). Total direct costs were acquired from the total of labor costs, material costs and capital costs.

Total cost of drug dispensing was 821,692.90 Baht. The labor cost became as the largest portion was 81.35% of total cost. The reason was many steps in the process of purchasing and uses the executive staffs; head of pharmacy department, head of drug purchasing unit and pharmacist. The record and print out purchasing order and sign to authorize by pharmacist and head of pharmacy department sub activity cost was highest (489,004.32 Baht), which accounted for 59.51% of total cost.

The purchasing cost was equivalent to 59.89 Baht per purchasing order. The purchasing process done in Ramathibodi hospital had different methods. In this
study, the purchasing cost analysis in the process of purchasing would assume that cost of each method was equal.

Total cost of drug inventory management was 2,566,851.52 Baht. The labor cost became as the largest portion was 79.05% of total cost. The drug inventory dispensing activity cost was the highest (1,651,461.84 Baht), which accounted for 64.34% of total cost. The record data in stock card sub activity cost was the highest (728,061.18 Baht), which accounted for 28.36% of total cost. The drug inventory dispensing was the highest activity cost from the most staff and time to perform this activity. The record data in stock card activity; staffs that responsible on each drug were count and record quantities of drug remain in inventory after drug dispensing and receiving. This sub activity was the highest cost. Since, this sub activity is a manual record that takes time to find stock card of each drug.

The carrying charge of drugs stored in refrigerator and drugs stored in room temperature were 0.0125 and 0.0120 (Baht/Baht/year) on average, respectively. This carrying charge implied that the carrying cost was 1.25% and 1.20% of the average inventory value. In this study assumes that more expensive items are apt to be riskier to carry and more expensive to handle or store.

In Thailand, The past studies of the cost of purchasing and inventory management, they were studied both private hospitals and public hospital. Some studies determined full cost of both direct and indirect cost but some concerned only direct cost. The studies were conducted in Sena hospital (39) and Chachoengsao hospital (40) revealed that the full cost drug stock was 751,422.22 Baht and 2,210,929.42 Baht respectively. Kattiviriyaoinyo K. studied about assessment of drug purchasing system of private hospitals in 1998 (18). The study conducted in 2 private hospitals showed that the direct cost of purchasing was 592,733 and 432,946 Baht. And the direct cost of inventory control was 2,294,497 Bath and 530,160 Baht.

In this study, the capital cost was the smallest portion because the drug purchasing unit and drug inventory management unit was located at building over 20 years, thus depreciation cost was determined as one Baht. The smallest portion of capital cost was similar to the study in Sena and Chachoengsao hospital (39) (40). The results of studies come out different. Thus, there were not constant optimal purchasing
and inventory management costs for all hospitals, but that they may depend on size of hospital, basic environment, private or public hospital and purchasing and inventory management.

**Part 3. Inventory model**

A major concern in an inventory management is to decide about the time when a replenishment order is to be placed and further what quantity of such replenishment is to be ordered. The \((s,S)\) model was applied in this study.

For the implementation the \((s,S)\) was concerned in drug regulation which might have problem. The result of this study, the \((s,S)\) model order drugs more often than the existing system. According to the Prime Minister Office Regulation on Procurement, 2535 B.E. purchasing process comprises five categories; price agreement, price enquiry, price bidding, special case method and special method. The problem of using the \((s,S)\) model under regulation, the price agreement would be the frequency of purchasing. Metformin and Vitamin B complex purchase by this method. The price agreement was the process of drug purchasing, which was so convenient. It has also fewer steps than others. If purchasers often used the price agreement, they would be judged that they intended to against the law by dividing the amount of amount of money in purchasing to fit this process.

The \((s,S)\) model assumes continuous review. The advantage of this model may be able to effectively cope with situation where demands are large. The disadvantage is variable order quantity. Suppliers could make errors more frequently; and they certainly prefer the predictability of a fixed order quantity.

**Part 4. Inventory performance**

The past studies of problems in drug purchasing and inventory management, they found the common problems such as lack of personnel, expired drug, storage space and low inventory performance \((4)\) \((9)\). Ramathibodi hospital has problems as similar as above.
The purpose of this study is to find out if re-order point model can improve the efficiency of drug inventory management at Ramathibodi Hospital by employing inventory performance data during the fiscal year 2006. Inventory management indicators were indicated the performance of inventory management. Indicators indicated only how well drug inventory system performance. Drug inventory indicators in this study were average inventory values, inventory turnover and inventory cost. It is widely accepted that good inventory management could be shown by the low inventory value, high turnover rate and low cost. The comparison of inventory performance indicators between the existing system and (s,S) model performed in this study.

**Average inventory values**

The inventory reduction represents one of the major benefits of the implementation inventory control system. The comparison of the average inventory value between two systems found that the (s,S) model decrease the average inventory value of Vitamin B Complex was the highest (57.05%), Eprex was lower (47.62 %) and Metformin was lowest (27.41%). In this study a service level was set at 99.9 percent. So, the (s,S) model are available for reducing inventory without reducing service levels.

**Inventory turnover**

Inventory turnover equals the ratio of the total number of items used per year to the average daily inventory. The Ministry of Public Health suggested an indicator in the development of the inventory management of a hospital. That indicator was inventory turnover. A good inventory system of hospital should have the inventory turnover not less than 4.

In this study, Eprex, Metformin and Vitamin B Complex showed that the inventory turnover of the existing was 12.68, 16.94 and 5.18 while the inventory turnover of the (s,S) model was 24.21, 23.34 and 12.06, respectively. The comparison of the inventory turnover between two systems found that in the (s,S) model increase
the inventory turnover of Vitamin B Complex was the highest (132.84 %), Eprex was lower (90.90%) and Metformin was lowest (37.76%).

The survey inventory turnover value studied among hospital in Thailand founds that the inventory turnover of public hospital was 6-9.3 and private hospital was 8.8-10.2 (38). Khon Kaen hospital had the inventory value 7.89. For all 3 drugs had the inventory turnover higher than the amount suggested by the Ministry of Public Health. Eprex and Metformin had the inventory turnover higher than range of the other hospitals except Vitamin B Complex.

Inventory cost

The objective of an inventory control system is to make that minimize the total cost of inventory. Most pharmacy inventory decisions involve replenishment. There are costs associated with pharmacy inventory such as ordering cost and carrying cost (41).

The comparison of total costs of drug inventory management between two systems among selected drugs showed that the (s,S) model decrease total costs of drug inventory management of Eprex was the highest (39.09%), Vitamin B Complex was lower (38.43 %) and Metformin was lowest (16.08%). The (s,S) model; the highest decreasing total costs of drug inventory management was Eprex. Due to Eprex was the high inventory value. If the inventory level reduction would lead to low cost of inventory management too.

Analysis of purchasing cost and carrying cost found that in the existing system incurred the purchasing cost lower than the (s,S) model. In the opposite, (s,S) model had the carrying cost and the total costs of drug inventory management lower than the existing system. Because the frequency of drug purchasing in the (s,S) model was higher than the existing system.

From the result of this study found that the (s,S) model reduced the average inventory value and inventory cost of Eprex equal 958,071.42 and 10,084.69 Baht in fiscal year 2006. So, this model appropriate saving budget for high value drug. For bulkiness drug are Metformin, inventory turnover rate would be considered. The increment of inventory turnover rate that would be reflects the problem of storage
space. Drug purchased from the Government Pharmaceutical Organization (GPO), Vitamin B complex. The result of comparing inventory performance between the existing system and (s,S) model of Vitamin B Complex tablet presented the best improvement of both the average inventory value and turnover rate. Anyway, the process of purchasing from GPO was more complicate than other suppliers.

**Part5. Limitation of this study**

This study had several limitations as follows:

1. This study was conducted in only one hospital that a government teaching hospital. It is more complicate than the other hospitals.
2. The three drugs case study can not reflect all drug items in hospital.
3. The only direct costs of drug purchasing and inventory management activities were analyze in this study.
4. Since data were collected retrospectively, some data were estimated because actual data were not available.
CHAPTER VI
CONCLUSION AND RECOMMENDATIONS

This chapter provides the conclusion and recommendations. The purpose of this study is to find out if re-order point model can improve the efficiency of drug inventory management at Ramathibodi Hospital by employing inventory performance data during the fiscal year 2006. Three drugs were selected as following: Eprex Prefilled Syringe 4000 U injection, Metformin 500 mg tablet and Vitamin B Complex tablet. The criteria for drugs selection divided by type of problems of drug inventory management.

Conclusion of the study

The analysis process of drug purchasing and inventory management was summarized as follows: the functional flow diagram and activity dictionary. In this study, it found that drug purchasing activity has 4 sub activities and drug inventory management has 5 activities and 19 sub activities. The total direct costs of drug purchasing and inventory management activities base on activity-based costing (ABC). The present study was conducted at the drug purchasing and drug inventory control unit of the pharmacy department, Ramathibodi Hospital. It found that the purchasing cost was equivalent to 59.89 Baht per purchasing order. The carrying charge of drug store in refrigerator and drug store in room temperature was 1.25% and 1.20% of the average inventory value.

The (s,S) model was applied in this study. The forecasting methods for the data use to find the Mean Square Error (MSE) and choose the method of the least error. The best forecasting method used to forecast the demand. Then the forecasting demands applied to find the appropriate re-order point and order up to level of each case study drugs.
Inventory performance indicators indicating the efficiency of drug inventory management composed of average inventory values, inventory turnover, and inventory costs. The comparison of inventory performance indicators between the existing system and (s,S) model performed in this study. The result of this study showed that based on the (s,S) model had lower average inventory value, higher turnover rate and lower cost than the existing system.

The study concludes that if the (s,S) model was implemented, the efficiency of drug inventory management would be improve.

**Recommendations**

There are some recommendations occur from the study.

1. For higher performance of inventory management hospitals should be more concerned with the quantity of drug purchasing.

2. The regulations for drug purchasing some obstacles for drug purchasing and inventory management in both the existing and (s,S) model. So to become successful in implement, the government should modify the regulations related to drug purchasing. They could set the frequency of purchasing in each item as many times as required such as of the price agreement purchasing method.

3. Electronic database and computer technology of the hospital is an important source of information and knowledge for hospital management. It can help in management and administration creates a system. For that reason, it should be continuously developed for improvement system of hospital.

Recommendations for future studies could be summarized as following.

1. Because only 3 case-study drugs were analyzed in this study, it would be beneficial to study in more characteristics.

2. The possibility study of (s,S) model the hospital inventory management should be conducted.
REFERENCES


3. คนองยุทธ กาญจนกูล, วิชิรพันธ์ จันทมาศ, เรณู สุขารมย์. โครงการศึกษาวิจัยต้นทุนโรงพยาบาลระดับจังหวัด. กรุงเทพมหานคร: โรงพิมพ์สำนักข่าวพานิช 2526.


10. จิรุตม์ ศรีรัตนบัลล์, สมเกียรติ โพธิสัตย์, ธัญญา สุนันท์ และคณะ. เครื่องชี้วัดคุณภาพโรงพยาบาลพันธ์ครั้งที่. กรุงเทพมหานคร: สถาบันพัฒนาและรับรองคุณภาพโรงพยาบาล 2543.


17. นิยรัตน์ ศรัทธานิPTS. การจัดระบบข้อมูลทางเภสัชกรรมเพื่อสนับสนุนบทบาทของคณะกรรมการเภสัชกรรมและการบริการ. ป.ที่; 2539.


29. ชัยสิทธิ์เฉลิมมีประเสริฐ. ความพร้อมของหน่วยงานภาครัฐในการบริหารจัดการระบบงบประมาณแบบมุ่งเน้นผลงานตามยุทธศาสตร์ชาติ (Strategic Performance Based Budgeting:SPBB) และกรณีตัวอย่างการบริหารจัดการงบประมาณสำหรับกรมควบคุมโรค (พิมพ์ครั้งที่ 2). กรุงเทพมหานคร: บัณฑิต นรรธาภิเษก จำกัด; 2544.


34. Methacanon, T. Activity-Based costing of the pharmacy dispensing service in the outpatient unit in Ladyao Hospital, Nakhonsawan Province, Thailand [Master degree of science (Public health)]. Bangkok: Mahidol University.

35. คณะแพทยศาสตร์โรงพยาบาลรามาธิบดี มหาวิทยาลัยมหิดล. รายงานประจำปี 2549 คณะแพทยศาสตร์โรงพยาบาลรามาธิบดี มหาวิทยาลัยมหิดล. กรุงเทพฯ; 2549.

36. ดร.มุกดา เมฆนิชทร์. อนุกรมเวลาและการพยากรณ์ Time series and Forecasting. กรุงเทพฯ: สำนักพิมพ์ประชาพิพัฒน์; 2549.


APPENDIX A
FUNCTIONAL FLOW DIAGRAM OF DRUG PURCHASING AND INVENTORY MANAGEMENT

Functional flow diagram of drug purchasing
Functional flow diagram of drug purchasing (cont.)

1. Send document

Receive document

Record permit purchasing order

Record date of supplier representative receive purchasing order

Deliver drug

Check document

Yes

Head of pharmacy department sign in

Send document to central inventory unit

Finish

No

Revise

1. Proceed in purchasing

Determine and Sign in purchasing order

Proceed in purchasing

Proceed in purchasing

Proceed in purchasing

Proceed in purchasing

Receive drug
Functional flow diagram of drug inventory dispensing process

<table>
<thead>
<tr>
<th>Drug rooms</th>
<th>Drug inventory control unit</th>
<th>Purchasing unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Request order 1</td>
<td>Stamp original and copy on request order</td>
<td>Original and copy request order</td>
</tr>
<tr>
<td>Consider narcotic drug request order</td>
<td>Arrange drug and record quantity in request order and stock card</td>
<td>Arrange check drug and record</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Copy</td>
<td>Original</td>
<td>Copy</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Check drug and record</td>
<td>Check correction of original and copy request order</td>
<td>Check correction of original and copy request order</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Revise</td>
<td>Revise</td>
<td>Revise</td>
</tr>
<tr>
<td>Delivery drug with copy request order</td>
<td>Summary dispensing report</td>
<td>Summary drug cannot dispensing report</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Revise</td>
<td>Revise</td>
<td>Revise</td>
</tr>
<tr>
<td>Check correction of record and drug cannot dispensing list by pharmacist</td>
<td>Check correction of record and drug cannot dispensing list by pharmacist</td>
<td>Check correction of record and drug cannot dispensing list by pharmacist</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Pharmacist sign in original request order and record report</td>
<td>Send original request order and record report</td>
<td>Send original request order and record report</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Update stock</td>
<td>Update stock</td>
<td>Update stock</td>
</tr>
<tr>
<td>Finish</td>
<td>Finish</td>
<td>Finish</td>
</tr>
<tr>
<td>Start</td>
<td>Start</td>
<td>Start</td>
</tr>
</tbody>
</table>
## Functional flow diagram of drug receiving

### Functional flow diagram of drug receiving process

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Drug inventory control unit</th>
<th>Purchasing unit</th>
<th>Central inventory department</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tax invoice: original and 3 copies</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PO: original and 2 copies</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Invoice: original and 8 copies</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quality report</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Revise</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drug deliver</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reject drug, return document and delete data</td>
<td>No (reject)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deliver staff sign in Receiving Report</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Check correction of documents

- Yes: Arrange Document
- No: Invoice copy 1, Invoice copy 2

### Record data for drug receiving

- Yes: Checking report and Receiving Report with name of committee
- No: No

### Check drug by committee from pharmacy department

- Yes: Check drug by inventory staff
- No: Check drug by committee from other department

### Check drug by committee from other department

- Yes: Check drug by inventory staff
- No: Reject drug, return document and delete data

### Record in receiving book

- Yes: Committee sign in Checking report and Receiving Report
- No: Reject drug, return document and delete data

### Committee sign in Checking report and Receiving Report

- Yes: Record in stock card
- No: Reject drug, return document and delete data

### Document for committee

- Yes: Invoice copy 1, Invoice copy 2
- No: No
Functional flow diagram of drug receiving (cont.)
Functional flow diagram of stock level checking

Inventory control unit

Start

Print out stock level

Report stock level

Check actual stock level compare with stock card

Yes

Pharmacist sign in stock card

Check stock card compare with report

Yes

Stamp date

Note: Check stock level every 3 month

Revise

No

Revise

No
Functional flow diagram of expensive and narcotic drug checking

Inventory control unit

- Start
- Check drug quantity in stock card compare with report
  - Yes
    - Pharmacist sign in stock card
    - Finish
  - No
    - Check and revise
- Note: Check every week

Functional flow diagram of nearly expired drug checking

Inventory control unit

- Start
- Checking nearly expired drugs
  - Yes
    - Record in report
  - No
    - Record in report
- Proceed in exchange nearly expire drug
- Finish
- Note: Check every month
APPENDIX B

DEMAND DISTRIBUTION


<table>
<thead>
<tr>
<th>Kolmogorov-Smirnov</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistic</td>
</tr>
<tr>
<td>0.0477</td>
</tr>
</tbody>
</table>

Histogram of Eprex demand per week during fiscal year 2005-2007

<table>
<thead>
<tr>
<th>Statistic</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0708</td>
<td>156</td>
<td>0.0539</td>
</tr>
</tbody>
</table>

Histogram of Metformin demand per week during fiscal year 2005-2007

<table>
<thead>
<tr>
<th>Kolmogorov-Smirnov</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistic</td>
</tr>
<tr>
<td>0.1126</td>
</tr>
</tbody>
</table>

Histogram of Vitamin B complex demand per week during fiscal year 2005-2007


<table>
<thead>
<tr>
<th>Kolmogorov-Smirnov</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistic</td>
</tr>
<tr>
<td>0.07981</td>
</tr>
</tbody>
</table>
BIOGRAPHY

NAME
Miss. Chuleeporn Laeiddee

DATE OF BIRTH
August 4th, 1981

PLACE OF BIRTH
Bangkok, Thailand

INSTITUTIONS ATTENDED
Huachiew Chalermprakiet University, 1999-2004: Bachelor of Science in Pharmacy
Mahidol University, 2009: Master of Science in Pharmacy (Pharmacy Administration)

EMPLOYMENT ADDRESS
Huachiew Hospital, Bangkok, Thailand
Position: Pharmacist
Tel. 02-2231351
E-mail: fon_chu@yahoo.com