

CHAPTER ONE

Introduction

1.1 Introduction:

Inventory management is an important aspect of any successful business. It is the process of overseeing and controlling the flow of inventory units a business uses in the production or manufacture of goods for sale or distribution. Inventories are usually made up of a combination of goods, raw materials and finished products, and effective management of these items is essential to ensure optimal stock levels and to maximize the earning potential of the company. It also allows a business to prevent or mitigate any inventory-associated losses.

Spare parts are kept in stock to support maintenance operations and to protect against equipment failures.

Spare parts inventories are different from other types of inventories in companies. Spare parts inventory are needed for maintenance and repair of final products, vehicles, industrial machines and equipment, frequently requiring high investments and significantly affecting customer satisfaction. Service parts management is the main component of a complete Strategic Service Management process that companies use to ensure that right spare parts and resources are at the right place (where the broken part is) at the right time.

Spare parts Management plays an important role in achieving the desired plant availability at an optimum cost. The unique problems faced by the organization in controlling/managing the spare parts are as follows.

Firstly, there is an element of uncertainty as to when a part is required and also the quantity of its requirement. This is due to the fact that the failure of a component, either due to wearing out or due to other reasons,

cannot be predicted accurately. Secondly, spare parts are not that easily available in the market as they are not fast moving items. These problems are to be faced by systematic spare parts management.

Spare parts inventories are required to be available at appropriate points within a supply chain, in order to provide after-sales services and to guarantee the achievement of pre-specified service targets. However, several factors render demand and inventory management for spare parts a very complex matter; among them:

- a) The high number of parts managed.
- b) The presence of lumpy demand patterns.
- c) The high responsiveness required due to downtime costs by customers.
- d) The risk of stock obsolescence.

1.2 Problem statement:

Most of engine companies need the spare parts for the maintenance and repair of industrial machines and equipment but, they waste in cost by saving unnecessary spare parts or saving it in improper method and without any policies, that is rise the cost of inventory (holding cost and ordering cost).

1.3 Significance of the Study:

Control inventory management within ensure the availability of spare parts for maintenance and repairs

1.4 Objective of the Study:

To ensure the availability of all spares parts according to customer's demand (Customer satisfaction) and make a policies to inventory control by using inventory control methods (ABC analysis) to obtain effective

management for inventories and reduce holding cost , ordering cost and carrying cost by calculating the economic order quantity for each part.

1.5 Scope:

Practical study for inventory management method in VOLVO Engineering

Company limited in a heavy equipment section in PENTA Diesel Generator.

CHAPTER TWO

Literature Review

2.1 Concept of Inventory:

Inventory refers to those goods which are held for eventual sale by the business enterprise.

In other words, inventories are stocks of the product a firm is manufacturing for sale and components that make up the product.

In the generally understood term, inventory means a physical stock of goods kept in store to meet the anticipated demand.

2.2 Types of inventory:

The forms of inventories existing in a manufacturing enterprise can be classified into three categories:

a) Raw materials:

These are those goods which have been purchased and stored for future productions.

b) Work-in-Progress:

These are the goods which have been committed to production but the finished goods have not yet been produced. In other words, work-in-progress inventories refer to 'semi-manufactured products.

c) Finished Goods:

These are the goods after production process is complete. Say, these are final products of the production process ready for sale.

2.3 Motives for Holding Inventories:

There are three major motives behind holding inventories in an enterprise:

1) Transaction Motive:

According to this motive, an enterprise maintains inventories to avoid bottlenecks in its production and sales. By maintaining inventories; the business ensures that production is not interrupted for want of raw material, on the one hand, and sales also are not affected on account of non-availability of finished goods, on the other.

2) Precautionary Motive:

Inventories are also held with a motive to have a cushion against unpredicted business. There may be a sudden and unexpected spurt in demand for finished goods at times. Similarly, there may be unforeseen slump in the supply of raw materials at some time. In both the cases, a prudent business would surely like to have some cushion to guard against the risk of such unpredictable changes.

3) Speculative Motive:

An enterprise may also hold inventories to take the advantages of price fluctuations. Suppose, if the prices of raw materials are to increase rather steeply, the enterprise would like to hold more inventories than required at lower prices.

There is a need for systematic actions while managing spare parts as given below:

There are many actions required to ensure the spare parts management effective, and these are:

- a. Identification of spare parts.
- b. Forecasting of spare parts requirement
- c. Inventory analyses
- d. Formulation of selective control policies for various categories

- e. Development of inventory control systems
- f. Stocking policies for capital & insurance spares
- g. Stocking policies for rotatable spares or sub-assemblies
- h. Replacement policies for spare parts
- i. Spare parts inspection
- j. Indigenization of spares
- k. Reconditioning of spare parts
- l. Establishment of spare parts bank
- m. Computer applications for spare parts management.

2.4 Classification of Spare Parts:

- i) Determine the adequate level of managerial attention;
- ii) Allow the choice of demand forecasting and inventory control methods.
- iii) Establish different performance goals at the inventory turnover and service levels between categories.

However, most of the surveyed works use the classification of parts only to choose the demand forecasting model instead of the inventory control method.

2.4.1 Demand Forecasting:

Most spare parts present intermittent demand .That is occur at given moments followed by long and variable periods without demand. Intermittent demands are particularly difficult to predict and shortage may result in extremely high costs.

Demand forecasts are absolutely necessary for the inventory levels planning.

Although forecasts are subject to errors, the knowledge of these errors enables the definition of the necessary safety stocks

2.4.2 To hold inventory or not:

Demands which are very low in the beginning of the life cycle (as well as in the end) lead the manager to question whether parts should be stored or not. For many items, the demand is so low that the decision of not storing, meeting the demand circumstantially after its occurrence may be the best decision.

- Initial orders:

Uncertainty about the demand growth hampers the planning of the initial orders.

- Inventory control:

Upon deciding that the part needs to be stored, a inventory replenishment routine is necessary, considering different goals (costs and/or service level) and demand behavior (trends and seasonality).

- Final orders:

High production and maintenance costs of the productive processes associated with low demands and expected lifespan of products lead companies to interrupt the production of parts at a given time. In some cases, the last production batch is increased to provide additional spare parts final inventory. These different decisions in each phase of the life cycle of parts are addressed in the following sections of this article.

2.5 Holding Costs:

Holding costs are the additional costs involved in storing and maintaining a piece of inventory over the course of a year. Holding costs are computed in the economic order quantity calculation that businesses use in order to decide the optimal time to order new inventory.

The holding costs concept is pretty simple. Businesses have to store inventory that isn't in use or on the showroom floor. So if a company orders too much of a product, the extra inventory has to be put in the back warehouse until it can be put out on the shelves for customers to buy.

Not only do businesses have to pay for the warehouse storage space, but they also have to pay for security, insurance, and protection of the inventory. For instance, the warehouse could be broken into or, even worse, employees could steal inventory from a disorganized storage room. All of these costs are considered holding costs.

2.6 Ordering Costs:

The ordering cost (also called setup costs, especially when producers are concerned), or cost of replenishing inventory, covers the friction created by orders themselves, that is, the costs incurred every time you place an order. These costs can be split in two parts:

- The cost of the ordering process itself: it can be considered as a fixed cost, independent of the number of units ordered. It typically includes fees for placing the order, and all kinds of clerical costs related to invoice processing, accounting, or communication. For large businesses, particularly for retailers, this might mainly boil down to the amortized cost of the EDI (electronic data interchange) system which allows the

ordering process costs to be significantly reduced (sometimes by several orders of magnitude).

- The inbound logistics costs: related to transportation and reception (unloading and inspecting). Those costs are variable. Then, the supplier's shipping cost is dependent on the total volume ordered, thus producing sometimes strong variations on the cost per unit of order.

It is not easy to produce even a rough estimate of the ordering cost, since it includes elements that are very business specific and even item specific: suppliers can be local or overseas, they can adopt rules to deliver only per palette instead of per unit, or only when a certain number of items is ordered; then of course, suppliers can provide volume discounts.

There are ways to try to minimize those costs, more precisely to determine the right trade-off of carrying costs vs. volume discounts, thus essentially balancing the cost of ordering too much and the cost of ordering too less (basically, a smaller inventory typically leads to more orders, which means higher ordering costs, but it also implies lower carrying costs). This is usually achieved through the calculation of the Economic Order Quantity (EOQ). Without going into details here, let's just add the following reminder: though a classical way often appears in the literature to compute the EOQ with the Wilson formula, this particular formula - going back to 1913 - is a poor fit for retailers, mainly because it assumes that the ordering cost is a flat. Nevertheless, it is possible to determine optimal order quantities by devising a cost function taking into account volume discounts, as detailed in our article.

2.7 Inventory Analysis and Selective Control:

For the successful spare parts management, it is essential to analyze the spare parts inventory based on various characteristics such as the frequency of issues, the annual consumption value, the criticality, the lead time and the unit price. This is essential as it would not be possible to exercise the same type of control for all items and it may not really be effective. Inventory analysis aids selection of policies for selective control.

Commonly used inventory analyses are:

- (1) FSN Analysis
- (2) ABC Analysis
- (3) VED Analysis
- (4) SDE Analysis
- (5) HML Analysis

2.7.1 FSN Analysis:

Classification based on frequency of issue/use:

F, S and N stand for fast moving, slow moving and non-moving items. This form of classification identifies the items frequently issued, less frequently issued for use and the items which are not issued for longer period, say, 2 years. For instance, the items can be classified as follows:

Fast Moving (F) = Items that are frequently issued, say More than one month.

Slow Moving (S) = Items that are issued less than once a month.

Non-Moving (N) = Items that are not issued\used for more than 2 years.

This classification helps spare parts management in establishing most suitable stores layout by locating all the fast moving items near the dispensing window to reduce the handling efforts. Also, attention of the management is focused on the Non-Moving items to enable decision as to whether they are required in the future or they can be salvaged. Experience shows that many industries which are more than 15 years old have more than 50% of the stock as non-moving spares. Even if a few of them are disposed off and the locked up capital is made available, it will make available additional working capital to the organization. Action for disposal should be taken based on the value of each item of spare.

2.7.2 SDE Analysis:

This classification is carried out based on the lead time required to procure the spare part. The classification is as follows:

Scarce (S): Items which are imported and those items which require more than 6 months' lead time.

Difficult (D): Items which require more than a fortnight but less than 6 months' lead time.

Easily Available (E): Items which are easily available, less than a fortnights' lead time.

This classification helps in reducing the lead time required at least in case of vital items. Ultimately, this will reduce stock-out costs in case of stock-outs. A comprehensive analysis may ultimately bring down lead time for more & more number of items. This will also result in streamlining the purchase and receiving systems and procedures.

2.7.3 VED Analysis:

Classification Based On Criticality:

Several factors contribute to the criticality of a spare part. If a spare is for a machine on which many other processes depend, it could be of very vital importance. Also if a spare is, say, an imported component for which procurement lead time could be very high its non-availability may mean a heavy loss. Similarly spares required for fighter aircraft at the time of war could be of great value in terms of fighting capability. In general, criticality of a spare part can be determined from the production downtime loss, due to spare being not available when required.

Based on criticality, spare parts are conventionally classified into three classes, viz. vital, essential and desirable.

VITAL (V): A spare part will be termed vital, if on account of its non-availability there will be very high loss due to production downtime and/or a very high cost will be involved if the part is procured on emergency basis. In a process industry, most spare parts for the bottleneck machine or process will be of vital nature for example, bearings for a kiln in a cement plant will be considered vital.

ESSENTIAL (E): A spare part will be considered essential if, due to its non-availability, moderate loss is incurred. For example, bearings for motors of auxiliary pumps will be classified as essential.

DESIRABLE (D): A spare part will be desirable if the production loss is not very significant due to its non-availability. Most of the parts will fall under this category for example, gaskets for piping connection.

The VED analysis helps in focusing the attention of the management on vital items and ensuring their availability by frequent review and reporting. Thus, the downtime losses could be minimized to a considerable extent

2.7.4 ABC Analysis:-

Classification Based on Consumption:

Another method of classifying spares is on the basis of (annual consumption value). As it is true for any inventory situation, Pareto's principle can be applied to classify maintenance spares based on consumption value.

Pareto principle: The significant items in a given group normally constitute a small portion of the total items in a group and the majority of the items in the total will, in aggregate, be of minor significance.

This way of classification is known as ABC classification.

CLASS A: 10% of total spares contributing towards 70% of total consumption value.

CLASS B: 20% of total spares which account for about 20% of total consumption value.

CLASS C: 70% of total spares which account for only 10% of total consumption value.

In a specific spares control system, it is quite possible that in a single year, many spares would not have been consumed at all. In such cases, it is better to perform ABC analysis on longer consumption period data, say 3 years. Then only spares will not be left out in this classification.

Policy for 'A' Items:

1. Maximum control
2. Value Analysis
3. More than one supplier
4. Control by top executives.

Policy for 'B' Items:

1. Minimum control
2. Bulk Orders
3. More items from same supplier.

2.7.5 HML Analysis:

Classification Based on Unit Price:

This classification is as follows:

High Cost (H): Item whose unit value is very high, Say, \$1000 and above.

Medium Cost (M): Item whose unit value is of medium value, say, above \$100 but less than \$1000

Low Cost (L): Item whose unit value is low, say, less than \$100

This type of analysis helps in exercising control at the shop floor level, at the use point. Proper authorization should be there for replacing a high value spare. Efforts may be necessary to find out the means for prolonging the life of high value parts through reconditioning and repair. Also, it may be worthwhile to apply the techniques of value analysis to find out a less expensive substitute.

2.8 ABC Analysis:

An ABC analysis divides items into three categories:

A: Important

B: Less important

C: Relatively unimportant

Maintaining of particular inventory level is one of the major goals in warehouse management. Spare parts inventory management provides problematic aspects for planning. On the one hand, advance purchase and storage is connected with bearing inventory costs, causes freezing of financial resources and, moreover, the chances are the stock will never be used.

On the other hand, lack of stock is associated with the risk of costs of machine stoppage time in the case of sudden breakdown. In order to avoid such situations, a list of spare parts i.e. safety stock, critical for inventory, is prepared. It allows for elimination of costs of machinery stoppage.

Except for safety stock, other spare parts being an essential element of determination of future warehouse needs are kept in warehouses. Difficulties connected with planning their level are associated with unpredictability of the frequency of replacement of parts, thus this stock should be analyzed in a statistical and economical way. ABC method of categorization of inventory items allows to focus on most expensive items (or other items strategic to the enterprise) 10. The obtained results aim to indicate items whose purchase and storage in the warehouse is the most or the least beneficial for companies. The results of analysis might help identify these machines and equipment which are most prone to failure.

Use of ABC method allows for planning of material demand towards most profit-generating goods with higher stock rotation rates. ABC method will be provided in the form of case study for warehouse in certain enterprise.

Once the items have been prioritized, a modified Pareto analysis (commonly referred to as the “80/20 rule”) is used to stratify the parts into categories. Typically three categories are used: “A”, “B”, and “C”, hence the name “ABC Analysis”.

“A” items are the most critical ones. These items require tight inventory controls; frequent review of demand forecasts and usage rates; highly accurate part data; and frequent cycle counts to verify perpetual inventory balance accuracy. Typically, these comprise 5 – 10% of the total item count, and represent the top 70 – 85% of the total annual dollar value of usage.

“B” items are of lesser criticality. These items require nominal inventory controls; occasional reviews of demand forecasts and usage rates; reasonably accurate part data; and less frequent but regular cycle counting. They typically comprise the next 15 – 25% of the total item count and represent the next 10–20% of the total annual dollar value of usage.

“C” items have the least impact in terms of warehouse activity and financials, and therefore require minimal inventory controls. In fact, depending on the nature of the items, these may be good candidates for free bin stores. Analysis of demand forecasts and usage rates on “C” items is sometimes waived in favor of placing infrequent orders – often in large quantities – to maintain plenty of stock on hand. “C” items typically

comprise 65 – 80% of the total item contend represent the last 5 – 10% of the total annual dollar value of usage.

Because of low usage, any dead or inactive inventory will normally fall into the “C” category.

There is no set rule for establishing the cutoffs between the categories. In fact, many CMMS/EAM11 systems will allow the user to define the cutoffs.

Generally, a good starting point would be to define “A” items as those that represent the top 80% of total annual usage based on the prioritized list; “B” items as the next 15%; and “C” items as the last 5%.

2.8.1 Optimization:

If the process were as simple as the mathematical exercise described above, it would have limited value. Like many other critical work processes, an effective ABC Analysis requires just that – analysis of the results.

Because of the impact of ABC classifications on other inventory management processes (described below), and the relative importance of “A” items, it is desirable to have the “A” category represent as much of the total annualized usage as possible, as long as the number of items is manageable.

Achieving this balance requires an understanding beforehand as to what each classification represents in terms of required activity levels in other Material Management processes. If necessary and appropriate, the cutoff for the “A” category can be adjusted upward or downward and the stratification rerun to obtain a better distribution of items. However, it is

generally a good idea to limit the “A” category to no more than 85% of total annual usage, nor less than 75%.

Before the analysis is considered complete, it may also be beneficial to review the results with other personnel. Maintenance/Operations Managers, Engineers, Technicians, may have further insight into future demand for particular items that would warrant modifying the ABC classification. This is not intended as an opportunity to “rethink” the entire analysis, or subvert the intent of it. Instead, it is an opportunity for subject matter experts to provide valuable input, and it should be done thoughtfully, but quickly.

There are also several ways that the process itself can be optimized:

1. Eliminate the impact of dead inventory – Transactions in the horizon for any inactive or obsolete items can result in overstating the true priority of “dead” inventory, and artificially force other active items to a lower priority and/or classification. In an environment where inactive and obsolete inventory is reviewed on a periodic basis, it is preferable to ensure that any items flagged as “dead” and awaiting disposition have no impact on the ABC classifications.

To accomplish this, any such item should be excluded from the prioritization process, or at least have its usage forced to zero.

2. Identify Critical Spares – These often will be very expensive, sometimes one of- a kind items, with long lead times. Because of the potential implications of an equipment failure requiring these parts, it is imperative to keep them in stock or readily available to minimize the impact on production should one be needed.

From a criticality standpoint, they would generally be thought of as “A”-type items; and if there is any usage in the horizon, they will almost always end up as “A” items through the prioritization and stratification process. However, because they often have extremely low usage (if any), there is a distinct possibility that they would end up at or near the bottom of the prioritized list, and therefore would end up in the “C” category during the stratification process. This poses a potential problem where Critical Spares might not get the attention they require.

One solution to this is to establish a fourth category (“D”) to designate Critical Spares. In this case, the Critical Spares would be identified up front, begins. Only the remaining (non- critical) items would be prioritized and stratified into “A,” “B,” and “C” classifications and segregated from the rest of the inventory items before the prioritization process.

2.8.2 Procurement and Warehouse Applications:

The results of an ABC Analysis extend into a number of other inventory control and management processes:

1. Review of stocking levels – As with investments, past results are no guarantee of future performance. However, “A” items will generally have greater impact on projected investment and purchasing spend, and therefore should be managed more aggressively in terms of minimum and maximum inventory levels.

2. Obsolescence review – By definition, inactive items will fall to the bottom of the prioritized list. Therefore, the bottom of the “C” category is the best place to start when performing a periodic obsolescence review.

3. Cycle counting – The higher the usage, the more activity an item is likely to have, hence the greater likelihood that transaction issues will result in inventory errors. Therefore, to ensure accurate record balances, higher priority items are cycle counted more frequently. Generally “A” items are counted once every quarter; “B” items once every 6 months; and “C” items once every 12 months.

4. Identifying items for potential consignment or vendor stocking – Since “A” items tend to have a greater impact on investment, these would be the best candidates to investigate the potential for alternative stocking arrangements that would reduce investment liability and associated carrying costs.

5. Turnover ratios and associated inventory goals – By definition, “A” items will have greater usage than “B” or “C” items, and as a result should have greater turnover ratios. When establishing investment and turnover metrics, inventory data can be segregated by ABC classification, with different targets for each category.

2.9 Economic Order Quantity (EOQ)

The Economic Order Quantity (EOQ) is the number of units that a company should add to inventory with each order to minimize the total costs of inventory— such as holding costs, order costs, and shortage costs. The EOQ is used as part of a continuous review inventory system in which the level of inventory is monitored at all times and a fixed quantity is ordered each time the inventory level reaches a specific reorder point. The EOQ provides a model for calculating the appropriate reorder point and the optimal reorder quantity to ensure the instantaneous replenishment of

inventory with no shortages. It can be a valuable tool for small business owners who need to make decisions about how much inventory to keep on hand, how many items to order each time, and how often to reorder to incur the lowest possible costs.

The EOQ model assumes that demand is constant, and that inventory is depleted at a fixed rate until it reaches zero. At that point, a specific number of items arrive to return the inventory to its beginning level. Since the model assumes instantaneous replenishment, there are no inventory shortages or associated costs. Therefore, the cost of inventory under the EOQ model involves a tradeoff between inventory holding costs (the cost of storage, as well as the cost of tying up capital in inventory rather than investing it or using it for other purposes) and order costs (any fees associated with placing orders, such as delivery charges). Ordering a large amount at one time will increase a small business's holding costs, while making more frequent orders of fewer items will reduce holding costs but increase order costs. The EOQ model finds the quantity that minimizes the sum of these costs and it's illustrated in figure (2.1) below.

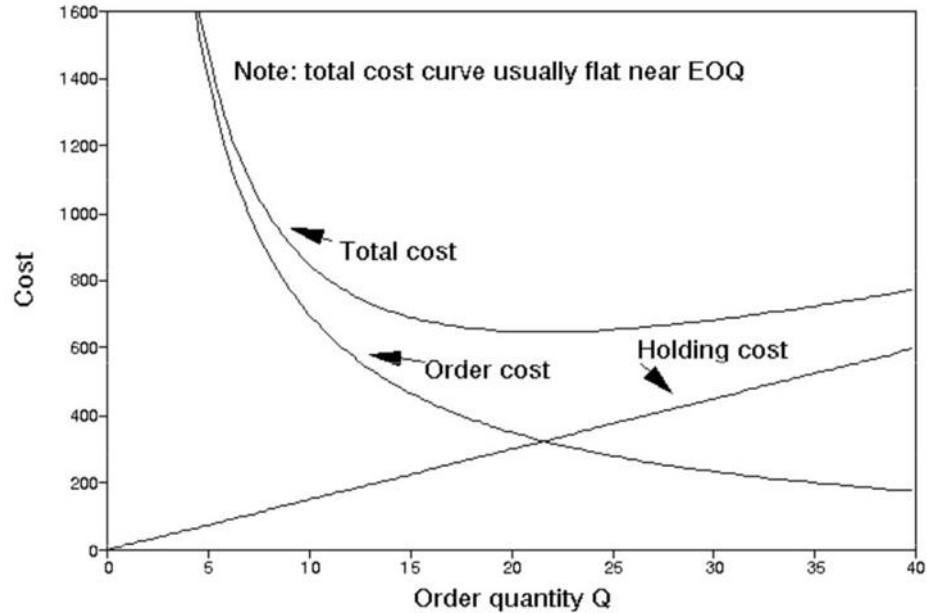


Figure (2.1): Illustrate the relationship between total cost, ordering cost and holding cost.

2.10 Previous Studies:

2.10.1 Spare Parts Inventory Management: (Al Sarrawi Automobile Spare Parts Industry):

Their case study in inventory management of spare parts in a company called Al Sarawi for Mercedes Spare parts. The company's core business is selling spare parts for Mercedes Cars to consumers. The company did not give adequate importance to inventory management due to various reasons including the disorganization of spare parts and the non availability of any inventory modeling system or ordering policy combined with inexperienced manpower.

As a result, there is an inefficient deployment of inventory .This study focused on the inventory management of spare parts for a specific model of Mercedes Cars called 416.After the forecasting of the demand, collecting the relevant costs and building the models the results were satisfying and a good amount of savings were achieved with considering the different ordering criteria that is being used by the company.

2.10.2 Spare Parts Inventory Analysis for Automobile Sector:

Their case study we have taken Tata car models and their critical components are obtained and spare requirement for each spare.

To determine the optimal allocation of spares for replacement of defective parts on-board of a usage. The minimization of the total supply chain cost can only be achieved when optimization of the base stock level is carried out at each member of the supply chain. A serious issue in the implementation of the same is that the excess stock level and shortage level is not static for every period. This has been achieved by using some forecasting and optimization techniques.

They used linear regression programming by using (C language) to determine the optimal allocation of spares for replacement of defective parts on-board of a usage and also to find demand.

By using the regression model the spare requirement for the 13thperiod has been predicted so, this demand prediction gives some automobile service sector to plan for their future spare requirement .They determined the stock levels by mathematical equation.

As a result, all the works that carried out here in this paper aims to keep up optimal inventory level in an automobile sector. This is the case for all problem sizes, for various part types and spare type. By doing so far the shortages in the spare parts and unavailability of spares can be made minimum compared to the previous methods which are adopted in the automobile sector. In future the further analysis is made to check out for the spare parts unavailability by using other optimization techniques.

CHAPTER THREE

Methodology

3.1 Introduction:

This chapter explains the main concepts of the ABC analysis by justifying the methodology and mathematical equations that used in data which gathered from part operations manager in VOLVO engineering company limited in engine equipment in PENTA Diesel Generator.

3.2 Methodology:

1. The Previous Studies:

Getting previous studies about the project to help us in the methodology and understand all aspects.

2. Gathering Data:

Visit an automobile and engines company. (All data information found available in VOLVO Engineering Company. After that selecting particular Diesel Generator called PENTA and gathering all required data from the parts operations manager.

3. Data Analysis:

Using ABC analysis techniques by utilizing (excel sheet) to analyze data to get the results and classify all spare parts in three categories (Class A, B and C) by the following steps:

Firstly, calculating the total volume and total value for each part and sum of or totality of the total volume and the total value after that create the percentage of the total volume and the total value after that get the classification of the spare parts (Class A, B and C) based on the sum of the percentage of the volume and the value After that calculating the holding and ordering cost of inventory by using the percentage of holding cost (6%)

and the percentage of ordering cost (65%) from the total cost of inventory. Finally, use the holding and ordering cost to calculate the economic order quantity (EOQ) for each part.

4. Results:

Getting results of the analysis and discussing it.

3.3 Mathematical Frame Work:

3.3.1 ABC Analysis:

Firstly, Sort the table of value and select combination of the spare parts that should be started from the first spare part to a suitable number of spare parts that help us to obtain the allowable percentage, all the spare parts will be located in this range can classified at class A.

Secondly, select combination of the spare parts start from the last spare part in class A to a suitable number of spare parts that help us to obtain the allowable percentage, all the spare parts will be located in this range can be classified at class B.

Finally, select combination of the spare parts start from the last spare part in class B to a suitable number of spare parts that help us to obtain the allows percentage, all the spare parts will be located in this range can classify at class C. The range of the percentages explained in table (3.1) below:

Table (3.1): shows the allowable percentage of the three classes A, B and C

<i>Category</i>	<i>Percentage of items</i>	<i>Percentage of annual consumption value</i>
A	10–20	70–80
B	20–30	10–25
C	60–70	5–15

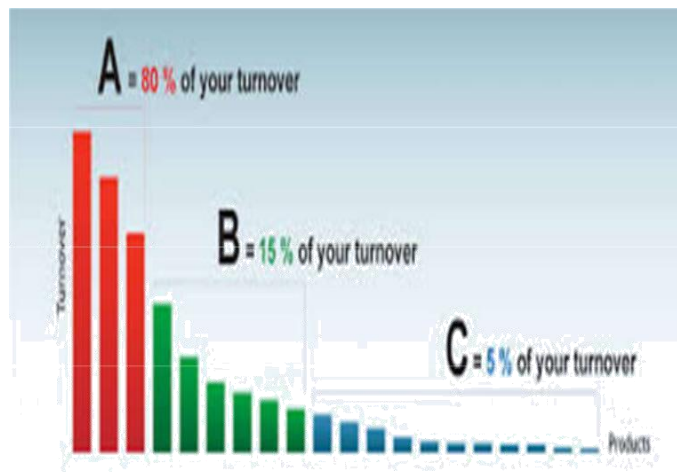


Figure (3.1): Illustrate the percentage rang of classes A, B and C

3.3.2 Economic Order Quantity (EOQ):

To reduce the cost of inventory (holding and ordering cost) and determine the quantity should be ordered, this can be establish by calculate the economic order quantity by the following steps and equation:

Holding cost (H) for one part = (Unit Price * 0.06)

Ordering cost (S) for one part = (Unit Price * 0.65)

$$EOQ = \sqrt{\frac{2DS}{H}}$$

D = Demand for the year.

S = Cost to place a single order.

H = Cost to hold one unit inventory for a year.

CHAPTER FOUR

Results and Discussion

4.1 Introduction:

This chapter explains the calculations of ABC analysis and economic order quantity by using excel sheet.

4.2 Data Analysis:

4.2.1 ABC analysis:

After inserting data to excel and applying the equations which mentioned in previous chapter, the results showed at the tables (4.1), (4.2) below.

Table (4.1) below shows the classification of spare parts based on consumption volume determining to the categories A, B and C. We calculate the Sub-Total order Volume in USD by summing the demand for 12 months to the quantity of parts available in store for each part:

$$\text{Sub-total order Volume} = \text{Demand for 12 months} + \text{Available in store}$$

Then we calculate the percentage volume using the following equation:

$$\text{Percentage Volume} = \frac{\text{Sub-Total Order Volume}}{\Sigma \text{ Demand for 12 months} + \Sigma \text{ Available in Store}}$$

After calculating the Percentage Volume for each part then we put the parts in an ascending order depending on the value we got for each one. In the last step we accumulate the percentages of the parts

until we reach a cumulative percentage that falls in the range of class A (10-20%), then the cumulative percentage of the parts that fall in the range of class B (20-30%), then the cumulative percentage of the parts that fall in the range of class C (60-70%) as per table (3.1).

Table (4.2) below shows the classification of spare parts based on consumption value determining to the categories A, B and C. We calculate the Sub-Total order Value in USD by multiplying the number of parts to be ordered (To Order) by the unit price of each part separately:

$$\text{Sub-Total Order Value} = \text{To Order} * \text{Unit Price}$$

Then we calculated the summation of the Sub-Total Order Value, then use it to calculate percentage value using the following equation:

$$\text{Percentage Value} = \frac{\text{Sub-Total Order Value for each part}}{\Sigma \text{Sub-Total Order Value}}$$

After calculating the percentage volume for each part then we put the parts in a descending order. In the last step we accumulate the percentages of the parts until we reach a cumulative percentage that falls in the range of class A (70-80%), then the cumulative percentage of the parts that fall in the range of class B (10-25%), then the cumulative percentage of the parts that fall in the range of class C (5-15%) as per table (3.1).

Table (4.1) shows the classification of spare parts by using ABC analysis based on consumption volume

No.	Part Number	Weight(g)	Package Quantity	Unit Price(\$)	Demand for 12 month	Available in Store	To Order	Sub-Total Order Value(\$)	Sub-Total Order Volume(\$)	Sub-Total weight(g)	% Percentage Value	% Percentage Volume	Classification	Percentage of Consumption Volume
1	9890554	20,000.00	1	1,000.00	5	3	2	2,000.00	8.00	20,000.00	5%	1%	A	
2	3336768	400.00	1	300.00	8	5	3	900.00	13.00	400.00	2%	1%	A	
3	5556788	90.00	1	98.00	15	6	9	882.00	21.00	90.00	2%	2%	A	
4	7684190	95.00	1	94.00	18	9	9	846.00	27.00	95.00	2%	2%	A	
5	1888166	44.00	1	100.00	20	11	9	900.00	31.00	44.00	2%	2%	A	
6	2654179	279.00	1	174.00	22	10	12	2,088.00	32.00	279.00	5%	2%	A	14%
7	3575722	389.00	1	220.00	20	13	7	1,540.00	33.00	389.00	3%	2%	A	
8	2760975	89.00	1	91.00	20	13	7	637.00	33.00	89.00	1%	2%	A	
9	8276654	296.00	1	189.00	26	9	17	3,213.00	35.00	296.00	7%	3%	B	
10	6665658	377.00	7	350.00	25	14	11	3,850.00	39.00	2,639.00	9%	3%	B	
11	1638265	265.00	1	156.00	28	13	15	2,340.00	41.00	265.00	5%	3%	B	20%
12	2517387	279.00	1	190.00	24	17	7	1,330.00	41.00	279.00	3%	3%	B	
13	8778787	20,000.00	1	80.00	40	18	22	1,760.00	58.00	20,000.00	4%	4%	B	
14	9008908	10,000.00	1	50.00	48	19	29	1,450.00	67.00	10,000.00	3%	5%	B	
15	1002345	96.00	1	20.00	60	38	22	440.00	98.00	96.00	1%	7%	C	
16	8255227	89.00	1	17.00	60	43	17	289.00	103.00	89.00	1%	7%	C	
17	5432657	564.00	1	200.00	60	44	16	3,200.00	104.00	564.00	7%	7%	C	
18	9836524	688.00	10	81.00	130	57	73	5,913.00	187.00	6,880.00	13%	13%	C	66%
19	5243899	693.00	10	83.00	140	65	75	6,225.00	205.00	6,930.00	14%	15%	C	
20	5427888	687.00	10	87.00	150	76	74	6,438.00	226.00	6,870.00	15%	16%	C	
					914	480		44,241.00			56,294.00	100%		
					1394									

Table (4.2) shows the classification of spare parts by using ABC analysis based on consumption value

No.	Part Number	Weight (g)	Package Quantity	Unit Price(\$)	Demand for 12 month	Available in Store	To Order	Sub-Total Order Value(\$)	Sub-Total Order Volume(\$)	Sub-Total weight(g)	% Percentage Value	% Percentage Volume	Classification	Percentage of Consumption Value
20	5427888	687.00	10	87.00	150	76	74	6,438.00	226.00	6,870.00	14%	16%	A	
19	5243899	693.00	10	83.00	140	65	75	6,225.00	205.00	6,930.00	13%	15%	A	
18	9836524	688.00	10	81.00	130	57	73	5,913.00	187.00	6,880.00	13%	13%	A	
17	6665658	377.00	7	350.00	25	14	11	3,850.00	39.00	2,639.00	8%	3%	A	
16	8276654	296.00	1	189.00	26	9	17	3,213.00	35.00	296.00	7%	2%	A	72%
15	5432657	564.00	1	200.00	60	44	16	3,200.00	104.00	564.00	7%	7%	A	
14	1638265	265.00	1	156.00	28	13	15	2,340.00	41.00	265.00	5%	3%	A	
13	2654179	279.00	1	174.00	22	10	12	2,088.00	32.00	279.00	5%	2%	A	
12	9890554	20,000.00	1	1,000.00	5	3	2	2,000.00	8.00	20,000.00	4%	1%	B	
11	8778787	20,000.00	1	80.00	40	18	22	1,760.00	58.00	20,000.00	4%	4%	B	
10	3575722	389.00	1	220.00	20	13	7	1,540.00	33.00	389.00	3%	2%	B	19%
9	9008908	10,000.00	1	50.00	48	19	29	1,450.00	67.00	10,000.00	3%	5%	B	
8	2517387	279.00	1	190.00	24	17	7	1,330.00	41.00	279.00	3%	3%	B	
6	1888166	44.00	1	100.00	20	11	9	900.00	31.00	44.00	2%	2%	B	
7	3336768	400.00	1	300.00	8	5	3	900.00	13.00	400.00	2%	1%	C	
5	5556788	90.00	1	98.00	15	6	9	882.00	21.00	90.00	2%	1%	C	
4	7684190	95.00	1	94.00	18	9	9	846.00	27.00	95.00	2%	2%	C	9%
3	2760975	89.00	1	91.00	20	13	7	637.00	33.00	89.00	1%	2%	C	
2	1002345	96.00	1	20.00	60	38	22	440.00	98.00	96.00	1%	7%	C	
1	8255227	89.00	1	17.00	60	43	17	289.00	103.00	89.00	1%	7%	C	
					919	483		46,241.00		76,249.00	100%			
					1402									

Figure (4.1) and Figure (4.2) below show bar charts illustrating the classification of spare parts depending on their consumption volume percentage and their consumption value percentage respectively.

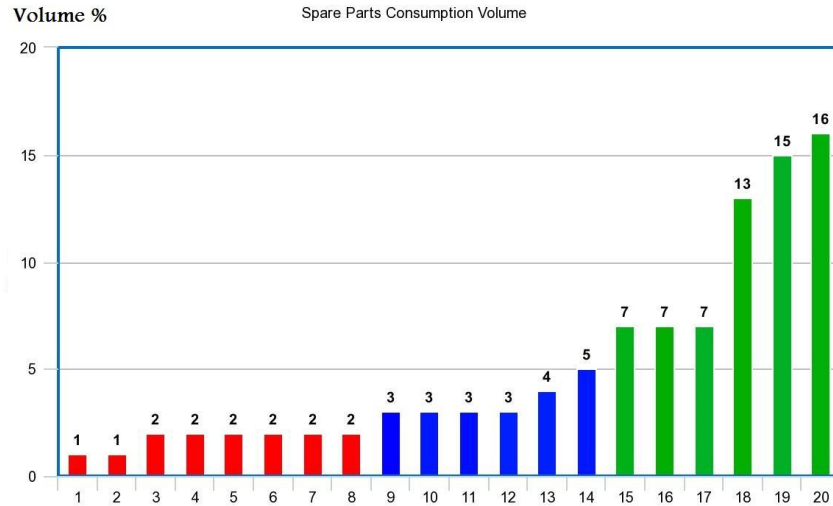


Figure (4.1): Illustrates the consumption volume of each spare part

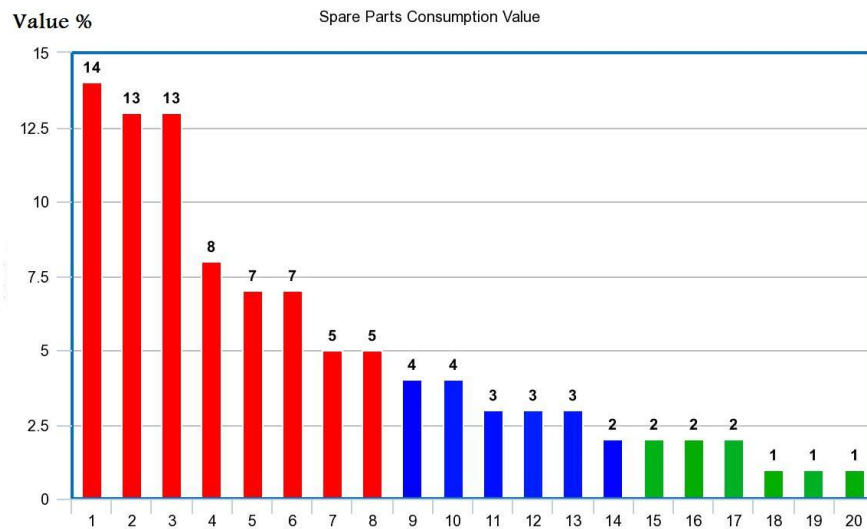


Figure (4.2): Illustrates the consumption value of each spare part

4.2.2 Economic Order Quantity:

The estimations of the economic order quantity for each part are shown in the tables (4.3) and (4.4) below.

In table (4.3) below we calculated the value of EOQ by calculating the Holding Cost and the Ordering Cost knowing the demand for 12 months using the following equation:

$$EOQ = \sqrt{\frac{2DS}{H}}$$

D = Demand for the year.

S = Cost to place a single order.

H = Cost to hold one unit inventory for a year.

Also:

Holding cost (H) for one part = (Unit Price * 0.06)

Ordering cost (S) for one part = (Unit Price * 0.65)

In table (4.4) below we made a comparison between the EOQ and the number of parts to be ordered (To Order) and we got negative and positive values. The positive values mean that there are unnecessary amounts that have been ordered which freezes the capital. And the negative values mean that there is a shortage in necessary parts which increases the lead time.

Table (4.3) shows the holding the calculations of EOQ

No.	Part Nnumber	Demand for 12 month(D)	Unite Price(\$)	Holding Cost(H)	Ordering Cost (S)	EOQ
1	9890554	150	1,000.00	60.00	650.00	57.01
2	6665658	140	350.00	21.00	227.50	55.08
3	3336768	130	300.00	18.00	195.00	53.07
4	3575722	24	220.00	13.20	143.00	22.80
5	5432657	28	200.00	12.00	130.00	24.63
6	2517387	22	190.00	11.40	123.50	21.83
7	8276654	26	189.00	11.34	122.85	23.73
8	2654179	20	174.00	10.44	113.10	20.82
9	1638265	60	156.00	9.36	101.40	36.06
10	1888166	60	100.00	6.00	65.00	36.06
11	5556788	40	98.00	5.88	63.70	29.44
12	7684190	48	94.00	5.64	61.10	32.25
13	2760975	60	91.00	5.46	59.15	36.06
14	5427888	15	87.00	5.22	56.55	18.03
15	5243899	18	83.00	4.98	53.95	19.75
16	9836524	20	81.00	4.86	52.65	20.82
17	8778787	8	80.00	4.80	52.00	13.17
18	9008908	20	50.00	3.00	32.50	20.82
19	1002345	25	20.00	1.20	13.00	23.27
20	8255227	5	17.00	1.02	11.05	10.41

Table (4.4) is a comparison between the items suggested to be ordered and the EOQ

No.	Part Nnumber	Demand for 12 month(D)	Unite Price(\$)	Holding Cost(H)	Ordering Cost (\$)	EOQ	To Order	COM
1	9890554	150	1,000.00	60.00	650.00	57.01	74.00	16.99
2	6665658	140	350.00	21.00	227.50	55.08	75.00	19.92
3	3336768	130	300.00	18.00	195.00	53.07	73.00	19.93
4	3575722	24	220.00	13.20	143.00	22.80	11.00	11.80-
5	5432657	28	200.00	12.00	130.00	24.63	17.00	7.63-
6	2517387	22	190.00	11.40	123.50	21.83	16.00	5.83-
7	8276654	26	189.00	11.34	122.85	23.73	15.00	8.73-
8	2654179	20	174.00	10.44	113.10	20.82	12.00	8.82-
9	1638265	60	156.00	9.36	101.40	36.06	2.00	34.06-
10	1888166	60	100.00	6.00	65.00	36.06	22.00	14.06-
11	5556788	40	98.00	5.88	63.70	29.44	7.00	22.44-
12	7684190	48	94.00	5.64	61.10	32.25	29.00	3.25-
13	2760975	60	91.00	5.46	59.15	36.06	7.00	29.06-
14	5427888	15	87.00	5.22	56.55	18.03	3.00	15.03-
15	5243899	18	83.00	4.98	53.95	19.75	9.00	10.75-
16	9836524	20	81.00	4.86	52.65	20.82	9.00	11.82-
17	8778787	8	80.00	4.80	52.00	13.17	9.00	4.17-
18	9008908	20	50.00	3.00	32.50	20.82	7.00	13.82-
19	1002345	25	20.00	1.20	13.00	23.27	22.00	1.27-
20	8255227	5	17.00	1.02	11.05	10.41	17.00	6.59

CHAPTER FIVE

Conclusions and Recommendations

5.1 Conclusions:

- After data analyzed it found that the economic order quantity results does not similar to the quantity which the company ordered that causes increasing in the cost of inventory (holding and ordering cost) or causing dissatisfaction for the customer.
- Utilizing ABC inventory analysis for spare parts help the company to place tighter and more frequent controls on high-priority inventory or class A inventory, It is important to constantly monitor the demand for class A and ensure stock levels match that demand.
- Under the ABC inventory analysis method, the company can allocate their resources more efficiently during cycle counts (A cycle count is the process of counting only certain items on scheduled dates).

5.2 Recommendations:

- Categorizing the stored materials into several subsystems (spare parts which have a same application) with ABC classification to insure more efficient handling of the resources and easy to control.
- Using software to classify the material (spare parts) automatically to insure flexibility and reliability of the system therefore, the system would update fast due to the current economic situation.
- Analyze the cost of inventory based on the economic consideration.
- Regular auditing and reconciliation can be useful because you'll be relying on software and reports from your warehouse to know how much spare parts you have in stock. However, it's important to make sure that the facts match up.

- Focus on the slow moving parts as much as you focus on the most profitable ones.
- Track the essential attributes of the parts such as genealogy and traceability because these has lately become at the top of inventory managers' must-have lists.

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Appendix



PENTA Diesel Generator



PENTA Diesel Generator spare parts



PENTA Diesel Generator engine