

**DEVELOPMENT AND ANALYSIS OF INVENTORY MODEL
FOR VITAL AND HIGH VALUE MEDICINE
IN RAMATHIBODI HOSPITAL**



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OF THE REQUIREMENTS FOR
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DEVELOPMENT AND ANALYSIS OF INVENTORY MODEL FOR VITAL AND HIGH VALUE MEDICINE IN RAMATHIBODI HOSPITAL

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ABSTRACT

Appropriate medicine inventory management in a hospital is important because it has a direct effect on patients. Medicines that are vital to the life of patients should not be in shortage. Many hospitals have stocked medicines in their warehouse. However, when medicine inventory is too high, the cost of management is increased. If the medicine inventory is not kept at adequate levels, shortages may occur. Therefore, this thesis aims to develop mathematical models to handle medicine inventory in order to stock medicine at proper amounts. High-value and vital (AV-type) medicines are considered in this study.

The results show that if the hospital in this study implements proposed policy base on developed models to manage AV-type medicines, the average medicine stock will decrease, with savings of 759,708.14 Baht, and the average medicine inventory turnover will increase. Moreover, the average number of orders per year, the average days of shortages per year, the average quantity of shortages per year, and the average number of times of stock shortage per year will decrease. Thus the proposed policy can reduce medicine stock and medicine management costs.

KEY WORDS: MEDICINE INVENTORY MANAGEMENT / UNCERTAIN
DEMAND / REORDER POINT / ORDER QUANTITY

165 pages

การวิเคราะห์และพัฒนาตัวแบบสำหรับการจัดการยาคลังในกลุ่มที่มีมูลค่าสูงและมีความสำคัญต่อชีวิตของโรงพยาบาลรามาทิบดี

DEVELOPMENT AND ANALYSIS OF INVENTORY MODEL FOR VITAL AND HIGH
VALUE MEDICINE IN RAMATHIBODI HOSPITAL

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บทคัดย่อ

การจัดการยาคลังในโรงพยาบาลให้เหมาะสมเป็นสิ่งที่มีความสำคัญอย่างมาก โดยเฉพาะการจัดการยาคลังที่มีความสำคัญมากต่อชีวิตของผู้ป่วย ซึ่งโรงพยาบาลส่วนใหญ่จะสำรองยาคลังประเภทนี้ให้มีปริมาณมากเกินไปเพื่อมิให้เกิดการขาดแคลน แต่การสำรองยาคลังในปริมาณมากจะเพิ่มต้นทุนในการบริหารยาคลัง หากสำรองน้อยเกินไปจะเกิดการขาดแคลน ดังนั้นเพื่อให้มีการสำรองยาคลังในปริมาณที่เหมาะสม งานวิจัยนี้จึงพัฒนาตัวแบบทางคณิตศาสตร์สำหรับการจัดการยาคลังในโรงพยาบาล โดยเลือกศึกษายาคลังในกลุ่มที่มีมูลค่าสูงและมีความสำคัญต่อชีวิต(AV) ของโรงพยาบาลรามาทิบดี จากนั้นทำการวิเคราะห์หาแนวโน้มและการแจกแจงของความต้องการใช้ยา และพัฒนาตัวแบบทางคณิตศาสตร์เพื่อคำนวณหาจุดสั่งซื้อ ปริมาณการสั่งซื้อ และระดับยาคลังสูงสุดที่เหมาะสม และเปรียบเทียบดัชนีชี้วัดยาคลังระหว่างนโยบายที่ได้กับนโยบายปัจจุบันของโรงพยาบาล

ผลการศึกษาพบว่า ถ้าโรงพยาบาลสั่งซื้อยาตามนโยบายที่นำเสนอจะสามารถลดปริมาณยาคลังคิดเป็นมูลค่าได้ประมาณ 759,708.14 บาท ลดการขาดแคลนของยาทั้งปริมาณที่ขาดแคลนและระยะเวลาที่ขาดแคลน นอกจากนี้ยังสามารถเพิ่มอัตราการหมุนเวียนของยาคลัง ดังนั้นนโยบายที่นำเสนอนี้สามารถลดปริมาณยาคลังและต้นทุนในการบริหารจัดการยาคลังของโรงพยาบาลได้

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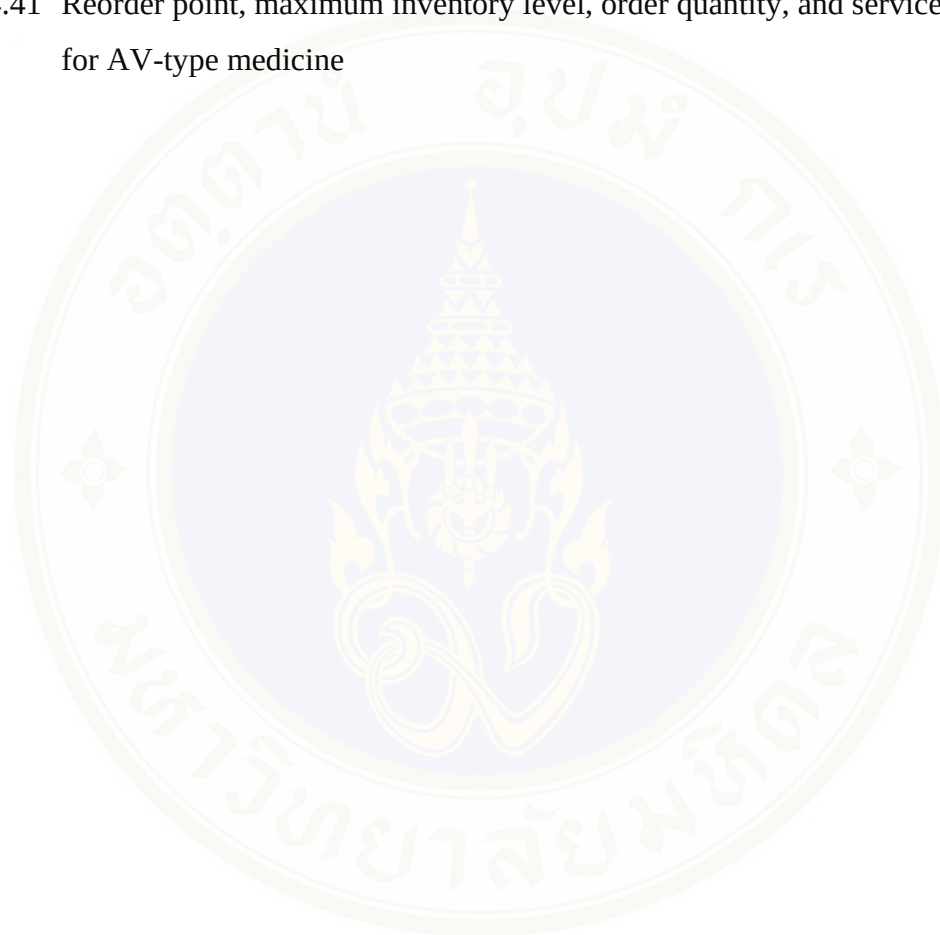
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CHAPTER I

INTRODUCTION

In this chapter, introduction, objectives of work, scope of work, and expected results will be explained. The details are as follows:

1.1 Introduction

Inventory management system is used for organizing, storing, and replacing inventory to distribute products according to customers' demand (Sudtiwadnarupud, Phamornstid, & Doungpatra, 2004, p.71). Inventories are related to raw materials, work in process (assembly line task), finished goods, the assembly or others material. Inventory management involves placing order, quality checking, stocking, sorting, and recording information. This system enables us to analyze cost and service level more easily. Therefore, many organizations pay attention to this system because it helps to balance demand and supply by maintaining inventory level and by controlling suitable cost (Lalitapon, 2006, pp. 230-232).

Generally, the stock of inventory is an investment that has the highest value in current asset. (Sudtiwadnarupud et al., 2004, p. 96; Sringkansiri, 2005, p.77) Thus, it requires cautious management. If inventory is over-stocked, the organization will waste money for stocking and holding it. As a result, the company will have less investment turnover because current asset cannot be used in other activities unless the inventory is distributed and converted back to money. Moreover, over-stocked inventory may affect business liquidity and profit. In contrast, if inventory is under-stocked, there will be inadequate products to deliver to customers, causing higher back order cost, penalty cost, customer lose, and less work efficiency.

Inventory management policies are crucial to inventory management, since they associate with time and quality of order. Presently, there are many inventory management policies constructed worldwide. In Thailand, inventory policies are

applied to various manufacturing industries. However, they are not widely applied to service industries especially in hospitals. From engineering perspective, hospitals, a kind of service industries, have many products such as medicine, medical equipment, and non medical equipment such as beds, cloths, and foods for patients, etc. Hospitals need to manage these products to satisfy patients' expectation, to raise the quality of service level, and to control the cost of hospitals.

This research applied inventory management in service industries, the hospital. Specifically, this paper is aim to research and analyze on how to manage inventory system of medicine stock in the hospital. Since medicine usage has significant impact on patients' lives and satisfaction, appropriate medicine inventory must contain high quality medicines, sufficient amount of medicines, and availability of all medicine items although they will be rarely use because medicines are essential and have direct effect on treatments. The excess inventory level will guarantee that there will be no shortage of medicines. However, it can lead to low liquidity. In contrast, if inventory is inadequate, it will not only have an effect on patients' health but also affect their mental health at the same time. For example, patients cannot be treated immediately due to the lack of medicine and patients may not be satisfied with services they received if they have to unnecessarily come back later. Nevertheless, there are other alternatives to solve the medicine shortage such as giving out prescription to a patient to purchase medicine at drug store. This leads to unsatisfaction of patients in terms of terrible services and bad management. Therefore, the inventory level has high impact on organization performance which results from inefficiency inventory management.

After interviewing people who are associated with the medicine inventory of the Ramathibodi hospital, there are two main problems currently occur in the hospital 1) some medicines are not sufficient for demand and 2) some medicines are being stored for long time and have shorter shelf life. There are contract agreements among the hospital and the supplier companies that the medicine can be exchanged, in fiscal year of 2008 medicine worth 7,350,000 Baht have been exchanged. This leads to high expenses including hiding cost occurred in medicine inventory processes when medicines is exchanged, opportunity cost of storage space utilization, the storage spaces of medicines which can be used for other purposes, the contact cost with

medicine companies. Furthermore, medicine companies may lose their opportunity to deliver the medicines to others hospitals and to other patients. The returned expired medicines will be buried or burnt which can be harmful to the environment. As a result, we can see that medicine improper management in hospital not only has a great impact to hospital and patients but also affects the manufacturers, other hospitals, other patients in the supply chain of such medicine, and our environment.

According to literature related to medicine inventory management, most of them have focused on Economic Order Quantity known as EOQ models. For example Rojsakga (2002) increased efficiency of inventory in pharmaceutical of Udon Thani hospital by using EOQ policy in order to calculate appropriate reorder point. The author solved the shortage problem of ten items of AV-type medicine and reduced the inventory cost 49,585.39 Baht. Suksrisomboon (2007) developed an inventory management system for The Royal Thai Air Force Medical Depot. He categorized medicines into different classifications; ABC and VEN classifications which will be discuss later in this paper. He only studied high value and life-critical medicine (AV-type medicine) and used EOQ model to calculate an appropriate inventory level, reorder point and order quantities. It is known that EOQ has limitations in constant demand which does not comply with all of medicines demand. According to the research of Kumsan (2006), he found only 9.79% or 166 items from total 1,695 items in health care facilities of Chiang Mai University have certain demand.

This research will analyze of ABC/VEN and focus on developing mathematical medicine inventory models with uncertain demand for medicines in AV-type. There are two main parts: forecasting the medicine demand and developing medicine inventory models. A new guideline of medical inventory management will be proposed.

1.2 Objectives of Work

The goal of this research is to analyze and to develop the medicine inventory models in the Ramathibodi hospital. In order to accomplish this goal, the objectives of this research are as follows:

- 1) Study the current processes of medicine inventory management and the ordering policy.
- 2) Propose the appropriate medicine inventory model in AV-type.
- 3) Recommend the guideline in order to develop the proper policy of medicine inventory management.

1.3 Scope of Work

This research developed new medicine inventory models of center warehouse in the Ramathibodi Hospital. First we classified medicine by using ABC/VEN categorization system and selected medicines in AV group, which is vital with highest value. This research analyzed data of dispensary medicines to patients, recorded between 2005 and 2008 in order to forecast medicine demands. Next, we studied the medicines characteristic such as the necessity of medicine, the methods of medicine storage, the shelf life of medicines, medicines storage space, the amount of dispensed medicines, the policy of ordering, lead time, reorder point, and quantity of ordering. Then, we developed medicine inventory models in AV-type. Finally, we compared key performance indicators of medicine inventory between the proposed policy and the current hospital's policy.

1.4 Expected Results

- 1) Understanding of the current processes and the problems of medicine inventory management in the Ramathibodi central warehouse.
- 2) Strategic suggestion to manage the medicine inventory and possible use of propose document to take part in general medicine inventory.

CHAPTER II

THEORETICAL BACKGROUND AND LITERATURE REVIEW

In this chapter, theoretical background and literature review related to the analysis of medicine inventory system in Ramathibodi hospital will be clarified. The details are as follows:

2.1 Theoretical Background

There are three streams of research related this research. Firstly, forecasting theories are used to forecast medicine demand pattern since the medicine demand is not constant. Secondly inventory theories which are the main stream of this research are used to develop medicine inventory. Thirdly, simulation is used to compare the proposed policy and the current policy.

2.1.1 Forecasting Theories

2.1.1.1 Measure of Dispersion

Boxplot is a graphical display differences between dataset that shows the median, the inter-quartile range, and the presence of possible outliers. Boxplot also gives an indication of the symmetry or skewness of the distribution. (Rice, 2007, pp. 402-404)

The median for each dataset is indicated by the black center line, and the first and third quartiles are the edges of the box area, which is known as the inter-quartile range (IQR). The outlier values are not included between the whiskers. They are within 1.5 times the inter-quartile range from the upper or lower quartile and should be plotted as a dot or small circle. Points at a greater distance from the median than 3 times the IQR are extreme values and should be plotted as star.

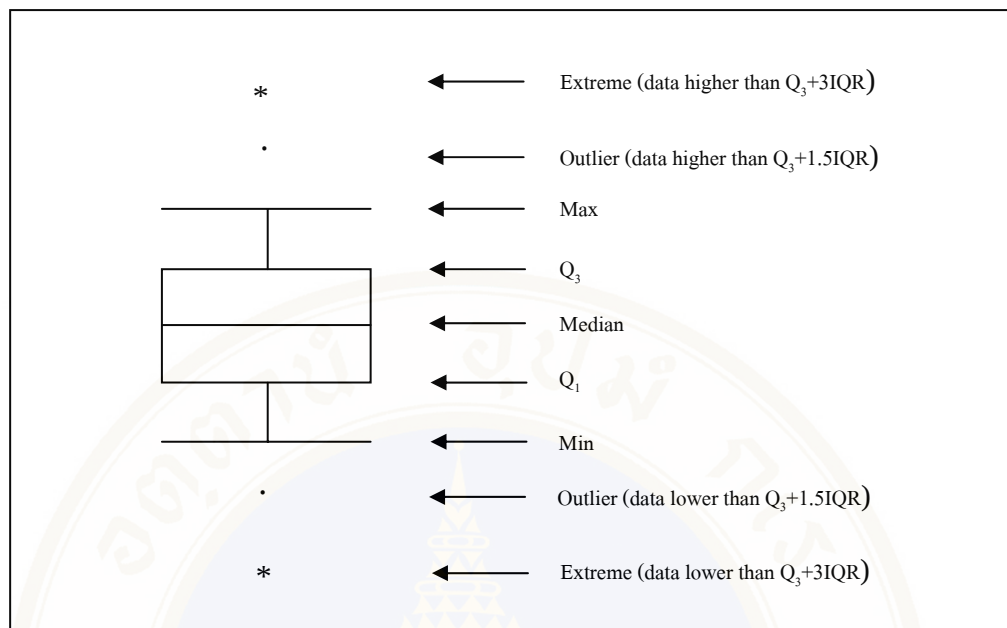


Figure 2.1 Boxplot

In this research, data set was tested by Boxplot. The outliers and the extremes were eliminated. Then the remaining data is used for further prediction.

2.1.1.2 Forecasting

Forecasting is a prediction of events that will occur in the future by studying historical data and using knowledge and techniques, proposed by previous study or use experience fortunetellers. Forecasting can be divided into two categories: qualitative and quantitative. Qualitative forecasting is mainly based on fortunetellers, while, quantitative forecasting is based on the historical data. In this research, the quantitative forecasting is applied. (Suwannawong, 2000, p. 2; Kedeam, 2005, pp. 1-6)

To do quantitative forecasting, it starts with collecting data. In order to determine the appropriate forecasting techniques, the collected data need to be cautiously examined since the data is crucial in determining the forecasting model; therefore, the step of data collecting should be carefully done in order to prevent errors that could affect the forecast results.

1) Regression Analysis

Regression analysis is the method that applied to determine a relationship between at least two variables. In the case that variables are not identified as independent or dependent variables, the method used to analyze this relationship is called correlation. On the other hand, if variables are identified, the analysis used is regression analysis. The analysis of the relationship of one variable, a dependent variable, and another variable, an independent variable, is called simple regression analysis, for example, time series analysis as time is an independent variable. The relationship of a dependent variables and a set of independent variables are called multiple regression analysis. However, the regression method selected in any analysis depends on the characteristic of the data. There are two types of regressions, linear regression and nonlinear regression (Suwannawong, 2000, pp. 13-14).

2) Time Series Techniques

Time series techniques are the technique used to analyze data by studying the movement of data that continuously collected in a period of time. The assumption of time series techniques is that the movement of the time series in the future will follow the pattern in the past. In general, time series techniques are normally used in economic or business analysis, as time is the important factors affecting the changes in business or economy data. It helps forecasting the growth or the contraction of the economy, in order to plan business and fiscal policy (Suwannawong, 2000, pp. 75-158; Kedeam, 2005, pp. 23-70).

Components of time series

There are four separated components of time series; Trend component, Seasonal variation, Cyclical variation and Irregular variations.

a. Trend component: Trend is the movement or the change of time series data that could be increase or decrease. Characteristics of trend could be linear or nonlinear. In addition, trend could demonstrate the influence of factors to the time series data.

How to test the trend components of time series

Run test is used to test whether the time series data is random or not. However, the data must be obtained from the same set of population and independent from each other. From the concept above, run test is applied in order to test if the time series have trend component or not.

The steps of run test

1. Calculate average, median or mode of data. Nonetheless, median is used in this research.

2. Give + to data that its value is more than median and give - for data that its value is less than median.

3. Count a run of the same sign data.

For example, ++++++ --- ++ ----- +
 1 run 1 run 1 run 1 run 1run = 5 run

4. Set the hypothesis

H_0 : There are random data.

(There is no trend component in the time series data)

H_1 : There are not random data.

(There is trend component in the time series data).

5. Statistic test

$$Z = \frac{R - E(R)}{S(R)} ; R = \text{the number of run}$$

$$\text{where } E(R) = \frac{n+2}{2} ; n = \text{the number of data}$$

$$S(R) = \sqrt{\frac{n(n-2)}{4(n-1)}}$$

Z is the standard normal random variable.

6. The run test is two-way test and the rejected area is

$$Z > z_{\alpha/2} \text{ and } Z < -z_{\alpha/2}$$

b. Seasonal variations: Seasonal variation is the movement of data that repeat occurs in the particular time of the year. In general, seasonal variation is usually shorter than one year, for example, by month or by quarter. The word “season” could mean climate conditions, social activities or cultural festivals.

How to test seasonal variations of time series

The Kruskal-Wallis test is a non parameters test used to test the differences in k group of population. The Kruskal-Wallis test is applied to test if there is seasonal variation of the time series data, which trend component has already been decomposed, or not.

The steps of Kruskal-Wallis test

1. Consider trend decomposed time series data and sort the data ascending. N is the number of data.

2. Set the hypothesis

H_0 : The average value of k groups are not different.

(There is no seasonal variation in the time series data.)

H_1 : The average value of k groups are different.

(There is seasonal variation in the time series data.)

3. Statistic test

$$H = \left[\frac{12}{N(N+1)} \sum_{i=1}^k \frac{R_i^2}{n_i} \right] - 3(N+1)$$

where k = the number of seasons.

R_i = the total number of the data ranked in the season i.

n_i = the number of data in the season i.

$$N = \sum_{i=1}^k n_i$$

4. Determine to accept or reject the main hypothesis. If $n_i \leq k$, $k \leq 5$, $N \leq 15$, the Kruskal-Wallis table is used. Else, χ^2 table is used. The reject area is $H > \chi_{\alpha, k-1}^2$

c. Cyclical variation: Cyclical variation is the movement of data periodically move up and down. Each period could be long as 3 years or even 10 years. The test of cyclical variation in time series data is often determined by plotting the graph. The data should be long collected data in order to identified cyclical time in the graph. To find the cyclical variation, the method is to decompose the Trend component (T), Seasonal variation (S) and Irregular variation (I) Finally, what is left is the cyclical variation.

d. Irregular variations: Irregular variation is the movements of data with uncertainties. Characteristic of the time series data with irregular variation is the events that can not be forecasted, for instance earthquakes or war.

How to test irregular variations (I) of time series

1. Eliminate trend variation (T) from the data by dividing the original data with trend variation.

$$\frac{Y}{Y_c} = \frac{TSCI}{T} = SCI$$

2. Eliminate seasonal variations (S) from the data that has already decomposed trend variation by dividing it with the relative value of the seasonal index.

$$\frac{TSCI}{TS} = CI$$

3. Remove cyclical variation from the data that has already eliminated trend variations and seasonal variations by dividing it with the variation of the relative cycle

$$\frac{TSCI}{TSC} = I$$

3) Probability Distribution

Theorem 1 Let X_i ; $i = 1, 2, \dots, n$ be independent random variables with normal distribution on parameters (μ_i, σ_i^2) , where $i = 1, 2, \dots, n$, then $\sum_{i=1}^n X_i$ is normal distribution with parameters $(\sum_{i=1}^n \mu_i, \sum_{i=1}^n \sigma_i^2)$.

Theorem 2 Let X_i ; $i = 1, 2, \dots, n$ be independent random variables with gamma distribution on parameters (t_i, λ) , where $i = 1, 2, \dots, n$ (mean = $t_i \lambda$, variance = $t_i \lambda^2$), then $\sum_{i=1}^n X_i$ is gamma distribution with parameters $(\sum_{i=1}^n t_i, \lambda)$.

Note: The proof of theorems 1 and 2 are in appendix C.

4) Forecast Precision

Comparison of forecasting methods in this research used the mean square error (MSE), which is a measure of the precision of the average sum of squared differences between actual and forecast data.

$$MSE = \sum_{i=1}^n \frac{(Y_i - \hat{Y}_i)^2}{n}$$

where Y_i = actual data

$\hat{Y}_i$ = forecast data

n = number of data

This thesis used Komogorov-Smirnov test for analyzes the demand distribution at significant level 0.05 with hypotheses;

For the normal distribution testing

H_0 : Data are sampled from normal distribution population.

H_1 : Data are not sampled from normal distribution population.

For the gamma distribution testing

H_0 : Data are sampled from gamma distribution population.

H_1 : Data are not sampled from gamma distribution population.

For the exponential distribution testing

H_0 : Data are sampled from exponential distribution population.

H_1 : Data are not sampled from exponential distribution population.

The statistics test

If $p\text{-value} < 0.05$ (significant level), reject H_0 .

If $p\text{-value} \geq 0.05$ (significant level), accept H_0 .

2.1.2 Inventory Theories

2.1.2.1 Inventory Management

Inventory is refers to goods, materials, or the stock of goods/materials. These include components that using in production processes or waiting for the next process, and finished goods which is ready to be sold.

The advantage of inventory is to facilitate the process flow. If there is no inventory, the shortage of goods or raw materials could occur and result in the idle process or the loss of customers. Storing inventory can also save costs due to economic of scales. However, in order to stock inventory, a company should concern on the budget of storing because it involves turnover asset. Therefore, a company should carefully manage inventory in order to balancing both cost reduction and liquidity management of the business. (Winston, 2004, pp. 846-848)

Inventory management is the most important functions of industrial which often has a great impact on their performance. (Nenes, Panagiotidou, & Tagaras, 2010, p. 313) Inventory management involves various inventory processes, it may starting with ordering, checking or examining, receiving, storing or holding, and transferring. (Sudtiwadnarupud et al., 2004, p. 79) The information of inventory will be recorded and used for policy planning. The inventory management depends on the type of business, such as, make to order, make to stock, or produced by customer (engineering to order). Each business has different inventory management. Therefore, the inventory management depends on the type of products and companies' inventory management policies.

2.1.2.2 Inventory Model and Inventory Policy

Inventory model can be classified into two types; single-period inventory model and multi-period inventory model. Single-period inventory model is an inventory model for a company with only order or produce goods one time. Numbers of inventory models in single period are based on festive product, such as souvenir in World Cup and Asian Games. Multi-period inventory model is a general inventory model for a company that continuously orders or produce goods, for example order goods for sell in a grocery or order medicine in a hospital

Inventory policy determines when and how to supply products. Practically, inventory policies have many forms. Inventory policies could generally be divided into two types which are *periodic inventory system* and *continuous inventory system* or popularly known as perpetual inventory system. (Sringkansiri, 2005, pp. 120-126)

Periodic inventory system is a system that inventory information is recorded in a specific time. For example, inventory information is updated on weekly or monthly basis by keeping tracks for inventory only at the beginning of the period, or purchases or sales. This system is suitable for products that are purchased and withdraw at certain period.

Continuous inventory system (perpetual inventory system) is a system that inventory quantity and availability information are updated on a continuous basis. The existing number of inventories will be recorded overtime. Hence, the number of inventories shown will always be in real time. This system is used for controlling important inventory items that should not shortage. However, the cost of inventory managing is quite high for its paperwork and its system as it requires more employees than periodic inventory system. This is generally accomplished by connecting the inventory system with order entry and the point of sale system. Currently, technologies are brought in to enhance the ability to implement a perpetual inventory system. The technologies mentioned earlier are, for instance, bar coding and radio frequency identification (RFID) labeling. These technologies allow computer systems to acquire and process inventory information as part of transaction processing. These systems provide accuracy information and the information can be used as a foundation information in inventory management.

Definition of each parameter in both inventory policies, periodic inventory system and continuous inventory system, are as follows;

S = maximum inventory levels or order-up-to

s = ordering point

Q = ordering quantity

T = time period between the two success orders

Inventory policies that widely known have the format of (a, b) where a is the reorder point and b is the order quantity. Moreover b can refer to a specific number of products to order or the number that provide inventory level back up to original level.

Examples of periodic inventory policies

- (T, Q) inventory policy is a policy that order goods every T periods with order quantity is constant Q .

- (T, S) inventory policy is a policy that order goods every T periods and order quantity that makes an inventory return to S units.

The advantage of the inventory policies (T, Q) and (T, S) is that it is easy to manage because of its periodical in time to order and the action plan. These policies spend less time and less cost in inventory management and are easy to check inventory stock. However, there are also disadvantages as the customer demand is uncertain. This can result in the shortage of inventory or over stored inventory. To determine the time period between the two success orders T is important. If T is too short, the order will be often made and the company must spend more ordering cost. On the other hand, if T is too long, the company needs more inventories capital investment used for storage inventories resulted in less liquidity.

Examples of continuous inventory policies

- (s, Q) inventory policy is the policy that order goods when the inventory level is less than s units with fix ordering quantity is Q .

- (s, S) inventory policy is the policy that order goods when the inventory level is lower than s units and order quantity is up to S units.

The inventory policies (s, S) and (s, Q) are continuous inventory system which means that the inventory must be observed at all time. When an

inventory level is lower than s units, an order must be placed immediately. In this case, demand is a random variable and time between orders is uncertain. Continuous inventory system is more difficult to manage than a periodic inventory system as the company must update its inventory level at real time. However, the advantage is to know the actual inventory level at real time. When inventory level decreases to s units, inventory must be increased immediately. Time period between the two success orders is uncertain and can reflect customer needs. If the orders are often made, it shows high turnover of the products. If the orders are rarely made, it shows low turnover of the products. The disadvantage of this system is its cost. The cost of inventory management in this system is higher than periodic inventory system because this system requires more employees to work. Presently, technological innovations such as barcode and RFID system not only help controlling inventory but also increase correctness. This technology stores information as database for inventory management.

Therefore, when the firm selects an inventory policy, it should consider its business characteristics: company's policy, the nature of goods, and customer demand.

2.1.2.3 Inventory Classification

Due to the fact that all inventories are not equally important, the idea to classify inventory for easier management was introduced by Vilfredo Pareto in 1906. (Winston, 2004, p. 911) Vilfredo Pareto proposed the ABC inventory classification inventory by calculate annual value usage of products. The classification of medicine inventory used in this thesis is following;

1) The ABC inventory classification system

ABC classification process is an analysis of items with different levels of significant by using annual value usage to ranging items and dividing into three categories (Tanwari et al., 2000 p. 2).

- Group A has inventory items approximately 5% -10% of total inventory items with the highest value. Their value is approximately 75% -80% of total value. Inventories in group A are very importance and most expensive inventories, requiring special care.

- Group B has inventory items approximately 20% -30% of total inventory items with the secondary value. Their value is approximately 15% of the total value. Inventories in group B are importance and require standard care.

- Group C is the rest of inventory items which has a little value. Inventories in group C are less importance and require little care.

2) The VEN inventory classification system

VEN (vital, essential, and nonessential) classification process is ranging the necessary of items and grouping items into three groups. Generally, the VEN analysis is applied in pharmaceutical medicine classification.

- Group V is very important for medical treatment and life saving must have a stock.

- Group E is a secondary important medicine, essential for treatment and should be hold in stock.

- Group N is a cured medicine, but it is needed in stock.

2.1.3 Simulation Theories

Simulation is the imitation of real circumstance, or real process in order to support decision making. The information used in simulation is based on virtual reality scenarios. Information represents certain key characteristics or behaviors of a selected physical or abstract system. Simulation is considered for the analysis and evaluation systems for decision making and problem solving. Simulation can be used as a problem solving tool in any situation where analytical method cannot be applied. There are number of definitions of “simulation”, propose in many terms, for examples;

- “Simulation refers to a board collection of methods and applications to mimic the behavior of real systems, usually on a computer with appropriate software. In fact, simulation can be an extremely general term since the idea applies across many fields, industries, and applications” (Kelton, Sadowski, & Sturrock, 2006, p. 1).

- Simulation is a technique to develop, test, and evaluate the system by study the model instead of the real system.
- Simulation is the act of imitating the behavior of some situation or some process by means of something suitably analogous (especially for the purpose of study or personnel training) (Banks, 1999, p. 7).
- Simulation is the technique of representing the real world by a computer program; "a simulation should imitate the internal processes and not merely the results of the thing being simulated".
- Simulation is the process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behavior of the system or of evaluating various strategies (within the limits imposed by a criterion or set of criteria) for the operating of the system (Shannon, 1998, p. 7).
- Simulation is the process of designing a mathematical or logical model of a real system and then conducting computer-based experiments with the model to describe, explain, and predict the behavior of the real system (Stewart et al., 1990).
- Simulation is a computer model that attempts to imitate the behavior of a real system or activity.

Presently, simulation is the important tools for analysis, especially in the context of supporting decision as problems is too complex or the experiment cannot be operated, since the real system is impossible, impractical, or expensive. Decision maker may not know the parameter values or certain parameter values which results in uncertain result. Decision maker may find a random set of parameter values and put in to the simulation model to determine these variables.

2.1.3.1 Types of Simulation

There are many ways to classify simulation model, but the useful way is classified by the following (Kelton et al., 2006, pp. 7-8);

- 1) Static simulation models and dynamic simulation models
 - Static simulation or Monte Carlo Simulation models are the simulation that does not depend on time. Static simulation is often used to evaluate the impacts of policy and risk involved in decision making.

- Dynamic simulation models are the simulation that parameters depend on time or events occur sequentially over time such as queue simulation.

2) Continuous simulation models and discrete simulation models

- Regarding continuous simulation models, a system will continuously change over time such as the volume of water in a reservoir.

- Regarding discrete simulation models, a system does not continuously change, but it change at specific time.

3) Deterministic simulation models and stochastic simulation models

- Deterministic simulation models are the model whose behavior is entirely predictable. The system is perfectly understood and no absolutely random behaviors. Thus, it is possible to precisely predict what will happen as variables are constant.

- Stochastic simulation models are the model whose behavior cannot entirely be predicted. The variables in stochastic simulation models can change by the probability. A system is upon random behaviors and the results of a simulation may never be the same as a previous simulation.

2.1.3.2 Processes of Simulation

Polsaen (2000, pp. 6-8) defines the simulation process by the follows;

1) Problem Formulation: Firstly, the problem should be extensively understood in order to set objectives, identify the scope of the problems, and correctly solve the question.

2) Model Building: The model must explain the operation of the system. There is no fixed formula to create a computer simulation model. Relationships in the model will be in the form of variables, parameters, and function.

3) Data Collection: All the data and information related to the research should be carefully collected.

4) Verification: The confirmation process can be done by evaluating a system or component to determine the software or models are satisfied. This process usually imposed at the start of development software. Verification activities consist of testing and reviewing. It is the process to make sure that the models are right. The test could be testing the accuracy of variable, parameter values or the assumptions.

5) Validation: To determine the correctness of the model development with respect to the user needs and requirements. It is usually done at the last stage of the development process by validating the model that the program can correctly work. It can be done by comparing between the consistency modeling behavior and behavior of real system or comparing data from the model and historical data of real system.

6) Experimental Design: Experimental design and the usage of the model should be planed to cover everything that is wants to be discovered. The process includes the process to find correct and accurate answers. Several trials could be done with the final result that equals to the average of results in each trial.

7) Production runs and Analysis: The model will be used and analyze the result by the research plan.

8) Implementation: The implementation results of the analysis and assessment will be used in order to help making decision.

2.1.3.3 Key Performance Indicator

Key performance indicator (KPI) is a type of performance measure used to evaluate factors that are crucial to the success of activities. KPIs are applied in organize to gauge organize trends and advise tactical courses of action.

2.1.3.4 Benefits of Simulation

“Simulation has many benefits over analytical or mathematical models for analyzing systems. First of all, the basic concept of simulation is easy to comprehend and hence often easier to justify to management or customers than some of the analytical models. In addition, a simulation model may be more credible because it's behavior has been compared to that of the real system or because it

requires fewer simplifying assumptions and hence captures more of the true characteristics of the system under study". (Shannon, 1998, pp. 7-8) Additional benefits are:

1) Simulation can be used with systems without doing the experiment in real situation.

- It saves resources, such as, pilots training, maneuver training, and medicine experimental. When we use simulation, pilots, soldiers, and patients are not lost.

- It saves time and cost because simulation is done in laboratory or computer which requires less cost and time than real practice.

2) Simulation can predict the future of real system by analyzing the results of the simulation scenario which will support the decision making.

2.2 Literature Review

Literature review falls into three areas: the forecasting, the inventory and the simulation.

In inventory management, forecasting acts as an important factor as it must rely on quantitative data of expected needs for each product. As a result, forecasting takes place in a sense of inconstant demands for products of which planners are unable to estimate. For general inventory management, a provision of future need for products, significantly called as forecasting, is firstly taken into account by planners. Aukraphasuchart (2003) used the average of previous demand to forecasting future demand in his study of inventory cost control: a case study of one factory in Lamphun province. Additionally, Hanpichanchai (2004) performed time-series forecasting to estimate customers' need in inventory management of small and medium frozen food enterprises. Besides, Songwattana (2005) studied probability distribution of cabbages demand to forecast cabbages demand. It was used for calculate an appropriate order quantity. Tangwiboonpanich (2005) relied on seasonal forecasting technique by Winter to find out demand for raw materials in studying inventory-controlled

improvement of coil industry. Suksrisomboon (2007) also, to forecast medicine demands, applied the same technique, seasonal forecasting, to stock management of medicine inventory in Institute of Aviation Medicine, RTAF. Jaruspetch (2005) conducted a research of inventory management in which uncertain needs of gas occurred in gas stations, based on frequency and probability functions. As far as all mentioned above, to reach the most efficient inventory management, it is necessary to forecast demands for products.

Becoming nowadays even more interested by a number of executives, an efficient inventory management provides a reduction in costs. Then, it has widely been studied by a number of researchers. What are going to be discussed in this research involve in two issues: researches relevant to inventory classification and researches related to inventory management policy.

To perform assortment of a range of products in annual-current-value-based inventory management by ABC analysis has been studied by a lot of researchers. Aukraphasuchart (2003) used ABC analysis to categorize inventory goods of a snack factory and ultimately picked up products in group A. Additionally, Tungwiboonpanich (2005) relied on ABC analysis to sort materials out in order to improve raw material inventory of a coil factory. Kumsan (2006) applied ABC technique to inventory control system of Special Medical Service Center, Chiang Mai University.

Afterwards, some researchers have developed new approach of inventory classification by combining ABC analysis with priority focus which may call two-dimension classification. Suksrisomboon (2007) also used both ABC and VEN Analysis to assist in ranking medicine inventory for Institute of Aviation Medicine, RTAF. Moreover, Chu, Liang, & Liao (2008) suggested, as all inventory goods, in practice, were unable to be thoroughly treated by warehouse controllers or valuable products needed to be stored specially, ABC-fuzzy classification (ABC-FC) to offset a weakness of ABC technique which relied on the only one factor, price, to classify products. Unlike ABC technique, there were a number of variables taken into account by leveling priority of products as 3×3 metric. The most valuable products were represented by A1 and A2 and A3 respectively and significance of product appeared to be (B1, B2 and B3) from maximum to minimum respectively. Then, product

classification was taken place as (A1B1, A1B2, A2B1), (A3B1, A2B2, A1B3) and (A3B2, A2B3, A3B3) from most to least important items severally. According to ABC/VEN analysis by sorting A1, A2, A3 as ABC and B1, B2, B3 as VEN, this method was rather similar to that of medicine inventory classification.

There are a variety of inventory management policies available in Thailand; however, the most popular one is more likely to be Economic Order Quantity or EOQ. Tungwiboonpanich (2005), for instance, adopted EOQ for calculating order quantity, reorder point, and buffer stock of a coil factory and found that the method helped ease procurement costs. Another example was held by Buranapansri (2006) which EOQ was used to examine purchasing quantity, reorder point in 36 items of building material inventory.

In terms of medicine inventory control in Thailand, there are a large number of existing EOQ-based approaches. Rojsakga (2002) enhanced an efficiency of drug warehouse management for Udon Thani hospital by utilizing EOQ to achieve purchasing quantity, reorders point of 10 drug items which were over stock or under stock. The result of her study enabled storing costs to dwindle by about 49,585 baht, accounted for 0.52% of total costs. Otherwise, Kumsan (2006) relied on EOQ technique to acquire constant need of 166 drug items, by 9.79% from total 1965 items of Special Medical Service Center, Chiang Mai University. Suksrisomboon (2007) also calculated reorder point and safety stock of 17 types of drugs which resulted in an expense reduction by 25.97% in high value and vital group (AV group).

From discussion above, all previous researches seemed to focus on EOQ in handling inventory management. EOQ method, however, may sometimes not be the most appropriate technique. Aukraphasuchart (2003) compared EOQ model to Newsboy model and pointed that EOQ model provided lower costs but caused more possibility to lack products than those of Newsboy model. More significantly, however, when including opportunity cost, Newsboy model contributed to even lower overall total costs. As a result, he suggested a factory Newsboy model rather than EOQ model. Subsequently, Sethi (2004) developed inventory policy by proposing (s,S) policy to find out appropriate and economic ordering quantity and compared total expenses arise from (s,S) policy to that of EOQ policy which its result presented (s,S) policy became more usable. Additionally, a research conducted by Sornyen

(2007), in animal feed factory, examined a comparison of overall costs between EOQ model and linear programming (LP) model. EOQ model helped corns and soybean fibers reduce their storing costs by 1.76% and 1.57% respectively, whereas LP model accounted for 0.09% and 0.13% severally. EOQ model, however, assumed that there were unchangeable needs for products in each period, contrary to the fact and leading to lost sales, while LP model became closer to real situation in practice. Thus, she recommended LP model for raw material inventory control of this factory.

Apart from a comparison of EOQ to other policies, there were a variety of researchers who were interested in taking any other policies to execute inventory control. Begin with Ouyang and Chuang (1999), their attempt to minimize stock-out costs by developing two models: continuous (Q,r,L) model and discontinuous (T,R,L) model, determining fixed service level, assigning random variables as backorder and lost sales with known mean and variance of lead time demand but unknown distribution pattern as well as relying on minimax decision successfully reached his expectation. Hanpichanchai (2004) also presented Mathematical Model, non-linear programming, to control inventory of small and medium food frozen enterprise. Otherwise, Verma (2006) utilized (Q,r) policy and simulation to study appropriate inventory level by specifying service level at 0.9 which allowed him to achieve Q value at minimum costs. Moreover, Sommawattana (2008) took a comparison of two policies: (s,S) and (s,Q) to consider material inventory management of dressing products. Furthermore, Khouja and Stylianou (2009) crated (Q,R) inventory model for studying a drop-shipping product. Such model subject to two conditions: when stock-out products were allowed to deliver later and when stock- out products lost their sales. Variables were valued and then equations were formed and resolved by calculus. Sensitivity Analysis started proceeding when final equation was done. Ultimately, the result showed drop shipping was inevitable for longer lead time, smaller ordering costs against carrying cost together with lower out-of-stock and late-delivered costs against carrying cost.

Later on policy development likely focused on business application and became more complicated. According to Maiti, et al., (2009), the average margin of fixed demand for a product at a moment was taken into account subject to when such demand depended on price, which stock-out products and discounts were allowed to

occur. To resolve the problem was held based on generalized reduced gradient (GRG) technique by C programming language and to reexamine relied on stochastic search genetic algorithm (GA). Eventually, sensitivity analyses were used to review if both GRG and GA model worked and provided similar results. Furthermore, Kutanoğlu and Mahajan (2009) studied how to minimize inventory costs when goods were transferred from primary warehouse to a wide range of dispersed sub warehouses. His study allowed service equipments to move within sub warehouses. Resolved equation by enumeration-base algorithm, it was found that without product allocation between warehouses, inventory goods and costs dramatically rose, but despite transferring costs product allocation somehow lead to overall cost reduction. Tsou (2009) also found out efficient inventory control policy to minimize total cost and considered backordering and lost sale inventories with Pareto optimizers, including multi-objective electromagnetism-like optimization (MOEMO) and multi-objective particle swarm optimization (MOPSO) calculations. The results, in final, were compared by program of simulation method. More importantly, Goyal and Chang (2009) examined a balanced proportion between ordering and delivering quantity from warehouse to shelf in retailers. The research aimed to obtain the highest average margin. An availability of stock-out products was exempted as well as available shelf areas, where the number of purchasing order depended on quantity of display goods, non value of delivering time from retailer to supplier, non value of delivering time from warehouse to shelf, Q quantity of purchasing order from retailer to supplier and q quantity of product mobility from warehouse to shelf were totally restricted. Calculus was used to resolve and sensitivity analysis was used to reexamine. The result presented the higher values of inventory products, the lower average margins, and when margins per unit were lesser or equal storing costs per unit, an average margin appeared to descend against display product level. Consequently, it was necessary for retailer to enlarge carrying times from warehouse to shelf which may ease frequent times from goods mobility. In contrast, if margins per unit were higher than storing costs per unit, retailer may increase volumes in transferring products from warehouse to shelf.

Other than business concern, some researchers additionally compared self-managed inventory control to external-outsourced control as Yaoa, et al., (2009) developed inventory policy for short-life-cycle products of a factory in order to

maximize its profit. There were two distribution channels in their study: distributors and electronic orders where customers had a right to select their own purchasing channel. They divided problems into three paths: (1) *Centralized inventory strategy*: both retail and e-tail authorized by factory (2) *Stackelberg (leader–follower) inventory strategy*: only e-tail subject to factory and retail controlled by retailers. *Outsourcing inventory strategy*: similar to second strategy but factory acted as VMI vendor-managed inventory to view overall perspective while 3PL third-party logistics took care of e-tail instead. To verify models started from the former type and then used to measure two remaining types in terms of a decrease in costs per unit for management by third-party logistics, an effect of costs per unit on hired 3PL, and how efficient third-party logistics worked. The result revealed the last two latter became more appropriate than the former which provided ambiguous result. The larger demands for both channels, the greater need for e-channel but the smaller need for retail channel. Otherwise, the first type resulted in higher inventory costs than those of second and third types, significantly possessed larger stocks. Its service level, however, became more worth. It also found that 3PL led an increase in costs per unit.

There are many researches involving simulation. Not only does simulation help researchers study working system but also to ameliorate working system must rely on its application as trial and error are able to take place as much as possible until the best approach will appear. As a result, simulation is used as a tool to support decision making in solving problems. Japakasetr (1999) analyzed vehicle routing system for Automobile Spare Part Distribution Center by emulating situation in order to trial a proposed routing method which varied in volume and priority of fixed-current system. Additionally, Surapeepong (2007) examined an efficient improvement of production line in roasted and ground coffee plant by using computer simulation model to prioritize works on two coffee roasters, to calculate such a proper number of workers for sorting process and to adjust timetable for packing workers. Based on such trial, the result showed an appropriate priority eased a waste of job-waiting time from either roaster. Otherwise, sufficient quantity of sorting workers by rotating them from other divisions contributed to a decrease in overtime work, and time adjustment allowed related resources to be maximized their utility. Chaichit (2008) used queuing

simulation model for Performance analysis of service system of Phasang hospital, Lamphun province. Also, Ahmed and Alkhamis (2009) utilized simulation for emergency department of state-owned hospital in Kuwait to find out 28% increase of workers resulted in 40% reduction of waiting time of patients.

There are researches, who using inventory simulation. For examples, Songwattana (2005) applied Monte Carlo simulator to ordering quantity analysis of fresh vegetable department. In-handed data were used to examine with previous-5-month data and presented 19.5% rise of company profits were derived from orders by simulation model. Sommwattana (2008) conducted trial of salad dressing inventory management by using ARENATM program to compare two inventory control policies of raw materials: (s,S) and (s,Q) . Consequently, overall perspective of their inventory management appeared to be as a part of purchasing decision making at lowest costs and service level before adopted.

In terms of medicine inventory management in Thailand, as mentioned above, most researches are available for only EOQ policy which obviously limits its own condition-fixed demand. In fact, preliminary study revealed demand for medicine seemed to be inconstant, unfit to EOQ policy and incompatible with real use which may result in stock-out or overstock of medicine inventory. As a result, researcher intends to develop distinct method from all previous studies by examining medicine inventory of AV group which all of them possess fluctuated demand and also relying on simulation to compare new proposed policy to current hospital policy.

CHAPTER III

MATERIALS AND METHODS

In this chapter, the methodology and research tools are described in sections 3.1 and 3.2 respectively. The research plan is shown below.

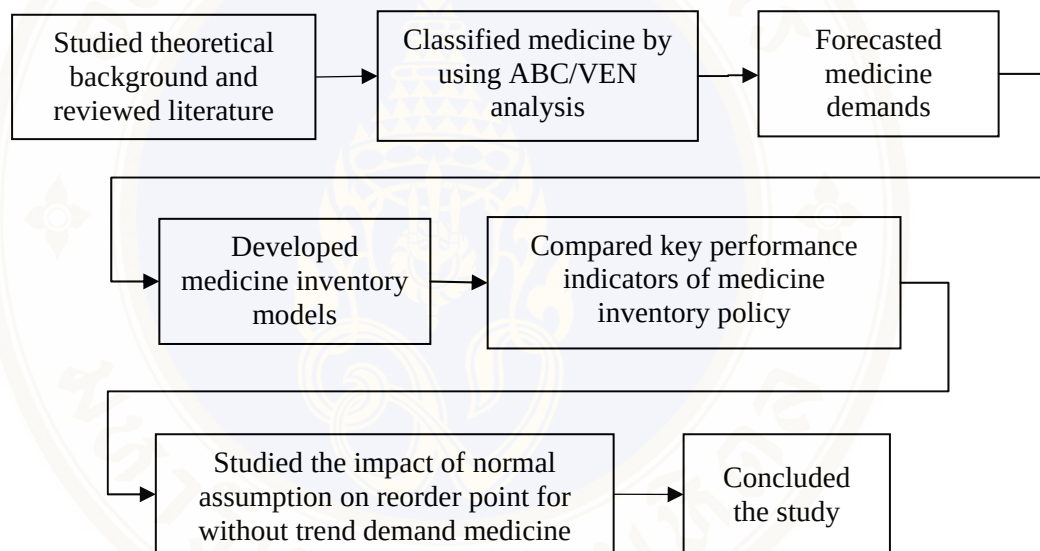


Figure 3.1 Research Plan

This research started with identified the primary problem, medicine inventory management and studied process in previous literature mentioned in chapter II. Then the research studied relevant document and interviewed pharmacists who work at the central medicine warehouse of Ramathibodi hospital. These are achieved by analyzing the system of the Ramathibodi hospital's medicine inventory via several appropriate documents related in hospital inventory system such manual of purchase, documentation of medicine exchange between suppliers, medicine storage floor plan, staff planners for medicine inventory management, record of medicine dispense from medicine warehouse to dispensary units and to patients, record of order and purchase

such as record of purchase requirements and purchase orders, records of medicine received in medicine warehouse and expenses records such as electricity bills and office supplies both durable and non durable goods. Also as part of this research, interviewing with pharmacists who work at central medicine warehouse at the Ramathibodi hospital are documented and analyzed for further case study. From then on, the current system of central warehouse obtains by interviewing pharmacists will be explain and discuss as course to recognize occurred problems and to analyze those problems in order to purpose a new design of model which aim to solve recognized problems occurred in current state of medicine inventory system management.

3.1 Methodology

The goal of this research is to solve medicine inventory problems as stated previously. First, the current system of medicine inventory was studied as preliminary study. Next, Medicines were classified by using ABC/VEN analysis. Next, demand trend and demand distribution were analyzed for AV-type medicine. Then, mathematical models were developed in calculate the reorder point, order quantity, and maximum stock level. Finally, comparison between the proposed and the current policy is determined. The details are as follow;

3.1.1 Preliminary Study

In order to accomplish a successful research, we study related documents in the research from both related domestic and foreign researches, such as, research papers, thesis, annual reports, statics theories, and study the current system of medicine inventory to identify the research tools and statics tools for developed medicine inventory model. The core of research focuses on development of medicine inventory for AV-type medicine.

3.1.2 Medicine Categorization by ABC/VEN Analysis

This research brought divided medicine base on VEN analysis from the hospital to analyze base on ABC/VEN analysis. Then, we explored specifically in the highest value usage medicines (group A) and vital medicines (group V). Medicines in

group A are high-value usage which is worth approximately 80% of total medicine inventory value usage. Hence, extra caution must be paid in order to prevent excess investment expenses. Meanwhile vital medicines in group V are critical to life therefore they must not be in shortage even though they are rarely used. This research categorized medicine accordingly to medicine usage data in fiscal year 2008: October 2007 to September 2008.

Once medicine categorizing process is completed, the next step is to forecast the medicine demand. The medicine inventory models are constructed based on the forecasted demand for purchase medicines in the future. The details are as follows:

3.1.3 Medicine Demand Forecast

This research developed appropriate medicine inventory models for the future demand. Therefore, the data from the Ramathibodi hospital on medicine dispensation are collected and forecasted for demand pattern of medicine dispensation. This research used time series techniques to identify trend components and analyzed demand distributions by Komogorov-Smirnov test. The main purpose of this research is to develop medicine inventory models so we used forecasting techniques that are simple, uncomplicated, accurate and reliable. The others forecasting techniques such as regression analysis has many variables associated with each medicine. These variables are required to give accurate forecast such as the offered price, medicine treatments, number of patients, medicine budget, dispensation policy, medicine auction, and the hospital's board approval, etc. However, some relevant variables associated with medicine demand are confidential such as offered prices from medicine suppliers. Hence, it is incommodious to forecast by regression analysis. For this reason, this research uses time series techniques. We use past data of dispensary medicines to patients to calculate the quantity of medicines that will be given to patients in the future.

The Mean Square Error (MSE) and Kolmogorov-Smirnov Test are used to compare the appropriate forecasting method for finding the trend the distribution. The significance level is set at 0.05. The p-value is used to analyze hypotheses. Medicines that cannot be found appropriate distribution have not been considering.

3.1.4 Medicine Inventory Models Development

There are many policies used to develop medicine inventory models. In this research considers (s,s) policy for no trend demand and (s,Q) policy for trend demand. We develop mathematical models for actual medicine demand. From a preliminary study, AV-type medicine has no budget limitation in each ordering because the hospital has contracts with AV-type medicine suppliers. Therefore, this research aims at elaborating proposal of general inventory management system and finding the appropriate reorder point and order quantity for hold medicines in one month demand (expect by the pharmacists). The conditions assumptions are as follows;

- 1) Each medicine demand is not constant,
- 2) Each medicine lead time is not equal to one another but constant,
- 3) Each medicine service level is not equal to one another.

3.1.5 The Comparison of Key Performance Indicators between Current Policy and Proposed Policy

After the medicine inventory models are developed, the hospital's current policy and proposed policy are compared. The simulation is use to compare key performance indicators of medicine inventory and analyze the appropriateness of policy. The key performance indicators of medicine inventory in one replication are as follows;

- 1) The average medicine stock per day: An average of medicine inventory per day.
The saved costs are calculated from average of medicine inventory per day multiple selling price per unit.
- 2) The medicine inventory turnover: The total medicine demand in one year per average medicine inventory (cost of medicine sold is secret).
- 3) The number of orders: The number of orders occurs in the considered time period.
- 4) The total days of shortages: The total days that the hospital cannot provide the medicines to the patients.

- 5) The quantity of shortages: The total amount of medicines needed for unsatisfied demands.
- 6) The number of times of stock shortage: The time that medicine is in shortage. For example, medicine shortage on day 14, 15, and 16 means the medicine shortage occurred one time.

In this research, thirty replications are simulated and the results are the average of each key performance indicator. The details are as follows;

- 1) The average medicine stock per day

Calculation: The summation of medicine stock per day in 30 replications / 30. For example, the amount of medicine stock per day in 30 replications is 9,550 units, so the average medicine inventory per day is $9,550 / 30 = 318.33$ units.

The saved costs of medicine stock are calculated from average medicine stock per day multiple selling price per unit.

- 2) The average medicine inventory turnover

Calculation: The summation of medicine inventory turnover in 30 replications / 30. For example, the amount of medicine inventory turnover in 30 replications is 540 times, so the average medicine turnover is $540 / 30 = 18$ times in one year.

- 3) The average number of orders per year

Calculation: The summation of orders per year in 30 replications / 30. For example, the number of orders per year in 30 replications is 389 times, so the amount of average number of order per year is $389 / 30 = 12.97$ times.

- 4) The average day of shortages per year

Calculation: The summation of shortage days in 30 replications / 30. For example, the total day of shortage in 30 replications is 7 days, so the amount of average day of shortage per year is $7 / 30 = 0.23$ days. Each simulation may or may not lack medicine.

- 5) The average quantity of shortages per year

Calculation: The summation of shortage medicines in 30 replications / 30. For example, the total shortage medicines in 30 replications are 55

units, the amount of average quantity of shortage per year is $55 / 30 = 1.83$ units. Each simulation may or may not lack medicine.

6) The average number of times of stock shortage per year

Calculation: The total numbers of time that medicine shortage in 30 replications / 30. For example, the total number of times that medicine shortage in 30 replications simulation is 16 times, so the amount of average number of times that medicine shortage per year is $16 / 30 = 0.53$ times. Each simulation may or may not lack of medicine.

3.1.6 The Comparison of Impacts on Reorder Point between Actual Demand Distribution and Normal Demand Distribution Assumption

From medicine demand forecast, there are two demand distribution patterns that are not normal distribution. There are exponential and gamma distributions. This research compared reorder point between actual demand distribution and normal demand distribution assumption. The factors included 1) service level 2) average usage quantity and 3) lead time. Firstly, the lead time and the average usage quantity are constant, but the service level is changed from 80.00% to 99.99%. Secondly, the lead time and the service level are constant, but the average demand is changed. Thirdly, the average demand and the service level are constant, but lead time is changed from 1 to 30 days.

3.2 Research Tools

3.2.1 Hardware

CPU	:	Intel Core 2 Duo P8400
RAM	:	2 GB
Hard Disk	:	250 GB
Monitor	:	Wide Screen Flat Panel LCD
Peripheral Devices	:	Printer

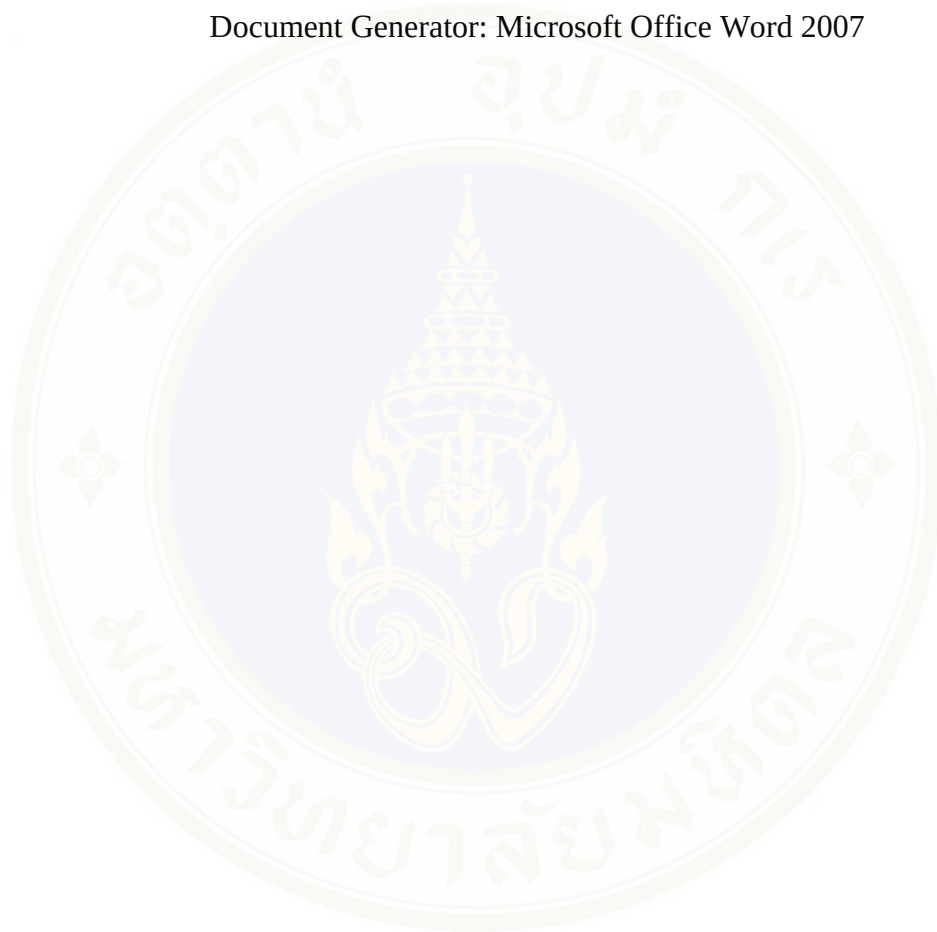
3.2.2 Software

Operating System : Microsoft window XP

Statistical Program : SPSS 15.0 for windows, Microsoft Office Excel
2007, and Arena 10.0

PDF View Tool : Adobe Acrobat 9.0 Professional

Document Generator: Microsoft Office Word 2007



CHAPTER IV

RESULTS

This chapter includes seven parts according to the research methodology from the previous chapter: 4.1) The Current System of Medicine Inventory 4.2) Medicine Categorization 4.3) Medicine Demand Forecasting 4.4) Medicine Inventory Models Development 4.5) A Comparison of Key Performance Indicators between Proposed Policy and Current Policy 4.6) A Comparison of Impacts on Reorder Point between Actual Demand Distribution and Normal Assumption Demand Distribution. 4.7) The Appropriate AV-Type Medicine Inventory Policy.

4.1 The Current System of Medicine Inventory

Central medicine warehouse of the Ramathibodi hospital is 280 square meters located on the first floor of the fifth building, holds up to 2,100 items, and operates by 3 pharmacists and 14 staff from 8.30 am. to 4.30 pm. Monday to Friday. The central medicine warehouse operations are as follows:

4.1.1 Ordering Medicines:

Ordering medicines is part of purchasing department of the hospital run by two pharmacists. The process begins with checking level of medicine inventory database from computer systems. As a result, if medicine levels are less than 80 percents of average monthly usage, computer is programmed to alert pharmacists about medicine level in stock. Then it is pharmacist duty to decide whether to order. However, in case of ordering, the order will be equal to or greater than average usage per month, and pharmacists will make purchasing requirement, wait for approval, and make purchasing order. The sources of order can be medicine companies, the Government Pharmaceutical Organization (GPO), and Food and Drug Administration (FDA).

Ordering medicines with medicine companies consist of two types of orders: medicine with contract and medicine with no contract. Contract is an agreement made between the hospital and suppliers, in this case, medicine companies, depending on contract's conditions. For example, hospital fiscal year 2007 has made buy-sell contract agreement of purchase medicine X with company A for 10 million Baht for the first 6 months and company B for 8 million Baht for six months later. Contract is usually written to restrict budget of medicine purchase per period of contract agreement. In addition, a company accepts that the Ramathibodi hospital's purchase department can place an order at any quantity any time during the contract period, and it will provide a receipt to the hospital. However, during the contract period in the first 6 months of fiscal year, total order from the Ramathibodi hospital's purchase department must not exceed 15 millions Baht. For the non-contract medicine, there is also a budget restriction. The Ramathibodi hospital's purchase department cannot make any purchasing more than 300,000 Baht each time. In the next year, the hospital is more likely to make contract with suppliers to cover all types of medicines.

In ordering process, after pharmacists at the purchasing department decide to make an order, they will ask board of the hospital for approval. Once an approval is made, purchasing department will contact medicine supplier to place an order of required amount of medicine, and wait for a confirmation on required amount of medicine from medicine supplier. Once purchasing department gets the confirmation on the suppliers, the purchasing department will determine the delivery date. In the case that medicines are not meet required amount for long time, the purchasing department will make notification to dispensary units in the hospital.

The process of ordering medicines with the Government Pharmaceutical Organization (GPO) is different from previously mentioned procedure. It cannot fix delivery date and it must sent preemption certificate for required medicines to GPO.

Another ordering process is the process of medicines with Food and Drug Administration (FDA) which involves narcotic drug and narcotic drug type two. FDA sets a limited number of drugs that each hospital can hold. The purchasing department must fill in the specific form made by FDA and send to FDA for approval. After the form is approved, purchasing department can make an order of required drugs for only the approved amount and it has to pick-up drugs by itself.

Hospital Order Policy

Pharmacists in purchasing department use the Min-Max policy to order medicines in AV-type. The Min-Max policy order medicine when the medicine inventory level is lower than 80% of the average monthly usage ($\hat{Y}_i$) and the order quantity are equal to 150% of the average monthly usage.

$$\min \hat{Y}_i = 80(0.5X_{i-1} + 0.5\hat{Y}_{i-1})$$

$$\max \hat{Y}_i = 150(0.5X_{i-1} + 0.5\hat{Y}_{i-1})$$

where

- $\min \hat{Y}_i$ = the ordering point
- $\max \hat{Y}_i$ = the order up to level
- $\hat{Y}_i$ = forecast demand in month i or average usage in month i
- $\hat{Y}_{i-1}$ = forecast demand in month i-1 or average usage in month i-1
- X_{i-1} = demand in month i-1

4.1.2 Receiving Medicines:

Medicine receiving processes are divided into two parts; check the medicine ordering documents in the morning and receive medicines in the afternoon. The process of checking medicine ordering documents begin with receiving and checking accuracy tax invoice, purchase order, and medicine certification of analysis from medicine suppliers, after all required documents are checked, staff then arrange queue to medicines delivery for each medicine supplier. In the afternoon, pharmacists will double check those documents and medicines, if any invalid is found, pharmacist will notify those errors by using the hospital's forms and return them to medicine suppliers along with medicines, it means that warehouse staff will not accept those medicines until correct documents and medicines are provided. On the other hand, if all documents and medicines are checked to be valid, staff will arrange for medicines to be stock in the warehouse.

Process of receiving medicines at warehouse requires three committees: a president of pharmacists, a person from pharmaceutical department, and a person from the other departments as a witness to prevent corruption and to double check for correctness. After all documents will be checked, medicine suppliers receive their

queue and deliver medicines to warehouse according to queue their received. The committees will check medicine names, an amount of medicines, characteristic of medicines and certificate of analysis. After that duty will be transfer to warehouse's staff (there are three people in section), checking for accuracy again and sort medicines into warehouse afterward. Different medicines may require different storage conditions. For example, some medicines can be stored at room temperature while other medicines are required at temperature of 2-8 degree Celsius. Subsequently, staff will check and update inventory levels immediately or at the end of the day. Daily average of medicine suppliers that make their delivery to warehouse is roughly fifteen suppliers, on daily bases, major suppliers will deliver up to twenty items in one day while small suppliers will deliver from one to two items.

4.1.3 Monitoring Medicine Inventory:

This part of system is essential as it is to assure that actual inventory quantity of medicines is the same as medicine inventory quantity in database. Database accuracy is checked every three months, it takes about five days to complete.

Monitoring medicine inventory starts from counting medicines in the warehouse. Medicine inventory level from counting must be the same as medicine inventory level from computer database. If the results do not match, the staff must find the error, recount the stock, and update computer database.

4.1.4 Distributing Medicines to The Sub-Warehouses:

This process mainly deals with medicine warehouse's operation. The process starts from getting a requirement order from the sub-warehouses and dispensing medicines according to received requirement order and then updating medicines quantities in the database of warehouse. Eleven staff, divided into the dispense medicine team and the inspection team, are required during process of medicine dispensary from the central medicine warehouse to sub-warehouses.

The process of medicines distribution begins with the submission of requisition order to central medicine warehouse by medicine sub-warehouse's staff. One copy is given to the dispensing team for checking out order and dispensing required medicines according to first expired first out basis. Dispense team will send

required medicines to inspection team. The second copy of requisition order, used for verifying the amount of medicines, is given to the inspection team. Then the team members would check details on both two copies of requisition orders to ensure that they are matched. If two copies do not match, the staff will have to re-check all received requisition orders and medicines again. After that the staff updates the medicine quantity in the database by inputting the information of dispensary items to get ten-digit material document numbers. Then, he will pass them to the sub-warehouses to key-in information of receiving medicines. Inspection team will submit a copy of requisition order and material document numbers along with medicines that will be delivered to sub-warehouse. After all items are received, the staff at the sub-warehouse has to verify by using ten-digit material document numbers and double check with central medicine warehouse computer system.

At the Ramathibodi hospital, medicine warehouse manages medicines and supply for the demand of seven major sub-warehouses. These seven major sub-warehouses are as follows;

- Central Dispensary Unit (A),
- General and Emergency Dispensary Unit (C),
- Eyes Ears Nose and Throat Dispensary Unit (D),
- Pediatric Dispensary Unit (F),
- Obstetrics and Gynecology Dispensary Unit (G),
- Internal Patients Department (IPD) on fifth floor (H),
- Internal Patients Department (IPD) on seventh floor (J).

The others medicine sub-warehouses are;

- Medicine Production Unit (K),
- Obstetrics and Gynecology Anesthesia Unit (N),
- Orthopedic Anesthesia Unit (O),
- Sirikit Building(Q),
- Surgery Anesthesia Unit (S),
- Eyes Ears Nose and Throat Anesthesia Unit (T).

Each sub-warehouse would write its medicine requisition orders and send them to the central medicine warehouse. Medicine quantity is determined by officials

who are responsible for each sub-warehouse. In the near future, Systems Applications and Products in Data Processing (SAP system) will be developed and able to determine medicine quantity of sub-warehouses by the computer program. Each sub-warehouse will be indicated the specific date to withdraw medicines as follows:

Table 4.1 The agreement of distribute day medicines applied to the sub-warehouses

Sub-warehouse	Dates scheduled				
	Monday	Tuesday	Wednesday	Thursday	Friday
Central Dispensary Unit (A)	✓		✓		✓
General and Emergency Dispensary Unit (C)		✓		✓	
Eyes Ears Nose Throat Dispensary unit (D)	✓		✓		✓
Pediatric Dispensary Unit (F)	✓		✓		✓
Obstetric and Gynecology Dispensary Unit (G)		✓		✓	
IPD at 5 floor Dispensary Unit (H)	✓	✓	✓	✓	✓
IPD at 7 floor Dispensary Unit (J)		✓		✓	
Medicine Production Unit (K)	✓	✓	✓	✓	✓
Obstetric and Gynecology Anesthesia Unit (N)	✓				
Orthopedic Anesthesia Unit (O)	✓				
Sirikit Building (Q)	✓				

Sub-warehouse	Dates scheduled				
	Monday	Tuesday	Wednesday	Thursday	Friday
Surgery Anesthesia Unit (S)	✓				
Eyes Ear Nose Throat Anesthesia Unit (T)	✓	✓	✓	✓	✓

After the central medicine warehouse receive requested list of medicines and volume of medicines from each sub-warehouse, central medicine warehouse will use medicine information to calculate average summation of each withdraw medicines, this can be called “the average usage of medicines per month”. The average monthly usage is calculated by computer programs. Purchasing department will use this information to determine whether the medicines are below 80% of the average monthly usage so that it will make a decision to order medicines up to 100% - 150% of the average monthly usage. However, the final decision depends on pharmacists in purchasing department.

4.1.5 The Problems of Medicine Inventory Management

1. Storage space of the central medicine warehouse is inadequate and currently unable to expand. Therefore, central medicine warehouse must manage the medicine inventory by balancing between medicine quantity and the storage spaces.

2. The monthly average medicine withdrawal by sub-warehouses is not actual medicines usage per month. As a consequence, inaccurate numerical values of dispend medicines, being used to calculate average rates of medicine usage per month, might lead to inappropriate reorder point and incorrect quantity of order.

3. Some types of medicines are not enough to meet the demand of hospital usage because of central medicine warehouse’s stock shortage and sub-warehouses’ unattainable demand medicine. Hospital will need to borrow medicine from medicine suppliers or other hospitals. There are two cases of medicine shortage;

- First, medicine manufactures are sometimes in stock shortage, the central medicine warehouse of the hospital will borrow medicines from nearby hospitals or affiliated hospitals such as the Siriraj hospital and the Phramongkutklo

Army hospital. However, if there are also in short of the same type of medicines, the pharmacist will change to the other medicines that have the same treatment.

- Second, the purchasing department cannot order the medicines on time, the central warehouse will borrow them from medicine suppliers. Then it informs purchasing department to issue purchasing order subsequently.

In both cases, when the central warehouse receives borrowed medicines, it will update the quantity of medicine in the system which is also available for purchasing department.

4. Sometimes the stock of medicines is much larger than hospital's demand. This causes the longer storage time which lead to less shelf life. The hospital can exchange medicines when shelf life is less than six months with new ones from medicine suppliers according to the contract agreement. In fiscal year 2008, medicine worth 7.35 millions Baht was exchanged; as a consequence, central medicine warehouse would have to re-process medicines in stock and update database on the system. This re-process of medicine stock can be time-consuming; for example, organizing and contacting medicine suppliers and re-stocking medicine would take more than a few hours to complete. Besides, the hidden cost in the exchange process also occurs such as, phone calls, office supplies, electricity, etc. They will increase the total expense of the hospital. At the same time, medicine suppliers also lose their opportunities to exchange this amount of medicines to other hospitals, having an impact on manufactures, hospitals, and patients involve in the supply chain of those medicines. Moreover, expired medicines are also hazardous to our environment, because they need to be destroyed by embedding or burning.

4.2 Medicine Categorization

Classification of medicine inventory can be divided into several categories depend on the criteria which classification. Such as medicine types, medicine properties, diseases and related health problems, diagnostic codes, procedural codes, pharmaceutical codes, usage patterns, etc. ABC analysis, VEN analysis, and ABC/VEN analysis are used to classified medicine in this research.

4.2.1 ABC Analysis

ABC analysis is medicine classification by using annual sales value to ranking medicine. The medicines are divided into three groups:

- Group A has 5% -10% of all medicine items that worth 75%-80% of the total medicine value,
- Group B has 20% -30% of all medicine items that worth 15%-20% of the total medicine value,
- Group C has 60% -75% of all medicine items that worth 5% -10% of the total medicine value.

Medicine classification by ABC analysis is showed in Table 4.2.

Table 4.2 Medicine classification by ABC analysis

Group	Items	Items (%)	Values (%)
A	264	12.52	75.18
B	526	24.95	20.05
C	1,318	62.53	4.77
Total	2,108	100.00	100.00

The medicine 2,108 items are classified into three groups based on their annual used values, the highest values fall under group A, accounted for 75.18 % of total values and covered 12.52 % of total 2,108 items. Group B dominates 20.05 % of all values and includes 24.95 % of total 2,108 items. Group C consist of the lowest total values of 4.77 % with the largest proportion 62.53% of total items.

4.2.2 VEN Analysis

VEN (vital, essential, and nonessential) analysis is medicine classification by classified according to their health impact. Generally, the VEN analysis is applied in pharmaceutical medicine classification. The medicines are divided into three groups according to their health impact:

- Group V is vital medicine and must be hold in stock,
- Group E is essential medicine and should be hold in stock,
- Group N is nonessential medicine but it is needed in stock.

Table 4.3 Medicine classification by VEN analysis

Group	Items	Items (%)	Values (%)
V	214	10.15	7.81
E	1,673	79.37	88.67
N	221	10.48	3.52
Total	2,108	100.00	100.00

From Table 4.3, there are three groups categorized from 2,108 items of medicines. Group V (vital medicine) is the most essential-for-life types, dominating 10.15% of all items, accounted for 7.81% of total values. Group E (essential medicine) is the second important group, consisting of the largest number of items and values with 79.37% and 88.67% respectively. Items lies in group N (non-essential medicine), accounting for 10.48% of total items and worth 3.52% of total values, appears to be the least necessary level but still needs to be reserved for generic cases.

4.2.3 ABC/VEN Analysis

ABC/VEN analysis is medicine classification by using annual sales value and the necessary of medicines. It combines the ABC analysis and VEN analysis together. The medicines are divided into nine groups as Table 4.4.

Table 4.4 Medicine classification by ABC/VEN analysis

Group	Items	Items (%)	Values (%)
AV	23	1.09	5.71
AE	231	10.96	67.81
AN	10	0.47	1.66
BV	42	1.99	1.60
BE	443	21.02	17.18
BN	41	1.95	1.26
CV	149	7.07	0.51
CE	999	47.39	3.67
CN	170	8.06	0.60
Total	2,108	100.00	100.00

Table 4.4 presents two-dimension classification including value and necessary level terms. A range of 2,108 items are categorized into nine groups by ABC/VEN analysis. Group AV holds the highest usage values and the most essential-for-life of medicines, accounting for 5.71% of usage values and 1.09% of total items. Group AE concentrates on the largest 67.81% of values and 10.96% of total number of medicines, possessing the second highest usage values and the second important level. Medicines in group AN, has high usage value but are a little importance than those in group AE, are only used for generic cases and needed to continually be stored were worth 1.66% of total and covering 0.47% of all items.

With their own moderate usage values and strong important level, medicines in group BV accounted for 1.50% of total usage values and 1.99% of total quantity. Medicines in group BE are the next class with their moderate usage values and important level and reached 17.18% of usage values and 21.02% of total quantity. For group BN, covers 1.26%, medium usage values and generic uses, these medicines account for 1.95% of all items and still need to be stocked. Medicines in group CV appear to hold such a small usage values but high important level, contributing to 0.51% and 7.07% of total values and items respectively. Medicines in group CE have tiny usage values and inferior important level with 3.67 of total values and 47.39% of all items. Finally, group CN is ranked on the basis of small usage values and generic uses but is require to be stocked. All medicines in this group account for 0.60% of total usage values and 8.06% of total items. Because of differences in significant level among nine groups of classified medicines, inventory management also must be differently prioritized.

Due to their high value and their importance to life, medicines' group AV is focused in this research. Applying ABC/VEN analysis, we find that 23 items of medicines are fallen into AV group. Preliminary information, however, indicates that one of them is no longer manufactured; as a result, the remaining of 22 medicine items is examined (the details present in Appendix A Properties of AV-Type Medicine). Table 4.5 shows medicine names, codes, types and sizes.

Table 4.5 Names, codes, types, and sizes of AV-type medicine

	Medicine names	Codes	Types	Sizes
1.	Albumin GCC	ALBK-I-	Inj.	20%
2.	Alphanate	ALPN-I-	Inj.	250 iu
3.	AmBisome	AMBS-I-	Inj.	50 mg
4.	ATG-Fresenius	ATGF-I-	Inj.	20 mg/ml
5.	Berodual Forte	BERF-X-	Ext U	
6.	Cancidas	CACD1I-	Inj.	50 mg
7.	Controloc	COTL-I-	Inj.	40 mg
8.	Desferal	DFRL-I-	Inj.	500 mg
9.	Feiba	FEIB2I-	Inj.	1000 U
10.	Gammaraas	GAMR1I-	Inj.	5 gm
11.	Hemofil-M	HEMF2I-	Inj.	500 iu
12.	Ilomedin-20	ILOM-I-	Inj.	0.02 mg
13.	Invanz	INVZ-I-	Inj.	1 gm
14.	Losec IV	LOSV-I-	Inj.	40 mg
15.	Meronem	MERN2I-	Inj.	1 gm
16.	Nexium IV	NEXM-I-	Inj.	40 mg
17.	Novoseven	NOSV-I-	Inj.	1.2 mg
18.	Sandostatin	SDTT1I-	Inj.	0.1 mg/ml
19.	Tienam IV	TIEN-I-	Inj.	500 mg
20.	Vfend IV	VFEN-I-	Inj.	200 mg
21.	Viagra	VIAG-T-	Tab.	50 mg
22.	Viagra	VIAG1T-	Tab.	100 mg

4.3 Medicine Demand Forecasting

Future demands for medicines are able to be classified into two groups: demand known in advance (k) and uncertain demand. Ilomedin-20, for example, is needed for medical students before each semester starts. This amount of medicine is known. Another stream of demand is medicines dispensed to patients. In this case, the demand relies upon doctors' diagnosing varied case by case. This type of demand is uncertain and needs to forecast. In this research, dispensation data from January to December, 2005-2007 are analyzed weekly. First, the trends are tested by the Runs Test. Trend patterns can be the linear model, cubic model, and quadratic model. Next, the R Squares and T-Test are determined for appropriate of trend models and coefficients in trend model. The Mean Square Error (MSE) is used to compare the appropriate forecasting method when the R Squares of trend models are nearby. Then, demand distributions are tested by SPSS and Arena program. The Kolmogorov-Smirnov Test is used to determine demand distribution patterns. The results show in Table 4.6 (please see details in Appendix B Medicine Demand Forecasting).

Table 4.6 Classification of AV-type medicine according to usage demands

Group	Demand trend	Demand distribution	Items
1	No	Normal	12
2	No	Gamma	1
3	No	Exponential	1
4	Yes	Normal	2

From Table 4.6, medicines were classified into four groups by demand trend and demand distribution. Twelve items fall into no trend group with Normal distribution, while the next item has no trend with Gamma distribution. There is one item having no trend and Exponential distribution. The last two items possess demand trend and Normal distribution. The other six items of medicines do not have proper distribution pattern, we will not mention further in the research. Weekly demand forecast for medicines in AV-type appeared on Table 4.7.

Table 4.7 Weekly demand forecast for AV-type medicine

Group	Medicine names	Weekly demand equations
1	ALBK-I-	NORM (304.06, 121.37)
	ALPN-I- ¹	NORM (37.00, 25.98)
	COTL-I-	NORM (79.98, 42.32)
	DFRL-I-	NORM (541.90, 223.23)
	GAMR1I-	NORM (55.99, 32.34)
	HEMF2I-	NORM (45.56, 24.05)
	LOSV-I-	NORM (466.63, 86.80)
	MERN2I-	NORM (307.42, 99.47)
	NEXM-I-	NORM (166.35, 62.75)
	SDTT1I-	NORM (97.25, 60.65)
	TIEN-I-	NORM (112.81, 62.47)
	VFEN-I-	NORM (15.37, 13.25)
2	VIAG-T-	GAMM(106.00, 1.19)
3	VIAG1T-	EXPO (56.60)
4	BERF-X- ²	NORM (2,452.420+6.467t, 403.235)
	INVZ-I- ²	NORM (100.195+0.884t+0.002t ² , 20.191)

Notes

¹ Equation for ALPN-I- specially used in the time where medicine is in national lists of essential medicines only.

² Demand trend of BERF-X- and INVZ-I- continues to be upward by:

t = the amount of weeks counted from the end of December 2007 ($t = 0, 1, 2, \dots$)

Distribution symbols identified in this research are as follows:

NORM(μ, σ) = Normal distribution

mean = μ , variance = σ^2

GAMM(β, α) = Gamma distribution

mean = $\alpha\beta$, variance = $\alpha\beta^2$

EXPO($\frac{1}{\lambda}$) = Exponential distribution is similar to gamma distribution by

substituting $\alpha = 1$ and $\beta = \frac{1}{\lambda}$, thus,

mean = $\frac{1}{\lambda}$, variance = $\frac{1}{\lambda^2}$

4.4 Medicine Inventory Models Development

In this research, ordering policy relevant to medicine forecasted demand is used. This policy is uncomplicated to manage. For medicines without trend, (s, S) policy is used. When medicine inventory level reduces to less than s level, the hospital will order that medicine, increasing the stock level equal to S . Generally, the value s and S are constant, but they will be change in the case of new forecast. In each order, inventory level at order point (I) may below than reorder point(s). As a result, the order quantity may be higher than $S - s$. For medicine with trend, (s, Q) policy is used. When medicine inventory level reduces to less than s level, the hospital will order that medicine equal to Q . Symbols for the model are expressed below:

D	Demand per week
S	The highest medicine inventory level (unit)
s	Reorder point (unit)
I	Medicine inventory level at reorder point (unit); $I \leq s$
Q	Ordering quantity (unit)
p	The number of in-package medicines
L	Lead time (from placing order to product receipt)
M	Storing period (day)
n	The number of days within one week (day)
sl	Service level $0 < sl < 1$
k	The estimated number of specifically used medicines
d_t	Forecasted demand value in week t in case of an occurrence of demand trend where t = the number of week counted from the end of December, 2007 ($t = 0, 1, 2, \dots$)

First, we determined the reorder point by using cycle service level. In this research, we develop for four instances according to demand trend and distribution-based classification. Equation is formed as follows:

$$P(D_L \leq s) = sl \quad (1)$$

Since AV-type medicine is vital, and then at least of 98% service level is used. In fact, service level for those medicines should be specified by pharmacists working in the hospital. In this research, we consider three levels setting by the pharmacists in the Ramathibodi hospital.

- 1) More than 98.00% of service level is determined to AV-type medicine that has substitute medicine and is not in the National List of Essential Medicines, such as ALBK-I- and GAMR1I-.
- 2) More than 99.00% of service level is determined to AV-type medicine that has substitute medicine and is in the National List of Essential Medicines, such as ALPN-I-, BERF-X-, COTL-I-, DFRL-I-, LOSV-I-, MERN2I-, SDTT1I-, and TIEN-I-.
- 3) More than 99.99% of service level is determined to apply to non substitute AV-type medicines, such as HEMF2I-, INVZ-I-, NEXM-I-, VFEN-I-, VIAG-T-, and VIAG1T-.

In the next section, we develop a mathematical formulation to find reorder point for four demand groups fundamentally handled with an assumption of the same distribution pattern and daily mean and variance.

4.4.1 Medicine Demand: Normal Distribution with no Trend

Specifications for medicine demand which is normal distribution with no trend are below:

- Weekly demand is normal distribution, its mean is μ_{week} and standard deviation is σ_{week} , which is equal to any others week.

- Daily demand is normal distribution, its mean is $\mu_{day} = \frac{\mu_{week}}{n}$ and standard deviation is $\sigma_{day} = \frac{\sigma_{week}}{\sqrt{n}}$, which is equal to any others day.

- From theorem1 in chapter 2, demand occurring in lead time of L days is based on Normal distribution with $\mu_L = L\mu_{day}$ mean and $\sigma_L = \sqrt{L}\sigma_{day}$ standard deviation.

Calculation of reorder point relies upon equation (1), $P(D_L \leq s) = sl$

From equation (1), demand for medicines in a period of lead time with Normal distribution, μ_L mean and σ_L standard deviation was resolved by the following equations:

$$P\left(\frac{D_L - \mu_L}{\sigma_L} \leq \frac{s - \mu_L}{\sigma_L}\right) = sl$$

$$P\left(z \leq \frac{s - \mu_L}{\sigma_L}\right) = sl$$

$$z\sigma_L \leq s - \mu_L$$

$$s \geq \mu_L + z\sigma_L$$

Since $\mu_L = L\mu_{day}$ and $\sigma_L = \sqrt{L}\sigma_{day}$, then

$$s \geq L\mu_{day} + z\sqrt{L}\sigma_{day}$$

Since $\mu_{day} = \frac{\mu_{week}}{n}$ and $\sigma_{day} = \frac{\sigma_{week}}{\sqrt{n}}$, then

$$s \geq L \cdot \frac{\mu_{week}}{n} + z\sqrt{L} \cdot \frac{\sigma_{week}}{\sqrt{n}}$$

$$s \geq \frac{L \cdot \mu_{week}}{n} + \frac{z \cdot \sqrt{nL}\sigma_{week}}{n}$$

$$s \geq \frac{L \cdot \mu_{week} + z \cdot \sqrt{nL}\sigma_{week}}{n}$$

$$\therefore s = \frac{L \cdot \mu_{week} + z \cdot \sqrt{nL}\sigma_{week}}{n} \quad (2)$$

Calculation of the highest level of medicine inventory is based on demand for sufficient in-stock medicines for M days, starting from 1st day to M day plus certain quantity and then plus inventory quantity at reorder point, and finally equations are as:

$$S = M\mu_{day} + k + s$$

Since $\mu_{day} = \frac{\mu_{week}}{n}$, then

$$S = M \frac{\mu_{week}}{n} + k + s \quad (3)$$

Calculation of ordering quantity proceeded by which the highest level of medicine inventory minus level of medicine inventory at reorder point and divide by packaging size and then round up as:

$$Q = \left\lceil \frac{S - s}{p} \right\rceil \quad (4)$$

As a result, normal distribution with no trend demand would possess reorder point, the highest level of inventory as well as ordering quantity as follow:

$$s = \frac{L \cdot \mu_{week} + z \cdot \sqrt{nL} \sigma_{week}}{n}, S = M \frac{\mu_{week}}{n} + k + s, \text{ and } Q = \left\lceil \frac{S - s}{p} \right\rceil \text{ respectively.}$$

4.4.2 Medicine Demand: Gamma Distribution with no Trend

Specifications of medicine demand which is gamma distribution with no trend are outlined below:

- Weekly demand is based on Gamma distribution with (β, α) parameter, its mean is $\alpha\beta$ and its variance is $\alpha\beta^2$.

- Daily demand is based on Exponential distribution parameter $(\frac{1}{\lambda})$ and its

mean is $\frac{1}{\lambda} = \frac{\alpha\beta}{n}$.

- From theorem 2 in chapter 2, demand occurring in lead time of L days is based on Gamma distribution with parameters are $(L, \frac{\alpha\beta}{n})$ and mean

is $\frac{L\alpha\beta}{n}$.

Calculation of reorder point runs upon the equation (1), $P(D_L \leq s) = sl$

From equation (1) demand for medicine at a period of lead time with Gamma distribution has $\frac{L\alpha\beta}{n}$ mean and $L \cdot \left(\frac{\alpha\beta}{n}\right)^2$ variance as the following equations:

$$\int_0^s \frac{\left(\frac{n}{\alpha\beta}\right)^L x^{L-1} e^{-\frac{nx}{\alpha\beta L}}}{\Gamma L} dx = sl$$

$$\frac{1}{(L-1)!} \left(\frac{n}{\alpha\beta}\right)^L \int_0^s x^{L-1} e^{-\frac{nx}{\alpha\beta L}} dx = sl \quad (5)$$

Notes: The calculation of reorder point relies upon Microsoft Excel Program by using function of GAMMAINV (probability, alpha, beta) = GAMMAINV $(sl, L, \frac{\alpha\beta}{n})$.

Calculation of the highest level of medicine inventory is based on demand for sufficient in-stock medicines for M days, starting from 1st day to M day plus certain quantity and then plus inventory quantity at reorder point, and finally equation is formed as:

$$S = M \frac{\alpha\beta}{n} + k + s \quad (6)$$

Calculation of ordering quantity is performed by calculating the highest level of medicine inventory minuses level of medicine inventory at reorder point and is divided by packaging size and then rounds up as:

$$Q = \left\lceil \frac{S - s}{p} \right\rceil$$

As a result, medicines which Gamma distribution has no trend provide reorder point, the highest level of inventory as well as ordering quantity as follow:

$$\frac{1}{(L-1)!} \left(\frac{n}{\alpha\beta}\right)^L \int_0^s x^{L-1} e^{-\frac{nx}{\alpha\beta L}} dx = sl, \quad S = M \frac{\alpha\beta}{n} + k + s, \quad \text{and} \quad Q = \left\lceil \frac{S - s}{p} \right\rceil \text{ respectively.}$$

4.4.3 Medicine Demand: Exponential Distribution with no Trend

As Exponential distribution is significantly considered a kind of Gamma distribution with parameter of $\alpha = 1$ and $\beta = \frac{1}{\lambda}$, its equations and specifications are rather similar to those of Gamma distribution (topic 4.4.2) which are:

- Weekly demand is based on Exponential distribution with parameter $(\frac{1}{\lambda})$

which is equal to mean. Its variance is $\frac{1}{\lambda^2}$.

- Daily demand is based on Gamma distribution with parameters are $(\frac{1}{n}, \frac{1}{\lambda})$. Its mean and variance are $\frac{1}{n\lambda}$ and $\frac{1}{n\lambda^2}$ respectively.

- From theorem 2 in the chapter 2, demand occurring in lead time of L days is based on Gamma distribution with $(\frac{L}{n}, \frac{1}{\lambda})$ parameter. Its mean and variance are $\frac{L}{n\lambda}$ and $\frac{L}{n\lambda^2}$ respectively.

Reorder point is speculated from equation (1), $P(D_L \leq s) = sl$

From equation (1), for demand for medicines at a period of lead time with $\frac{L}{n\lambda}$ mean and $\frac{L}{n\lambda^2}$ variance, equations are formed as:

$$\int_0^s \frac{\lambda e^{-x\lambda} (\lambda x)^{\frac{L}{n}-1}}{\Gamma(\frac{L}{n})} dx = sl$$

$$\frac{\lambda^{\frac{L}{n}}}{\Gamma(\frac{L}{n})} \int_0^s e^{-x\lambda} x^{\frac{L}{n}-1} dx = sl \quad (7)$$

Notes: The calculation of reorder point relies upon Microsoft Excel Program by using function of GAMMAINV (probability, alpha, beta) = GAMMAINV $(sl, \frac{L}{n}, \frac{1}{\lambda})$

The highest level of medicine inventory was calculated from demand for sufficient in-stock medicines for M days, starting from 1st day to M day plus certain quantity and then plus an inventory quantity at are order point as follow:

$$S = M \frac{1}{n\lambda} + k + s \quad (8)$$

Ordering quantity is performed by calculating the highest level of medicine inventory minuses a level of medicine inventory at reorder point and is divided by packaging size and then round up as:

$$Q = \left\lceil \frac{S - s}{p} \right\rceil$$

As a result, medicines with Exponential distribution with no trend provided reorder point, the highest level of inventory, and ordering quantity as follow:

$$\frac{\lambda^{\frac{L}{n}}}{\Gamma(\frac{L}{n})} \int_0^s e^{-x\lambda} x^{\frac{L}{n}-1} dx = s!, \quad S = M \frac{1}{n\lambda} + k + s, \quad \text{and} \quad Q = \left\lceil \frac{S - s}{p} \right\rceil \text{ respectively.}$$

4.4.4 Medicine Demand: Normal Distribution with Trend

Specifications for medicine demand which is normal distribution with trend are outlined below:

- Weekly demand is based on Normal distribution. The mean in week t is $f(d_t)$ and standard deviation is σ_{week} which is equal to any other weeks.

- Daily demand is based on Normal distribution with $\int_{t=a}^{t=a+1} f(d_t) dt$ mean

and $\sigma_{day} = \frac{\sigma_{week}}{\sqrt{n}}$ standard deviation when n represents the number of days within a week.

- Demand occurring in lead time of L days is based on Normal

distribution with $\mu_L = \int_{t=c}^{t=d} f(d_t) dt$ mean $\sigma_L = \sqrt{L} \sigma_{day}$ and standard

deviation.

Reorder point is calculated from equation (1), $P(D_L \leq s) = sl$.

From equation (1), demand for medicines at a period of lead time with Normal distribution, μ_L mean and σ_L variable, is calculated by the following equations:

$$P\left(\frac{D_L - \mu_L}{\sigma_L} \leq \frac{s - \mu_L}{\sigma_L}\right) = sl$$

$$P\left(z \leq \frac{s - \mu_L}{\sigma_L}\right) = sl$$

$$z\sigma_L \leq s - \mu_L$$

$$s \geq \mu_L + z\sigma_L$$

$$s = \int_{t=c}^{t=d} f(d_t)dt + z\sqrt{L}\sigma_{day} \quad (9)$$

where $d - c = L$

$$c = (t_w - 1) + \frac{t_d}{27} ; \text{ordering day}$$

$$d = (t_w - 1) + \frac{t_d}{27} ; \text{on-handed delivering day}$$

(t_w, t_d) values of c unequal to (t_w, t_d) values of d

$t_w = 0, 1, 2, \dots$; the number of weeks from the end of December, 2007

$t_d = 1, 2, \dots, 7$; where 1=Monday, 2=Tuesday, 3=Wednesday,

4=Thursday, 5=Friday, 6=Saturday, 7=Sunday

Ordering quantity is calculated from demand for sufficient in-stock medicines for M days, from a to b plus known quantity and divide by packaging size and then round up as:

$$Q = \left\lceil \frac{\int_{t=a}^{t=b} f(d_t)dt + k}{p} \right\rceil \quad (10)$$

where $b - a = M$

$$a = (t_w - 1) + \frac{t_d}{27} ; \text{a starting day of stocking medicines.}$$

$b = (t_w - 1) + \frac{t_d}{27}$; a last day of stocking medicines when

(t_w, t_d) values of a are unequaled to (t_w, t_d) values of b .

$t_w = 0, 1, 2, \dots$; week next to the end of December, 2007

$t_d = 1, 2, \dots, 7$; where 1=Monday, 2=Tuesday, 3=Wednesday,

4=Thursday, 5=Friday, 6=Saturday, 7=Sunday

The highest level of medicine inventory performed by which the order quantity multiply by packing size and plus level of medicine inventory at reorder point as:

$$S = Qp + s \quad (11)$$

Regarding medicine demand which has normal distribution and trend, the reorder point, the highest level of inventory, and the ordering quantity can be calculate from the following equation:

$$s = \int_{t=c}^{t=d} f(d_t) dt + z\sqrt{L}\sigma_{day}, \quad Q = \left\lceil \frac{\int_{t=a}^{t=b} f(d_t) dt + k}{p} \right\rceil, \text{ and } S = Qp + s \text{ respectively.}$$

Developed medicine inventory policy can be used to form a series of equation for resolving level of the highest level of medicine inventory, the reorder point and the ordering quantity of all four types of demands as shown on Table 4.8.

Table 4.8 Developed AV-type medicine inventory policy

Demand pattern	Order up to level (S)	Reorder point (s)	Order quantity (Q)
Normal distribution with no trend	$S = M \frac{\mu_{week}}{n} + k + s$	$s = \frac{L \cdot \mu_{week} + z \cdot \sqrt{nL}\sigma_{week}}{n}$	$Q = \left\lceil \frac{S - s}{p} \right\rceil$
Gamma distribution with no trend	$S = M \frac{\alpha\beta}{n} + k + s$	$\frac{1}{(L-1)!} \left(\frac{n}{\alpha\beta} \right)^L \int_0^s x^{L-1} e^{\frac{-nx}{\alpha\beta L}} dx = sl$	

Demand pattern	Order up to level (S)	Reorder point (s)	Order quantity (Q)
Exponential distribution with no trend	$S = M \frac{1}{n\lambda} + k + s$	$\frac{\lambda^{\frac{L}{n}}}{\Gamma(\frac{L}{n})} \int_0^s e^{-x\lambda} x^{\frac{L}{n}-1} dx = sl$	$Q = \left\lceil \frac{S-s}{p} \right\rceil$
Normal distribution with trend	$S = Qp + s$	$s = \int_{t=c}^{t=d} f(d_t)dt + z\sqrt{L}\sigma_{day}$	$Q = \left\lceil \frac{\int_{t=a}^{t=b} f(d_t)dt + k}{p} \right\rceil$

4.5 The Comparison of Key Performance Indicators between Current Policy and Proposed Policy

This topic provides a comparison of inventory key performance indicators between proposed policy and current hospital policy for medicine group AV. The proposed policy focuses on ordering medicines for one month usage in order not to increase workload for hospital's staff. For example, a hospital has four purchasing staff who are in charge of 2,000 items of medicines. If each item is ordered once a month, each staff must take care of monthly 500 items. On the other hand, if the number of order reaches 3 times a month, each worker must be responsible for monthly up to 1,500 items.

From an interview, hospital officers revealed orders are activated when inventory level decreases to 80% of monthly average usage ($\hat{Y}_i$) and ordering quantity must be filled up to 150% of monthly average usage, known as Min-Max policy.

$$\min \hat{Y}_i = 80(0.5X_{i-1} + 0.5\hat{Y}_{i-1})$$

$$\max \hat{Y}_i = 150(0.5X_{i-1} + 0.5\hat{Y}_{i-1})$$

where $\hat{Y}_i$ forecasting values in month i

$\hat{Y}_{i-1}$ forecasting values in month i-1

X_{i-1} total values of average usage of month i-1

To compare key performance indicators of proposed policy to current policy and to preliminarily calculate policy performed at specified service level

simulation is held within 1 year with 30 replications of simulations. s and S can be calculated from designated service level. Key performance indicators included 1) average stock per day 2) average medicine inventory turnover 3) average number of orders per year 4) average day of shortages per year 5) average quantity of shortages per year 6) average number of times of stock shortage per year.

4.5.1 The Comparison of Key Performance Indicators for Each Item of AV-Type Medicines

1) Albumin GCC (ALBK-I-)

Albumin GCC is used to treatment of hypovolemic syndrome & the aversion of CV collapse, hypovolaemic Shock, infection. It excludes from National List of Essential Medicines. In addition, since there is no substituted medicine, it is vital to stock adequate volumes in order to meet certain demand. Calculation initially starts at 99.99% of service levels with startup inventory of 1,600 units and 13-day lead times.

Table 4.9 A comparison of key performance indicators between current policy and proposed policy of ALBK-I-

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	1,198.24	1,186.36	-0.99	lower
2) Average medicine inventory turnover	14.78	14.37	-2.77	lower
3) Average number of orders per year	14.97	13.00	-13.15	lower
4) Average day of shortages per year	0.00	0.00	-	same
5) Average quantity of shortages per year	0.00	0.00	-	same
6) Average number of times of stock shortage per year	0.00	0.00	-	same

When simulation is done (see Table 4.9), it is found that proposed policy contributed to a decrease in the average stock per day and the average number of orders per year by 0.99% or 16,146.16 Baht and 13.15% or 1.97 times respectively while the average medicine inventory turnover of proposed policy is lower than

current policy. The average day of shortages per year, the average quantity of shortage per year, and the average number of times of stock shortage per year are zero which are the same as current policy.

The reorder point at the 99.99% of service level may result in higher medicine inventory. Therefore, the service level is reduced to 99.90% without any shortage of medicine. The results of simulations at the 99.99% of service level show in Table 4.10.

Table 4.10 A comparison of key performance indicators between current policy and proposed policy of ALBK-I- (revised)

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	1,197.43	1,083.48	-9.52	lower
2) Average medicine inventory turnover	14.81	15.86	7.08	higher
3) Average number of orders per year	15.13	12.87	-14.94	lower
4) Average day of shortages per year	0.00	0.00	-	same
5) Average quantity of shortages per year	0.00	0.00	-	same
6) Average number of times of stock shortage per year	0.00	0.00	-	same

From Table 4.10, the proposed policy dropped the average stock per day 9.52% which value is 154,585.27 Baht. The average medicine inventory turnover is 15.86 which increase 7.08% from current policy. The average number of orders per year decreased 14.94% or 2.26 times. The average day of shortages per year, the average quantity of shortages per year, and the average number of times of stock shortage per year are zero as well as current policy. This means they are not shortage. The number of orders and the reorder point of proposed policy are lower than current policy. The order quantity in each time of proposed policy is enough for demand in one month but the current policy order medicine for demand that less than one month, so the order frequency of current policy is higher than proposed policy.

2) **Alphanate (ALPN-I-)**

Alphanate is used to protect and control Hemophilia in patients who need factor 8. This medicine was previously excluded from and subsequently included in National List of Essential Medicines on 2007. There are available substitutes. To calculate reorder point, initial inventory is 157 units, lead time is 11 days, and service level is 99.00%. Only data possessed by National List of Essential Medicines are taken into account.

Table 4.11 A comparison of key performance indicators between current policy and proposed policy of ALPN-I-, only in National list of Essential Medicines

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	167.67	133.14	-20.59	lower
2) Average medicine inventory turnover	15.78	18.81	19.20	higher
3) Average number of orders per year	16.60	15.43	-7.05	higher
4) Average day of shortages per year	0.17	0.53	211.76	higher
5) Average quantity of shortages per year	0.60	2.23	271.67	higher
6) Average number of times of stock shortage per year	0.10	0.27	170.00	higher

From Table 4.11, after preceded by simulation, the average stock per day of proposed policy reduces 20.59% as many as 124,170.70 Baht compared to those of current policy. The average medicine inventory turnover is 18.81 which increase 19.20% from current policy. The average number of orders per year reduced 7.05% or 1.17 times. However, the average day of shortages per year, the average quantity of shortages per year, and the average number of times of stock shortage per year conversely arose due to an increase in coefficient variation, 3.45 of daily average usage. It was necessary to improve the reorder points and the maximum inventory levels by raising service levels from 99.0% to 99.9%. The renewing reorder points and maximum inventory levels are 159 and 318 units respectively.

Table 4.12 A comparison of key performance indicators between current policy and proposed policy of ALPN-I-, only in National list of Essential Medicines (revised)

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	166.88	156.84	-6.02	lower
2) Average medicine inventory turnover	15.77	16.12	2.23	higher
3) Average number of orders per year	16.87	15.83	-6.16	lower
4) Average day of shortages per year	0.13	0.00	-100.00	lower
5) Average quantity of shortages per year	0.77	0.00	-100.00	lower
6) Average number of times of stock shortage per year	0.10	0.00	-100.00	lower

According to Table 4.12, after the reorder points and the maximum inventory levels are mended, the average stock per day decreased by 6.02% which worth 36,131.43 Baht. The average medicine inventory turnover increases from 15.77 to 16.12 or increase 2.23%. The average number of orders per year decreases from 16.87 to 15.83 or decreases 6.16%. Otherwise, the average day of shortages per year, the average quantity of shortages per year, and the average number of times of stock shortage per year decrease 100.00%. This means shortage is not occurred. Proposed policy benefited hospital a more effective service as stock-out medicines and stock-out times were lessened, contributing to a decrease in inventory and overload jobs elimination.

3) **Berodual Forte** (BERF-X-)

Berodual Forte is used to protect and cure symptoms in chronic obstructive airway disorders with reversible bronchospasm. It is excluded from National List of Essential Medicines. It has substitutes. This medicine has linear demand trend and coefficient of variance demand is 0.19. Reorder point calculation was based on 99.00% of service level, 5,200 units of initial inventory, and 12 days of lead time. Purchasing quantity must be referred to 20-times base. The outcomes presented in Table 4.13.

Table 4.13 A comparison of key performance indicators between current policy and proposed policy of BERF-X-

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	8,204.19	6,937.82	-15.44	lower
2) Average medicine inventory turnover	16.64	19.68	18.29	higher
3) Average number of orders per year	17.73	12.37	-30.26	lower
4) Average day of shortages per year	0.00	0.00	-	same
5) Average quantity of shortages per year	0.00	0.00	-	same
6) Average number of times of stock shortage per year	0.00	0.00	-	same

From Table 4.13, the average stock per day reduces from 8,204.19 units to 6,937.32 units or 15.44% which worth 45,589.15 Baht. The average medicine inventory turnover is higher 18.29%. The average number of orders per year decreases 5.36 times or 30.26%. Consequently, without stock-out inventory, job load and inventory costs were eased.

4) **Controloc (COTL-I-)**

Controloc is used to treat Gastro Esophageal Reflux Disease (GERD), a condition in which backward flow of acid from the stomach causes heartburn and injury of the food pipe (esophagus). It is included in National List of Essential Medicines with substitutes. Service level of 99.00%, initial inventory of 500 units and lead time of 13 days were determined for reorder point calculation.

Table 4.14 A comparison of key performance indicators between current policy and proposed policy of COTL-I-

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	334.14	275.53	-17.54	lower
2) Average medicine inventory turnover	15.37	18.13	17.97	higher
3) Average number of orders per year	15.17	13.50	-10.99	lower
4) Average day of shortages per year	0.33	0.53	60.00	higher

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
5) Average quantity of shortages per year	4.10	7.73	88.62	higher
6) Average number of times of stock shortage per year	0.10	0.23	133.33	higher

From Table 4.14, it is found that the average stock per day fall by 17.54%, from 334.14 to 275.53 units. The average medicine inventory turnover increases 17.97%. The average number of orders per year decreases 10.99%. On the other hand, the number of average day of shortages per year, the average quantity of shortages per year and the average number of times of stock shortage per year became more worth than those of current policy. As daily demand appeared to be volatile with 1.99 coefficient of demand variance, this led to stock-out inventory. To improve COTL-I- inventory, service level is modified to be 99.9%, resulting in new reorder points and maximum levels of inventory as 327 units and 670 units. The results of simulation show in Table 4.15.

Table 4.15 A comparison of key performance indicators between current policy and proposed policy of COTL-I- (revised)

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	334.60	316.02	-5.55	lower
2) Average medicine inventory turnover	15.37	16.34	6.30	higher
3) Average number of orders per year	15.27	13.93	-8.73	lower
4) Average day of shortages per year	0.20	0.00	-100.00	lower
5) Average quantity of shortages per year	4.10	0.00	-100.00	lower
6) Average number of times of stock shortage per year	0.13	0.00	-100.00	lower

An improved ordering policy at 99.90% of service level rises in reorder points, maximum inventory levels, and quantities of inventory. The average stock per day and the shortages are lower than those from Table 4.14. Consequently, difficulty in shortage inventory management was removed as the average day of shortages per

year, the average quantity of shortages per year, and the average number of times of stock shortage per year. Inventory shortage occasionally occurred when conducting simulation, the average numbers were not in a form of integers. Proposed policy contributed to a decrease in the average stock per day by 5.55% with worth 6,616.50 Baht. The average medicine inventory turnover increases 6.30%. The average number of orders per year decreases 8.73% or 1.34 times. Regarding developed and improved policy, inventory quantity and overload jobs are decreased but inventory turnover is increased. Increasingly service is able to be delivered to patients due to relieve of inventory shortage.

5) **Desferal (DFRL-I-)**

Desferal is used to treat iron overload caused by blood transfusions in adults and children at least 3 years old. It has substitutes. 99.00% of service level is set to calculate reorder point. Initial inventory is 1,600 units and lead time is 12-day. In procurement process, quantity must be integers which able to be divided by 10. According to simulation, the average stock per day and the average number of orders per year became lower than those of current policy by 23.05% and 11.21% respectively. The average medicine inventory turnover increases 24.18%. Medicine inventory, nonetheless, may possibly be scarce in proposed policy rather than in current policy as data on Table 4.16. It is necessary to adjust proposed policy by raising service level to 99.90% and to replace 1,833 units and 4,155 units as new reorder points and maximum inventory level. The results are presented on Table 4.17.

Table 4.16 A comparison of key performance indicators between current policy and proposed policy of DFRL-I-

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	2,228.01	1,714.52	-23.05	lower
2) Average medicine inventory turnover	14.43	17.91	24.18	higher
3) Average number of orders per year	14.87	13.20	-11.21	lower
4) Average day of shortages per year	0.00	0.20	-	higher
5) Average quantity of shortages per year	0.00	10.83	-	higher

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
6) Average number of times of stock shortage per year	0.00	0.20	-	higher

Table 4.17 A comparison of key performance indicators between current policy and proposed policy of DFRL-I- (revised)

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	2,228.82	1,918.34	-13.93	lower
2) Average medicine inventory turnover	14.42	16.19	12.27	higher
3) Average number of orders per year	14.97	13.27	-11.36	lower
4) Average day of shortages per year	0.00	0.00	-	same
5) Average quantity of shortages per year	0.00	0.00	-	same
6) Average number of times of stock shortage per year	0.00	0.00	-	same

Once service levels were raised to 99.90%, there were a reduction in the average day of shortage per year, the average quantity of shortage per year, and the average number of times of stock shortage per year. From Table 4.17, the numbers of key performance indicators 4), 5), and 6) between two policies notably resembled. In addition, the average stock per day and the average number of orders per year abated by 13.93% as many as 68,617.17 Baht, and 11.36% or 1.70 times a year respectively. The average medicine inventory turnover increases 12.27%. Finally, hospital may utilize the proposed policy to decrease inventory and overload jobs.

6) **Gammaraas (GAMR1I-)**

Gammaraas is used for cure Human Immunoglobulin and excludes from National List of Essential Medicines. Due to such a high variance of demand with coefficient 2.34 and without its substitutes, this item could not be deficient. Reorder points were calculated at 99.99 % of service levels, with 300 units of startup inventory and 15-day lead times.

Table 4.18 A comparison of key performance indicators between current policy and proposed policy of GAMR1I-

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	219.89	257.80	17.24	higher
2) Average medicine inventory turnover	17.51	14.06	-19.67	lower
3) Average number of orders per year	16.13	15.00	-7.02	lower
4) Average day of shortages per year	1.20	0.00	-100.00	lower
5) Average quantity of shortages per year	11.50	0.00	-100.00	lower
6) Average number of times of stock shortage per year	0.70	0.00	-100.00	lower

After applied to the simulation according to Table 4.18, proposed policy did not result in medicine scarcity, being ideally significant case for non-substitute medicines. The average medicine inventory turnover decreases 19.67%. The average number of orders per year decreases 7.02%. Because of highly specified service levels, the average stock per day by 17.24%; as a result, researcher decided to demote service levels to 99.90%, which did not lead to scarcity but only a reduction in inventory. Newly set reorder points and maximum levels of inventory became 267 units and 507 units. All results displayed on Table 4.19.

Table 4.19 A comparison of key performance indicators between current policy and proposed policy of GAMR1I- (revised)

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	219.89	231.22	5.15	higher
2) Average medicine inventory turnover	17.39	15.69	-9.80	lower
3) Average number of orders per year	16.20	15.10	-6.79	lower
4) Average day of shortages per year	1.23	0.00	-100.00	lower
5) Average quantity of shortages per year	11.57	0.00	-100.00	lower
6) Average number of times of stock shortage per year	0.67	0.00	-100.00	lower

Revised service levels to 99.90% caused the average stock per day to be lessened but still higher than those of current policy. Table 4.20 presented the average stock per day rose by 5.15% from 219.89 to 231.22 units. The average medicine inventory turnover declined from 17.39 to 15.69 or by 9.80%. The average number of orders per year declined from 16.20 to 15.10 times by 6.79%. More significantly, proposed policy effectively led to no shortage for AV-type medicines which owned the highest important level. Totally 100% of the average day of shortages per year, the average quantity of shortages per year, and the average number of times of stock shortage per year were removed if compared to those of current policy.

7) **Hemofil-M (HEMF2I-)**

Hemofil-M is used to treat or prevent bleeding episodes in adults and children with hemophilia A. It excludes from National List of Essential Medicines and has substitutes. 98.00% of service levels, 200 units of initial inventory, and 15 days of lead time are assigned to simulation. The results show as Table 4.20.

Table 4.20 A comparison of key performance indicators between current policy and proposed policy of HEMF2I-

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	155.30	148.48	-4.39	lower
2) Average medicine inventory turnover	18.60	18.59	-0.05	lower
3) Average number of orders per year	16.93	14.03	-17.13	lower
4) Average day of shortages per year	3.13	1.43	-54.26	lower
5) Average quantity of shortages per year	22.13	8.60	-61.14	lower
6) Average number of times of stock shortage per year	1.10	0.77	-30.30	lower

Compared to current policy, proposed policy provided a reduction in all key performance indicators including the average stock per day, the average medicine inventory turnover, the average number of orders per year, the average day of shortages per year, the average quantity of shortages per year, and the average number of times of stock shortage per year by 4.39%, 0.05%, 17.13%, 54.26%, 61.14%, and

30.30% respectively. According to Table 4.20, there was medicine shortage in both policies as demand was more likely to be volatile with 1.95 Coefficient of Variance. An increase of 99.60% service levels was held to relieve such a shortage, offering 191 units of new reorder points and 387 units of maximum inventory levels. Overall results were available on Table 4.21.

Table 4.21 A comparison of key performance indicators between current policy and proposed policy of HEMF2I- (revised)

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	155.84	169.55	8.80	higher
2) Average medicine inventory turnover	18.77	16.73	-10.84	lower
3) Average number of orders per year	16.87	14.03	-16.80	lower
4) Average day of shortages per year	3.00	0.07	-97.78	lower
5) Average quantity of shortages per year	22.50	0.33	-98.52	lower
6) Average number of times of stock shortage per year	1.07	0.03	-96.88	lower

Improved policy rather seemed to be successful in terms of a least shortage reduction, a primary principle for AV-type medicines. When service levels reached 99.60%, the average stock per day climbed to 169.55 units, increased by 8.80% as many as 68,240.38 Baht. The average medicine inventory turnover decreases 10.84%. However, the average number of orders per year, the average day of shortages per year, the average quantity of shortages per year, and the average number of times of stock shortage per year conversely went down by 16.80% (decrease from 16.87 times to 14.03 times), 97.87% (decrease from 3 days to 0.07 days), 98.52% (decrease from 22.50 units to 0.33 units) and 96.88% respectively (decrease from 1.07 times to 0.03 times).

8) **Invanz** (INVZ-I-)

Invanz is is used to treat severe bacterial infections of the skin, lungs, stomach, pelvis, and urinary tract. It is out of National List of Essential Medicines. It has substitutes and its upward demand trend. To solve simulation was handled with

300 startup units of inventory, 98.00% service levels, and 13-day lead times. The results showed 18.45% decline in the average stock per day, worth about 120,938.20 Baht. The average medicine inventory turnover of proposed policy is higher 21.20% than current policy. Moreover, the average number of orders per year reduces 36.28%, from 19.10 to 12.17 times a year. On the other hand, the average day of shortages per year, the average quantity of shortages per year, and the average number of times of stock shortage per year are not occur (see Table 4.22). Overall aspect of proposed policy likely seemed to be more effective than that of current policy according to decrease in inventory costs and overload jobs but increase in inventory turnover.

Table 4.22 A comparison of key performance indicators between current policy and proposed policy of INVZ-I-

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	397.36	324.07	-18.45	lower
2) Average medicine inventory turnover	16.38	19.86	21.20	higher
3) Average number of orders per year	19.10	12.17	-36.28	lower
4) Average day of shortages per year	0.00	0.00	0.00	same
5) Average quantity of shortages per year	0.00	0.00	0.00	same
6) Average number of times of stock shortage per year	0.00	0.00	0.00	same

9) **Losec IV (LOSV-I-)**

Losec IV is used to cure Gastric Ulcer, Duodenal Ulcer as well as moderate to severe Reflux Esophagitis. It able to be replaced by others and includes in National List of Essential Medicines. The simulation is calculated on the basis of 1,750 startup units, 99.00% service level and 10-day lead time. Table 4.23 included all results.

Table 4.23 A comparison of key performance indicators between current policy and proposed policy of LOSV-I-

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	1,569.25	1,208.33	-23.00	lower
2) Average medicine inventory turnover	15.73	20.07	27.64	higher
3) Average number of orders per year	17.00	11.90	-30.00	lower
4) Average day of shortages per year	0.00	0.20	-	lower
5) Average quantity of shortages per year	0.00	3.50	-	lower
6) Average number of times of stock shortage per year	0.00	0.20	-	lower

Table 4.23 presents the average stock per day and the average number of order per year dropped by 23% and 30% respectively, opposed to the average day of shortages per year, the average quantity of shortages per year, and the average number of times of stock shortage per year which appeared to increase from existing policy. Underestimated service levels may likely attribute to those rises. Service levels were amended up to 99.90%, leading to latest reorder points and maximum inventory levels of 988 units and 2,988 units respectively. Improved results are available on Table 4.24.

Table 4.24 A comparison of key performance indicators between current policy and proposed policy of LOSV-I- (revised)

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	1,569.13	1,298.11	-17.27	lower
2) Average medicine inventory turnover	15.69	18.59	18.47	higher
3) Average number of orders per year	17.00	11.87	-30.20	lower
4) Average day of shortage per year	0.00	0.00	-	same
5) Average quantity of shortage per year	0.00	0.00	-	same
6) Average number of times of stock shortage per year	0.00	0.00	-	same

Modified service level at 99.90% did not cause a shortage and the average stock per day and the average number of orders per year reduction by 17.27% or 108,408.07 Baht (from 1,569.13 units to 1,298.11 units) and 30.20% or 5.13 times severally. The average medicine inventory turnover of proposed policy is higher than current policy 18.47%. Also, inventory costs fell by 108,408.07 Baht.

10) **Merone** (MERN2I-)

Merone is used to reduce the development of drug-resistant bacteria and maintain the effectiveness of MERREM® I.V. and other antibacterial drugs, and should be used to treat or prevent infections that are proven or strongly suspected to be caused by bacteria. It includes in National List of Essential Medicines and has substitutes. 380 startup units, 99.00% service levels, and 10-day lead times are formed to simulation. Purchasing quantity must be integral numbers which can be dividing by 10. From Table 4.25, the average stock per day and the average number of orders per year became smaller than those of current policy, accounted for 16.75% worth 263,065.39 Baht and 28.22% or approximately 5.03 times a year. The average medicine inventory turnover is higher than current policy 17.64%. The average day of shortages per year, the average quantity of shortages per year, and the average number of times of stock shortage per year are the same with current policy that are zero, do not shortage.

Table 4.25 A comparison of key performance indicators between current policy and proposed policy of MERN2I-

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	1,065.64	887.17	-16.75	lower
2) Average medicine inventory turnover	16.09	18.93	17.64	higher
3) Average number of orders per year	17.83	12.80	-28.22	lower
4) Average day of shortages per year	0.00	0.00	-	same
5) Average quantity of shortages per year	0.00	0.00	-	same
6) Average number of times of stock shortage per year	0.00	0.00	-	same

11) Nexium IV (NEXM-I-)

Nexium IV is used to treat Gastro Esophageal Reflux Disease (GERD) and other conditions involving excessive stomach acid such as Zollinger-Ellison syndrome. It excludes from National List of Essential Medicines. 610 units of initial inventory, 98.00% of service levels, and 10 days of lead times acted as calculation of reorder point and simulation.

Table 4.26 A comparison of key performance indicators between current policy and proposed policy of NEXM-I-

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	603.29	490.06	-18.77	lower
2) Average medicine inventory turnover	15.48	19.07	23.22	higher
3) Average number of orders per year	16.87	12.50	-25.89	lower
4) Average day of shortages per year	0.00	0.37	-	higher
5) Average quantity of shortages per year	0.00	4.20	-	higher
6) Average number of times of stock shortage per year	0.00	0.33	-	higher

The results (see Table 4.26) provided a drop of 18.77% in the average stock per day from 603.29 units to 490.06 units and 25.89% in the average number of orders per year from 16.87 times to 12.50. The average medicine inventory turnover decreases 23.22%. However, the average day of shortages per year, the average quantity of shortages per year, and the average number of times of stock shortage per year are increase from current policy. It was necessary for researcher to re-estimate new service levels of 99.60% resulting in reorder points and maximum inventory levels at 437 units and 1,150 units subsequently. The results of simulation show at Table 4.27.

Table 4.27 A comparison of key performance indicators between current policy and proposed policy of NEXM-I- (revised)

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	603.00	536.21	-11.08	lower
2) Average medicine inventory turnover	15.47	17.43	12.63	higher
3) Average number of orders per year	16.87	12.37	-26.68	lower
4) Average day of shortages per year	0.00	0.00	-	same
5) Average quantity of shortages per year	0.00	0.00	-	same
6) Average number of times of stock shortage per year	0.00	0.00	-	same

After modified by 99.60% of service levels, the proposed policy was no shortage. Moreover, the proposed policy contributed to a more reduction in average stock per day by 11.08%, valued at 26,647.88 Baht. The average medicine inventory turnover increases 12.63%. The average number of orders per year reduces 26.68% or 4.5 times a year. It is obvious that hospital can benefit lesser inventory quantity, reduced inventory cost, and cut-off overload jobs without any shortage from this newly developed and improved policy.

12) Sandostatin (SDTT1I-)

Sandostatin is used for control and relieve irregular growth hormone syndromes (GH) and IGF1 in Acromegalia patients who are unable to heal up by operation or radiation treatment. It includes in National List of Essential Medicines and has substitutes. 99.00% of service level is set to calculated reorder point. Simulation started with 590 units of initial inventory, 12-day of lead times, and purchasing quantity must hold with any integers which could be divided by 5. The results show in Table 4.28.

Table 4.28 A comparison of key performance indicators between current policy and proposed policy of SDTT1I-

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	390.60	351.36	-10.05	lower
2) Average medicine inventory turnover	16.55	18.32	10.70	higher
3) Average number of orders per year	16.33	14.07	-13.88	lower
4) Average day of shortages per year	0.47	0.47	0.00	same
5) Average quantity of shortages per year	6.00	4.60	-23.33	lower
6) Average number of times of stock shortage per year	0.20	0.27	33.33	higher

From Table 4.28, the average stock per day, the average number of orders per year, and the average quantity of shortages per year devalued 10.05%, 13.88% and 23.33% respectively. The average medicine inventory turnover increases 10.70%. On the other hand, the average day of shortages per year still remained the same as that of current policy, while the average number of times of stock shortage per year increased by 33.33%. Stagnant number of the average stock per day, a decrease in the average quantity of shortages per year, and an increase in the average number of times of stock shortage per year significantly reflected a more frequent shortage in proposed policy than in current policy in spite of lesser quantity and continuity. Such a varying daily demand with coefficient of variance at 2.72 could attribute to such a shortage. Policy modification continued to proceed in order to reduce a shortage, and its result presented on Table 4.29.

Table 4.29 A comparison of key performance indicators between current policy and proposed policy of SDTT1I- (revised)

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	390.70	391.82	0.29	higher
2) Average medicine inventory turnover	16.54	16.45	-0.54	lower
3) Average number of orders per year	16.43	14.60	-11.16	lower
4) Average day of shortages per year	0.40	0.03	-91.67	lower

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
5) Average quantity of shortages per year	6.13	0.60	-90.22	lower
6) Average number of times of stock shortage per year	0.23	0.03	-85.71	lower

When service level stood at 99.80%, the reorder points and the maximum inventory levels correspondently moved to 396 units and 813 units. From Table 4.29, the average stock per day became higher than that of current policy by 0.29%, worth 837.12 Baht. The average medicine inventory turnover decreases 0.54%. In contrast, there are reduction in the average number of orders per year, the average day of shortages per year, the average quantity of shortages per year, and the average number of times of stock shortage per year by 11.16%, 91.67%, 90.22%, and 85.71% respectively. Due to vastly significant level, an increase of only 1-2 units or 0.29% from current policy may lead to an enormous decrease of a shortage up to 90%. The trial policy notably contributed to lower stock-out inventories and overload jobs.

13) Tienam IV (TIEN-I-)

Tienam IV (TIEN-I-) is an injection for treatment of mixed infections caused by susceptible strains of aerobic & anaerobic bacteria. It includes in National List of Essential Medicines and has substitutes. Such a fluctuated demand was estimated by 2.15 coefficient of variance. 99.00% service level, 10-day lead time, and 1,050 startup units are set up to perform simulation resulting in Table 4.30.

Table 4.30 A comparison of key performance indicators between current policy and proposed policy of TIEN-I-

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	519.12	411.75	-20.68	lower
2) Average medicine inventory turnover	13.93	17.96	26.05	higher
3) Average number of orders per year	14.77	12.83	-13.09	lower
4) Average day of shortages per year	0.00	0.17	-	higher

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
5) Average quantity of shortages per year	0.00	1.73	-	higher
6) Average number of times of stock shortage per year	0.00	0.13	-	higher

From Table 4.30, not only the average stock per day went down by 20.68% but the average number of orders per year also disappeared by 13.09%. Moreover, the average medicine inventory turnover increases 26.05%. However, the average day of shortages per year, the average quantity of shortages per year, and the average number of times of stock shortage per year conversely shifted by 0.17 days, 1.73 units and 0.13 times a year. As a result, the service levels were re-determined to 99.80% in line with 377 units and 860 units of reorder points and maximum inventory levels.

Table 4.31 A comparison of key performance indicators between current policy and proposed policy of TIEN-I- (revised)

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	519.06	443.54	-14.55	lower
2) Average medicine inventory turnover	13.95	16.30	16.87	higher
3) Average number of orders per year	14.87	13.07	-12.11	lower
4) Average day of shortages per year	0.00	0.00	-	same
5) Average quantity of shortages per year	0.00	0.00	-	same
6) Average number of times of stock shortage per year	0.00	0.00	-	same

After increase service level to 99.80%, the average stock per day and the average number of orders per year become lower by 14.55% which worth 54,750.47 Baht and 12.11% or 13.07 times a year. Despite no shortage of both policies, proposed policy achieved more efficacy than current policy in terms of a reduction in the average inventories and the number of orders and increment of inventory turnover.

14) Vfend IV (VFEN-I-)

Vfend IV or Voriconazole is an injection and used to treatment of the following fungal infections. It excludes from National List of Essential Medicines and has substitutes. Coefficient of demand variation is 5.20. 98.00% of service levels, 10 days of lead times, and 85 units of initial inventory are set as determinants for the simulation.

Table 4.32 A comparison of key performance indicators between current policy and proposed policy of VFEN-I-

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	78.71	55.52	-29.47	lower
2) Average medicine inventory turnover	15.05	21.36	41.79	higher
3) Average number of orders per year	16.47	16.37	-0.61	lower
4) Average day of shortages per year	0.00	0.97	-	higher
5) Average quantity of shortages per year	0.00	2.43	-	higher
6) Average number of times of stock shortage per year	0.00	0.53	-	higher

From Table 4.32, it is found that the lesser both the average stock per day and the average number of orders per year by 29.47% and 0.61%, the lower inventory costs and overload jobs. The average medicine inventory turnover increases 41.79%. The average day of shortages per year, the average quantity of shortages per year, and the average number of times of stock shortage per year, nevertheless, rose from those of current policy. It was important for service levels to be raised up to 99.90% in line with to renew reorder points and maximum inventory levels to 71 units and 137 units as Table 4.33 displays its results.

According to revised policy, without any shortages, the average stock per day, in spite of ascending quantity from pre-modified simulation, lessened by 9.01% worth 49,926.04 Baht from current policy. The average medicine inventory turnover increases 9.28%. The average number of orders per year shifted from 16.43 times a year to 16.50 times a year, accounted for 0.41%. Apart from shortage elimination,

specified policy helped inventory costs and inventory quantity is smaller than those of existing policy.

Table 4.33 A comparison of key performance indicators between current policy and proposed policy of VFEN-I- (revised)

Key performance indicator	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	78.57	71.49	-9.01	lower
2) Average medicine inventory turnover	15.11	16.51	9.28	higher
3) Average number of orders per year	16.43	16.50	0.41	higher
4) Average day of shortages per year	0.00	0.00	-	same
5) Average quantity of shortages per year	0.00	0.00	-	same
6) Average number of times of stock shortage per year	0.00	0.00	-	same

15) **Viagra (VIAG-T-)**

Viagra VIAG-T is 50-mg size. It is used to cure Erectile Dysfunction: ED and Pulmonary Arterial Hypertension: PAH. Its characteristics consist of being excluded from National List of Essential Medicines and being available for any substitutes. To calculate reorder points conducted with 98.00% of service levels, 10 days of lead times, and 896 of startup units. More importantly, VIAG-T- must be specially and separately stored in locked containers due to being medicine control each package enclosed four pills. The results form Table 4.34 expose the average stock per day and the average number of orders per year fell by 25.98% and 17.78% contrary to the average day of shortages per year, the average quantity of shortages per year, and the average number of times of stock shortage per year which rose from existing policy. As a result, the service level needed to be revalued up to 99.60% leading to new reorder points 368 units and maximum inventory levels 908 units. Overall results presented on Table 4.35.

Table 4.34 A comparison of key performance indicators between current policy and proposed policy of VIAG-T-

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	567.86	420.32	-25.98	lower
2) Average medicine inventory turnover	11.64	15.72	35.04	higher
3) Average number of orders per year	13.50	11.10	-17.78	lower
4) Average day of shortages per year	0.00	0.20	-	higher
5) Average quantity of shortages per year	0.00	2.37	-	higher
6) Average number of times of stock shortage per year	0.00	0.20	-	higher

Table 4.35 A comparison of key performance indicators between current policy and proposed policy of VIAG-T- (revised)

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	567.84	471.67	-16.94	lower
2) Average medicine inventory turnover	11.64	14.00	20.32	higher
3) Average number of orders per year	13.47	11.10	-17.57	lower
4) Average day of shortages per year	0.00	0.00	-	same
5) Average quantity of shortages per year	0.00	0.00	-	same
6) Average number of times of stock shortage per year	0.00	0.00	-	same

It is found that 99.60% service levels enabled the average day of shortages per year, the average quantity of shortages per year, and the average number of times of stock shortage per year to decrease from previous simulation. The higher service levels, the more reorder points and maximum inventory units arose, and the larger number of inventory quantity, finally leading to a shortage reduction. The average stock per day and the average number of orders per year decreases 16.94% and 17.57%. The average medicine inventory turnover increases 20.32%. Otherwise, not only the average stock per day dropped by 16.94% worth 40,775.36 Baht, lesser than

those from 98.00% service levels, but the average number of orders per year also fell by 17.57% or 2.37 times a year, rather similar to the former simulation. An adoption of proposed policy was able to benefit a reduction of 16.94% in inventory quantity, dominating 9.00% of storing room and in purchasing times to be only 2.37 times a year without any shortages.

16) **Viagra (VIAG1T-)**

Viagra VIAG1T- is 50-mg size. It is used to cure Erectile Dysfunction: ED and Pulmonary Arterial Hypertension: PAH. It excludes from National List of Essential Medicines. This medicine allows other substitutes to replace but its substitutes become more costly at the same quantity. To calculate reorder points and simulation, the 98.00% service level, 10-day lead times, and 280 startup units are specified.

Table 4.36 A comparison of key performance indicators between current policy and proposed policy of VIAG1T-

Key performance indicators	Current policy	Proposed policy	Differentiation (%)	Remark
1) Average stock per day	307.22	320.83	4.43	higher
2) Average medicine inventory turnover	9.88	9.46	-4.25	lower
3) Average number of orders per year	11.47	10.80	-5.81	lower
4) Average day of shortages per year	2.50	0.57	-77.33	lower
5) Average quantity of shortages per year	25.87	1.67	-93.56	lower
6) Average number of times of stock shortage per year	0.57	0.13	-76.47	lower

After simulation process, those determinants contributed to a slight increase in the average stock per day by 4.43% worth 7,268.45 Baht. The average medicine inventory turnover decreases 4.25%. However, the average number of orders per year, the average day of shortages per year, the average quantity of shortages per year, and the average number of times of stock shortage per year substantially dropped by 5.81%, 77.33%, 93.56% and 76.47% respectively. (see Table 4.36) Shortage, although overload jobs and inventory costs decreased, may possibly take place

because of such a varying demand. To avoid the problem, in spite of an increase in medicine stocks which may lead to higher costs, more than 98.00% of service levels could be raised to deliver service by far more conveniently to customers, and ultimately hospital could retain its customers as much as possible from their stronger satisfaction.

4.5.2 The Comparison of Key Performance Indicators for All AV-type Medicines

The comparison of key performance indicators between current policy and proposed policy for all AV-type medicines shows in Table 4.37 and 4.38.

Table 4.37 presents a comparison of key performance indicators results: the average stock per day, the average medicine inventory turnover, and the average number of orders per year. The difference of the average stock is a saved cost based on a comparison of proposed policy to current policy for sixteen AV-type medicine items. It is found that the proposed policy is likely to reduce the average stock per day and the average number of orders per year. Moreover, it increases the average medicine inventory turnover. If the hospital adopts the proposed policy to purchase 16 medicine items in group AV, it will allow inventory costs to reduce significantly by at least 759,700 Baht. MERN2I- can reduce the highest value of inventory costs, 263,065.39 Baht, followed by ALBK-I- can reduce inventory costs 154,585.27 Baht. In term of the average medicine inventory turnover, 12 of 16 items increase inventory turnover, proposed policy has more effective inventory flow. In term of the average number of orders per year reduction, INVZ-I- succeeds in the highest amount of reduction to approximately 6.93 times a year, accounted for 36.28%.

Table 4.37 A comparison of the average stock per day, the average medicine inventory turnover, and the average number of orders per year between current policy and proposed policy of AV-type medicines

KPIs	Average stock per day (units)			Average medicine inventory turnover		Average number of orders per year (times)	
	Current policy	Proposed policy	Saved cost (Baht)	Current policy	Proposed policy	Current policy	Proposed policy
ALBK-I-	1,197.43	1,083.48	-154,585.27	14.81	15.86	15.13	12.87
ALPN-I-	166.88	156.84	-36,131.43	15.77	16.12	16.87	15.83
BERF-X-	8,204.19	6,937.82	-45,589.15	16.64	19.68	17.73	12.37
COTL-I-	334.60	316.02	-6,616.50	15.37	16.34	15.27	13.93
DFRL-I-	2,228.82	1,918.34	-68,617.17	14.42	16.19	14.97	13.27
GAMR1I-	219.89	231.22	137,817.11	17.39	15.69	16.20	15.10
HEMF2I-	155.84	169.55	68,420.38	18.77	16.73	16.87	14.03
INVZ-I-	397.36	324.07	-120,938.20	16.38	19.86	19.10	12.17
LOSV-I-	1,569.13	1,298.11	-108,408.07	15.69	18.59	17.00	11.87
MERN2I-	1,065.64	887.17	-263,065.39	16.09	18.93	17.83	12.80
NEXM-I-	603.00	536.21	-26,647.88	15.47	17.43	16.87	12.37
SDTT1I-	390.70	391.82	837.12	16.54	16.45	16.43	14.60
TIEN-I-	519.06	443.54	-54,750.74	13.95	16.30	14.87	13.07
VFEN-I-	78.57	71.49	-47,926.04	15.11	16.51	16.43	16.50
VIAG-T-	567.84	471.67	-40,775.36	11.64	14.00	13.47	11.10
VIAG1T-	307.22	320.83	7,268.45	9.88	9.46	11.47	10.80
Total	18,006.17	15,558.18	-759,708.14	-	-	-	-

The example interpretation of ALBK-I- from the Table 4.37, the average stock per day of proposed policy can reduce daily medicine inventory from 1,197.43 to 1,083.48 units which worth 154,585.27 Baht. Moreover, the average medicine inventory turnover increases from 14.81 to 15.86 and the number of orders per year reduces from 15.13 to 12.87 times.

In addition, the proposed policy can decrease the average of medicine inventory in twelve medicine items. However, there were four medicine items which increase stocked of medicine inventories worth 214,343.06 Baht. Such a spending cost

aimed to ease any shortages according to Table 4.38. In terms of the average number of orders per year, proposed policy allowed purchasing orders to decrease from current policy which generated purchasing orders.

Table 4.38 A comparison of the average day of shortages per year, the average quantity of shortages per year, and the average number of times of stock shortage per year between current policy and proposed policy of AV-type medicines

KPIs	Average day of shortages per year (days)		Average quantity of shortages per year (units)		Average number of times of stock shortage per year (times)		Remark
	Current policy	Proposed policy	Current policy	Proposed policy	Current policy	Proposed policy	
ALBK-I-	0	0	0	0	0	0	same
ALPN-I-	0.13	0	0.77	0	0.10	0	lower
BERF-X-	0	0	0	0	0	0	same
COTL-I-	0.20	0	4.10	0	0.13	0	lower
DFRL-I-	0	0	0	0	0	0	same
GAMR1I-	1.23	0	11.57	0	0.67	0	lower
HEMF2I-	3.00	0.07	22.50	0.33	1.07	0.03	lower
INVZ-I-	0	0	0	0	0	0	same
LOSV-I-	0	0	0	0	0	0	same
MERN2I-	0	0	0	0	0	0	same
NEXM-I-	0	0	0	0	0	0	same
SDTT1I-	0.40	0.03	6.13	0.60	0.23	0.03	lower
TIEN-I-	0	0	0	0	0	0	same
VFEN-I-	0	0	0	0	0	0	same
VIAG-T-	0	0	0	0	0	0	same
VIAG1T-	2.50	0.57	25.87	1.67	0.57	0.13	lower
Total	7.60	0.67	70.94	2.60	2.77	0.19	lower

According to Table 4.38, in terms of the average day of shortages per year, the average quantity of shortages per year, and the average number of times of stock shortage per year for all sixteen items, it is found that proposed policy contributed to a

shortage reduction in six items, and remaining ten items appeared to be the same and without any shortages. HEMF2I-, held a dramatic decrease in the average day of shortage per year from 3.00 days to only 0.07 days a year, and its average quantity of shortage per year substantially changed from 22.50 units to only 0.33 units; additionally, its average number of times of stock shortage totally diminished from 1.07 times to 0.03 times. It was obvious that proposed policy became successful in downsizing a shortage of HEMF2I-. Otherwise, all numbers on Table 4.38 appeared to be decimals because 30 replications of simulations took place, and their results were subsequently reformed to achieve average results. Items, possessing such a varying demand were solved by leveling service levels in order to stock more inventories and to stall a shortage. VFEN-I-, for instance, with its demand equation as NORM (15.37, 13.252) and 5.20 coefficient of variance for daily demand, was shifted its service levels from 98.00% to 99.90% in order to prevent a shortage or to decrease inventory costs, conversely from initial higher specified service levels to lower modified service levels without any shortages such as GAMR1I which its 99.99% service levels came to be 99.90% without any shortages.

4.6 The Comparison of Impacts on Reorder Point between Actual Demand Distribution and Normal Demand Distribution Assumption

On this topic, the impact of three factors on reorder point is studied: 1) service level 2) average usage quantity and 3) lead time. Currently, reorder point designation is based on the assumption that medicine demand relies on normal distribution; however, according to results derived from performing a study of demand distribution patterns (Topic 4.3), reveals that such assumption is matched with only a few medicines. The impact of such assumption and the three factors aforementioned on reorder point are studied. Two kinds of Av-type medicine that has no trend and do not have normal distribution are studied: VIAG-T- and VIAG1T-. Their weekly demand patterns are GAMM (106.00, 1.19) and EXPO (56.60) respectively. The results are as follows:

4.6.1 An Effect of Service Level on Reorder Point

Since it is the most life-saving and the most important group, medicines in AV group should be in high level of service. Therefore, reorder points at the service level between 80.00% and 99.99% are studied. Average usage quantity is determined as constants according to real data and lead time is assigned to cover five days. The results show the higher service level, the more proper reorder points in a range from 80% to 96% of service level. When service level nearly reached 99.99%, reorder point will sharply increase. From the comparison between proper reorder points by using actual distribution and reorder points by using normal distribution, it was found that proper reorder points with normal distribution (ROP-Normal) are higher than those of gamma (ROP-Gamma) and exponential (ROP-Expo) distributions as presented in Figure 4.1 and 4.2. This could be inferred that an assumption of normal distribution is overestimated. Reorder point is higher than it should be, leading to ordering medicines before the appropriate reorder points increased stock as a result.

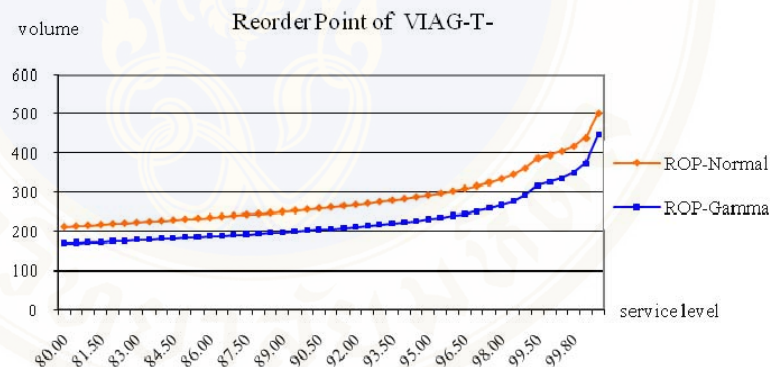


Figure 4.1 Reorder points of Normal and Gamma distribution of VIAG-T- with service level 80.00%-99.99%

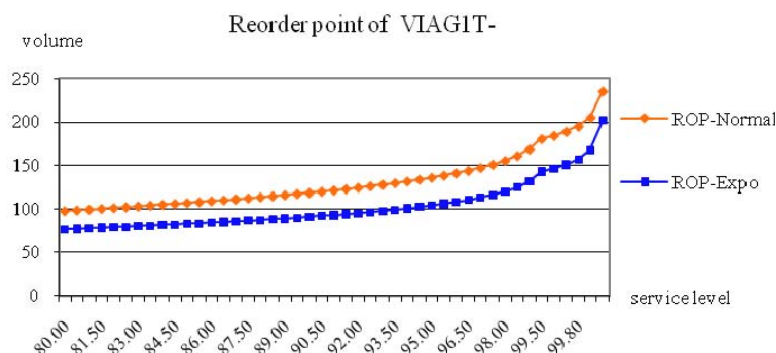


Figure 4.2 Reorder points of Normal and Exponential distribution of VIAG1T- with service level 80.00%-99.99%

Table 4.39 A comparison of saved cost, when reorder points are calculated by actual distributions with gamma and exponential distributions at different service levels

Service level	VIAG-T-	VIAG1T-	Total
	Saved cost (Baht)	Saved cost (Baht)	Saved cost (Baht)
80.00	17,808	10,680	28,488
85.00	19,928	12,816	32,744
90.00	22,896	14,952	37,848
95.00	26,288	17,088	43,376
96.00	27,136	17,622	44,758
97.00	27,560	18,156	45,716
98.00	28,408	19,224	47,632
99.00	29,256	19,758	49,014
99.50	29,256	20,292	49,548
99.99	22,896	18,156	41,052

Table 4.39 presents a comparison of saved cost for medicines with Gamma and Exponential distributions when reorder points are calculated by actual distributions at different service levels. The results show that replacing reorder points from normal distribution with those from actual distribution allows hospital to reduce expenses. It will achieve more cost saving from VIGA-T- than that form VIGA1T-, by about 28,488 Baht at 80% of service levels and by between 37,848 Baht and 49,548 Baht at a range from 90.00% to 99.99% of service levels. The result presents that when service levels increase, total saved cost does not always increase. For example, at the service level 99.99%, the total saved cost is lower than at the service level 99.50%.

4.6.2 An Effect of Average Usage Quantity on Reorder Point

To examine an effect of average usage quantity on appropriate reorder point. 95% of service levels and five days are determined as constants. Average usage quantity is set in a range from 10% to 300% of previous values. The results show that the higher number of average usage quantity, the more increase in reorder points. The reorder points from actual distributions (ROP-Gamma, ROP-Expo) change more rapidly than those from assumption of normal distribution (ROP-Normal). When

average usage quantity goes down, ROP-Normal appeared to be higher than ROP-Gamma and ROP-Expo, whereas when average usage quantity rises, the difference between ROP-Normal and ROP-Gamma, and the difference between ROP-Normal and ROP-Expo are narrowed. When average usage quantity continued to increase, ROP-Gamma and ROP-Expo start to climb up until they are higher than ROP-Normal as shown in Figure 4.3 and Figure 4.4. It could be inferred that subject to an assumption of normal distribution, an overestimated reorder points would occur in case of low average usage quantity, whereas underestimated reorder points would occur in case of high average usage quantity.

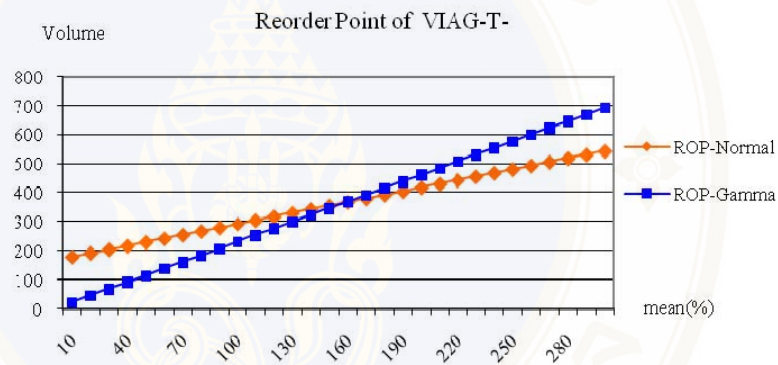


Figure 4.3 Reorder points of Normal and Gamma distribution of VIAG-T- at different average usage quantity

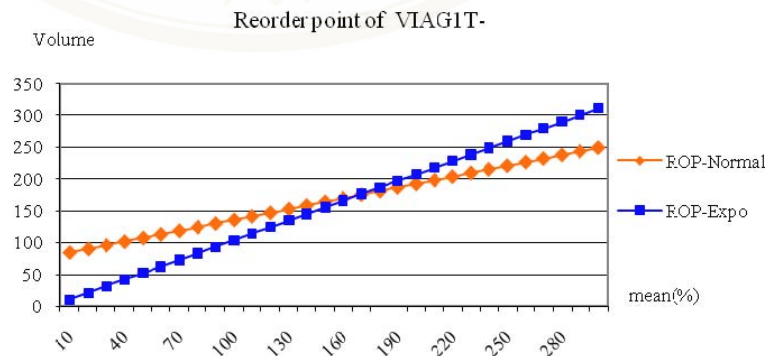


Figure 4.4 Reorder points of Normal and Exponential distribution of VIAG1T- at different average usage quantity

4.6.3 An Effect of Lead Time on Reorder Point

A lead time parameter varies from 1 to 30 days. An increase of lead time results in an increase in appropriate reorder point of assumed Normal distribution and appropriate reorder point of actual distribution. If short lead times take place and values of ROP-Normal nearly would reach those of ROP-Gamma and ROP-Expo, it means that reorder points in equation (1) appears to be an effective estimator. Nevertheless, the longer lead times, the greater possibility for ROP-Normal to originating errors. Values of ROP-Normal is higher than those of ROP-Gamma and ROP-Expo which caused reorder point derived from equation (1) to become higher than it could be, resulting in early ordering medicines and higher inventory level. Graph displayed in Figure 4.5 and 4.6 illustrates proper reorder points for two types of medicines at varying lead times from 1 to 30 days.

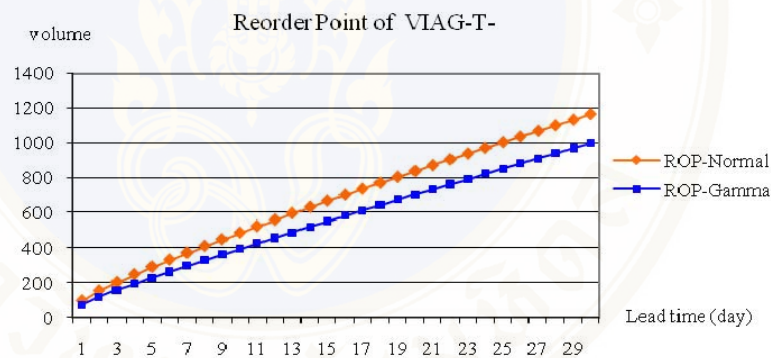


Figure 4.5 Reorder points of Normal and Gamma distribution of VIAG-T- at different lead times

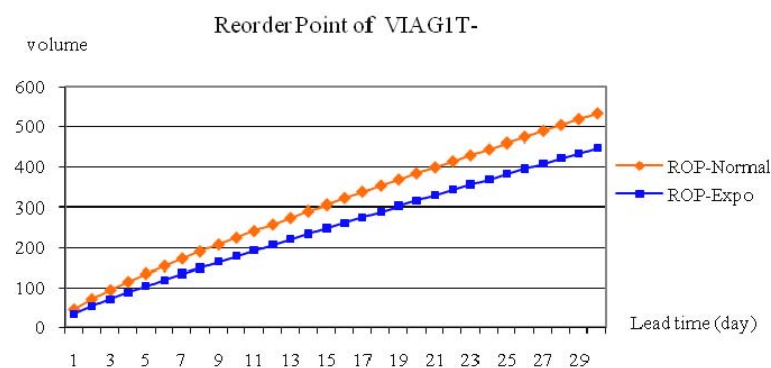


Figure 4.6 Reorder points of Normal and Exponential distribution of VIAG1T- at different lead times

Table 4.40 A comparison of saved cost, when reorder points are calculated by actual distributions for medicines with gamma and exponential distributions at different lead times

Lead time (days)	VIAG-T-	VIAG1T-	Total
	Saved cost (Baht)	Saved cost (Baht)	Saved cost (Baht)
5	26,096	17,039	43,135
10	38,659	25,126	63,785
15	48,378	31,392	79,770
20	56,591	36,695	93,286
25	63,831	41,379	105,210
30	70,378	45,619	115,997

Table 4.40 shows a comparison of saving cost for medicines with actual distributions when reorder points are calculated at various lead times. Contrary to an assumption of Normal distribution, reorder points arise from actual distributions (Gamma and Exponential distributions), enabling expenses for two types of medicines to slump to approximately 43,135 Baht for five days, and more importantly, the longer lead times, the lesser expenses as hospital is able to reduced 115,997 Baht of expenses in 30 days.

4.7 The Appropriate AV-Type Medicine Inventory Policy

The proposed AV-type medicine inventory policy for demand distribution with trend and no trend has developed from the (s, S) policy and the (s, Q) policy. For the (s, S) policy, when the medicine inventory level below to s units, the purchasing will order up to level S units. For the (s, Q) policy, when the medicine inventory level below to s units, the purchasing will order Q units. The developed policies are order medicine quantity for one month usage. The calculation of the reorder point, order up to level, and order quantity calculated on usual situation. The proper reorder point, maximum inventory level, order quantity, and service level of proposed policy show in Table 4.41.

Table 4.41 Reorder point, maximum inventory level, order quantity, and service level for AV-type medicine

Medicine name	s Reorder point (units)	S Maximum inventory level (units)	Q Order quantity (units)	sl Service level
ALBK-I-	1,076	2,379	-	99.90%
ALPN-I-	159	318	-	99.90%
BERF-X-*	5,436	-	10,620	99.00%
COTL-I-	327	670	-	99.90%
DFRL-I-	1,833	4,155	-	99.90%
GAMR1I-	267	507	-	99.90%
HEMF2I-	191	387	-	99.60%
INVZ-I-*	193	-	445	98.00%
LOSV-I-	988	2,988	-	99.90%
MERN2I-	716	2,034	-	99.00%
NEXM-I-	437	1,150	-	99.60%
SDTT1I-	396	813	-	99.80%
TIEN-I-	377	860	-	99.80%
VFEN-I-	71	137	-	99.90%
VIAG-T-	368	908	-	99.60%
VIAG1T-	271	514	-	98.00%

Note: * BERF-X- and INVZ-I- have demand tend, so reorder point and order quantity will be increased for later weeks

Example of ALBK-I- ordering, from Table 4.41, if the medicine inventory level at the end of first day is equal to 1,100 units, the purchasing will not order medicine. If the end of second day medicine inventory level dropped to 1,050 units, the purchasing will order medicine on the morning of third day 1,329 units for increase medicine inventory level to 2,379 units.

For ordering medicine with demand tend, the reorder point and the order quantity are change every week. However, we can calculate them for the future. Example of BERF-X- ordering in the first week, if the medicine inventory level at the end of the first day decreased to 5,623 units, the purchasing will not order medicine. At the end of second day, if medicine inventory level dropped to 5,461 units, the

purchasing will not order medicine, too. At the end of third day, if medicine inventory level dropped to 5,398 units, the purchasing will order medicine on the morning of fourth day 10,620 units. In second week, the reorder point will increase to 5,438 units and the order quantity is 10,640 units.

Limitation of Proposed Policy

- 1) The proposed policy applied for the medicine demands that had the distribution pattern.
- 2) The proposed policy does not consider ordering costs, holding costs, discounts, or premium products.
- 3) The accuracy of the proposed policy is related to the forecast. Therefore, the medicine demand should be forecast every 3 months for accuracy and data update.

Recommendations for The Hospital

The recommendations for the hospital are following;

- 1) To use proposed policy, the hospital should improve forecasts every three months to update data, because the parameters derived from the forecasts will be used to calculate the reorder point and the order quantity of proposed policy. However, the unusual situation may result to increasing of medicine demand. The hospital should update forecasting immediately. For example, the medicine excluded in National List of Essential Medicines in the past, but it will be include in National List of Essential Medicines next month. Therefore, the medicine demands in next month will be higher than the past.
- 2) The hospital should consider demand variation for set the service levels besides the consideration of medicine importance because the hospital's major goal is to reduce the shortage medicines. If the service level of high variance medicine demand is lower than 99.00%, it will cause a shortage of medicines.
- 3) The hospital can change the service level for appropriate medicine inventory level and without the shortages. For example, the service level of 99.99% leads to stock most medicines inventory. If the hospital reduces service level to 99.90% with without a shortage, the medicine inventory will lower. The results of this

study from topic 4.5 found that the appropriate services levels are from 99.00% to 99.90%.

4) The hospital should use the actual distributions in order to use proposed policy. The medicine demand that assume a normal distribution instead of the actual distribution will result in an inappropriate medicine inventory levels. The shortage may occur or inventory stock will be kept over demand.

5) The hospital should consider lead time reducing because it can reduce the amount of unnecessary medicine inventory and decline the inventory cost without affection the service levels.



CHAPTER V

CONCLUSION

This chapter is divided into two sections. Section 5.1 presents the conclusion of this research. Section 5.2 suggests the recommendations for the hospital and recommendations for future research. The details are as follows:

5.1 Conclusion

This thesis has analyzed and developed the models for medicine inventory in the Ramathibodi hospital by classifying medicines based on their annual value and their health impact (ABC/VEN analysis). AV-type medicine (the highest value and vital medicine) is chosen to study the demand patterns and to forecast these demands. Medicine inventory literature in Thailand suggests that most of the models are calculated based on the assumption of constant demand using EOQ model or normal distribution. The results showed that all demands of AV-type medicine are not constant. There are only twelve of twenty-two types of medicine, or about 54.55% that have normal distribution without trend. As a result, this assumption cannot be applied to all types of medicine inventory management. This thesis studied the impact of this assumption especially medicines in AV-type that are vital to the patient's life. In addition, this thesis has developed mathematical models for medicine purchasing for real medicine demand patterns and also compared medicine inventory key performance indicators between the current hospital's policy and the proposed policy.

Medicines classified by ABC/VEN analysis: It will provide the proportion of volume and value. It is used to manage medicine inventory base on their significances. In this thesis, the most value and vital medicines or AV-type medicine which has twenty-two items have studied.

Forecasting the AV-type medicine demands: We found that all medicine demands cannot assumed to be constant and can be divided into four patterns: 1) twelve items are normal distribution with no trend 2) one item is gamma distribution with no trend 3) one item is exponential distribution with no trend 4) two items are normal distribution with trend. The others that do not have an appropriate distribution have not been considering.

The development of medicine inventory policy: To manage the medicine inventory, we calculated order up to level, reorder point, and order quantity for different demand patterns. The results are shown in Table 4.8.

Table 4.8 Developed AV-type medicine inventory policy

Demand pattern	Order up to level (S)	Reorder point (s)	Order quantity (Q)
Normal distribution with no trend	$S = M \frac{\mu_{week}}{n} + k + s$	$s = \frac{L \cdot \mu_{week} + z \cdot \sqrt{nL} \sigma_{week}}{n}$	$Q = \left\lceil \frac{S - s}{p} \right\rceil$
Gamma distribution with no trend	$S = M \frac{\alpha\beta}{n} + k + s$	$\frac{1}{(L-1)!} \left(\frac{n}{\alpha\beta} \right)^L \int_0^s x^{L-1} e^{-\frac{nx}{\alpha\beta}} dx = sl$	
Exponential distribution with no trend	$S = M \frac{1}{n\lambda} + k + s$	$\frac{\lambda^{\frac{L}{n}}}{\Gamma(\frac{L}{n})} \int_0^s e^{-x\lambda} x^{\frac{L}{n}-1} dx = sl$	
Normal distribution with trend	$S = Qp + s$	$s = \int_{t=c}^{t=d} f(d_t) dt + z\sqrt{L} \sigma_{day}$	$Q = \left\lceil \frac{\int_{t=a}^{t=b} f(d_t) dt + k}{p} \right\rceil$

A Comparison of medicine key performance indicators between current and proposed policies: Overall, the current policy of the hospital forces the hospital to order medicine before the appropriate time, leading to the higher medicine inventory levels. If the hospital uses the proposed policy, the medicine inventory levels will decrease. For sixteen medicine items, the adoption of proposed policy will reduce the medicine inventory cost approximate 759,708.14 Baht and also decrease the average orders per year and the shortage medicines. Therefore, the proposed policy can reduce medicine inventory levels and staff workload.

The impacts on the reorder point: The impacts on the reorder point were compared between the actual distribution and normal distribution, which is a common assumption. We determine the different cases.

- **Lead time and average usage quantity are constant, but the service level is changed.** When the service level increases, the reorder point will increase. For the service level between 80.00% and 99.99%, the appropriate reorder point of the normal distribution assumption is higher than the reorder point of actual distribution. The results show that if the hospital uses normal assumption, the hospital will increase the cost from 37,848 to 49,548 Baht with the service level between 90.00% and 99.99% for the two medicine items.

- **Lead time and service level are constant, but the average usage quantity is changed.** When the average usage quantity increases, the reorder point will increase. The reorder point rate of actual distribution is more sensitive than the reorder point rate of normal distribution assumption. When the average usage quantity is low, the reorder point of normal distribution assumption is higher than the reorder point of actual distribution. When the average usage quantity is higher, the reorder point of actual distribution is higher than the reorder point of normal distribution assumption. It could be inferred that the appropriate reorder point under the normal distribution assumption is overestimated in the case of low average usage quantity, whereas the underestimated reorder point would occur in case of high average usage quantity.

- **Average usage quantity and service level are constant, but lead time is changed.** When lead time increases, the reorder point will increase. When lead time is short, the reorder point of normal distribution assumption is closed to the reorder point rate of actual distribution. Therefore, the reorder point of normal distribution assumption is proper for short lead time. However, when lead time increases, the reorder point of normal distribution assumption yield more errors because the proper reorder point of normal distribution assumption is higher than the proper reorder point of actual distribution. Consequently, the hospital tends to purchase medicine too early, resulting in the higher medicine inventory level.

For usual situation, the hospital should check and review the parameters of the medicine demand forecast in the proposed policy to achieve the accuracy. On the other hand, in case of predictable unusual situation, the hospital must check and review the parameters of the medicine demand forecast immediately. For example, in this month, the medicine is not in National List of Essential Medicine but it will be in the National List of Essential Medicine next month, the medicine demand may increase and parameters of medicine demand forecast may change.

5.2 Recommendation

Recommendations for The Hospital

1. The reorder point, order quantity and maximum medicine inventory of proposed policy is calculated on usual situation. If a change occurs, such as, pestilence disease or epidemics, the medicine demands will higher than usual. The old reorder point and order quantity do not proper. The hospital should to update data and forecast demand to use new parameters for calculates reorder point and order quantity of proposed policy, so the proposed policy is effectively without the shortages.

2. The hospital should improve forecasts every three months to update data for usual situation, because the parameters derived from the forecasts will be used to calculate the reorder point and order quantity. However, there is not regular situation, for example, the medicine excluded in National List of Essential Medicines in the past, but it will be include in National List of Essential Medicines next month, may result to increasing of medicine demand. The hospitals should improve forecast immediately.

3. The hospital should consider demand variation for set the service levels besides the consideration of medicine importance. For a high variance of medicine demand, if the service level is lower than 99.00%, it will cause a shortage of medicines. The hospital's first goal is least of shortages medicine or not shortage occurs. The second gold is reduction medicine inventory and staff's workload.

4. The hospital can change the service level for appropriate medicine inventory level without the shortages. For example, the service level of 99.99% makes higher medicine inventory stock. If the hospital reduces service level to 99.90% and

without a shortage, the medicine inventory will lower. The results of this study found that the appropriate service levels are from 99.00% to 99.90%.

5. The hospital should use the actual distributions in order to use proposed policy. The medicine demand that assume a normal distribution instead of the actual distribution will result in an inappropriate medicine inventory levels. Sometimes the shortage is occurs or inventory level is more than necessary.

6. The hospital should consider lead time reducing because it can reduce the amount of unnecessary medicine inventory and decline the inventory cost without affection the service levels.

Finally, researchers hope that this study will be beneficial to hospitals in medicine management especially in reordering policy of AV-type medicine which is critical and has high value.

Recommendations for Future Research

1. Appropriate medicine inventory models for other medicine types except AV-type medicine of medicines classified as ABC/VEN analysis should be developed.
2. Appropriate medicine inventory models for substitute medicines should be further studied.

REFERENCES

- Ahmed, M. A. & Alkhamis, T. M. (2009). Simulation optimization for an emergency department healthcare unit in Kuwait. *European Journal of Operational Research*, 198, 936–942.
- Anuparbpraiboon, S. (2004). *Inventory management in small and medium shoes factories*. Unpublished master's thesis, Chiang Mai University, Thailand.
- Aukraphasuchart, W. (2003). *Inventory cost control: A case study of one factory in Lamphun province*. Unpublished master's thesis, Chiang Mai University, Thailand.
- Banks, J. (1999). Introduction to simulation. *Proceedings of the 1999 Winter Simulation Conference*. Retrieved July 1, 2009, from portal.acm.org/ft_gateway.cfm?id=324142&type=pdf
- Buranapansri, S. (2006). *Inventory management of construction materials store: Case study in Sin Chiang Lee Registered Ordinary Partnership (branch)*. Unpublished master's thesis, Chiang Mai University, Thailand.
- Chaichit, S. (2008). *Performance Analysis of Out Patient Service System of Pasang Hospital, Lamphun Province Using Queuing Simulation Model*. Unpublished master's thesis, Chiang Mai University, Thailand.
- Chu, C. W., Liang, G. S., & Liao, C. T. (2008). Controlling inventory by combining ABC analysis and fuzzy classification. *Computers and Industrial Engineering*, 55(4), 841-851.
- Chu, C. W., Liang & Mahajan, M. (2009). An inventory sharing and allocation method for a multi-location service parts logistics network with time-based service levels. *European Journal of Operational Research*, 194, 728–742.
- Goyal, S. K. & Chang, C. T. (2009). Optimal ordering and transfer policy for an inventory with stock dependent demand. *European Journal of Operational Research*, 196, 177–185.

- Hanpichanchai, A. (2004). *Optimum inventory management for small and medium frozen food enterprises*. Unpublished master's thesis, Chiang Mai University, Thailand.
- Japakasetr, U. (1999). *Simulation of vehicle routing for distribution center: A case of automobile spare part*. Unpublished master's thesis, Kasetsart University, Thailand.
- Jaruspetch, S. (2007). *Inventory management with uncertain demand: A case study of liquid petroleum gas filling station*. Unpublished master's thesis, Burapha University, Thailand.
- Kedeam, S. (2005). *Forecasting techniques*. Thailand: Department of Mathematics, Faculty of Sciences, Thaksin University.
- Kelton, W. D., Sadowski, R. P., & Sturrock, D. T. (2006). *Simulation with Arena*. 4th ed., English: McGraw-Hill.
- Khouja, M. & Stylianou, A. C. (2009). A (Q, R) inventory model with a drop-shipping option for e-business. *Omega*, 37, 896 – 908.
- Kritchanchai, D., et al., (2008). *Research and develop logistics and supply chain management in service industries: Hospital*. Thailand: Faculty of Engineering, Mahidol University.
- Kumsan, P. (2006). *The application of ABC analysis for pharmaceutical inventory control in special service center Chiang Mai university*. Unpublished master's thesis, Chiang Mai University, Thailand.
- Lalitapon, P. (2006). *Production planning and control*. 12th ed., Bangkok, Thailand: Technology Promotion Association (Thailand-Japan).
- Maiti, A. K., Maiti, M. K., & Maiti, M. (2009). Inventory model with stochastic lead-time and price dependent demand incorporating advance payment. *Applied Mathematical Modelling*, 33, 2433–2443.
- Nenes, G., Panagiotidou, S., & Tagaras, G. (2010). Inventory management of multiple items with irregular demand: A case study. *European Journal of Operational Research*, 205, 313–324.
- Nodem, F. I. D., Kenne, J. P., & Gharbi, A. (2009). Hierarchical decision making in production and repair/replacement planning with imperfect repairs under uncertainties. *European Journal of Operational Research*, 198, 173–189.

- Ouyang, L. Y. & Chuang, B. R. (1999). A minimax distribution free procedure for stochastic inventory models with a random backorder rate. *Journal of the Operations Research Society of Japan*, 42(3).
- Polsaen, S. (2000). Use of simulation for performance improvement of head gimbals assembly line. Unpublished master's thesis, Chulalongkorn University, Thailand.
- Rice, J.A. (2007). *Mathematical Statistics and Data Analysis*. 3rd ed., United States of America: Thomson.
- Rojsakga, W. (2002). *Increased efficiency of inventory in pharmaceutical of Udon Thani hospital*. Unpublished master's thesis, Mahasarakam University, Thailand.
- Roy, A., Maiti, M. K., Kar, S., & Maiti, M. (2009). An inventory model for a deteriorating item with displayed stock dependent demand under fuzzy inflation and time discounting over a random planning horizon. *Applied Mathematical Modelling*, 33, 744–759.
- Sethi, S. P. (2004). *Stochastic Inventory models with continuous and poisson demands and discounted and average costs*. Retrieved March 10, 2009, from <http://www.utdallas.edu/~sethi/Postscript/Inv013004submit.pdf>
- Shannon, R. E. (1998). Introduction to the art and science of simulation. *Proceedings of the 1998 Winter Simulation Conference*. Retrieved July 1, 2009, from <http://www.informs-sim.org/wsc98papers/001.PDF>
- Sommawattana, C. (2007). *The application of simulation technique to inventory management for raw materials of agro-industry (case study: Salad Cream)*. Unpublished master's thesis, Songkla University, Thailand.
- Songwattana, J. (2005). *Simulation model for order optimal sizing of vegetable goods department: a case study of modern detail business*. Unpublished master's thesis, Burapha University, Thailand.
- Sornyen, P. (2007). *Raw material inventory management of a feed mill*. Unpublished master's thesis, Kasetsart University, Thailand.
- Sringkansiri, C. (2005). *Production Planing and Control*. 12th ed., Bangkok, Thailand: Technology Promotion Association (Thailand-Japan).

- Stewart, V., Perry Addison, H. F., & Perry Addison, R.F. (1990). *SIMULATION – A problem solving approach*. Retrieved July 1, 2009, from http://sim.sagepub.com/cgi/pdf_extract/56/3/203
- Sudtiwadnarupud, K., Phamornstid S., & Doungpatra J. (2004). *Supply chain and logistics management*. Bangkok, Thailand: McGraw-Hill.
- Suksrisomboon, C. (2007). *The development of an inventory management system for The Royal Thai Air Force Medical Depot*. Chulalongkorn University, Thailand.
- Surapeepong, T. (2007). *An application of computer simulation and value stream mapping for roasted and ground coffee plant*. Unpublished master's thesis, Kasetsart University, Thailand.
- Suwanwong, S. (2000). *Forecasting Techniques: Time series*. Thailand: Department of Mathematics, Faculty of Sciences, Mahidol University.
- Tangwiboonpanich, S. (2005). *Improvement of raw material inventory control: A case study of coil manufacturing industry*. Unpublished master's thesis, King Mongkut's University of Technology North Bangkok, Thailand.
- Tanwari, A., Lakhari, A. K., & Shikh, G. Y. (2000). ABC Analysis as an inventory control technique. *Quaid-e-Awam University Research Journal of Engineering, Science & Technology*, 1(1). Retrieved October 1, 2010, from www.quest.edu.pk/Rjournals/SampleCopy/P8_PDF.pdf
- Tsou, C. S. (2009). Evolutionary Pareto optimizers for continuous review stochastic inventory systems. *European Journal of Operational Research*, 195, 364–371.
- Verma, A. K. (2006). Stochastic models for enhancing agility of supply chains. *Proceedings of the 2006 IJME - INTERTECH Conference*. Retrieved March 10, 2009, from http://www.ijme.us/cd_06/PDF/ENT%20P501-122.pdf
- Viboonsunti, C., Kumprakorb, U., & Sirisa-ard, P. (2003). Stock management of drug inventory control in the community pharmacy laboratory, Faculty of Pharmacy, Chiang Mai University. *Thai J. Pharm. Sci.*, 27(3-4), 139-148.
- Winston, W. L. (2004). *Operation Research: Applications and Algorithms*, 4th ed., Canada: Thomson.

- Yao, D. Q., Yue, X., Mukhopadhyay, S. K., & Wang Z. (2009). Strategic inventory deployment for retail and e-tail stores. *Omega*, 37, 646 – 658.





APPENDIX A

PROPERTIES OF AV-TYPE MEDICINE

Properties of the AV-type medicine are shown as the following;

1. Albumin GCC

Indications	Prevention or treatment of hypovolemic syndrome & the aversion of CV collapse, Emergency treatment of shock, Burns, Hypoproteinemia & edema, Neonatal hyperbilirubinemia
Code	ALBK-I-
Type	Inj. 20%
Storage	Temperature 2-8 C
Pack	1
Lead time	13 days
Note	Exclude the National List of Essential Medicine

2. Alphanate

Indications	Prevention & control of bleeding in patients factor VIII deficiency due to hemophilia A or acquired factor VIII deficiency
Code	ALPN-I-
Type	Inj. 250 iu
Storage	Temperature 2-8 C
Pack	1
Lead time	11 days
Note	Exclude the National List of Essential Medicine

3. AmBisome

Indications	Treatment of serious, life-threatening fungal infections, including a certain form of meningitis in people infected with HIV
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Code	AMBS-I-
Type	Inj. 50 mg
Storage	Temperature 2-8 C
Pack	1
Lead time	10 days
Note	Exclude the National List of Essential Medicine

4. ATG-Fresenius

Indications	Prevention & treatment of the rejection of organ & tissue transplant & treatment of graft-versus-host disease (GVHD). Treatment of severe aplastic anemia.
Code	ATGF-I-
Type	Inj. 20 mg/ml
Storage	Temperature 2-8 C
Pack	1
Lead time	12 days
Note	Include the National List of Essential Medicine

5. Berodual Forte

Indications	Prevention and treatment of symptoms in chronic obstructive airway disorders with reversible bronchospasm eg, bronchial asthma and especially chronic bronchitis with or without emphysema. Concomitant anti-inflammatory therapy should be considered for patients with bronchial asthma and steroid-responsive chronic obstructive pulmonary disease (COPD).
Code	BERF-X-
Type	Ext U
Storage	Room temperature less than 30 C
Pack	20
Lead time	12 days
Note	Include the National List of Essential Medicine

6. Cancidas

Indications	Cancidas or Caspofungin is an antibiotic that fights infections caused by fungus. It is used to treat fungal infections that involve the stomach, lungs, esophagus, or other internal body areas.
Code	CACD1I-
Type	Inj. 50 mg
Storage	Temperature 2-8 C
Pack	1
Lead time	10 days
Note	Exclude the National List of Essential Medicine

7. Controloc

Indications	Controloc or Pantoprazole is used to treat gastroesophageal reflux disease (GERD), a condition in which backward flow of acid from the stomach causes heartburn and injury of the food pipe (esophagus). It is also used to treat conditions where the stomach produces too much acid, such as Zollinger-Ellison syndrome. It works by decreasing the amount of acid made in the stomach.
Code	COTL-I-
Type	Inj. 40 mg
Storage	Room temperature less than 30 C
Pack	1
Lead time	13 days
Note	Include the National List of Essential Medicine

8. Desferal

Indications	Desferal or Deferoxamine binds to iron and removes it from the blood stream. It is used to treat iron overload caused by blood transfusions in adults and children at least 3 years old.
Code	DFRL-I-
Type	Inj.500 mg
Storage	Temperature 2-8 C

Pack	10
Lead time	12 days
Note	Include the National List of Essential Medicine

9. Feiba

Indications	Controlling bleeding episodes or bleeding during surgery in patients who have hemophilia A or B with inhibitors. It should not be used to treat patients with other bleeding disorders.
Code	FEIB2I-
Type	Inj. 1000 u
Storage	Temperature 2-8 C
Pack	1
Lead time	14 days
Note	Exclude the National List of Essential Medicine

10. Gammaraas

Indications	Primary immunodeficiency syndrome, Human Immunoglobulin.
Code	GAMR1I-
Type	Inj. 5 gm
Storage	Temperature 2-8 C
Pack	1
Lead time	15 days
Note	Include the National List of Essential Medicine

11. Hemofil-M

Indications	Hemofil-M or Human antihemophilic factor is used to treat or prevent bleeding episodes in adults and children with hemophilia A. It is also used to control bleeding related to surgery or dentistry in a person with hemophilia.
Code	HEMF2I-
Type	Inj. 500 iu
Storage	Temperature 2-8 C

Pack	1
Lead time	15 days
Note	Exclude the National List of Essential Medicine

12. Ilomedin-20

Indications	Treatment of advanced thromboangiitis obliterans (Buerger's disease) with critical limb ischemia in cases where revascularization is not indicated. Treatment of patients with severe peripheral arterial occlusive disease (PAOD), particularly those at risk of amputation and in whom surgery or angioplasty is not possible.
Code	ILOM-I-
Type	Inj. 0.02 mg
Storage	Room temperature less than 30 C
Pack	5
Lead time	13 days
Note	Exclude the National List of Essential Medicine

13. Invanz

Indications	Invanz or Ertapenem is used to treat severe bacterial infections of the skin, lungs, stomach, pelvis, and urinary tract. It is also used to prevent infection in people having certain types of surgery.
Code	INVZ-I-
Type	Inj.1 gm
Storage	Room temperature 25-28 C
Pack	5
Lead time	10 days
Note	Exclude the National List of Essential Medicine

14. Losec IV

Indications	Treatment of ulcers (sores in the lining of the stomach or small intestine); gastroesophageal reflux disease (GERD), a condition in which backward flow of acid from the stomach causes heartburn and
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injury of the esophagus (tube that connects the mouth and stomach);
and erosive esophagitis (swelling and wearing away of the lining of
the esophagus)

Code	LOSV-I-
Type	Inj. 40 mg
Storage	Room temperature 25-28 C
Pack	1
Lead time	10 days
Note	Include the National List of Essential Medicine

15. Meronem

Indications To reduce the development of drug-resistant bacteria and maintain the effectiveness of MERREM® I.V. (meropenem for injection) and other antibacterial drugs, and should be used only to treat or prevent infections that are proven or strongly suspected to be caused by bacteria.

Code	MERN2I-
Type	Inj. 1 gm
Storage	Room temperature less than 30 C
Pack	10
Lead time	10 days
Note	Include the National List of Essential Medicine

16. Nexium IV

Indications Treatment of gastroesophageal reflux disease (GERD) and other conditions involving excessive stomach acid such as Zollinger-Ellison syndrome. It is also used to promote healing of erosive esophagitis (damage to your esophagus caused by stomach acid). It may also be given to prevent gastric ulcer caused by infection with helicobacter pylori (H. pylori), or by the use of nonsteroidal anti-inflammatory drugs (NSAIDs).

Code	NEXM-I-
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Type	Inj. 40 mg
Storage	Room temperature less 30 C
Pack	1
Lead time	10 days
Note	Exclude in the National List of Essential Medicine

17. NovoSeven

Indications	Prevention or treatment of bleeding in people with hemophilia A or hemophilia B, or factor VII deficiency
Code	NOSV-I-
Type	Inj. 1.2 mg
Storage	Temperature 2-8 C
Pack	1
Lead time	10 days
Note	Exclude in the National List of Essential Medicine

18. Sandostatin

Indications	Sandostatin (octreotide acetate) is indicated to reduce blood levels of growth hormone and IGF-I (somatomedin C) in acromegaly patients who have had inadequate response to or cannot be treated with surgical resection, pituitary irradiation, and bromocriptine mesylate at maximally tolerated doses. The goal is to achieve normalization of growth hormone and IGF-I (somatomedin C) levels.
Code	SDTT1I-
Type	Inj. 0.1 mg/ml
Storage	Temperature 2-8 C
Pack	5
Lead time	12 days
Note	Include the National List of Essential Medicine

19. Tienam IV

Indications	Treatment of polymicrobial & mixed aerobic/anaerobic infections. Initial therapy prior to the identification of the causative organisms. Indicated for the treatment of intra-abdominal infections, lower tract infections, gynecological infections, septicemia, GUT infections, bone & joint infections, skin & soft tissue infections, endocarditis. Treatment of mixed infections caused by susceptible strains of aerobic & anaerobic bacteria.
Code	TIEN-I-
Type	Inj. 500 mg
Storage	Room temperature less than 25 C
Pack	1
Lead time	10 days
Note	Include the National List of Essential Medicine

20. VFEND IV

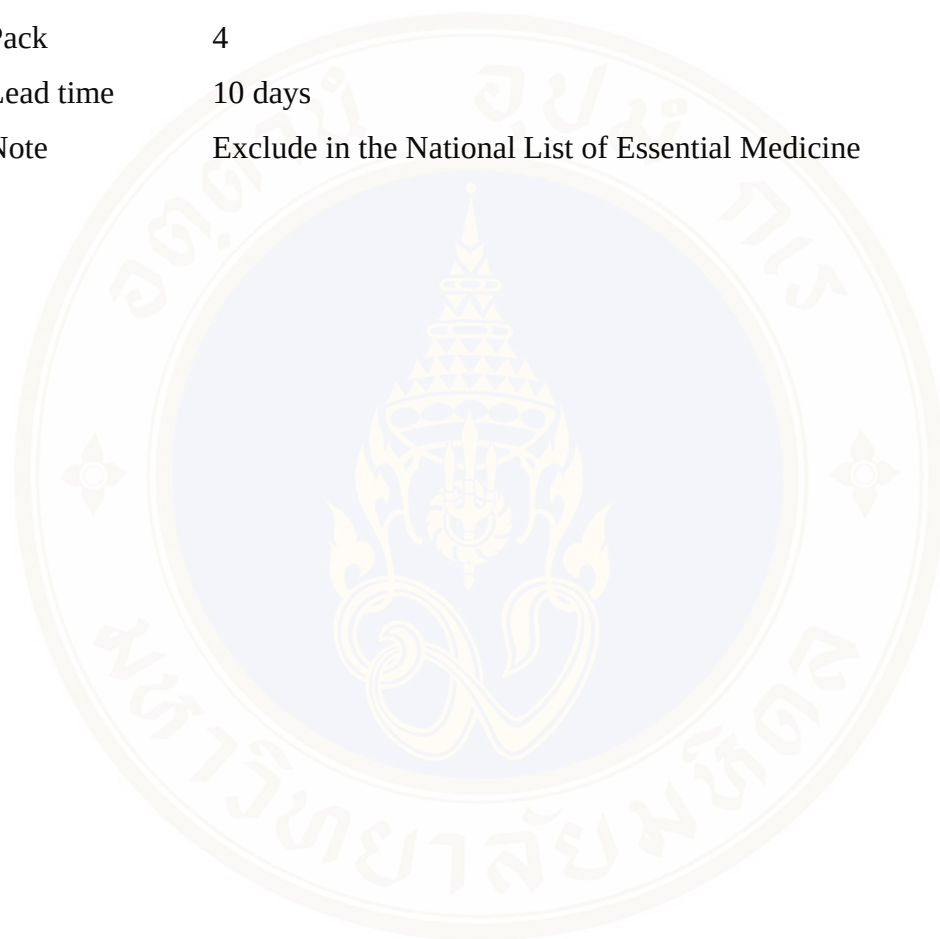
Indications	Treatment of the following fungal infections
Code	VFEN- I-
Type	Inj. 200 mg
Storage	Room temperature less than 25 C
Pack	1
Lead time	10 days
Note	Exclude in the National List of Essential Medicine

21. Viagra

Indications	Erectile dysfunction
Code	VIAG-T-
Type	Tab. 50 mg
Storage	Room temperature less than 30 C
Pack	4
Lead time	10 days
Note	Exclude in the National List of Essential Medicine

22. Viagra

Indications	Erectile dysfunction
Code	VIAG1T-
Type	Tab 100 mg
Storage	Room temperature less than 30 C
Pack	4
Lead time	10 days
Note	Exclude in the National List of Essential Medicine



APPENDIX B

FORECASTING MEDICINE DEMANDS

Forecasting demands for AV-type medicines are as follows;

1. Albumin GCC (ALBK-I-)

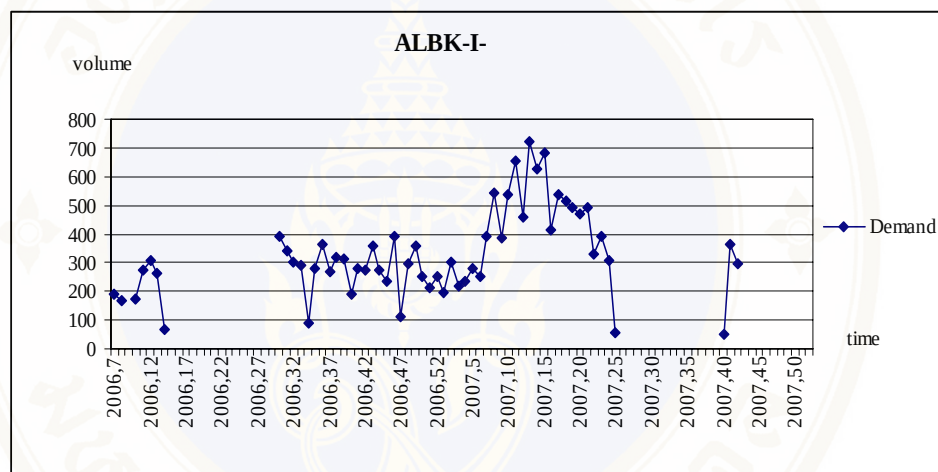


Figure B1: ALBK-I- weekly demand between week 7, 2006 to week 52, 2007

Characteristics of ALBK-I-

	N	Minimum	Maximum	Mean	Std. Deviation
ALBK-I-	54	52	545	304.06	121.373
Valid N (listwise)	54				

Analysis of demand trend and demand seasonal

1. Analysis of ALBK-I- demand trend

Hypothesis H_0 : There is no trend component in the time series data.

H_1 : There is trend component in the time series data.

Computation of Runs Test from SPSS

Runs Test

	ALBK-I-
Test Value(a)	298
Cases < Test Value	27
Cases >= Test Value	27
Total Cases	54
Number of Runs	21
Z	-1.923
Asymp. Sig. (2-tailed)	.054

a Median

There is no trend component in this time series data at significant level 0.05.

2. The ALBK-I- demands do not have enough data to analyze the components of seasonal variation.

Analysis of demand distribution

Analysis of ALBK-I- demand distribution

Hypothesis H_0 : The data are sampled from normal distribution population.

H_1 : The data are not sampled from normal distribution population.

Computation of Kolmogorov-Smirnov Test from SPSS

One-Sample Kolmogorov-Smirnov Test

	ALBK-I-
N	54
Normal Parameters(a,b)	Mean 304.06
	Std. Deviation 121.373
Most Extreme Differences	Absolute .078
	Positive .078
	Negative -.066
Kolmogorov-Smirnov Z	.577
Asymp. Sig. (2-tailed)	.894

a Test distribution is Normal.

b Calculated from data.

The data are sampled from normal distribution population at significant level 0.05.

ALBK-I- demand does not have trend and has normal distribution with mean is 304.06 and standard deviation is 121.373.

2. Alphanate (ALPN-I-)

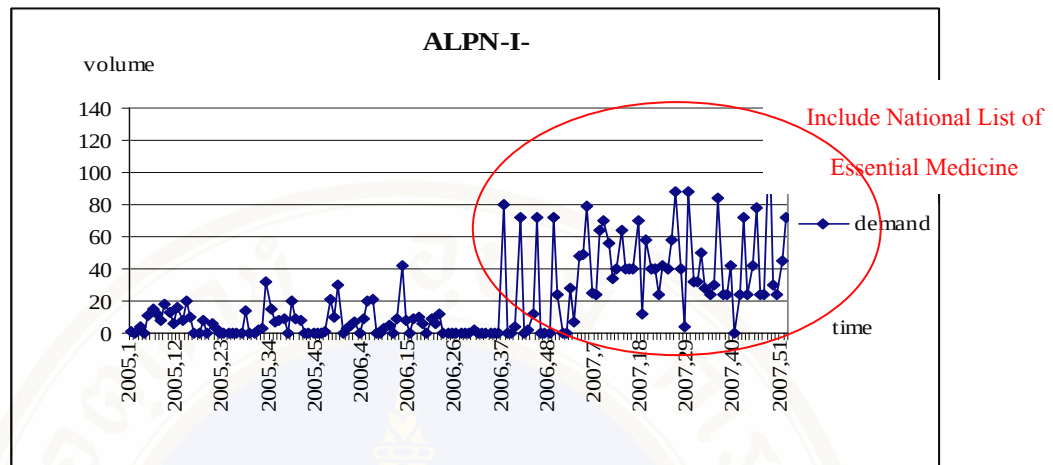


Figure B2: ALPN-I- weekly demand between week 1, 2005 to week 52, 2007

We considered ALPN-I- demands that only in National list of Essential Medicines.

Characteristics of ALPN-I-

	N	Minimum	Maximum	Mean	Std. Deviation
ALPN-I-	67	.00	88.00	37.0000	25.98076
Valid N (listwise)	67				

Analysis of demand trend and demand seasonal

1. Analysis of ALPN-I- demand trend.

Hypothesis H_0 : There is no trend component in the time series data.

H_1 : There is trend component in the time series data.

Computation of Runs Test from SPSS

Runs Test	
	ALPN-I-
Test Value(a)	34.00
Cases < Test Value	33
Cases >= Test Value	34
Total Cases	67
Number of Runs	29
Z	-1.353
Asymp. Sig. (2-tailed)	.176

a Median

There is no trend component in this time series data at significant level 0.05.

2. The ALPN-I- demands that include National List of Essential Medicine do not have enough data, so ALPN-I- demands cannot analyze seasonal variation components.

Analysis of demand distribution

Analysis of ALPN-I- demand distribution

Hypothesis H_0 : The data are sampled from normal distribution population.

H_1 : The data are not sampled from normal distribution population.

Computation of Kolmogorov-Smirnov Test from SPSS

One-Sample Kolmogorov-Smirnov Test

		ALPN-I-
N		67
Normal Parameters(a,b)	Mean	37.0000
	Std. Deviation	25.98076
Most Extreme Differences	Absolute	.095
	Positive	.095
	Negative	-.092
Kolmogorov-Smirnov Z		.780
Asymp. Sig. (2-tailed)		.576

a Test distribution is Normal.

b Calculated from data.

The data are sampled from normal distribution population at significant level 0.05.

ALPN-I- demand does not have trend and has normal distribution with mean is 304.06 and standard deviation is 121.373.

3. AmBisome (AMBS-I-)

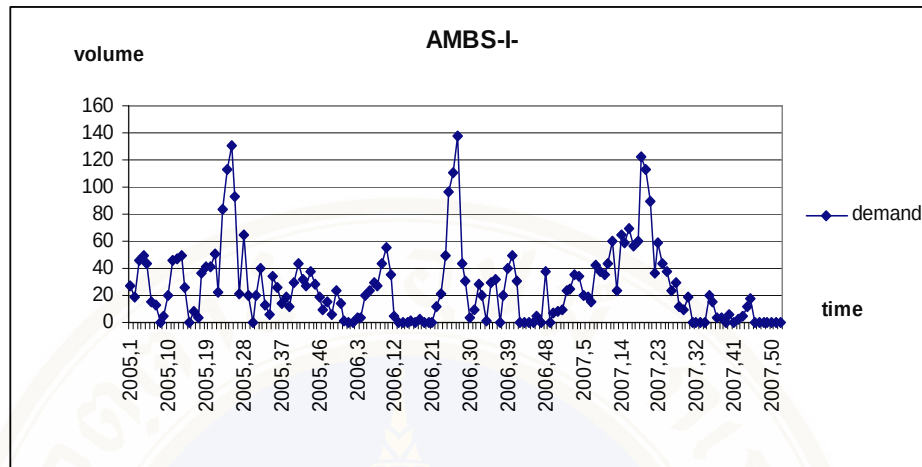


Figure B3: AMBS-I- weekly demand between week 1, 2006 to week 52, 2007

AMBS-I- demands do not have an appropriate distribution so we have not been considering.

4. ATG-Fresenius (ATGF-I-)

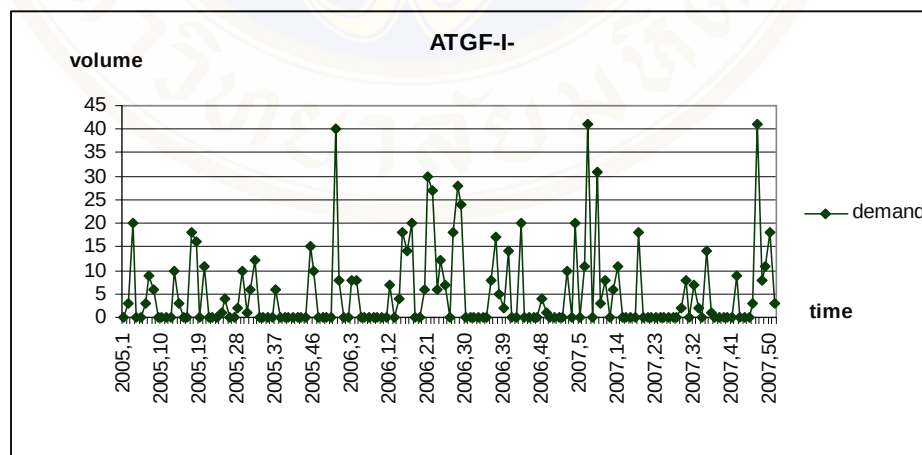


Figure B4: ATGF-I- weekly demand between week 1, 2005 to week 52, 2007

ATGF-I- demand does not have an appropriate distribution so we have not been considering.

5. Berodual Forte (BERF-X-)

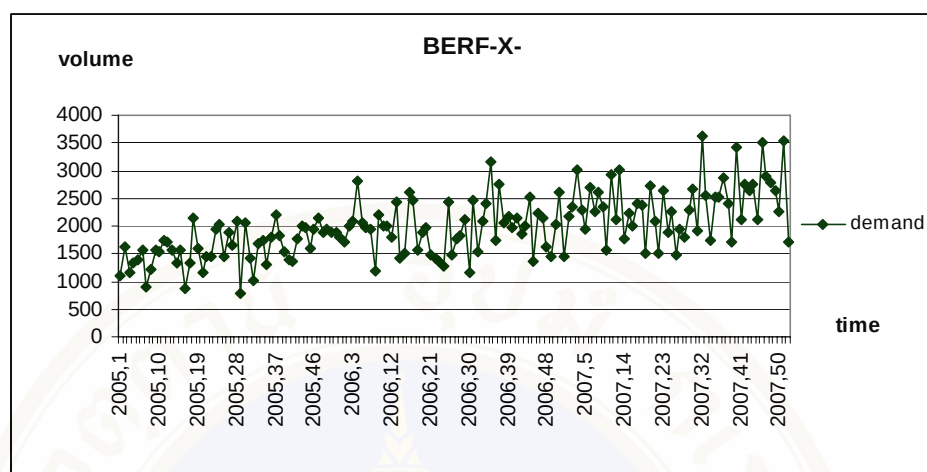


Figure B5: BERF-X- weekly demand between week 1, 2005 to week 52, 2007

Characteristics of BERF-X-

	N	Minimum	Maximum	Mean	Std. Deviation
BERF-X-	152	775	3156	1938.95	495.078
Valid N (listwise)	152				

Analysis of demand trend and demand seasonal

1. Analysis of BERF-X- demand trend

Hypothesis H_0 : There is no trend component in the time series data.

H_1 : There is trend component in the time series data.

Computation of Runs Test from SPSS

Runs Test	
	BERF-X-
Test Value(a)	1941
Cases < Test Value	76
Cases >= Test Value	76
Total Cases	152
Number of Runs	63
Z	-2.279
Asymp. Sig. (2-tailed)	.023

a Median

There is trend component in this time series data at significant level 0.05.

Analysis of BERF-X- demand trend

Model Summary and Parameter Estimates

Dependent Variable: BERF-X-

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.337	76.223	1	150	.000	1442.105	6.476		
Quadratic	.343	38.877	2	149	.000	1356.137	9.789	-.021	
Cubic	.346	26.152	3	148	.000	1276.184	15.857	-.119	.000

Model Cubic

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
Time	9.273	7.511	.831	1.235	<u>.219</u>
time ** 2	.076	.111	1.114	.691	<u>.491</u>
time ** 3	.000	.000	.903	.897	<u>.371</u>
(Constant)	2444.876	139.139		17.572	.000

Not appropriate

Model Quadratic

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
Time	3.098	2.999	.278	1.033	<u>.303</u>
time ** 2	-.021	.018	-.312	-1.163	<u>.247</u>
(Constant)	2361.319	103.272		22.865	.000

Not appropriate

Model Linear

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
Time	6.476	.742	.580	8.731	.000
(Constant)	2452.420	67.344		36.416	.000

Appropriate

From calculated demand trend, BERF-X- demand at week t is

$$\hat{Y}_t = 2,452.420 + 6.467t$$

where t = the number of week counted from the end of December, 2007 ($t = 0, 1, 2, \dots$).

2. Analysis of BERF-X- demand seasonal.

Hypothesis H_0 : There is no seasonal component in the time series data.

H_1 : There is seasonal component in the time series data.

Computation of Kruskal-Wallis Test from SPSS

Test Statistics(a,b)

	BERF-X-
Chi-Square	40.258
Df	51
Asymp. Sig.	.860

a. Kruskal Wallis Test

b. Grouping Variable: week

There is no seasonal component in the time series data at significant level 0.05.

Analysis of demand distribution

Hypothesis H_0 : The data are sampled from normal distribution population.

H_1 : The data are not sampled from normal distribution population.

Computation of Kolmogorov-Smirnov Test from SPSS

One-Sample Kolmogorov-Smirnov Test

		Error for BERF-X- with time from CURVEFIT, MOD_4 LINEAR
N		152
Normal	Mean	
Parameters(a,b)		.0000
	Std. Deviation	403.13494
Most Extreme	Absolute	.063
Differences	Positive	.043
	Negative	-.063
Kolmogorov-Smirnov Z		.780
Asymp. Sig. (2-tailed)		.576

a. Test distribution is Normal.

b. Calculated from data.

The data are sampled from normal distribution population at significant level 0.05.

BERF-X- demand has trend and has normal distribution with mean at week t is $2,452.420 + 6.467t$ and standard deviation at week t is 403.135; where t = the number of week counted from the end of December, 2007 ($t = 0,1,2,\dots$).

6. Cancidas (CACD1I-)

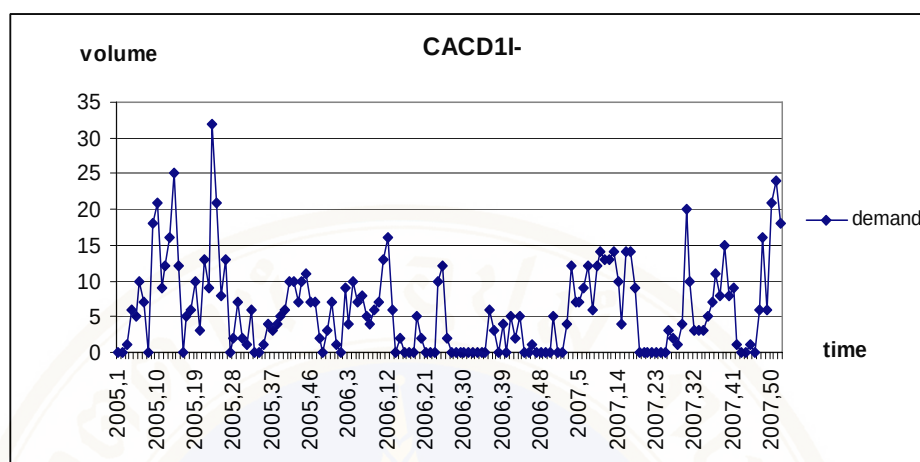


Figure B6: CACD1I- weekly demand between week 1, 2005 to week 52, 2007

CACD1I- demand does not have an appropriate distribution so we have not been considering.

7. Controloc (COTL-I-)

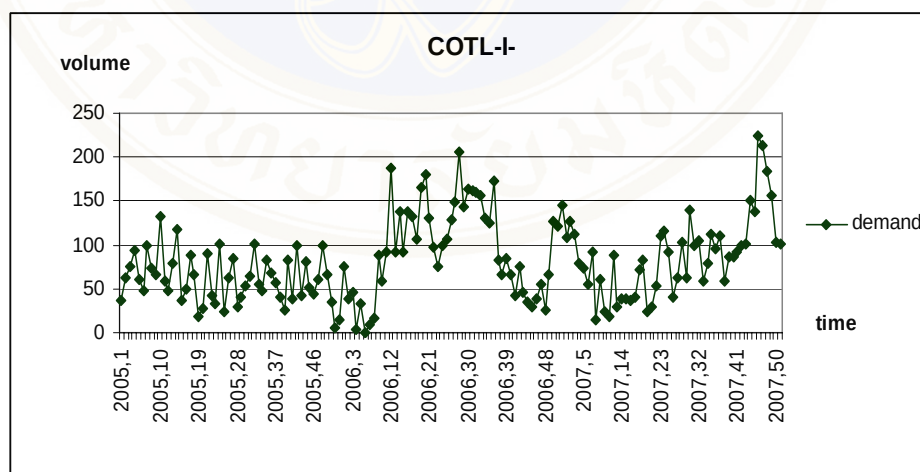


Figure B7: COTL-I- weekly demand between week 1, 2005 to week 52, 2007

Characteristics of COTL-I- after remove Outlier

	N	Minimum	Maximum	Mean	Std. Deviation
COTL-I-	153	0	188	79.08	42.318
Valid N (listwise)	153				

Analysis of demand trend and demand seasonal

1. Analysis of COTL-I- demand trend.

Hypothesis H_0 : There is no trend component in the time series data.

H_1 : There is trend component in the time series data.

Computation of Runs Test from SPSS

Runs Test

	COTL-I-
Test Value(a)	75
Cases < Test Value	74
Cases >= Test Value	79
Total Cases	153
Number of Runs	56
Z	-3.478
Asymp. Sig. (2-tailed)	.001

a Median

There is trend component in this time series data at significant level 0.05.

Analysis of COTL-I- demand trend

Model Summary and Parameter Estimates

Dependent Variable: COTL-I-

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.062	6.060	1	151	.062	97.582	.236		
Quadratic	.063	5.025	2	150	.008	95.797	.168	.000	
Cubic	.069	3.672	3	149	.014	104.745	.843	.010	4.60E-005

Model Cubic

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
time	.843	.750	.893	1.124	<u>.263</u>
time ** 2	.010	.011	1.770	.930	<u>.354</u>
time ** 3	4.60E-005	.000	1.167	.983	<u>.327</u>
(Constant)	104.745	13.691		7.651	.000

Not appropriate

Model Quadratic

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
Time	.168	.301	.178	.558	<u>.578</u>
time ** 2	.000	.002	-.074	-.232	<u>.817</u>
(Constant)	95.797	10.225		9.369	.000

Not appropriate

Model Linear

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
Time	.236	.074	.250	3.172	<u>.062</u>
(Constant)	97.582	6.712		14.538	.000

Not appropriate

The tests concluded that demand trend is not appropriate so we are not considering demand trend.

2. Analysis of COTL-I- demand seasonal.

Hypothesis H_0 : There is no seasonal component in the time series data.

H_1 : There is seasonal component in the time series data.

Computation of Kruskal-Wallis Test from SPSS.

Test Statistics(a,b)

	COTL-I-
Chi-Square	33.196
Df	51
Asymp. Sig.	.975

a Kruskal Wallis Test

b Grouping Variable: week

There is no seasonal component in the time series data at significant level 0.05.

Analysis of demand distribution

Analysis of COTL-I- demand distribution

Hypothesis H_0 : The data are sampled from normal distribution population.

H_1 : The data are not sampled from normal distribution population.

Computation of Kolmogorov-Smirnov Test from SPSS.

One-Sample Kolmogorov-Smirnov Test			COTL-I-
N			153
Normal Parameters(a,b)	Mean		79.08
	Std. Deviation		42.318
Most Extreme Differences	Absolute		.070
	Positive		.070
	Negative		-.039
Kolmogorov-Smirnov Z			.865
Asymp. Sig. (2-tailed)			.443

a Test distribution is Normal.

b Calculated from data.

The data are sampled from normal distribution population at significant level 0.05.

COTL-I- demand has no trend and has normal distribution with mean is 79.08 and standard deviation is 42.318.

8. Desferal (DFRL-I-)

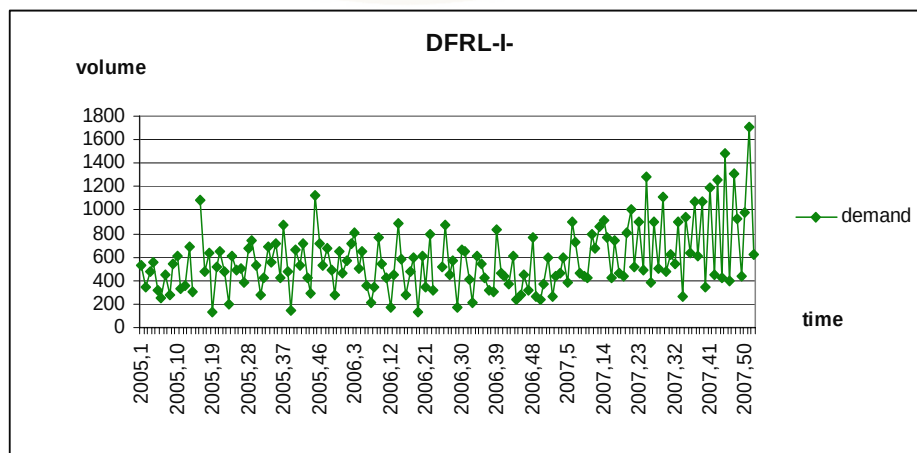


Figure B8: DFRL-I- weekly demand between week 1, 2005 to week 52, 2007

Characteristics of DFRL-I-

	N	Minimum	Maximum	Mean	Std. Deviation
DFRL-I-	148	130	1120	541.90	223.229
Valid N (listwise)	148				

Analysis of demand trend and demand seasonal

1. Analysis of DFRL-I- demand trend

Hypothesis H_0 : There is no trend component in the time series data.

H_1 : There is trend component in the time series data.

Computation of Runs Test from SPSS

Runs Test	
	DFRL-I-
Test Value(a)	506
Cases < Test Value	74
Cases >= Test Value	74
Total Cases	148
Number of Runs	81
Z	.990
Asymp. Sig. (2-tailed)	.322

a Median

There is no trend component in this time series data at significant level 0.05.

2. Analysis of DFRL-I- demand seasonal.

Hypothesis H_0 : There is no seasonal component in the time series data.

H_1 : There is seasonal component in the time series data.

Computation of Kruskal-Wallis Test from SPSS

Test Statistics(a,b)	
	DFRL-I-
Chi-Square	35.634
Df	51
Asymp. Sig.	.950

a Kruskal Wallis Test

b Grouping Variable: week

There is no seasonal component in this time series data at significant level 0.05.

Analysis of demand distribution

Hypothesis H_0 : The data are sampled from normal distribution population.

H_1 : The data are not sampled from normal distribution population.

Computation of Kolmogorov-Smirnov Test from SPSS

One-Sample Kolmogorov-Smirnov Test			DFRL-I-
N			148
Normal Parameters(a,b)	Mean		541.90
	Std. Deviation		223.229
Most Extreme Differences	Absolute		.074
	Positive		.074
	Negative		-.044
Kolmogorov-Smirnov Z			.897
Asymp. Sig. (2-tailed)			.397

a Test distribution is Normal.

b Calculated from data.

The data are sampled from normal distribution population at significant level 0.05.

DFRL-I- demand has no trend and has normal distribution with mean is 541.90 and standard deviation is 223.229

9. Feiba (FEIB2I-)

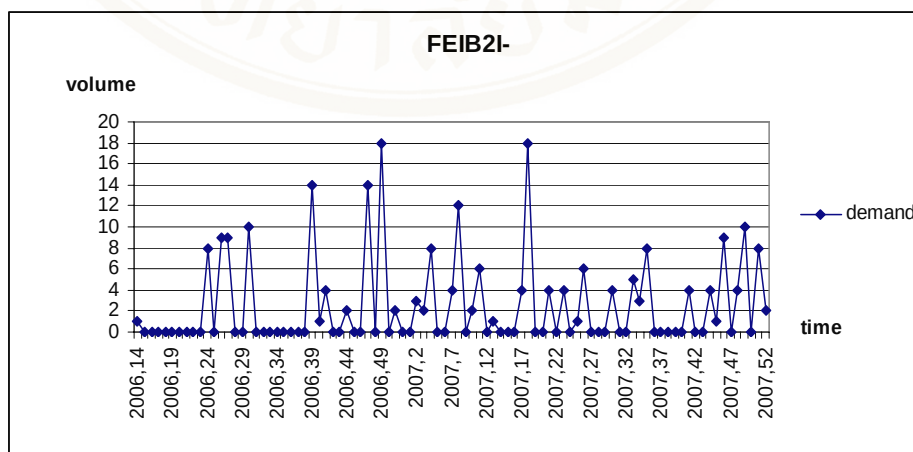


Figure B9: FEIB2I- weekly demand between week 14, 2006 to week 52, 2007

FEIB2I- demand does not have an appropriate distribution so we have not been considering.

10. Gammaraas (GAMR1I-)

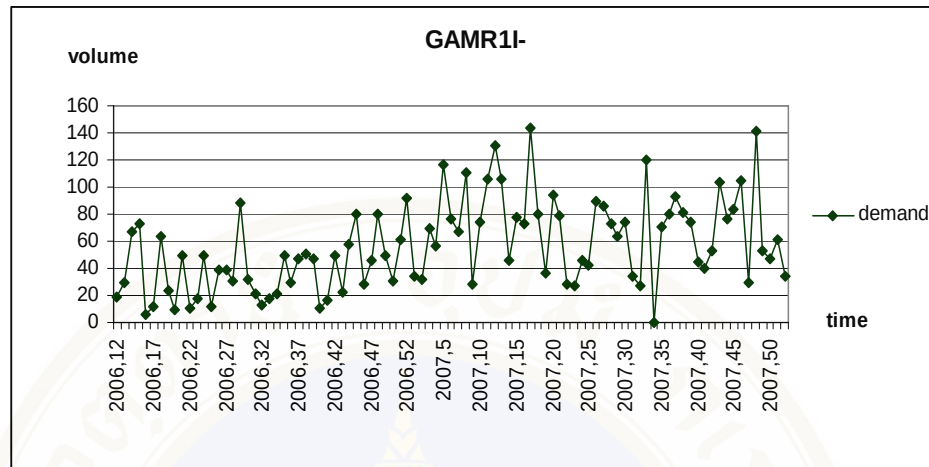


Figure B10: GAMR1I- weekly demand between week 12, 2006 to week 52, 2007

Characteristics of GAMR1I-

	N	Minimum	Maximum	Mean	Std. Deviation
GAMR1I-	93	0	143	55.99	32.399
Valid N (listwise)	93				

Analysis of demand trend and demand seasonal

1. Analysis of GAMR1I- demand trend.

Hypothesis H_0 : There is no trend component in the time series data.

H_1 : There is trend component in the time series data.

Computation of Runs Test from SPSS

Runs Test

	GAMR1I-
Test Value(a)	49
Cases < Test Value	43
Cases $\geq$ Test Value	50
Total Cases	93
Number of Runs	43
Z	-.889
Asymp. Sig. (2-tailed)	.374

a Median

There is no trend component in this time series data at significant level 0.05.

2. Analysis of GAMR1I- demand seasonal.

Hypothesis H_0 : There is no seasonal component in the time series data.

H_1 : There is seasonal component in the time series data.

Computation of Kruskal-Wallis Test from SPSS

Test Statistics(a,b)

	GAMR1I-
Chi-Square	47.204
Df	51
Asymp. Sig.	.625

a Kruskal Wallis Test

b Grouping Variable: week

There is no seasonal component in this time series data at significant level 0.05

Analysis of demand distribution

Hypothesis H_0 : The data are sampled from normal distribution population.

H_1 : The data are not sampled from normal distribution population.

Computation of Kolmogorov-Smirnov Test from SPSS

One-Sample Kolmogorov-Smirnov Test

	GAMR1I-
N	93
Normal Parameters(a,b)	
Mean	55.99
Std. Deviation	32.399
Most Extreme Differences	
Absolute	.091
Positive	.091
Negative	-.052
Kolmogorov-Smirnov Z	.875
Asymp. Sig. (2-tailed)	.428

a Test distribution is Normal.

b Calculated from data.

The data are sampled from normal distribution population at significant level 0.05.

GAMR1I- demand has no trend and has normal distribution with mean is 55.99 and standard deviation is 32.399.

11. Hemofil-M (HEMF2I-)

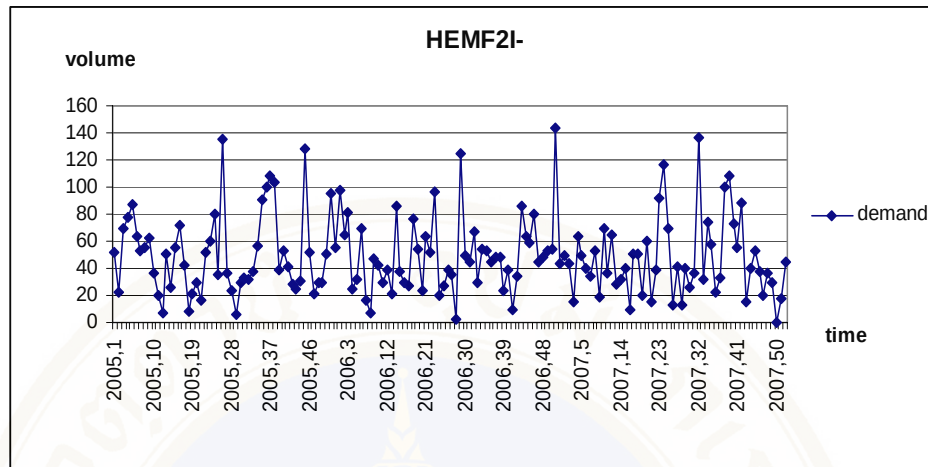


Figure B11: HEMF2I- weekly demand between week 1, 2005 to week 52, 2007

Characteristics of HEMF2I-

	N	Minimum	Maximum	Mean	Std. Deviation
HEMF2I-	150	0	108	45.56	24.050
Valid N (listwise)	150				

Analysis of demand trend and demand seasonal

1. Analysis of HEMF2I- demand trend.

Hypothesis H_0 : There is no trend component in the time series data.

H_1 : There is trend component in the time series data.

Computation of Runs Test from SPSS

Runs Test

	HEMF2I-
Test Value(a)	42
Cases < Test Value	75
Cases >= Test Value	75
Total Cases	150
Number of Runs	55
Z	-3.441
Asymp. Sig. (2-tailed)	.001

a Median

There is trend component in this time series data at significant level 0.05.

Analysis of HEMF2I- demand trend

Model Summary and Parameter Estimates

Dependent Variable: HEMF2I-

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.004	.564	1	148	.454	43.016	-.033		
Quadratic	.004	.291	2	147	.748	42.379	-.058	.000	
Cubic	.006	.276	3	146	.843	39.926	-.253	-.003	-1.36E-005

Model Cubic

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
Time	-.253	.429	-.477	-.590	<u>.556</u>
time ** 2	-.003	.006	-1.007	-.516	<u>.607</u>
time ** 3	-1.36E-005	.000	-.611	-.498	<u>.619</u>
(Constant)	39.926	7.627		5.235	.000

Not appropriate

Model Quadratics

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
Time	-.058	.173	-.108	-.333	<u>.739</u>
time ** 2	.000	.001	-.048	-.149	<u>.882</u>
(Constant)	42.379	5.812		7.292	.000

Not appropriate

Model Linear

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
Time	-.033	.044	-.062	-.751	<u>.454</u>
(Constant)	43.016	3.917		10.981	.000

Not appropriate

The tests concluded that demand trend is not appropriate so we are not considering demand trend.

2. Analysis of HEMF2I- demand seasonal.

Hypothesis H_0 : There is no seasonal component in the time series data.

H_1 : There is seasonal component in the time series data.

Computation of Kruskal-Wallis Test from SPSS

Test Statistics(a,b)

	HEMF2I-
Chi-Square	46.093
Df	51
Asymp. Sig.	.669

a Kruskal Wallis Test

b Grouping Variable: week

There is no seasonal component in the time series data at significant level 0.05.

Analysis of demand distribution

Analysis of HEMF2I- demand distribution

Hypothesis H_0 : The data are sampled from normal distribution population.

H_1 : The data are not sampled from normal distribution population.

Computation of Kolmogorov-Smirnov Test from SPSS

One-Sample Kolmogorov-Smirnov Test

	HEMF2I-
N	150
Normal Parameters(a,b)	Mean 45.56
	Std. Deviation 24.050
Most Extreme Differences	Absolute .087
	Positive .087
	Negative -.047
Kolmogorov-Smirnov Z	1.070
Asymp. Sig. (2-tailed)	.203

a Test distribution is Normal.

b Calculated from data.

The data are sampled from normal distribution population at significant level 0.05.

HEMF2I- demand has no trend and has normal distribution with mean is 45.56 and standard deviation is 24.05.

12. Ilomedin-20 (ILOM-I-)

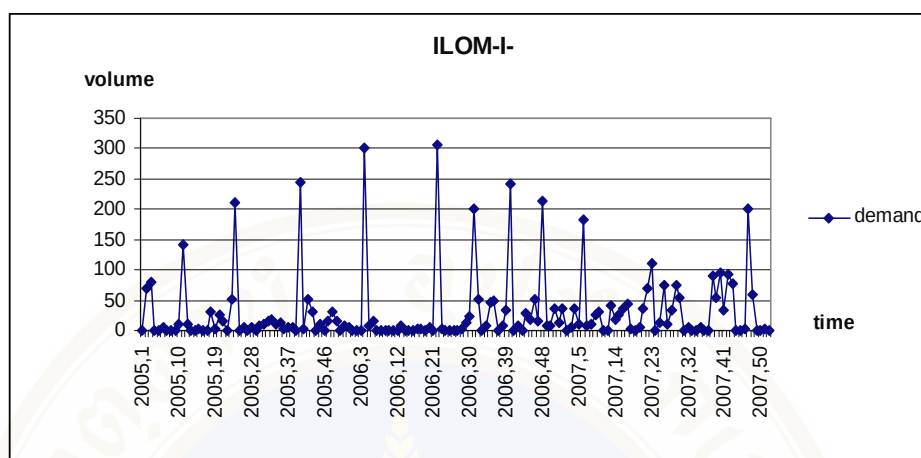


Figure B12: ILOM-I- weekly demand between week 1, 2005 to week 52, 2007

ILOM-I- demand does not have an appropriate distribution so we have not been considering.

13. Invanz (INVZ-I-)

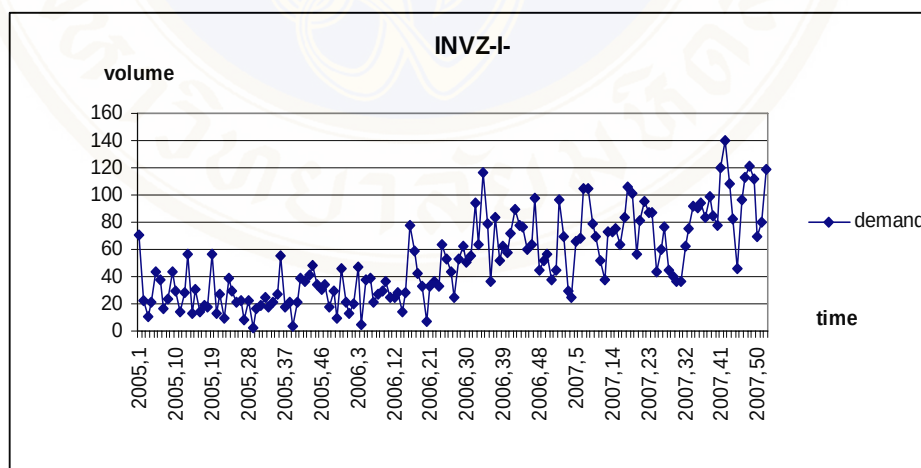


Figure B13: INVZ-I- weekly demand between week 1, 2005 to week 52, 2007

Characteristics of INVZ-I-

	N	Minimum	Maximum	Mean	Std. Deviation
INVZ-I- Valid N (listwise)	156	2	140	51.46	30.708

Analysis of demand trend and demand seasonal

1. Analysis of INVZ-I- demand trend.

Hypothesis H_0 : There is no trend component in the time series data.

H_1 : There is trend component in the time series data.

Computation of Runs Test from SPSS

Runs Test	
	INVZ-I-
Test Value(a)	45.00
Cases < Test Value	77
Cases >= Test Value	79
Total Cases	156
Number of Runs	31
Z	-7.710
Asymp. Sig. (2-tailed)	.000

a Median

There is trend component in this time series data at significant level 0.05.

Analysis of INVZ-I- demand trend

Model Summary and Parameter Estimates

Dependent Variable: INVZ-I-

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.546	185.466	1	154	.000	90.393	.502		
Quadratic	.568	100.444	2	153	.000	100.195	.884	.002	
Cubic	.580	70.024	3	152	.000	91.469	.198	-.009	-4.78E-005

Model Cubic

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Time	.198	.352	.291	.561	.575
time ** 2	-.009	.005	-2.037	-1.635	.104
time ** 3	-4.78E-005	.000	-1.663	-2.130	.035
(Constant)	91.469	6.283		14.558	.000

Not appropriate

Model Quadratic

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
Time	.884	.144	1.301	6.155	.000
time ** 2	.002	.001	.580	2.746	.007
(Constant)	100.195	4.820		20.789	.000

Appropriate

From calculated demand trend of quadratic model, INVZ-I- demand at week t

$$\text{is } \hat{Y}_t = 100.195 + 0.884t + 0.002t^2$$

where t = the number of week counted from the end of December, 2007 ($t = 0, 1, 2, \dots$).

Model Linear

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
Time	.502	.037	.739	13.619	.000
(Constant)	90.393	3.307		27.335	.000

Appropriate

From calculated demand trend of linear model, INVZ-I- demand at week t is

$$\hat{Y}_t = 90.393 + 0.502t$$

where t = the number of week counted from the end of December, 2007 ($t = 0, 1, 2, \dots$).

Next, the forecast from two equations were tested with the real data in 2008 to calculated Mean Square Error.

Model	Mean Square Error
$\hat{Y}_t = 100.195 + 0.884t + 0.002t^2$	981.16
$\hat{Y}_t = 90.393 + 0.502t$	1,059.87

The Mean Square Error of the quadratic model is less than linear model, so the trend of INVZ-I- demand at week t is

$$\hat{Y}_t = 100.195 + 0.884t + 0.002t^2$$

where t = the number of week counted from the end of December, 2007 ($t = 0, 1, 2, \dots$).

2. Analysis of INVZ-I- demand seasonal.

Hypothesis H_0 : There is no seasonal component in the time series data.

H_1 : There is seasonal component in the time series data.

Computation of Kruskal-Wallis Test from SPSS

Test Statistics(a,b)

	INVZ-I-
Chi-Square	47.866
Df	51
Asymp. Sig.	.599

a Kruskal Wallis Test

b Grouping Variable: week

There is no seasonal component in the time series data at significant level 0.05.

Analysis of demand distribution

Hypothesis H_0 : The data are sampled from normal distribution population.

H_1 : The data are not sampled from normal distribution population.

Computation of Kolmogorov-Smirnov Test from SPSS

One-Sample Kolmogorov-Smirnov Test

		Error for INVZ-I- with time from CURVEFIT, MOD_4 QUADRATIC
N		156
Normal Parameters(a,b)	Mean	.0000000
	Std. Deviation	20.19164616
Most Extreme Differences	Absolute	.064
	Positive	.064
	Negative	-.047
Kolmogorov-Smirnov Z		.794
Asymp. Sig. (2-tailed)		.554

a Test distribution is Normal.

b Calculated from data.

The data are sampled from normal distribution population at significant level 0.05.

INVZ-I- demand has trend and has normal distribution with mean at week t is $100.195 + 0.884t + 0.002t^2$ and standard deviation at week t is 20.191; where t = the number of week counted from the end of December, 2007 ($t = 0, 1, 2, \dots$).

14. Losec IV (LOSV-I-)

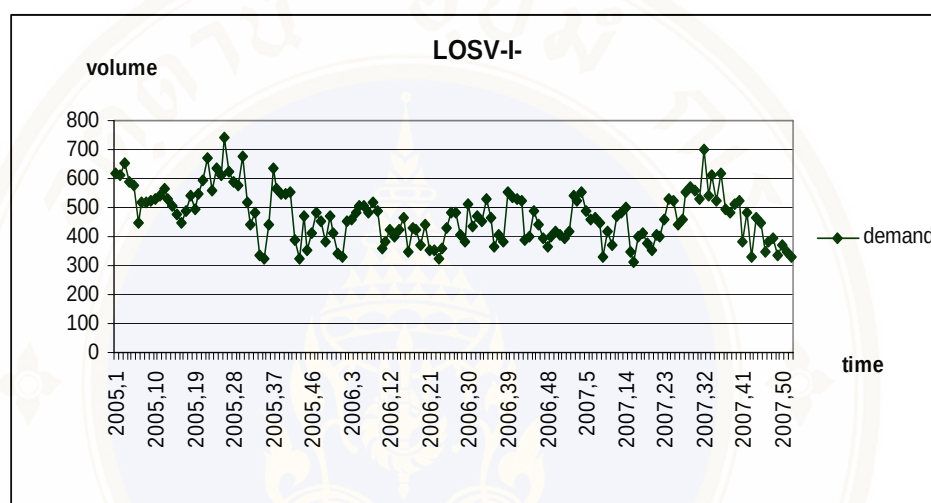


Figure B14: LOSV-I- weekly demand between week 1, 2005 to week 52, 2007

Characteristics of LOSV-I-

	N	Minimum	Maximum	Mean	Std. Deviation
LOSV-I-	155	313	701	466.63	86.804
Valid N (listwise)	155				

Analysis of demand trend and demand seasonal

1. Analysis of LOSV-I- demand trend.

Hypothesis H_0 : There is no trend component in the time series data.

H_1 : There is trend component in the time series data.

Computation of Runs Test from SPSS

Runs Test

	LOSV-I-
Test Value(a)	464
Cases < Test Value	77
Cases >= Test Value	78
Total Cases	155
Number of Runs	42
Z	-5.882
Asymp. Sig. (2-tailed)	.000

a Median

There is trend component in the time series data at significant level 0.05.

Analysis of LOSV-I-demand trend

Model Summary and Parameter Estimates

Dependent Variable: LOSV-I-

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.103	17.516	1	153	.000	419.059	-.617		
Quadratic	.193	18.198	2	152	.000	475.921	1.600	.014	
Cubic	.233	15.319	3	151	.000	431.873	-1.868	-.042	.000

Cubic Model

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
Time	-1.868	1.347	-.971	-1.386	<u>.168</u>
time ** 2	-.042	.020	-3.478	-2.065	.041
time ** 3	.000	.000	-2.967	-2.812	.006
(Constant)	431.873	24.015		17.984	.000

Not appropriate

Quadratic Model

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
time	1.600	.555	.832	2.883	<u>.055</u>
time ** 2	.014	.003	1.191	4.128	.000
(Constant)	475.921	18.612		25.571	.000

Not appropriate

Linear Model

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
time	-.617	.147	-.321	-4.185	.000
(Constant)	419.059	13.157		31.850	.000

The tests concluded that LOSV-I- demand has linear trend. The R square of linear trend is 0.103. It means that linear trend can describe the data as 10.3%, which is less, so this trend is not appropriate. We do not use demand trend.

2. Analysis of LOSV-I- demand seasonal.

Hypothesis H_0 : There is no seasonal component in the time series data.

H_1 : There is seasonal component in the time series data.

Computation of Kruskal-Wallis Test from SPSS

Test Statistics(a,b)

	LOSV-I-
Chi-Square	57.903
Df	51
Asymp. Sig.	.236

a Kruskal Wallis Test

b Grouping Variable: week

There is no seasonal component in the time series data at significant level 0.05.

Analysis of demand distribution

Analysis of LOSV-I- demand distribution

Hypothesis H_0 : The data are sampled from normal distribution population.

H_1 : The data are not sampled from normal distribution population.

Computation of Kolmogorov-Smirnov Test from SPSS

One-Sample Kolmogorov-Smirnov Test

		LOSV-I-
N		155
Normal Parameters(a,b)	Mean	466.63
	Std. Deviation	86.804
Most Extreme Differences	Absolute	.062
	Positive	.062
	Negative	-.043
Kolmogorov-Smirnov Z		.773
Asymp. Sig. (2-tailed)		.589

a. Test distribution is Normal.

b. Calculated from data.

The data are sampled from normal distribution population at significant level 0.05.

LOSV-I- demand has no trend and has normal distribution with mean is 466.63 and standard deviation is 86.804.

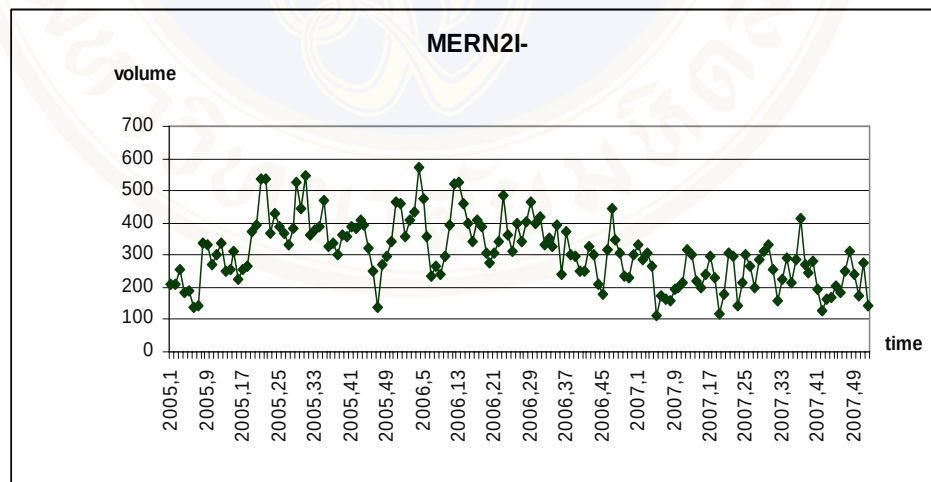
15. Meronem (MERN2I-)

Figure B15: MERN2I- weekly demand between week 1, 2005 to week 52, 2007

Characteristics of MERN2I-

	N	Minimum	Maximum	Mean	Std. Deviation
MERN2I-	156	113	574	307.42	99.466
Valid N (listwise)	156				

Analysis of demand trend and demand seasonal

1. Analysis of MERN2I- demand trend.

Hypothesis H_0 : There is no trend component in the time series data.

H_1 : There is trend component in the time series data.

Computation of Runs Test from SPSS

Runs Test	
	MERN2I-
Test Value(a)	303
Cases < Test Value	78
Cases >= Test Value	78
Total Cases	156
Number of Runs	37
Z	-6.747
Asymp. Sig. (2-tailed)	.000

a Median

There is trend component in the time series data at significant level 0.05.

Analysis of MERN2I- demand trend

Model Summary and Parameter Estimates

Dependent Variable: MERN2I-

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.154	28.073	1	154	.000	240.423	-.865		
Quadratic	.288	30.933	2	153	.000	160.889	-3.963	-.020	
Cubic	.406	34.561	3	152	.000	247.446	2.848	.090	.000

Cubic Model

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta	B	Std. Error
time	2.848	1.357	1.293	2.098	.058
time ** 2	.090	.020	6.562	4.425	.000
time ** 3	.000	.000	5.094	5.483	.000
(Constant)	247.446	24.218		10.218	.000

Not appropriate

Quadratic Model

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
time	-3.963	.597	-1.800	-6.636	.000
time ** 2	-.020	.004	-1.454	-5.361	.000
(Constant)	160.889	20.034		8.031	.000

Linear Model

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
time	-.865	.163	-.393	-5.298	.000
(Constant)	240.423	14.625		16.439	.000

The tests concluded that MERN2I- demand has quadratic and linear trends. The R square of quadratic and linear trends are 0.288 and 0.154. It means that quadratic and linear trend can describe the data as 28.8% and 15.4%, which are least, so these trends are not appropriate. We do not use demand trend.

2. Analysis of MERN2I- demand seasonal.

Hypothesis H_0 : There is no seasonal component in the time series data.

H_1 : There is seasonal component in the time series data.

Computation of Kruskal-Wallis Test from SPSS

Test Statistics(a,b)

	MERN2I-
Chi-Square	37.230
Df	51
Asymp. Sig.	.925

a Kruskal Wallis Test

b Grouping Variable: week

There is no seasonal component in the time series data at significant level 0.05.

Analysis of demand distribution

Analysis of MERN2I- demand distribution

Hypothesis H_0 : The data are sampled from normal distribution population.

H_1 : The data are not sampled from normal distribution population.

Computation of Kolmogorov-Smirnov Test from SPSS

One-Sample Kolmogorov-Smirnov Test			MERN2I-
N			156
Normal Parameters(a,b)	Mean		307.42
	Std. Deviation		99.466
Most Extreme Differences	Absolute		.041
	Positive		.041
	Negative		-.028
Kolmogorov-Smirnov Z			.508
Asymp. Sig. (2-tailed)			.959

a Test distribution is Normal.

b Calculated from data.

The data are sampled from normal distribution population at significant level 0.05.

MERN2I- demand has no trend and has normal distribution with mean is 307.42 and standard deviation is 99.466.

16. Nexium IV (NEXM-I-)

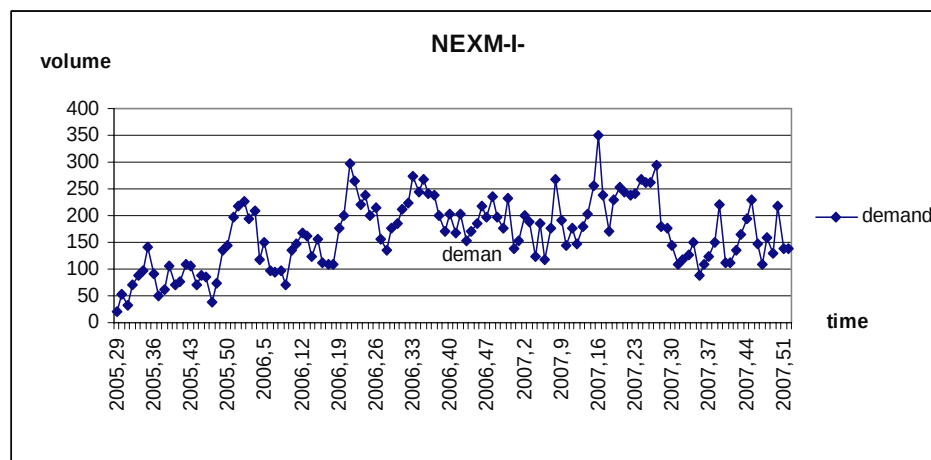


Figure B16: NEXM-I- weekly demand between week 1, 2005 to week 52, 2007

Characteristics of NEXM-I-

	N	Minimum	Maximum	Mean	Std. Deviation
NEXM-I- Valid N (listwise)	127 127	31	351	166.35	62.747

Analysis of demand trend and demand seasonal

1. Analysis of NEXM-I- demand trend.

Hypothesis H_0 : There is no trend component in the time series data.

H_1 : There is trend component in the time series data.

Computation of Runs Test from SPSS

Runs Test

	NEXM-I-
Test Value(a)	168
Cases < Test Value	63
Cases >= Test Value	64
Total Cases	127
Number of Runs	27
Z	-6.681
Asymp. Sig. (2-tailed)	.000

a Median

There is trend component in the time series data at significant level 0.05.

Analysis of NEXM-I- demand trend

Model Summary and Parameter Estimates

Dependent Variable: NEXM-I-

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.139	20.201	1	125	.000	206.407	.636		
Quadratic	.411	43.280	2	124	.000	135.227	-2.781	-.027	
Cubic	.411	28.621	3	123	.000	135.020	-2.801	-.028	-2.11E-006

Quadratic Model

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
Time	-2.781	.467	-1.631	-5.961	.000
time ** 2	-.027	.004	-2.071	-7.567	<u>.061</u>
(Constant)	135.227	12.721		10.631	.000

Not appropriate

Cubic Model

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
Time	-2.801	1.159	-1.643	-2.416	.017
time ** 2	-.028	.021	-2.101	-1.284	<u>.202</u>
time ** 3	-2.11E-006	.000	-.019	-.019	<u>.985</u>
(Constant)	135.020	16.800		8.037	.000

Not appropriate

Linear Model

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
Time	.636	.141	.373	4.495	.000
(Constant)	206.407	10.312		20.015	.000

The tests concluded that NEXM-I- demand has linear trends. The R square of linear trends is 0.139. It means that linear trend can describe the data as 13.9%, which is least, so linear trend is not appropriate. We do not use demand trend.

2. Analysis of NEXM-I- demand seasonal.

Hypothesis H_0 : There is no seasonal component in the time series data.

H_1 : There is seasonal component in the time series data.

Computation of Kruskal-Wallis Test from SPSS

Test Statistics(a,b)

	Nexm
Chi-Square	43.997
Df	51
Asymp. Sig.	.746

a Kruskal Wallis Test

b Grouping Variable: week

There is no seasonal component in the time series data at significant level 0.05.

Analysis of demand distribution

Analysis of NEXM-I- demand distribution

Hypothesis H_0 : The data are sampled from normal distribution population.

H_1 : The data are not sampled from normal distribution population.

Computation of Kolmogorov-Smirnov Test from SPSS

One-Sample Kolmogorov-Smirnov Test

	Nexm
N	127
Normal Parameters(a,b)	
Mean	166.35
Std. Deviation	62.747
Most Extreme Differences	
Absolute	.047
Positive	.047
Negative	-.039
Kolmogorov-Smirnov Z	.532
Asymp. Sig. (2-tailed)	.940

a Test distribution is Normal.

b Calculated from data.

The data are sampled from normal distribution population at significant level 0.05.

NEXM-I- demand has no trend and has normal distribution with mean is 166.35 and standard deviation is 62.747.

17. Novoseven (NOSV-I-)

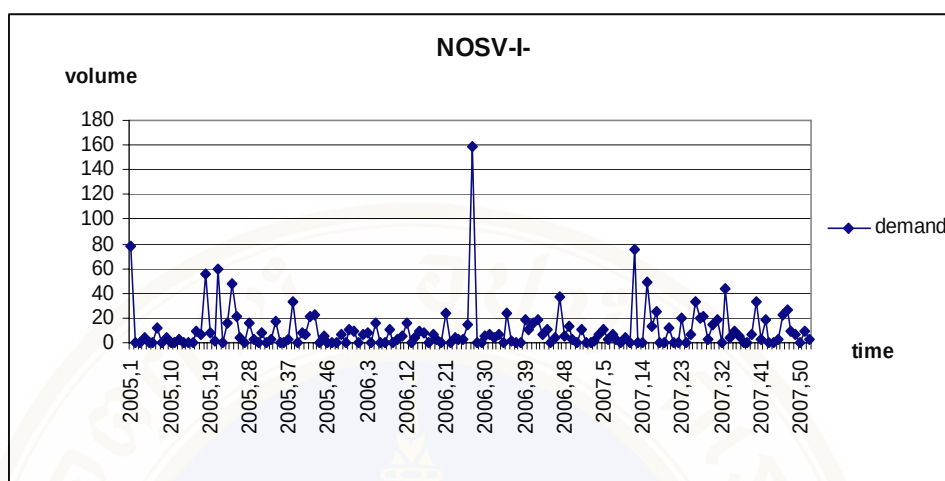


Figure B17: NOSV-I- weekly demand between week 1, 2005 to week 52, 2007

NOSV-I- demand does not have an appropriate distribution so we have not been considering.

18. Sandostatin (SDTT1I-)

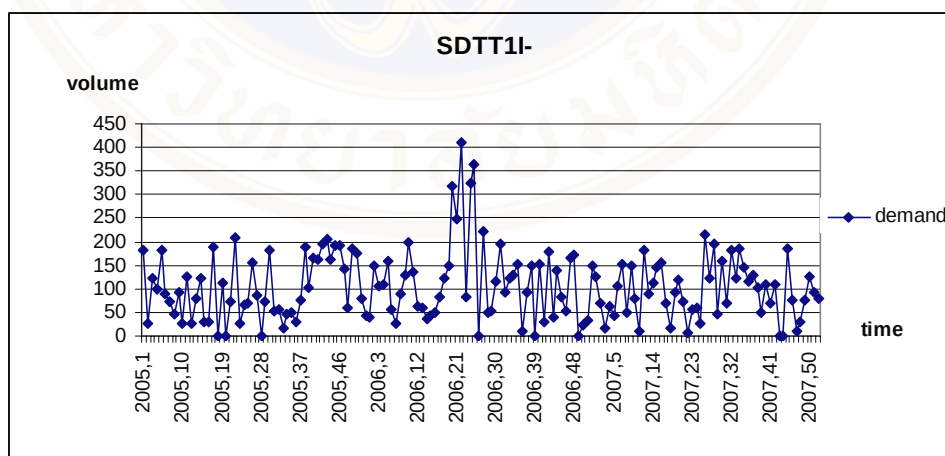


Figure B18: SDTT1I- weekly demand between week 1, 2005 to week 52, 2007

Characteristics of SDTT1I-

	N	Minimum	Maximum	Mean	Std. Deviation
SDTT1I- Valid N (listwise)	152	0	249	97.25	60.653

Analysis of demand trend and demand seasonal

1. Analysis of SDTT1I-demand trend.

Hypothesis H_0 : There is no trend component in the time series data.

H_1 : There is trend component in the time series data.

Computation of Runs Test from SPSS

Runs Test	
	SDTT1I-
Test Value(a)	90
Cases < Test Value	76
Cases >= Test Value	76
Total Cases	152
Number of Runs	70
Z	-1.139
Asymp. Sig. (2-tailed)	.255

a Median

There is no trend component in this time series data at significant level 0.05.

2. Analysis of SDTT1I- demand seasonal.

Hypothesis H_0 : There is no seasonal component in the time series data.

H_1 : There is seasonal component in the time series data.

Computation of Kruskal-Wallis Test from SPSS

Test Statistics(a,b)	
	SDTT1I-
Chi-Square	34.395
Df	51
Asymp. Sig.	.964

a Kruskal Wallis Test

b Grouping Variable: week

There is no seasonal component in the time series data at significant level 0.05.

Analysis of demand distribution

Analysis of SDTT1I- demand distribution

Hypothesis H_0 : The data are sampled from normal distribution population.

H_1 : The data are not sampled from normal distribution population.

Computation of Kolmogorov-Smirnov Test from SPSS

One-Sample Kolmogorov-Smirnov Test

		SDTT1I-
N		152
Normal Parameters(a,b)	Mean	97.25
	Std. Deviation	60.653
Most Extreme Differences	Absolute	.071
	Positive	.071
	Negative	-.062
Kolmogorov-Smirnov Z		.877
Asymp. Sig. (2-tailed)		.425

a. Test distribution is Normal.

b. Calculated from data.

The data are sampled from normal distribution population at significant level 0.05.

SDTT1I- demand has no trend and has normal distribution with mean is 97.25 and standard deviation is 60.653.

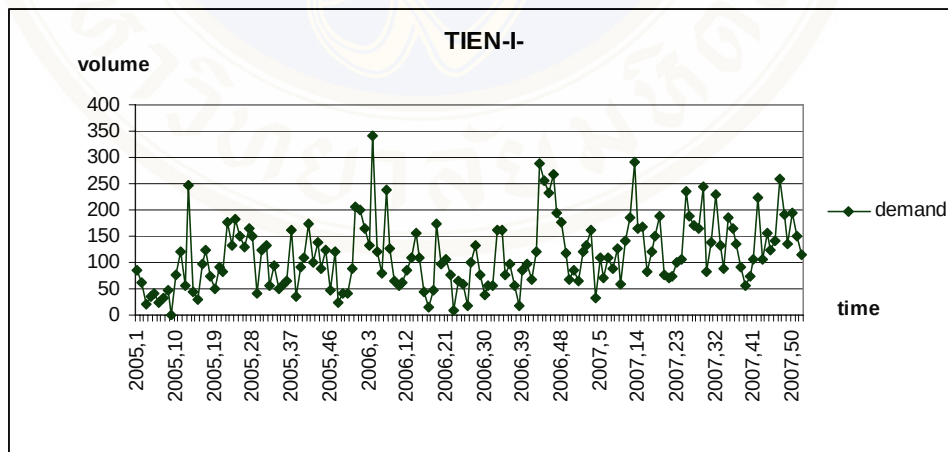
19. Tienam IV (TIEN-I-)

Figure B19: TIEN-I- weekly demand between week 1, 2005 to week 52, 2007

Characteristics of TIEN-I-

	N	Minimum	Maximum	Mean	Std. Deviation
TIEN-I-	155	0	291	112.81	62.472
Valid N (listwise)	155				

Analysis of demand trend and demand seasonal

1. Analysis of TIEN-I- demand trend.

Hypothesis H_0 : There is no trend component in the time series data.

H_1 : There is trend component in the time series data.

Computation of Runs Test from SPSS

Runs Test	
	TIEN-I-
Test Value(a)	106
Cases < Test Value	77
Cases >= Test Value	78
Total Cases	155
Number of Runs	56
Z	-3.626
Asymp. Sig. (2-tailed)	.000

a Median

There is trend component in the time series data at significant level 0.05.

Analysis of TIEN-I- demand trend

Model Summary and Parameter Estimates

Dependent Variable: TIEN-I-

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.123	21.550	1	153	.000	150.300	.485		
Quadratic	.124	10.780	2	152	.000	154.059	.631	.001	
Cubic	.130	7.512	3	151	.000	165.925	1.567	.016	6.53E-005

Cubic Model

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	T		Sig.
	B	Std. Error	Beta	B	Std. Error	
time	1.567	1.032	1.136	1.517		<u>.131</u>
time ** 2	.016	.016	1.871	1.037		<u>.301</u>
time ** 3	6.53E-005	.000	1.120	.990		<u>.324</u>
(Constant)	165.925	18.406		9.015		.000

Not appropriate

Quadratic Model

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta	B	Std. Error
time	.631	.417	.458	1.513	<u>.132</u>
time ** 2	.001	.003	.110	.363	<u>.717</u>
(Constant)	154.059	13.970		11.028	.000

Not appropriate

Linear model

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta	B	Std. Error
time	.485	.104	.351	2.642	<u>.060</u>
(Constant)	150.300	9.351		16.073	.000

Not appropriate

The tests concluded that demand trend is not appropriate, so we are not considering demand trend.

2. Analysis of TIEN-I- demand seasonal.

Hypothesis H_0 : There is no seasonal component in the time series data.

H_1 : There is seasonal component in the time series data.

Computation of Kruskal-Wallis Test from SPSS

Test Statistics(a,b)

	TIEN-I-
Chi-Square	42.960
Df	51
Asymp. Sig.	.781

a Kruskal Wallis Test

b Grouping Variable: week

There is no seasonal component in the time series data at significant level 0.05.

Analysis of demand distribution

Analysis of TIEN-I- demand distribution

Hypothesis H_0 : The data are sampled from normal distribution population.

H_1 : The data are not sampled from normal distribution population.

Computation of Kolmogorov-Smirnov Test from SPSS

One-Sample Kolmogorov-Smirnov Test

		TIEN-I-
N		155
Normal Parameters(a,b)	Mean	112.81
	Std. Deviation	62.472
Most Extreme Differences	Absolute	.071
	Positive	.071
	Negative	-.045
Kolmogorov-Smirnov Z		.882
Asymp. Sig. (2-tailed)		.418

a Test distribution is Normal.

b Calculated from data.

The data are sampled from normal distribution population at significant level 0.05.

TIEN-I- demand has no trend and has normal distribution with mean is 112.81 and standard deviation is 62.472.

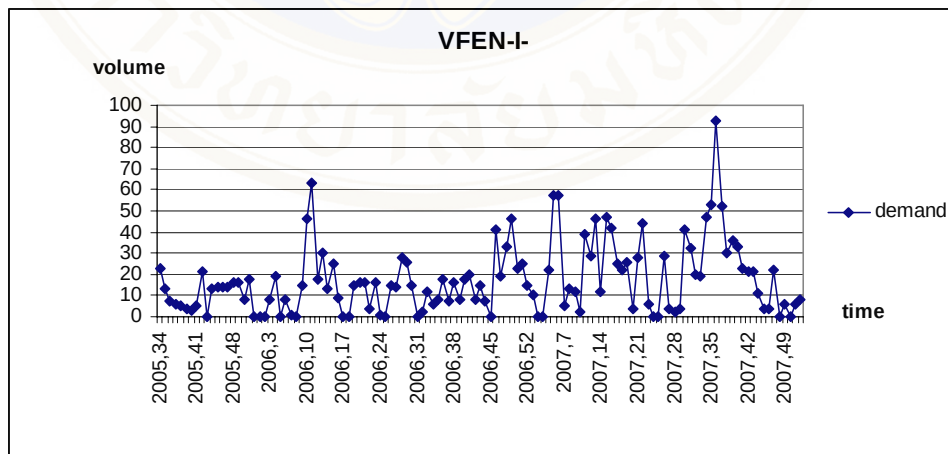
20. VFEND IV (VFEN-I-)

Figure B20: VFEN-I- weekly demand between week 1, 2005 to week 52, 2007

Characteristics of VFEN- I- after remove outlier

	N	Minimum	Maximum	Mean	Std. Deviation
VFEN- I- Valid N (listwise)	118 118	0	52	15.37	13.252

Analysis of demand trend and demand seasonal

1. Analysis of VFEN-I- demand trend.

Hypothesis H_0 : There is no trend component in the time series data.

H_1 : There is trend component in the time series data.

Computation of Runs Test from SPSS

Runs Test	
	VFEN- I-
Test Value(a)	14
Cases < Test Value	58
Cases >= Test Value	60
Total Cases	118
Number of Runs	44
Z	-1.899
Asymp. Sig. (2-tailed)	.058

a Median

There is no trend component in the time series data at significant level 0.05.

2. Analysis of VFEN-I- demand seasonal.

Hypothesis H_0 : There is no seasonal component in the time series data.

H_1 : There is seasonal component in the time series data.

Computation of Kruskal-Wallis Test from SPSS

Test Statistics(a,b)	
	VFEN- I-
Chi-Square	47.525
Df	51
Asymp. Sig.	.612

a Kruskal Wallis Test

b Grouping Variable: week

There is no seasonal component in the time series data at significant level 0.05.

Analysis of demand distribution

Analysis of VFEN-I- demand distribution

Hypothesis H_0 : The data are sampled from normal distribution population.

H_1 : The data are not sampled from normal distribution population.

Computation of Kolmogorov-Smirnov Test from SPSS

One-Sample Kolmogorov-Smirnov Test		VFEN- I-
N		118
Normal Parameters(a,b)	Mean	15.37
	Std. Deviation	13.252
Most Extreme Differences	Absolute	.123
	Positive	.118
	Negative	-.123
Kolmogorov-Smirnov Z		1.336
Asymp. Sig. (2-tailed)		.056

a Test distribution is Normal.

b Calculated from data.

The data are sampled from normal distribution population at significant level 0.05.

VFEN-I- demand has no trend and has normal distribution with mean is 15.37 and standard deviation is 13.252.

21. Viagra (VIAG-T-)

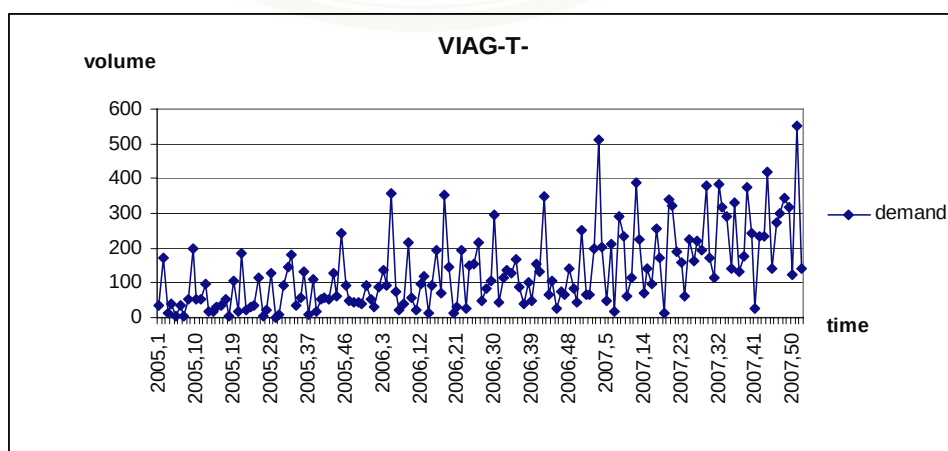


Figure B21: VIAG-T- weekly demand between week 1, 2005 to week 52, 2007

Characteristics of VIAG-T-

	N	Minimum	Maximum	Mean	Std. Deviation
VIAG-T-	153	0	387	125.93	101.251
Valid N (listwise)	153				

Analysis of demand trend and demand seasonal

1. Analysis of VIAG-T- demand trend.

Hypothesis H_0 : There is no trend component in the time series data.

H_1 : There is trend component in the time series data.

Computation of Runs Test from SPSS

Runs Test	
	VIAG-T-
Test Value(a)	97
Cases < Test Value	75
Cases $\geq$ Test Value	78
Total Cases	153
Number of Runs	70
Z	-1.212
Asymp. Sig. (2-tailed)	.225

a Median

There is no trend component in this time series data at significant level 0.05.

2. Analysis of VIAG-T- demand seasonal.

Hypothesis H_0 : There is no seasonal component in the time series data.

H_1 : There is seasonal component in the time series data.

Computation of Kruskal-Wallis Test from SPSS

Test Statistics(a,b)	
	VIAG-T-
Chi-Square	39.378
Df	51
Asymp. Sig.	.882

a Kruskal Wallis Test

b Grouping Variable: week

There is no seasonal component in the time series data at significant level 0.05.

Analysis of demand distribution

Kolmogorov-Smirnov Test by SPSS is used to test normal distribution. If data set is not normal distribution, Arena will use to determine the distribution.

1. Analysis of VIAG-T- demand distribution

Hypothesis H_0 : The data are sampled from normal distribution population.

H_1 : The data are not sampled from normal distribution population.

Computation of Kolmogorov-Smirnov Test from SPSS

One-Sample Kolmogorov-Smirnov Test

		VIAG-T-
N		153
Normal Parameters(a,b)	Mean	125.93
	Std. Deviation	101.251
Most Extreme Differences	Absolute	.121
	Positive	.121
	Negative	-.108
Kolmogorov-Smirnov Z		1.494
Asymp. Sig. (2-tailed)		.023

a Test distribution is Normal.

b Calculated from data.

The data are not sampled from normal distribution population at significant level 0.05.

2. Analysis of VIAG-T- demand distribution by fit distribution

The results obtained from arena program

Function	Expression	Sq Error	Chi Square Test	Kolmogorov-Smirnov Test
Gamma	GAMM(106, 1.19)	0.004682	Corresponding p-value = 0.192	Corresponding p-value > 0.15
Weibull	WEIB(132, 1.16)	0.004767	Corresponding p-value = 0.245	Corresponding p-value > 0.15
Erlang	ERLA(126, 1)	0.007486	Corresponding p-value = 0.0485	Corresponding p-value > 0.15
Exponential	EXPO(126)	0.007486	Corresponding p-value = 0.0904	Corresponding p-value > 0.15

The distribution is chosen by considering the hypothesis of Chi square test and Kolmogorov-Smirnov test. If more than one distribution are accepted H_0 , then we will choose the distribution with the lowest square error.

From the results, it can be concluded that VIAG-T- demand has no trend and no seasonal. It has gamma distribution with mean is 126.14 and standard deviation is 13,370.84.

22. Viagra (VIAG1T-)

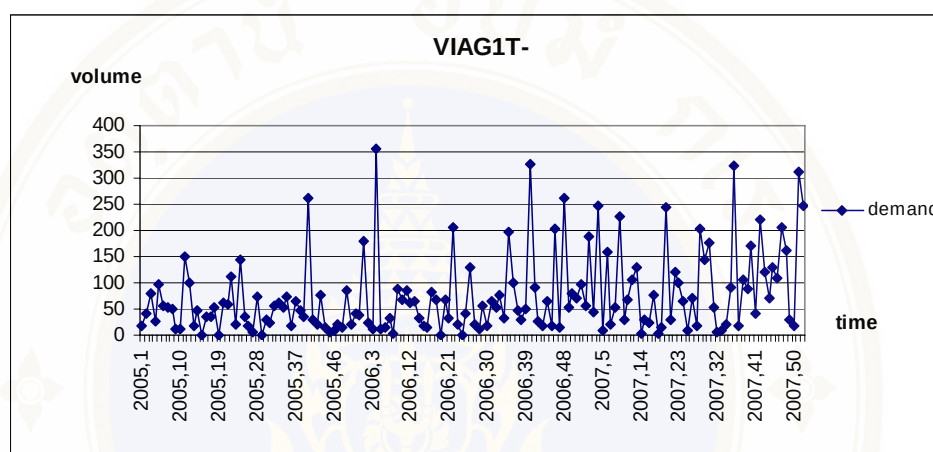


Figure B22: VIAG1T- weekly demand between week 1, 2005 to week 52, 2007

Characteristics of VIAG1T-

	N	Minimum	Maximum	Mean	Std. Deviation
VIAG1T-	143	0	202	56.63	47.965
Valid N (listwise)	143				

Analysis of demand trend and demand seasonal

1. Analysis of VIAG1T- demand trend.

Hypothesis H_0 : There is no trend component in the time series data.

H_1 : There is trend component in the time series data.

Computation of Runs Test from SPSS

Runs Test

	VIAG1T-
Test Value(a)	46
Cases < Test Value	71
Cases >= Test Value	72
Total Cases	143
Number of Runs	69
Z	-.587
Asymp. Sig. (2-tailed)	.557

a Median

There is no trend component in this time series data at significant level 0.05.

2. Analysis of VIAG1T- demand seasonal.

Hypothesis H_0 : There is no seasonal component in the time series data.

H_1 : There is seasonal component in the time series data.

Computation of Kruskal-Wallis Test from SPSS

Test Statistics(a,b)

	VIAG1T-
Chi-Square	45.163
Df	51
Asymp. Sig.	.704

a Kruskal Wallis Test

b Grouping Variable: week

There is no seasonal component in the time series data at significant level 0.05.

Analysis of demand distribution

Kolmogorov-Smirnov Test by SPSS is used to test normal distribution. If dataset is not normal distribution, then Arena is used to determine the distribution.

1. Analysis of VIAG1T- demand distribution

Hypothesis H_0 : The data are sampled from normal distribution population.

H_1 : The data are not sampled from normal distribution population.

Computation of Kolmogorov-Smirnov Test from SPSS

One-Sample Kolmogorov-Smirnov Test

		VIAG1T-
N		143
Normal	Mean	56.63
Parameters(a,b)	Std. Deviation	47.965
Most Extreme	Absolute	.121
Differences	Positive	.121
	Negative	-.119
Kolmogorov-Smirnov Z		1.447
Asymp. Sig. (2-tailed)		.030

a Test distribution is Normal.

b Calculated from data.

The data are not sampled from normal distribution population at significant level 0.05.

2. Analysis of VIAG1T- demand distribution by fit distribution

The results obtained from arena program

Function	Expression	Sq Error	Chi Square Test	Kolmogorov-Smirnov Test
Weibull	WEIB(56.9, 1.02)	0.005058	Corresponding p-value= 0.185	Corresponding p-value> 0.15
Exponential	EXPO(56.6)	0.005771	Corresponding p-value= 0.236	Corresponding p-value> 0.15
Erlang	ERLA(56.6, 1)	0.005771	Corresponding p-value= 0.157	Corresponding p-value> 0.15
Gamma	GAMM(62.3, 0.909)	0.007936	Corresponding p-value= 0.0886	Corresponding p-value= 0.0622

The distribution is chosen by considering the hypothesis of Chi square test and Kolmogorov-Smirnov test. If more than one distribution are accepted H_0 , then we choose the distribution with the lowest square error.

From the results, it can be concluded that VIAG1T- demand has no trend, no seasonal and has exponential distribution with mean is 56.6 and standard variance is 3,203.56.

APPENDIX C

PROOF OF THEOREMS 1 AND 2

Theorem 1 Let X_i ; $i = 1, 2, \dots, n$ be independent random variables with normal distribution on parameters (μ_i, σ_i^2) , where $i = 1, 2, \dots, n$, then $\sum_{i=1}^n X_i$ is normal distribution with parameters $(\sum_{i=1}^n \mu_i, \sum_{i=1}^n \sigma_i^2)$.

Proof

1 basic step

$$\text{Let } f_{X_3}(x_3) = \iint_{x_1 x_2} f_{X_1, X_2, X_3}(x_1, x_2, x_3) dx_1 dx_2$$

For X_1 and X_2 are independent random variables

$$f_{X_3}(x_3) = \iint_{x_1 x_2} f_{X_1}(x_1) f_{X_2}(x_2) f_{X_3}(x_3 | x_1, x_2) dx_1 dx_2$$

Since $f_{X_3}(x_3 | x_1, x_2) = \delta(x_3 - (x_1 + x_2))$, then

$$f_{X_3}(x_3) = \iint_{x_1 x_2} f_{X_1}(x_1) f_{X_2}(x_2) \delta(x_3 - (x_1 + x_2)) dx_1 dx_2$$

Since δ is Dirac's delta function and $x_2 = (x_3 - x_1)$, we find that

$$f_{X_3}(x_3) = \int_{x_1} f_{X_1}(x_1) f_{X_2}(x_3 - x_1) dx_1$$

The convolution of X_1 and X_2 is

$$(f * g)(x) = \int_{-\infty}^{\infty} f(u) g(x - u) du$$

let $\mu_1 = \mu_2 = 0$ without loss of generality, we find probability density function

$$f(x) = \frac{1}{\sigma_1 \sqrt{2\pi}} e^{-\frac{x^2}{2\sigma_1^2}} \quad \text{and} \quad g(x) = \frac{1}{\sigma_2 \sqrt{2\pi}} e^{-\frac{x^2}{2\sigma_2^2}}$$

The convolution is

$$\begin{aligned} &= [\text{constant}] \cdot \int_{-\infty}^{\infty} \exp\left(-\frac{u^2}{2\sigma_1^2}\right) \exp\left(-\frac{(x-u)^2}{2\sigma_2^2}\right) du \\ &= [\text{constant}] \cdot \int_{-\infty}^{\infty} \exp\left(-\frac{(\sigma_2^2 u^2 + \sigma_1^2 (x-u)^2)}{2\sigma_1^2 \sigma_2^2}\right) du \end{aligned}$$

Consider $\int_{-\infty}^{\infty} \exp(-(u-A)^2) du$ and let $w = u - A$, $dw = du$ (integrate is not depend on A)

$$\begin{aligned}
 &= [\text{constant}] \cdot \int_{-\infty}^{\infty} \exp\left(\frac{-(\sigma_2^2 u^2 + \sigma_1^2 (x-u)^2)}{2\sigma_1^2 \sigma_2^2}\right) du \\
 &= [\text{constant}] \int_{-\infty}^{\infty} \exp\left(\frac{-(\sigma_1^2 + \sigma_2^2)(u - \frac{\sigma_1^2}{\sigma_1^2 + \sigma_2^2} x)^2}{2\sigma_1^2 \sigma_2^2} + \frac{-x^2}{2(\sigma_1^2 + \sigma_2^2)}\right) du \\
 &= [\text{constant}] \exp\left(\frac{-x^2}{2(\sigma_1^2 + \sigma_2^2)}\right) \int_{-\infty}^{\infty} \exp\left(\frac{-(\sigma_1^2 + \sigma_2^2)(u - \frac{\sigma_1^2}{\sigma_1^2 + \sigma_2^2} x)^2}{2\sigma_1^2 \sigma_2^2}\right) du \\
 &= [\text{constant}] \cdot \exp\left(\frac{-x^2}{2(\sigma_1^2 + \sigma_2^2)}\right) \cdot [\text{constant}]
 \end{aligned}$$

Where [constant] is not depend on x_1 so probability density function is

$$\begin{aligned}
 &[\text{constant}] \exp\left(\frac{-x^2}{2(\sigma_1^2 + \sigma_2^2)}\right) \cdot \\
 &\therefore f_{X_1+X_2}(x) = \frac{1}{(\sigma_1 + \sigma_2)\sqrt{2\pi}} e^{\frac{-(x-(\mu_1+\mu_2))^2}{2(\sigma_1^2+\sigma_2^2)}}
 \end{aligned}$$

2 inductive steps

$$\text{Suppose } f_{X_1+X_2+\dots+X_n}(x) = \frac{1}{\sum_{i=1}^n \sigma_i \sqrt{2\pi}} e^{\frac{-(x-\sum_{i=1}^n \mu_i)^2}{2\sum_{i=1}^n \sigma_i^2}}$$

We will show that

$$f_{X_1+X_2+\dots+X_n+X_{n+1}}(x) = \frac{1}{(\sum_{i=1}^n \sigma_i + \sigma_{n+1})\sqrt{2\pi}} e^{\frac{-(x-\sum_{i=1}^n \mu_i + \mu_{n+1})^2}{2(\sum_{i=1}^n \sigma_i^2 + \sigma_{n+1}^2)}}$$

Let $U = X_1 + X_2 + \dots + X_n$

$$p = \mu_1 + \mu_2 + \dots + \mu_n$$

$$q = \sigma_1 + \sigma_2 + \dots + \sigma_n$$

$$q^2 = \sigma_1^2 + \sigma_2^2 + \dots + \sigma_n^2$$

$$f_U(x) = \frac{1}{q\sqrt{2\pi}} e^{-\frac{(x-p)^2}{2q^2}}$$

$$f_{X_{n+1}}(x) = \frac{1}{\sigma_{n+1}\sqrt{2\pi}} e^{-\frac{(x-\mu_{n+1})^2}{2\sigma_{n+1}^2}}$$

$f_{U+X_{n+1}}(x)$ is the sum of probability density function of random variables X_u and X_{n+1} denote with f and g . Hence the convolution is

$$(f * g)(x) = \int_{-\infty}^{\infty} f(u)g(x-u)du$$

Let $p = \mu_{n+1} = 0$ without lose of generally, we find probability density function

$$f(x) = \frac{1}{q\sqrt{2\pi}} e^{-\frac{x^2}{2q^2}} \quad \text{and} \quad g(x) = \frac{1}{\sigma_{n+1}\sqrt{2\pi}} e^{-\frac{x^2}{2\sigma_{n+1}^2}}$$

The sum of convolution is

$$\begin{aligned} & [\text{constant}] \cdot \int_{-\infty}^{\infty} \exp\left(-\frac{u^2}{2q^2}\right) \exp\left(-\frac{(x-u)^2}{2\sigma_{n+1}^2}\right) du \\ &= [\text{constant}] \cdot \int_{-\infty}^{\infty} \exp\left(-\frac{(\sigma_{n+1}^2 u^2 + q^2 (x-u)^2)}{2q^2 \sigma_{n+1}^2}\right) du \end{aligned}$$

Consider $\int_{-\infty}^{\infty} \exp(-(u-A)^2) du$ and let $w = u - A$, $dw = du$ (integrate is not depend on A)

$$\begin{aligned} & [\text{constant}] \cdot \int_{-\infty}^{\infty} \exp\left(-\frac{(\sigma_{n+1}^2 u^2 + q^2 (x-u)^2)}{2q^2 \sigma_{n+1}^2}\right) du \\ &= [\text{constant}] \cdot \int_{-\infty}^{\infty} \exp\left(-\frac{(q^2 + \sigma_{n+1}^2)(u - \frac{q^2}{\sigma_1^2 + \sigma_{n+1}^2} x)^2}{2q^2 \sigma_{n+1}^2} + \frac{-x^2}{2(q^2 + \sigma_{n+1}^2)}\right) du \\ &= [\text{constant}] \cdot \exp\left(\frac{-x^2}{2(q^2 + \sigma_{n+1}^2)}\right) \int_{-\infty}^{\infty} \exp\left(-\frac{(q^2 + \sigma_{n+1}^2)(u - \frac{q^2}{q^2 + \sigma_{n+1}^2} x)^2}{2q^2 \sigma_{n+1}^2}\right) du \\ &= [\text{constant}] \cdot \exp\left(\frac{-x^2}{2(q^2 + \sigma_{n+1}^2)}\right) \cdot [\text{constant}] \\ &= [\text{constant}] \cdot \exp\left(\frac{-x^2}{2(\sigma_1^2 + \sigma_2^2 + \sigma_3^2 + \dots + \sigma_n^2 + \sigma_{n+1}^2)}\right) \quad \text{where } [\text{constant}] \text{ is not} \end{aligned}$$

depend on x_1

Hence the probability density function is

$$[\text{constant}] \exp\left(\frac{-x^2}{2(\sigma_1^2 + \sigma_2^2 + \sigma_3^2 + \dots + \sigma_n^2 + \sigma_{n+1}^2)}\right)$$

From induction, we have

$$f_{X_1+X_2+\dots+X_n}(x) = \frac{1}{\sum_{i=1}^n \sigma_i \sqrt{2\pi}} e^{\frac{-(x - \sum_{i=1}^n \mu_i)^2}{2 \sum_{i=1}^n \sigma_i^2}}$$

$$\text{Thus, } f_{X_1+X_2+\dots+X_n}(x) = \frac{1}{\sum_{i=1}^n \sigma_i \sqrt{2\pi}} e^{\frac{-(x - \sum_{i=1}^n \mu_i)^2}{2 \sum_{i=1}^n \sigma_i^2}} \text{ is normal distribution with}$$

$$\text{parameters } \left(\sum_{i=1}^n \mu_i, \sum_{i=1}^n \sigma_i^2 \right) \cdot \square$$

Theorem 2 Let X_i ; $i = 1, 2, \dots, n$ be independent random variables with gamma distribution on parameters (t_i, λ) , where $i = 1, 2, \dots, n$ (mean = $t_i \lambda$, variance = $t_i \lambda^2$) then

$\sum_{i=1}^n X_i$ is gamma distribution with parameters $(\sum_{i=1}^n t_i, \lambda)$.

Gamma distribution

$$f(x) = \begin{cases} \frac{\lambda e^{-x\lambda} (\lambda x)^{t-1}}{\Gamma(t)} & \text{if } x \geq 0 \text{ and } \Gamma(t) = \int_0^\infty a^{t-1} e^{-a} da \\ 0 & \text{otherwise;} \end{cases} \dots\dots\dots (*)$$

Proof

1 basic step

$$f_{X_1+X_2}(a) = \frac{1}{\Gamma(t_1)\Gamma(t_2)} \int_0^a \lambda e^{-\lambda(a-x_2)} [\lambda(a-x_2)]^{t_1-1} \lambda e^{-\lambda x_2} (\lambda x_2)^{t_2-1} dx_2$$

$$f_{X_1+X_2}(a) = \frac{\lambda^{t_1+t_2} e^{-\lambda a}}{\Gamma(t_1)\Gamma(t_2)} \int_0^a (a-x_2)^{t_1-1} (x_2)^{t_2-1} dx_2$$

Since $m = \frac{x_2}{a}$, we see that

$$f_{X_1+X_2}(a) = \frac{\lambda^{t_1+t_2} e^{-\lambda a}}{\Gamma(t_1)\Gamma(t_2)} \int_0^1 a^{t_1+t_2-2} (1-m)^{t_1-1} m^{t_2-1} a dm$$

$$f_{X_1+X_2}(a) = \frac{\lambda^{t_1+t_2} e^{-\lambda a} a^{t_1+t_2-1}}{\Gamma(t_1)\Gamma(t_2)} \int_0^1 (1-m)^{t_1-1} m^{t_2-1} dm$$

$$\begin{aligned}
 f_{X_1+X_2}(a) &= \frac{\lambda^{t_1+t_2} e^{-\lambda a} a^{t_1+t_2-1}}{\Gamma(t_1+t_2)} \\
 f_{X_1+X_2}(a) &= \frac{\lambda e^{-\lambda a} (\lambda a)^{t_1+t_2-1}}{\Gamma(t_1+t_2)} \\
 \therefore f_{X_1+X_2}(x) &= \frac{\lambda^{t_1+t_2} e^{-\lambda x} x^{t_1+t_2-1}}{\Gamma(t_1+t_2)} \\
 \therefore f_{X_1+X_2}(x) &= \frac{\lambda e^{-\lambda x} (\lambda x)^{t_1+t_2-1}}{\Gamma(t_1+t_2)}
 \end{aligned}$$

2 inductive steps

Suppose
$$f_{X_1+X_2+\dots+X_n}(x) = \frac{\lambda^{\sum_{i=1}^n t_i} e^{-\lambda x} x^{\sum_{i=1}^n t_i-1}}{\Gamma(\sum_{i=1}^n t_i)}$$

We will show that
$$f_{X_1+X_2+\dots+X_n+X_{n+1}}(x) = \frac{\lambda^{\sum_{i=1}^{n+1} t_i} e^{-\lambda x} x^{\sum_{i=1}^{n+1} t_i-1}}{\Gamma(\sum_{i=1}^{n+1} t_i)}$$

Let
$$U = X_1 + X_2 + \dots + X_n$$

$$q = t_1 + t_2 + \dots + t_n$$

$$f_U(x) = \frac{\lambda^q e^{-\lambda x} x^{q-1}}{\Gamma(q)}$$

$$f_{X_{n+1}}(x) = \frac{\lambda^{t_{n+1}} e^{-\lambda x} x^{t_{n+1}-1}}{\Gamma(t_{n+1})}$$

$$f_{U+X_{n+1}}(x) = \frac{1}{\Gamma(q)\Gamma(t_{n+1})} \int_0^x \lambda e^{-\lambda(x-x_{n+1})} [\lambda(x-x_{n+1})]^{q-1} \lambda e^{-\lambda x_{n+1}} (\lambda x_{n+1})^{t_{n+1}-1} dx_{n+1}$$

$$f_{U+X_{n+1}}(x) = \frac{\lambda^{q+t_{n+1}} e^{-\lambda x}}{\Gamma(q)\Gamma(t_{n+1})} \int_0^x (x-x_{n+1})^{q-1} x_{n+1}^{t_{n+1}-1} dx_{n+1}$$

Since $m = \frac{x_{n+1}}{x}$, we see that

$$f_{U+X_{n+1}}(x) = \frac{\lambda^{q+t_{n+1}} e^{-\lambda x}}{\Gamma(q)\Gamma(t_{n+1})} \int_0^1 (x-mx)^{q-1} (mx)^{t_{n+1}-1} x dm$$

$$f_{U+X_{n+1}}(x) = \frac{\lambda^{q+t_{n+1}} e^{-\lambda x}}{\Gamma(q)\Gamma(t_{n+1})} \int_0^1 x^{q-1} (1-m)^{q-1} m^{t_{n+1}-1} x^{t_{n+1}-1} x dm$$

$$f_{U+X_{n+1}}(x) = \frac{\lambda^{q+t_{n+1}} e^{-\lambda x} x^{q+t_{n+1}-1}}{\Gamma(q)\Gamma(t_{n+1})} \int_0^1 (1-m)^{q-1} m^{t_{n+1}-1} dm$$

$$f_{U+X_{n+1}}(x) = \frac{\lambda^{q+t_{n+1}} e^{-\lambda x} x^{q+t_{n+1}-1}}{\Gamma(q+t_{n+1})}$$

$$f_{U+X_{n+1}}(x) = \frac{\lambda^{q+t_{n+1}} e^{-\lambda x} x^{q+t_{n+1}-1}}{\Gamma(q+t_{n+1})}$$

$$f_{X_1+X_2+\dots+X_n+X_{n+1}}(x) = \frac{\lambda^{t_1+t_2+\dots+t_n+t_{n+1}} e^{-\lambda x} x^{t_1+t_2+\dots+t_n+t_{n+1}-1}}{\Gamma(t_1+t_2+\dots+t_n+t_{n+1})}$$

$$f_{X_1+X_2+\dots+X_n+X_{n+1}}(x) = \frac{\lambda^{\sum_{i=1}^{n+1} t_i} e^{-\lambda x} x^{\sum_{i=1}^{n+1} t_i-1}}{\Gamma(\sum_{i=1}^{n+1} t_i)}$$

From induction, we have

$$f_{X_1+X_2+\dots+X_n}(x) = \frac{\lambda^{\sum_{i=1}^n t_i} e^{-\lambda x} x^{\sum_{i=1}^n t_i-1}}{\Gamma(\sum_{i=1}^n t_i)}$$

$$\therefore f_{X_1+X_2+\dots+X_n}(x) = \frac{\lambda^{\sum_{i=1}^n t_i} e^{-\lambda x} x^{\sum_{i=1}^n t_i-1}}{\Gamma(\sum_{i=1}^n t_i)} \text{ is gamma distribution with parameters}$$

$$(\sum_{i=1}^n t_i, \lambda). \quad \square$$

$$\text{From } f_{X_1+X_2+\dots+X_n}(x) = \frac{\lambda^{\sum_{i=1}^n t_i} e^{-\lambda x} x^{\sum_{i=1}^n t_i-1}}{\Gamma(\sum_{i=1}^n t_i)} \text{ notice that } t_i=1; i=1,2,\dots,n \text{ we can find that}$$

random variables $X_i; i=1,2,\dots,n$ are exponential distribution with parameter (λ) and

$$f_{X_1+X_2+\dots+X_n}(x) = \frac{\lambda^n e^{-\lambda x} x^{n-1}}{\Gamma(n)}$$

$$f_{X_1+X_2+\dots+X_n}(x) = \frac{\lambda e^{-\lambda x} (\lambda x)^{n-1}}{(n-1)!} \text{ is gamma distribution with parameter } (n, \lambda) \dots (**)$$

From (**), the sum of n exponential random variables with parameter (λ) and mean $= \frac{1}{\lambda}$ is a gamma distribution with parameter (n, λ) and mean $= \frac{n}{\lambda}$. $\square$

On the other hand, from (*) and (**), If a gamma distribution, with parameters (β, α) and mean $= \alpha\beta$, come from the sum of n exponential random variables with parameter (λ) , the mean of an exponential distribution is $\frac{\alpha\beta}{n}$ and the variance of an exponential distribution is $(\frac{\alpha\beta}{n})^2$. $\square$

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