CHAPTER 2
LITERATURE SURVEY AND THEORETICAL CONSIDERATION

2.1 Literature Survey

2.1.1 Literature survey for forecasting

Berry (1972) presented the reason of demand forecasting that is not equal form period to period in term of EOQ. Normally, it occurs in a large industry or industry that has a large inventory. The effect from mistake forecasting is the carrying cost. This occurs from the mismatch between the order quantities and the demand values so it makes the excess inventory to be carried in the future.

Archibald (1974) researched the decision rule to determining the safety stock due to the demand forecast error. They is separated into two cases that are:

Case 1: Demand over replenishment leadtime $\geq$ 10 units

From this case, they assumes and concludes that a statistical forecast system will establish error forecasting from the actual demand trend before to be normally distributed.

Case 2: Demand over replenishment leadtime $<$ 10 units

They observed and found that the Laplace distribution is a better fit for distribution of total leadtime demand than the normal distribution.

Antosh (1977) presented the topic of forecasting and inventory control for small manufacturer. He studied a real case in small garment industry. It has many problems involve inventory control. The problems are consisted of excessive inventory, poor scheduling of work, stock out from missed sales, and customer dissatisfaction. The objectives of this study are improved the scheduling of work, control stock out, and control inventory.

The main method that he used is forecasting demand because if an industry knows the estimate demand, it can control the inventory in term of raw material, work in process, and finish goods. He used the orders recorded on each inventory card and divided by 12 to get an average monthly order quantity. Thus he knows the correct ordering and can forecasting effectiveness in each month. The cards were separated and arranged into 25 groups of item types and find out the percentage of total sales and put it in document form. The next step, he establishes the forecast demand and reserve in document form. Final step, he combines the new forecast and existing inventory in order to control the problems. The results are stockout reduction 16%, finish goods decrease 23%, raw material inventory decrease 20%, and scheduling of work is better due to a smoother flow of the necessary size.

Gardner and Dannenbring (1980) presented the forecasting model within an industry. They're using exponential smoothing models to forecast because it's simple and inexpensive. The decision maker met some difficult problem of smoothing model so they have to fixed smoothing constants and used adaptive model that have varies smoothing constant and shorten response lag during period of demand shift.

They presented a group of smoothing model in various conditions. They point out the result and show the disadvantage of adaptive model is about the tendency to generate unstable forecast although average demand is stable.

Amnaj (1996) studied the development of forecasting, production planning, and scheduling models for a pressure container factory. It is consisted of three parts of implementation but in this case is focused on forecasting. In a part of forecasting, he tried and used many method of forecasting to find out the nearest exact solution that mean he compares all solution and choose the best one. After all comparisons, he concluded that Winter's and Decomposition models are suitable for initially forecast the seasonal demand because the result is smaller error. Then he used ARIMA model to resolve and compare with the previous model and the result is smaller than the previous model because ARIMA model is a good model in term of statistical to find out the solution.

2.1.2 Literature survey for inventory management

Eisenhut (1975) developed an algorithm to calculate lot sizing for manufacturing. The algorithm use for fluctuation and uncertainly demand. He developed from the classical Winson's EOQ formula. From Winson's formula, it less calculation for a single product, however, a new algorithm is provided which parallel of the Silver and Meal's formula. A new algorithm use when the situation is extended where it limited on the production rate. A new algorithm will prevent the production exceeding the limit. Moreover, it prevents the production line when the demand is sudden increased.

Hebbar and Brani (1976) presented the inventory control system that how to balance between reduction in inventory investment, backorders, and/or shortages and the efforts requirement in planning and controlling. They used the computer to support in work and used mathematical method to find out the solution then issued the reports for ordering, expediting, and canceling orders. Types of inventory that they control are leadtime requirement planning, order point system, min-max control, and physical review control. The results help to cancel out the unnecessary cost.

Singh (1983) researched the EOQ calculations plus limited order cycles help with inventory management. He presented the EOQ calculation. It can set safety stock and inventory monitoring procedure.

EOQ calculation: Q* = lot sizing and T* = time between order

$$Q^* = \sqrt{\frac{2AD}{Vr}} \qquad T^* = \sqrt{\frac{2A}{DVr}}$$

A = ordering cost per instance

D = demand rate in units per time

V = unit cost for the item

r = interest rate or cost of inventory per unit time for each inventory dollar

The advantage of these equations is having relatively few ordering policies such as every week, every two weeks, etc. Moreover, it presents like the ABC analysis of inventory such as one group would be order on a weekly, another on a biweekly. It allows ordering to be evenly scheduled so the order processing is more uniformly.

Swann (1984) researched the key to success of any system for management material flow control. He focused on improvement of inventory planning and control. First of all, he mentions the visual view. In his meaning, visual view is a common inventory control technique that based on head of worker, for example, the worker used own experience to estimate reorder point and order quantity. The inevitable effect of this technical is stock outs and excessive inventory. It is the most informal system.

To achieve this problem, he offered two-bin technique. First bin of parts is opened. Second bin of parts is unopened. When the first bin is emptied, the second bin is opened and a new order is ordered for a first bin.

In addition, he mentioned to min/max technique. It shows how to control the level of quantities level in two-bin. One technique to find out is the statistical method included EOQ equation from F.W. Harirs. This technique balances the costs of carrying and cost of ordering in order to make it lowest total cost. Table 2.1 shows the comparison between visual view technique and principle technique.

Table 2.1: The comparison between visual view technique and principle technique

	Order Point	Order Quantity
Visual Review	Judgment	Judgment
Two-bin	Zero free stock	Bin size
Min/Max	Minimum	Max - Min
Statistical	Forecast of demand during replenishment leadtime + safety stock	

Reedy, Tirumala, and Sarma (1992) researched the inventory control a case of photo films in a hospital. The constraints of their problem are storage facilities, and uncertainty in supply and the service required. In a hospital, it has a large number of items so they expect to control the level of inventory in each of item groups and suitable for its purpose. They split the items into two groups from namely that are medical and surgical. They determine and control EOQ (Economic Order Quantity) and make minimize the total cost of ordering and holding stock. Moreover they control lead-time from suppliers. For example, films x-ray can be stored in a maximum period that is 3 months under normal condition.

Dr. Shah and Dr. Jani (1992) studied about inventory management in several commodities that store in the warehouse with the quantity discount and mark-up variation. They assumed the suppliers fixed the price in each commodity and mark-up at the same time in order to giving quantity discount for the bulk items. They solved the problem—such as EOQ--by a numerical method for several commodities with the willingness of businessman in term of profit margin, consumers, and achieve in quantity discount. In addition, they want to ensure the adequate stock of raw materials and finish goods for businessman to run the business independently and efficiently.

2.2 Theoretical Consideration

Theoretical consideration shows the theory for use in step of implementation. It's classified into three main topics that are ABC analysis, forecasting, and inventory control.

2.2.1 ABC analysis

Normally, inventory is consisted of many items to concern it but which items that should be concerned. ABC analysis method is the best way out to find the important items in inventory. The concept of ABC analysis is based on the idea that a small percentage of items represent the majority of inventory value.

In the nineteenth century, the Italian economist Vilfredo Pareto studied the distribution of wealth and found that 20 percent of the people controlled 80 percent of the wealth. This concept is called the **Pareto principle** or **80/20 rule**.

In ABC analysis, it's separated into three different classes that are A, B, and C. In each class of inventory is different to control—class A is the highest level that should take care the most and following to level B and C. It can conclude that it tries to separate the important items from unimportant items. In Figure 2.1, it shows the Pareto curve.

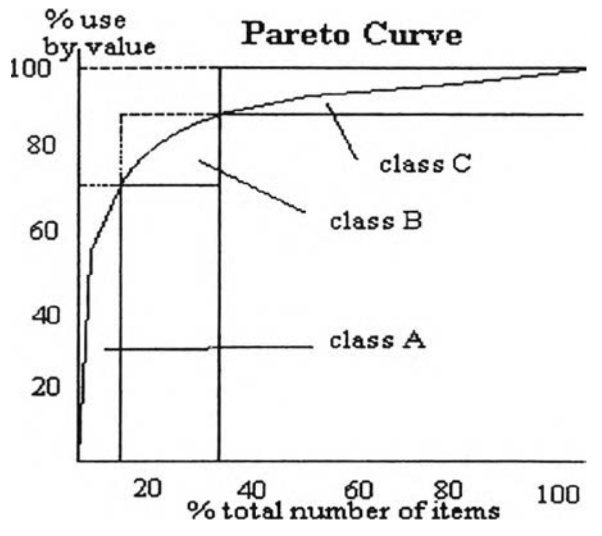

Figure 2.1: Pareto curve

The concept to classify in each class is:

1. Class A represents 10-20 percent of the items in inventory and 60-80 percent of the inventory value.
2. Class B represents 20-40 percent of the items in inventory and 15-30 percent of the inventory value.
3. Class C is a small impact that represents 50-60 percent of the items in inventory and 5-10 percent of the inventory value.

2.2.2 Forecasting

Forecasting is the method to plan for the future. It depends on several factors such as time frame, demand behavior, and causes of behavior. In this study, it use for forecast in term of demand used of raw materials. The main factors that related with this study are time frame and demand behavior.

2.2.2.1 Time Frame

Time frame is the time horizontal that vary and following with the purpose of type of forecast. Forecasts are usually classified into three range of time. There are short-range, intermediate-range, and long-range.

1. *Short-range:* Normally, time frame of short-range look on daily, weekly, or monthly, and sometime up to approximately a year into the future. It used for

short-run control such as purchasing, job scheduling, etc. These forecasts depend on the decision making of manager and type of industry.

2. *Intermediate-range:* It have time frame from one quarter, one season to two years. These forecasts are most commonly used for aggregate production planning such as sales planning, inventory control, production planning, etc.
3. *Long-range:* Generally, these forecasts are for more than two years up to five years or more. Normally, long-range forecasts use for business planning such as product planning, research planning, capital planning, etc.

2.2.2.2 Demand Behavior

Demand behavior is the habit pattern of demand such as trend behavior, and repetitive pattern. Demand behaviors are separated into three types that are trends, cycles, and seasonal patterns.

2.2.2.3 Multiplicative Seasonal Model in Time Series Decomposition

A time series is a sequence of past data that consisting of four components that are trend, seasonal, cyclical, and random component. Decomposition time series identifies and separates it into these components.

Multiplicative seasonal model is consisting of trend and seasonal demand pattern. Figure 2.2 shows the multiplicative seasonal model. In seasonal pattern, it is the pattern that oscillating movement in demand that occurs periodically then repeats it again in the next period. Therefore the concept of multiplicative seasonal model is the trend multiplied by the seasonal factors. The equation of this model is:

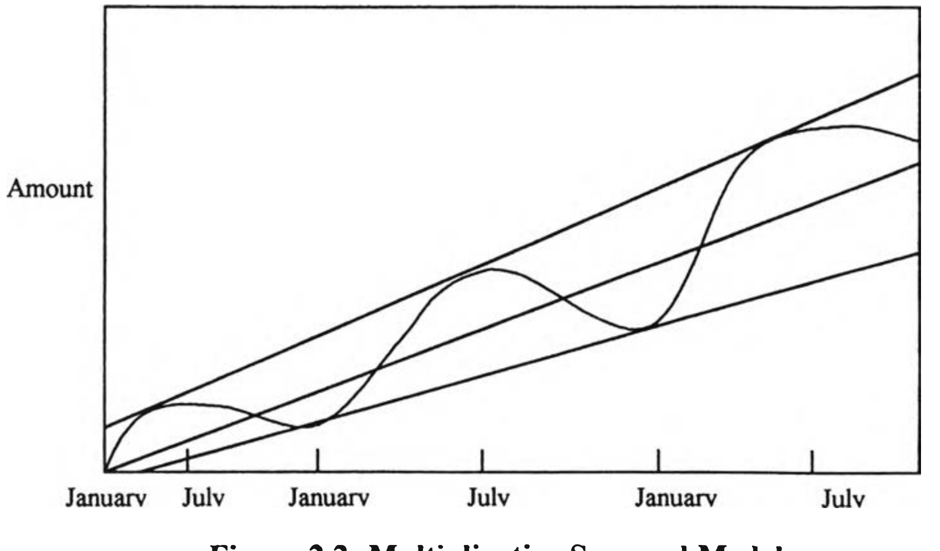

Figure 2.2: Multiplicative Seasonal Model

$$F_t = [a + bt]c_s$$

where F_t = forecasting value

a = F_t intercept

b = slope of the line

c_s= seasonal factor

Seasonal Factor

Seasonal factor is the amount of correction in a time series. It use for adjust the season of the year.

2.2.2.4 Linear Regression For Trend Process

It can be defined as a functional relationship between two or more correlated variables. It is a straight line that useful for medium term to long term forecasting. The equation of linear trend process is:

$$F_t = a + bt$$

where F_t = forecasting value

a = F_t intercept

b = slope of the line

t = time period

The equations of a and b are:

$$b = \frac{n(\sum x_i y_i) - (\sum x_i)(\sum y_i)}{n(\sum x_i^2) - (\sum y_i)^2}$$

$$a = [(\sum y_i)/n] - b[(\sum x_i)/n]$$

where n = number of data points

x = x value at each data point

y = y value at each data point

2.2.3 Inventory Control

2.2.3.1 Definition of Inventory

Inventory is the item stock or resource that used in organisation of both internal and external for meet customer demand. Normally, manufacturing inventory is classified into five sections: raw materials, finished products, component parts, supplies, and work in process.

Inventory Cost

Inventory size effects to any costs. The costs is consisting of:

1. *Holding costs:* Holding costs or carrying costs are the cost of holding one unit of an item in a period of time. These costs are varying with the level of inventory. Holding costs are consisted of capital cost, storage costs (land, and building—own, leased, or rented), service costs (assessments—taxes and insurance, processing—material handling and physical inventory), risk costs (obsolescence costs and shrinkage costs—pilferage, disappearance, damage, spoilage, and devaluation of selling price). These are expressed as Baht per unit per a period of time.
2. *Ordering costs:* it is the processing costs that occur from preparing to purchase order or production order. Ordering costs start from inform order until to receive the items to storage. These are expressed as a Baht amount per order. This cost is always constant. It is not regard in quantities of items but it changes into the number of orders.
3. *Storage costs:* it is the cost to store the items that consisted of rent cost, overhead cost, etc. These costs may include in holding cost if it is the same direction with holding cost.
4. *Stockout costs:* when raw materials or finished-goods inventory are not enough for demands, the costs will be occurred. Stockout can also include lost sales and dissatisfied customers.

Inventory Model

Inventory model is the inventory system that controls the level of inventory such as how much to order, and when to order. Inventory model is classified into two main models: fixed-order quantity models (Q-model) and fixed-time period models (P-model)

2.2.3.2 Fixed-Order Quantity Models (Q model)

This models focus on the quantities. The quantities will take place when the level of raw materials falls to a critical inventory level. This point is called reorder point. According to Richard Chase represented the fixed-order quantity system that is shown in Figure 2.3.

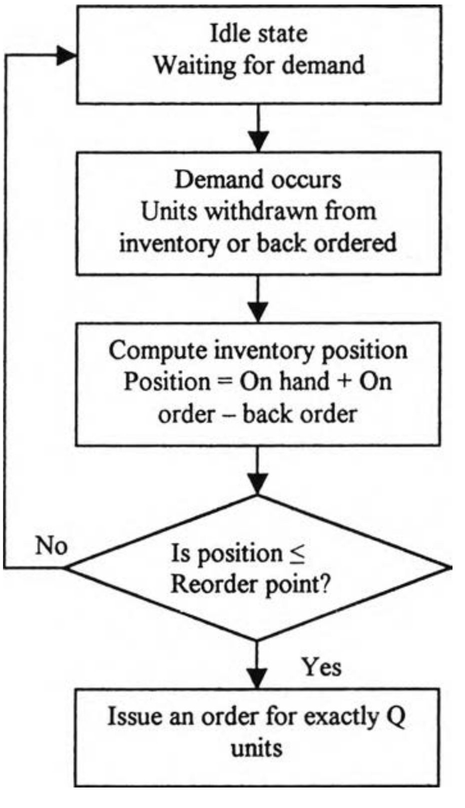

Figure 2.3: Fixed-Order Quantity System

Economic Order Quantity Model

According to, in 1913, F. W. Harris developed a rule for determining the optimal number unit to purchase. The EOQ formula in the type of keeping many items in the same storage is:

$$EOQ = \sqrt{\frac{2C_oD}{C_h}}$$

where C_o = Ordering cost (Baht per order)

D = Demand of usage (units per unit time)

C_h = Holding cost (Baht per unit per unit time)

Orders for Discrete Units

When the EOQ present in decimal number (not integer) and an organisation has to decide the exact order, EOQ must be rounded up or rounded down—e.g. if EOQ equals to 14.26 kg then how should be ordered between 14 kg or 15 kg. To find out this question, an organisation must be compared the cost between EOQ = 14 and EOQ = 15 then round up when the variables cost of ordering in 15 kg is less than the variable cost of ordering in 14 kg. Therefore the equation for decision in round up or round down is:

$$Q' * (Q' - 1) \leq Q_0^2$$

where Q' = the integer number when round up of Q_0

$Q' - 1$ = the integer number when round down of Q_0

The concept to choose number round up or round down is: if $Q'*(Q'-1)$ is less than or equal to Q_0^2, order Q'. In the other hand, if $Q'*(Q'-1)$ is greater than or equal to Q_0^2, order $Q'-1$.

Reorder Point

Reorder point identifies the point of inventory level for reorder again when the inventory level fall to this point. Reorder point equals to the number of units used during the leadtime (demand during leadtime) plus safety stock. The equation of reorder point is:

$$RP = DDLT + SS$$

where DDLT = Demand during leadtime = $\bar{d}$ * LT

SS = Safety stock

* The units of $\bar{d}$ and LT must be the same

Safety Stock with Service Level

Safety stock is the amount of items to protect the uncertainty of demand. If the demand is higher than amount of stock, it is called stockout, safety stock will protect in this reason. Moreover, it protects the stockout when leadtime is uncertainty such as supplier delivery delay. All of these are the event that effect to the financial risk. The amount of safety stock depends on the service level desired of a company policy. This service level refers to the probability that a stockout will not occur during leadtime. Safety stock is:

$$SS = z\sigma_L = z\sqrt{LT * \sigma_d^2}$$

where Z = the deviation in a standardized normal distribution (depends on the risky of stockout that a manager desire)

σ_L = standard deviation of leadtime demand

σ_d = standard deviation of demand per period

Standard deviation of demand per period (σ_p) is equaled to:

$$\sigma_d = \sqrt{\frac{\sum(a - \bar{a})^2}{n}}$$

where a = demand in each period

$\bar{a}$ = average demand in a period of time

n = the number of time periods

Total Material Cost (TMC)

Total material cost is the sum cost of holding, ordering, and purchase cost. Assume the purchase cost is a constant due to no quantity discounts.

The equation is:

TMC = ordering cost + holding cost + purchase cost

$$TMC = C_o\left[\frac{D}{Q}\right] + C_h\left[\frac{Q}{2}\right] + pD$$

where p = unit cost

From total material cost, if TMC is regarded on purchase cost, it becomes total stocking cost (TSC).

2.2.3.3 Fixed-Time Period Models (P model)

Fixed-time period models concerns in the fixed time intervals for review inventory levels. It is not need to monitor until the next review and order quantities in each time are not equal. The time tc order is the key decision in this model.

According to Richard Chase, he represented the flow chat of fixed-time period system that shown in the Figure 2.4.

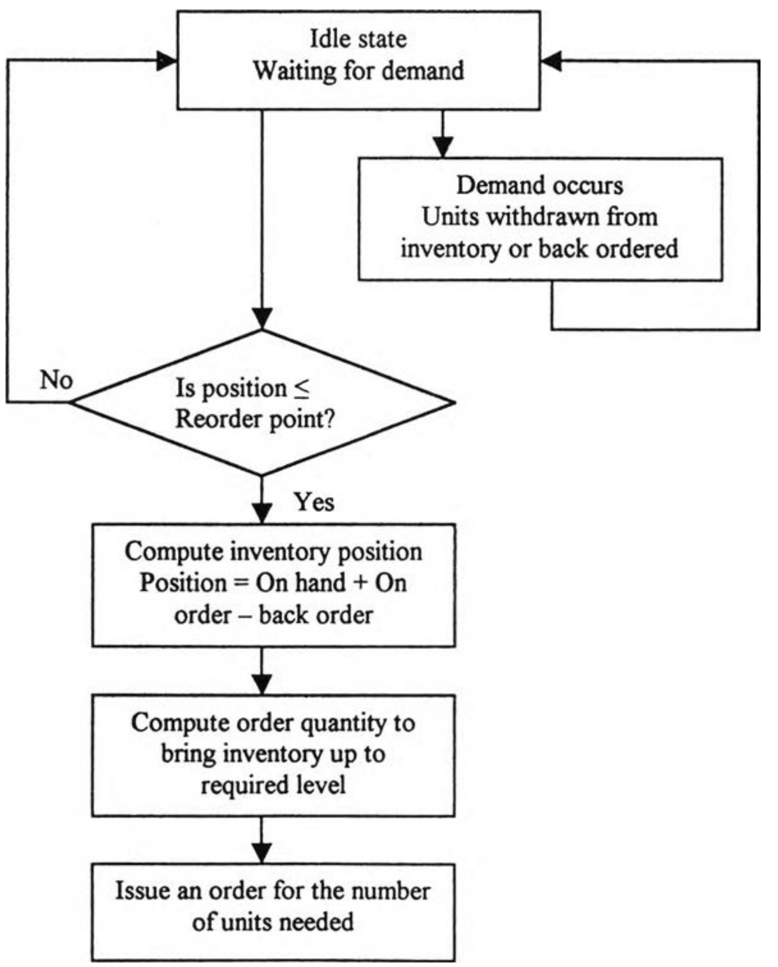

Figure 2.4: Fixed-time period models

Safety Stock with Service Level

In this model, the safety stock require a higher level than a fixed-order quantity system due to it is not need to monitor inventory level. The equation of safety stock is:

$$SS = z\sigma_{T+L} = z\sqrt{(T + LT)\sigma_d^2}$$

where Z = the deviation in a standardized normal distribution (depends on the risky of stockout that a manager desire)

σ_{T+L} = standard deviation of demand over the review and leadtime

T = the number of time period between reviews

LT = leadtime

σ_d = standard deviation of demand per period

Order Quantity

Order quantity in fixed-time period equals to the sum of average demand over the vulnerable period and safety stock and minus inventory on hand. The equation is:

$$q = Q + (\bar{d} + LT) + z\sigma_{T+L} - I$$

If Q = (đ)(T), so the equation of order quantity is

$$q = \bar{d}(T + LT) + z\sigma_{T+L} - I$$

where q = quantity to be ordered

đ = average demand in a period of time

Q = economic order quantity

I = Current inventory level

Total Stocking Cost (TSC)

Total stocking cost is the sum of holding costs and ordering costs. The equation of TSC is:

$$TSC = \left(\frac{DT}{2}\right)C_h + \frac{C_o}{T}$$

where C_h = holding cost

C_o = ordering cost

2.2.3.4 Comparison Between Q Model and P Model

Both models are focused on different point of view. Q model focus on quantities and reorder point. In the other hand, P model focus on time to review order. The order quantity in P model depends on the inventory position at that time. Table 2.2 shows the different of Q model and P model

Table 2.2: Different between Q model and P model

Feature	Q model	P model
Order quantity	Q constant	q variable
When to place order	Reorder point	Review period (T)
Record keeping	Each time a withdrawal or addition is made	Counted only at review period
Size of inventory	Less than P model	Larger than Q model
Time to maintain	Higher due to perpetual record keeping	
Type of items	Higher-priced, critical, or important items	