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Minimizing Total Inventory Cost of the Mechanical Spare Parts (Case of Messobo Cement Industry)

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Abstract: *Messobo cement factory is one of the competitive companies in Ethiopia even in east Africa. The importance, relevance, and organizational structure of inventory management and control have been gradually recognized throughout the developed countries. However, the degree of attention given is not up to the required level. Good and sufficient inventory management system will help the firm to be strong and highly competitive in an existing market situation. In Messobo cement factory there is maximum inventory costs. As I have seen this maximum inventory costs happen due to failure of machines, not well inventory management and technical control system. This problem could solve by using ABC and HML classification of inventory control analysis and economic order quantity (EOQ) model. The reason for choosing this inventory planning and control department for my research area are, due to be high inventory cost and the above explained problem. The objective of this thesis is minimizing total inventory cost by identifying the categories of mechanical spare parts requiring greater managerial control, because not all inventories need to be controlled with equal attention and also identifying when the spare parts are to be ordered, number of spare parts per order and the time between numbers of order. Data analysis of ABC classification based on cost criteria was formulated for prioritization of mechanical spare parts. The HML analysis is useful for keeping control over consumption at departmental levels, for deciding the frequency of physical verification, and for controlling purchase classification type of inventory control analysis is classified spare parts based on unit cost per item (per piece). The third method is Economic Order Quantity (EOQ) which has been proposed to determine 'when' and 'how much' the order should be placed. By using these analyses, the company could minimize the existing inventory costs of mechanical spare parts.*

Keywords: ABC inventory classification method, HML inventory classification method, economic order quantity model and Minitab software.

1. Introduction

Most of the production systems contain inventories. Inventory is the quantity of the raw materials, consumable items, components and spares, semi-processed materials, fuel and lubricants, finished goods, etc. that ought to be stocked for the smooth process of the company. The inventory management system in the Messobo cement factory was inefficient in the previous years hence inventories were passed from project erection by a Turkish construction company as beginning balance. Since beginning of its operation in 2000, inventories from the project were used without formal standardized inventory planning and control system. However, generally its important imposes pressure to make close control; to avoid the gap in operation, protecting inventories from deterioration and mischief. Moreover, stores are identified and similar items are categorized in fourteen (14) categories as; Auto spare parts, bag store, energy, materials, explosives, factory spare parts, finished goods, finished products, fixed asset, fuel oil and lubricants, general materials, production consumables, raw materials, refractory, tire and tube. By considering the bulk and complexity of the inventory, supply management system (SMS) was introduced in July 2004. In this interdependent world the requirement of spares is vital and their management is influenced by a variety of different factors.

Spare parts may look small and appear cheaper than the machine or raw materials, but they play an essential role in maintaining, ensuring and reinforcing the reliability of any equipment. Thus, the study deals with assessing the current status of mechanical spare part stock-take managements and control performance in determining the optimum quantity with the minimum cost. Spare parts inventory has required for maintenance and overhaul of final products, industrial machines and equipment, frequently requiring high investments, significantly affecting customer satisfaction and vehicles. One alternative for the reduction of spare parts inventory level is the critical revision of the need to maintain or not each one of the items active. Models developed under the premise that all items must be stored should be reconsidered. Is it worth bearing the costs of storage, even for only one unit, or would it be better to acquire the item under demand? This section discusses the question of either or not to stock a given item [1].

In Ethiopia there are many cement factories are existed, the Messobo cement factory is one of those factories. In order to meet its objective and goals it should have a competitive company and to do so, it prefers to have too much inventory that smooth the production process and as the same time too little inventory for not having high working capital tied up. These two conflicting decisions by the company come from lack of an appropriate inventory control system that optimizes both holding and shortage cost of the company. Firstly, this study focuses on inventory control techniques to classify inventory of mechanical spare parts based on the annual consumption value and price of spare parts. Secondly, analysis of economic order quantity which means analyze when to order and how to much order. Lastly, the selecting of inventory control policy to set the reorder point, order quantity, orders up to level and safety stock.
Economic order quantity (EOQ) is the optimal order quantity that minimizes total inventory cost. This includes holding, ordering and backordering if any cost is offered. Control of inventory is necessary to minimize expenses. The model was

developed by Harris in 1913 (Harris, 1913), and extensively applied by Wilson (1934). The underlying assumptions in a basic EOQ model are that demand for a product is known and constant, and that each new order is delivered instantaneously, whenever inventory reaches to zero. Holding cost is taken as a certain percent of raw material cost. Ordering cost is kept fixed and considered to be independent of the quantity of items ordered. Inventory control is one of the important areas of operation management. A proper control of inventory can significantly bring down operating expenses and increase profits. The economic order quantity (EOQ) model has evolved impressively over the past decades on the strength of incorporating realistic factors. Currently, interest has been geared towards studying the effect of reverse flow of products in inventory system. The problem of inventory is when to order and how much to order the quantities when there is reverse flow of items into the system is addressed in the form of profit maximization [2].

2. Statement of the Problem

Messobo cement factory is one of the competing companies in Ethiopia even in east Africa. The importance, relevance, and organizational structure of inventory management and control have been gradually recognized throughout the developed countries. However, the degree of attention given is not up to the required level. Good and sufficient inventory management system will help the firm to be strong and highly competitive in an existing market situation. In the Messobo cement factory there are maximum inventory costs of mechanical spare parts. As I have seen, this maximum mechanical spare parts inventory costs have happened due to ordering many numbers of mechanical spare parts at one time, not well inventory management and technical control system. At the Messobo cement factory spare parts are ordered one time per year in order to minimize annual setup cost, this ordering system increases annual holding inventory costs. This problem could solve by using ABC and HML classification of inventory control analysis and economic order quantity (EOQ) model. Then, the company should develop its inventory management system and minimize inventory costs of mechanical spare parts in order to increase its competitiveness in the market. The general objective of the study is to increase the company's profit by minimizing the total inventory.

3. Literature Review

3.1. Supply chain management

According to [3], supply chain is a set of methods which is used to join supplier, warehouse and stores, manufacturers and distributers so that merchandize is distributed at the right location or places with the right quantity at the right time in order to minimize system wide costs while satisfying service level requirements. It has provided the management of materials and information across the entire chain from supplier to distributer, retailers, producers and customers. Traditionally, each company performs production, purchasing and marketing activities independently, so that it is hard to make an optimum plan for the whole chain. In recent time, it has been realized that activities taken by one member of the chain can impact all others in the chain. Most of the companies have gradually accepted that each of them serves as part of a supply chain against other supply chains in terms of competition, rather than as a single firm against other individual one. "A supply chain is a network of facilities and delivery options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these products to customers." All activities, functions and facilities associated with the flow and transformation of goods and services from raw materials to customers. Even All facilities, functions, and activities associated with the flow and transformation of goods and services from raw materials to customers, source, make, and products.

The study on supply chain management has been mainly focused on the three key issues. The first is the behavior of information flow through a supply chain. The second issue deals with inventory management, which regards a supply chain as a multi-echelon inventory system. The last issue is oriented to planning and operations management of a supply chain based on queuing systems [4].

3.2. Concept of supply chain

Customers: - starts the chain of events when they decide to purchase a product that has been offered for sale by a company. Contact the sales department of the company, which enters the sales order for a specific quantity or quality to be delivered on a specific date.

Planning: - the requirements of activated by the customer's sales planning department will be combined with other orders. The planning department will create a production plan to produce the products to fill the customers.

Purchasing: - this department receives a list of raw materials and services required by the production department to complete the customer's orders. The department sends purchase orders to selected suppliers to deliver the necessary raw materials to the manufacturing site on the required date.

Inventory: - raw materials are received from suppliers, checked for quality& accuracy and moved into the warehouse. The suppliers will than send an invoice to the company for the items they delivered. The raw materials are stored until they are required by the production department.

Production: - based on production plan, raw materials are moved inventory to the production area. Finished products ordered by the customer are manufactured using the raw materials purchased from supplier. Affair the items have been completed & tested; they are stored back in the warehouse pair to deliver to the customers.

Transportation: - when finished products arrive in the warehouse, the shipping department determines the most efficient method to ship the products so that they are delivered on or before the date specified by the customer. When the goods are received by the customer, the company will send on invoice for the delivered products**.**

3.3. Inventory management

The objective of inventory management is to have the appropriate amounts of materials in the right place, at the right time, and at low cost. Therefore, inventory decision problem can be solved by busing economic criteria. One of the important pre-requisites is an understanding of the more relevant costs to inventory system. Systems that need inventory can range from raw materials, spare parts, cash, and finished goods to hotel rooms and airline flight seats. The major decisions in inventory control concern when a replenishment order should be placed and what the quantity of such an order should be. Effective inventory management is upheld to be a potential driver for enhancing profit margins. Minimizing total inventory of cost through identifying an optimum level of inventory that an organization holds is the way forward. A well-functioning inventories management will bring both economic benefit in terms of profitability and bring good image to the company [6].

Inventory is the stock of any item or resource used in an organization, including raw materials, component parts, and work in process, supplies, and finished goods. It is one of the most expensive assets of many organizations, representing as much as 50% of total invested capital. Because of the large portion of expenditures, the effective management of inventory is crucial to the performance of many organizations (including manufacturers, wholesalers, retails, hospitals, universities, governments, etc.). Inventory is a necessary part of doing business and provided by most organizations in any sector of economy. It is existing because supply and demand are difficult to synchronize perfectly and it takes time to perform material related operation. Inventory can be a source of conflict among different managers in organization because different managers have different roles to play which involve the use of inventory. The conflicting roles of managers must not be allowed to impair the organization as a whole. To overcome this conflict, inventory management should be everybody's concern [5].

In very large inventory systems, it may not be feasible to set stock levels and difficult to visualize items in warehouse. Inventory management of resources may be better utilized by managing the "significant few" and not the "trivial many". Such an approach to inventory management may be achieved by the classification and grouping of inventory items. In addition, subsequent assignment of inventory policies according to the characteristics of a group is essential. Classification systems serve to prioritize inventory items by certain criteria and allow expenditure of management resources in proportion to an item's value in the system. These vital few items can be segregated for the closer control to ensure productivity. Effective inventory management plays an important role in the success of the organizations in this competitive business environment. It is not clearly possible for the organizations that store hundreds of inventory items to economically design an inventory management policy for each inventory item separately. Moreover, various inventory items may play quite different roles in the business of the organization. Hence, the managers need to classify these items in order to control each inventory category properly based on its importance rating. Item's classification is an essential part of the inventory management systems, in order to determine the adequate level of managerial attention. It allows the choice of demand forecasting and inventory control methods. Moreover, establish different performance goals at the inventory turnover. However, in the factory there is no such an explicit ways of classifying inventory items [6], [7].

3.4. Inventory control techniques

Inventory control techniques are extremely important for business operations because their success and cost reduction of the firm's expenditure necessitate improved supply chain performance and knowledge to the employees. These techniques are critical and knowledge in them is highly desirable thus, managers and procurement staff need to be able to apply the techniques for the benefit of the organization [8]. There are basic categories of policies for controlling inventories: fixed order quantity policies and fixed time period policies. In the first, as the name implies, the order quantity is always the same but the time between orders will vary depending on demand, lead-time variation and the current inventory levels. Specifically, inventory levels are continuously monitored and an order is placed whenever the inventory level drops below a predetermined reorder point. For this reason, this type of policy is also called a continuous review policy. In fixed time period policies, the time between orders is constant but the quantity ordered each time varies with demand and the current level of inventory. Because ordering follows a fixed cycle, these policies are also called periodic-review policies. We will see both polices in detail to select the appropriate policy for items that fits best [1].

As mentioned in [1], this two basic inventory control models are for high and stationary demand items but for low demand inventory items the base stock (B) policy is used. Here, at each withdrawal from inventory an order of the same amount is made for replacing the base line, keeping the inventory position (inventory on hand plus on orders) constant and equal to "B". The base stock is more suitable for items with low demand. When the base stock applies to items with very low demand, the replenishment orders will usually be scattered orders from a single piece. Policies based on ABC analysis, leverage the sales imbalance outlined by the Pareto principle. This implies that each item should receive a weighed treatment corresponding to its class:

A –Items should have tight inventory control, more secured storage areas and better sales forecasts. Reorders should be frequent, with weekly or even daily reorder. Avoiding stock outs on **A-**items are a priority.

B-Items benefit from an intermediate status between A and C. An important aspect of class B is the monitoring of potential evaluation toward class A or, in the contrary, toward the class C.

Reordering **C-**items are made less frequently. A typically inventory policy for C-items consist of having only one unit on hand, and of reordering only when an actual purchase is made. This approach leads to stock out situation after each purchase which can be an acceptable situation, as the C-items, the question is not so much how many units do we store? But rather do we even keep this item in the store?

Splitting items in A, B, and C classes is relatively arbitrary. This grouping only represents a rather straight forward interpretation of the Pareto principle. In practice, sales volume is not the only metric that weighs the importance of an item. Margin but also the impact of a stock out of the business of the client should also influence the inventory strategy. In inventory management system, there are many inventory control techniques. From these the major techniques are:

3.4.1. ABC classification (classification based on annual consumption value)

It is one of the widely used techniques to identify various items of inventory for the purpose of inventory control. In other words, it is very effective and useful tool for classifying, monitoring and control of inventories. The firm should not keep same degree of control on all the items of inventory. It is based on Pareto's Law. The firm should put maximum control on those items whose value is the highest, with the comparison of the other two items. This technique concentrates on important items and is also known as control by importance. It's one of the inventory classification techniques which are used to draw managers' attention on the critical few (A-items) and not on trivial many (C-items). Inventory optimization is critical in order to keep costs under control within the supply chain. Yet, in order to get the most from management efforts, it is efficient to focus on items that cost most to the business.

The Pareto principle states that 80% of the overall consumption value is based on only 20% of total items. In other words, demand is not evenly distributed between items: top sellers vastly outperform the rest. The ABC approach states that, when reviewing inventory, accompany should rate items from A to C, basing its ratings on the following rules:

A - Items are goods which annual consumption value is the highest. The top 70-80% of the annual consumption value of the company typically accounts for only 10-20% of total inventory items.

B – Items are the interclass items, with a medium consumption value. That 15-25% of annual consumption value typically accounts for 30-35% of total inventory items.

C – Items are, on the contrary items with the lowest consumption value. The lower 5% of the annual consumption value typically accounts for 50-55% of total inventory items.

3.4.2. HML classification (classification based on unit price or unit cost)

This analysis is similar to ABC analysis, but here the criterion is price instead of usable value. The items in this analysis are classified into three groups which means, high, low and medium. The management has decided the cutoff lines or prices for the three categories. This analysis helps to keep control over consumption as per the price and helps to assess storage and security requirements, i.e. higher priced items are to be stored in the cupboards. It helps to outline the buying policies to delegate authorities to buyers. This classification is as follows: High Cost (H): Items whose unit value is very high, Medium Cost (M): Items whose unit value is of medium value, Low Cost (L): Items whose unit value are low. This type of analysis helps in exercising control at the shop floor level, i.e., at the use point. Proper authorization should be replaced for 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.

3.4.3. VED classification

While in ABC, classification inventories are classified on the basis of their consumption value and in HML analysis the unit value is the basis, criticality of inventories is the basis for vital, essential and desirable categorization. The VED analysis is done to determine the criticality of an item and its effect on production and other services. If a part is vital it is given V classification, if it is essential, then it is given E classification and if it is not so essential, the part is given a D classification. For V items, a large stock of inventory is generally maintained, while for D items, minimum stock is enough.

3.4.4. SDE classification

The SDE analysis is based upon the availability of items and is very useful in the context of scarcity of supply. In this analysis, S- refers to scarce items, generally imported, and those which are in short supply. D -refers to difficult items which are available indigenously, but are difficult items to produce. Items which have to come from distant places or for which reliable suppliers are difficult to come by a fall into D category. E-refers items which are easy to acquire and which are available in the local markets. The SDE classification, based on problems faced in procurement, is vital to the lead time analysis and in deciding on purchasing strategies.

3.4.5. FSN classification

FSN stands for fast moving, slow moving and non-moving. Here, classification is based on the pattern of issues from stores and is useful in controlling obsolescence. To carry out an FSN analysis, the date of receipt or the last date of issue, whichever is later, is taken to determine the number of months, which have lapsed since the last transaction. The items are usually grouped in a period of 12 months. It is helpful in identifying active items which need to be reviewed regularly and surplus items which have to be examined further. Nonmoving items may be examined further and their disposal can be considered.

3.5. Continuous and periodic review inventory control systems

This inventory control system is appropriate and favors more for expensive items because average inventory is lower. Again, the fixed–order quantity model is more appropriate for important items such as critical repair parts because there is closer monitoring and therefore quicker response to potential stock out. The previous inventory control system used for items which are expensive and critical to reduce the average inventory in stock. However, for items with high demand and not expensive one, the periodic review model is more suitable.

3.6. Types of costs in inventory models

3.6.1. Holding Costs: - the cost of carrying inventory begins with the investment. Money tied up in the acquisition of stock is prevented from earning a return elsewhere (opportunity cost). This cost is associated with keeping items in inventory for a period of time. The carrying or holding cost is typically charged as a percentage of dollar or consumption value per unit time. In practice, this cost typically range from 15%-30% per year. The holding cost consists of the following components

a) Cost of capital: This represents accost of foregone opportunities for other investments, which is assigned to inventory as an opportunity cost. Capital cost is the most significant holding costs.

b) Cost of storage: This cost includes variable space cost, insurance, and taxes. Storage cost is dependent on quantity of goods to be stored.

c) Cost of obsolescence, deterioration, and loss: Obsolescence costs should be assigned to items that have a high risk of becoming obsolete. Perishable products should be charges with deterioration costs when the item deteriorates over time. The costs of loss include pilferage and breakage costs associated with holding items in inventory. Higher inventory level may create additional warehouse ownership. Materials handling costs efforts are likely to increase.

6.1.2. Material (item) costs: - is the cost of buying or producing the individual inventory items. The item cost is usually expressed as a cost per unit multiplied by the quantity produced. Material costs are not affected by the decision to maintain inventories. Most inventory control procedures do not recognize price fluctuation.

6.1.3. Ordering Costs: - is a cost associated with ordering a batch or a lot of items. It does not depend on the item cost, but assigned to the entire batch, including transportation costs, receiving costs, inspection costs, and materials handling costs, placing an order cost or setup costs which includes paperwork costs the costs required to setup the production equipment for a run. For purchase orders, these costs may take the form of higher total freight charges or failure to quality for quantity discounts.

6.1.4. Shortage Costs: - stock out cost reflects the economic consequences of running out of stock, including back ordered cost and loss sales. When a stock out occurs, demand cannot be satisfied out of inventory. This has a number of consequences are the demand (sales) may be lost, Unsatisfied demand may be backlogged Demand can be satisfied from an alternate source.
No matter which of the three outcomes occurs, a certain amount of ill will (with an intangible cost) is generated. Shortage costs are the most significant inventory- related costs; it is most difficult to measure. Organization should ensure that they take specific to optimize the inventory level with the minimum total annual inventory cost and they implement the actions consistently. But, to determine which actions are the right ones for the organizations, they first carry out the detailed analysis of the inventory. The results of the analysis can be used as a basis for defining the appropriate inventory optimization measures.

3.7. Procurement and warehouse application

The results of an ABC analysis extend into a number of other inventory control and management processes:
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. 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.
Cycle counting: - the higher usage, the more activity an item is likely to have; hence the greater likelihood that transaction issues will results in inventory errors. Therefore, to ensure accurate record balances, higher priority items are cycle counted more frequently. Generally, “A” items are counted once each month; **“**B” items once every quarter; and “C” items counted once every six months.
Identifying items for potential consignment or vender 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.
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 differ targets for each category.
Inventory turnover: - a ratio showing how many times company’s inventory is sold and replaced over a period

$$\text{Inventory turnover} = \frac{\text{cost of goods sold}}{\text{average inventory}}$$

3.8. Related works

Different authors have been generated and presented significant approaches on the inventory modeling and controlling system. In reference [9], inventories represent an important part of any company due to its implications in the costs of capital invested, storage, maintenance and ordering. These allow meeting internal and external demand, generating high levels of satisfaction when they are well managed. An optimization approach for independent demand inventory was proposed to establish the best inventory policy in a company specialized in the commercialization of disposable product. In today’s competitive market, inventory management is certainly one of the most challenging problems for organizations. This is a sequel to the fact that keeping inventory is tied up in the financial resources of organizations. The importance of inventory management has been growing recently as it has been found that the agility of organizations highly depends on the efficient management of inventories. In this regard, organizations try to manage their stock efficiently which requires keeping safety stocks for situations where unexpected events such as fluctuations in demand, market structural changes and machinery deficiencies are experienced [10]. According to reference [11], inventory planning and control is essentially concerned with the design, operation and control of an inventory system. While design involves the specification of inventory system procedures, operation and control of an inventory system are primarily concerned with answering two fundamental questions: (1) what should the order (production) quantity be? (2) When and how frequent should an order (production) be placed (initialized)? The problem of determining the most desirable order quantity under rather stable conditions is commonly known as the classical economic order quantity (EOQ) inventory problem. Two major assumptions in the classical EOQ model are that demand is constant and deterministic and that the unit price (unit production cost) is independent of the order (production) quantity.

To develop an applicable model, different technical, physical, and strategic constraints are considered such as available budget, warehouse capacity, total permissible holding cost, and total permissible backordering cost constraints. The goal is to determine the lengths of inventory cycles, where the inventory level is positive and negative such that the total inventory costs are minimized. In addition, backordering rate during shortage period for each product is considered as a decision variable which can significantly reduce the total inventory costs [12]. According to [13], one of the most frequent decisions faced by operations managers is “how much” or “how many” items are they to make or buy in order to satisfy external or internal requirements for the item. Replenishment in many cases is made using the economic order quantity (EOQ) model. The model considers the tradeoff between ordering cost and storage cost in choosing the quantity to use in replenishing items in inventories. The retail merchant wants enough supply to satisfy customer demands, but ordering too much increases holding costs and the risk of losses through obsolescence or spoilage. An order too small increases the risk of lost sales and unsatisfied customers. The operations manager sets a master production schedule considering the imprecise nature of forecasts of future demands and the uncertain lead time of the manufacturing process. These situations are common, and the answers one gets from a deterministic analysis very often are not satisfactory when uncertainty is present. The decision maker faced with uncertainty does not act in the same way as the one who operates with perfect knowledge of the future.

Economic order quantity (EOQ) model has been used extensively over a century. Many studies have altered and modified the model in order to imitate the actual inventory problem. The finding of the optimal replenishment cycle time for the inventory issues where items received are partly with imperfect quality and involve deterioration after the inspection time. Also, for the financial safety, for the supplier, when the permissible delay in payments can promote their sales and reduce their on-hand stock level. In order to minimize the total relevant inventory cost, mathematical theorems have been developed to determine the existence and the uniqueness of the optimal solution. Numerical calculations and illustrations demonstrate the application and the performance of the proposed theories. The economic order quantity (EOQ) model has evolved greatly over past decades on the strength of incorporating realistic factors. In recent times, interest has been geared towards studying the effect of reverse flow of products into inventory system. In practice, businesses may operate return policy (and may reuse products and material) in an effort to increase customer loyalty and recover assets. The inventory problem of when to order and how much quantity to order when there is reverse flow of items into the system is addressed in the form of profit maximization [14], [15]. According to [16] conclusion an EOQ inventory model is proposed, which combines inventory replenishment and valuing choices for item in an inventory system. The stochastic Demand requests for new and old items passed on by means of direct elements of their costs. This model with differential matrix is utilized to get ideal answer for this inventory system.

The effective inventory management plays an important role in the success of the organizations in the new business environment. It is not clearly possible for the organizations that store hundreds of inventory items to economically design an inventory management policy for each inventory item separately. To have an efficient control of a huge amount of inventory items, traditional approach is to classify the inventory into different groups. Different inventory control policies can then apply to different groups. The well-known ABC classification is simple to understand and easy to use. Moreover, various inventory items may play quite different roles in the business of the organization. Hence, the managers need to classify these items in order to control each inventory category properly based on its importance rating. In order to create a perfect inventory control system, various inventory items should be classified into the significant categories based on appropriate criteria and standards. Various models and methods have been so far presented to classify inventory among which, ABC and HML analysis approach are one of the most common methods which is widely used for planning and inventory control. Inventory classification based on ABC analysis allows the organization to classify its inventory into the significant categories.

It is expected that the application of Economic Order Quantity, Marginal Analysis, Just-in-Time, Simulation, Order batching, Vendor Managed Inventory and ABC Analysis will improve company performance. As the organization staff understands the strengths of having these techniques, then the unnecessary costs incurred will be avoided [8], [17]. Therefore, the techniques will improve performance in the following ways:

Table 1

Inventory Management Techniques. Source:[8]

No	Inventory Management Techniques	How Performance Improvement will be achieved
I	Economic Order Quantity	Ability to know how much and when to replenish inventory
Ii	Marginal Analysis	Reduce loss for inventory that is perishable within a short period of time by ensuring they are ordered at the right time.
iii	Just-in-time	Ordering inventory when they are required thus reducing storage/holding costs
iv	Simulation	Capability of laying out inventory management plans for the organization
v	Order Batching	Minimizing on unnecessary costs on transport
vi	Vendor Managed Inventory	Improving on inventory management systems by engaging outsourced suppliers to management inventory monitoring and replenishment.
vii	ABC Analysis	The organization is able to account for each inventory according to its classification and this can be achieved through the Pareto analysis.

Inventory management is very crucial to any organization that is improving on its performance and attaining high levels of customer satisfaction. The material held by an organization makes up for most of the organization assets. Most organization invests so much money in materials and it is important for the organization to put in place a good material management system in order to manage the stock properly. Poor inventory management system can negatively affect the profitability of an organization. The management has very devastating effect on the performance of the organization about the material management system put in place to determine the performance of the said material and the general performance of the organization. In most cases where inventory management decisions have been effective, inventory planning models have been developed and implemented focusing especially on the twin problems of inventory size and timing. Usually, inventory management models are designed to achieve a balance between the costs of acquiring and holding inventory and in so doing it makes it possible to know whether companies are earning profits or not. A large accumulation of inventory causes a high carrying cost. The incompatibility in the number of demands with the quantity produced results in the emergence of the other costs so that the company loses the opportunity to get maximum profit. Therefore, it is necessary to analyze the inventory quantity to reduce carrying costs. The company optimizes the inventory quantity based on the concept of the Economic

Order Quantity using the quantity of safety stock as a minimum inventory point so that the company can plan the production number in the next periods [6], [7].

Spare parts inventory is needed for maintenance and repair of final products, vehicles, industrial machines and equipment, frequently requiring high investments and significantly affecting customer satisfaction. Inventory management is complex due to the large number of different items and low demands. Spare parts inventories are different from other types of inventories in companies. Different researchers have pointed out some important factors in the management of these inventories: •
Customers have rising expectations concerning quality of associated products and services. The occurrence of failure is already a concern and the delay in repairing due to lack of spare parts worsens clients' negative perception;

- Some items have high demand (parts with great wearing and those related to preventive maintenance), but the great majority has intermittent demand and;
- The increasing complexity of products and the life cycles reduction generate an increase on the amount of active codes and risk of obsolescence.

Initially, it is important to distinguish disposable parts from repairable ones. Spare parts are extremely expensive in some segments, and their repair (instead of discard) is feasible; damaged units can be replaced either by new units or by repaired ones [18]. In many segments, including automotive, products have little differentiation among brands and other factors gained increased attention to maintain customer satisfaction and loyalty. After sales activities have received strong attention, as quick response and high-quality services help companies to accomplish their objectives. Spare parts have significant impact over these services, so good management practices on inventory control are desired. Studies on spare parts inventory control considered different time buckets for demand recording, including individual orders and different time buckets (weekly, monthly, bi-monthly and quarterly) [9]. Engineering supply chain management is currently widely used, increasing profits while reducing costs. At present, supply chain management ideas have applied to many industries, such as aviation, retail, and manufacturing, especially in the manufacturing industry. In the material inventory, materials of the same type are often used, and the role played by them is quite different. Therefore, in the research of material inventory management model and cost optimization process, it is necessary to analyze the application scenario. When a small number of spare parts are left, they are generally treated as special spare parts, which are only used for important needs, thus maximizing the overall benefits. When the stock level drops to a certain level and all remaining materials are considered important spare parts, the stock level is an important level. Therefore, the material will be replenished instantaneously at the end of the early period, at which point the customer will end the shortage of important spare parts and secondary spare parts [19].

As we have seen from the different researcher conclusion effective inventory control management is crucial for both manufacturing and service industry. In order to satisfying customers' needs and smoothing the operation line managing the inventory system is an important issue. Based on the above literature review; using the various inventory classification methods to minimize the total inventory cost. From different inventory controlling techniques EOQ, ABC and HML are used in this research.

4. Research Methodology

4.1. Data collection methods

In this research both primary and secondary sources were used to collect the necessary data and how to collect the data used in my thesis. Such as observation, interview with different workers, workers in foreign & local purchasing department and the head of mechanical spare parts. Even though, data is collected from different reports and documents of the purchasing & inventory department. The necessary information has gathered through the following data collecting methods.

4.1.1. Primary source of data

a) Observation

This method has been used to observe the overall performance of the Company's activities, and to come up with some real ideas. It also gave a general understanding of what will be done to solve the problems. Observation was used to collect the necessary information's about the inventory cost and to identify the when & how many spare parts are ordered.

b) Interview

Face to face interview was used to get the critical mechanical spare parts and spares which were failed most of the time and by distributed 22 questionnaires paper to the company. Then I have taken data sampling by using this information.

4.1.2. Secondary source of data

Different type of books, internets and unpublished documents were used in this study paper to collect holding cost per unit, setup cost per order & lead time.

3.2. Methodology of the study

This paper utilizes qualitative and quantitative approaches to study, investigate and identify the root causes of spare parts management at the spare part warehouse. The qualitative approach includes interviewing the workers of the company regarding problems and their attitude towards their work. Annual reports and other company reports are also playing a vital role in collecting data about the company. After identifying the root causes of the problem, we have analyzed the problem by using ABC, HML and EOQ tools.

3.2.1. ABC inventory control analysis method

Is an inventory categorization method which consists in dividing items into three categories (A, B, C): A-being the most valuable items, B-being the medium valuable items & C-being the least valuable items.

a) Steps of ABC analysis

Step-one: - Find out the unit cost and the usage of each material over a given period.
Step-two: - Multiply the unit cost by the estimated annual usage to obtain the net value.
Step-three: -List out all the items and arrange them in the descending value (annual value).

Step-four: -Accumulate value and add up the number of items and calculate percentage of total inventory in value and in number.

$$\text{Cumulative percentage of item} = \frac{\text{Item number grouped in one category}}{\text{Total number of items}}$$

$$\text{Annual consumption value percentage} = \frac{\text{Annual consumption value of item}}{\text{Total annual consumption value}}$$

Step-five: - Draw a curve of percentage items and percentage value.
Step-six: - classified these spare parts into A, B, and C category.
Step-seven: - analysis number of items counted per day.

3.2.2. HML inventory control analysis method

This type of inventory control analysis is classified spare parts based on cost per item (per piece). High-cost items (H), Medium Cost items (M) and Low-Cost item (L) help in bringing controls over consumption at the departmental level. H- Items should be stored as safety stock in warehouse, M- Items are not so much stored in warehouse as H and L- Items are low stored.

3.2.3. Optimal economic order quantity (EOQ)

In a continuous, or fixed-order-quantity, system when inventory reaches a specific level, referred to as the reorder point, a fixed amount is ordered. The most widely used and traditional means of determining how much to order in a continuous system is the economic order quantity (EOQ) model, also referred to as the economic lot size model. The earliest published derivation of the basic EOQ model formula in 1915 is credited to Ford Harris, an employee at Westinghouse.
The function of the EOQ model is to determine the optimal order size that minimizes total inventory costs. There are several variations of the EOQ model, depending on the assumptions made about the inventory system. We will describe two model versions, including the basic EOQ model and the EOQ model with no instantaneous receipt. Is appoint at which holding and ordering costs are equal.

3.3. Mathematical analysis of economic order quantity model

The basic EOQ model is a formula for determining the optimal order size that minimizes the sum of carrying costs and ordering costs. The model formula is derived under a set of simplifying and restrictive assumptions, as follows:

- Demand is known, constant & independent.
- Stock out can be completely avoided.
- Lead time for the receipt of orders is constant.
- The order quantity is received all at once.
- Only variable costs are setup & holding.
- Quantity discounts are not possible.

These basic model assumptions are describing the continuous-inventory order cycle system inherent in the EOQ model. An order quantity, Q, is received and is used up over time at a constant rate. When the inventory level decreases to the recorder point, R, a new order is placed; a period of time, referred to as the lead time, is required for delivery. The order is received all at once just at the moment when demand depletes the entire stock of inventory--the inventory level reaches 0, so there will be no shortages. This cycle is repeated continuously for the same order quantity, reorder point, and lead time.
As we mentioned, the economic order quantity is the order size that minimizes the sum of carrying costs and ordering costs. These two costs react inversely to each other. As the order size increases, fewer orders are required, causing the ordering cost to decline, whereas the average amount of inventory on hand will increase, resulting in an increase in carrying costs. Thus, in effect, the optimal order quantity represents a compromise between these two inversely related costs. The total annual ordering cost is computed by multiplying the cost per order, designated as Co, times the number of orders per year. Since annual demand, D, is assumed to be known and to be constant, the number of orders will be $\frac{D}{Q}$, where Q is the order size and annual ordering cost(S) = $\frac{\text{Co x D}}{\text{Q}}$.

The only variable in this equation is Q; both Co and D, are constant parameters. Thus, the relative magnitude of the ordering cost is dependent upon the order size. Total annual carrying cost is computed by multiplying the annual per-unit carrying cost, designated as Cc, times the average inventory level, determined by dividing the order size, Q, by 2: Q/2;

Annual carrying cost (H) = $\frac{\text{Cc x Q}}{2}$.

The total annual inventory cost (TIC) is the sum of the ordering and carrying costs:

$$\text{TIC} = \text{S} + \text{H} = \frac{\text{Co x D}}{\text{Q}} + \frac{\text{Cc x Q}}{2}$$

Total cost is the sum of the ordering cost + holding cost + product cost:

$$\text{TC} = \frac{\text{D}}{\text{Q}} + \frac{\text{Co x D}}{\text{Q}} + \text{PD}$$

$$\text{Expected number of orders (N)} = \frac{\text{Annual demand}}{\text{Order quantity}} = \frac{\text{D}}{\text{Q}}$$

$$\text{Expected time between orders (T)} = \frac{\text{Number of working days per year}}{\text{Number of orders}}$$

Average inventory (I) = $\frac{\text{Q}}{2}$

Length of an order cycle (C) = $\frac{\text{Q}}{\text{D}}$ x number of working days per year.

Flow time of order (Ft) = $\frac{\text{I}}{\text{D}}$ x number of working days

3.4. Reorder points

Economic order quantity is answering the “how much” question. The reorder point tells “when” to order and minimum level of on hand inventory that triggers replenishment. Lead time (L) - is the time between placing and receiving an order.
Rop = (demand per day) x (lead time for a new order in days).
Where, d = demand per year/number of working days in a year. The optimal order quantity occurs at the point in Figure 12.2 where the total cost curve is at a minimum, which coincides exactly with the point where the carrying cost curve intersects the ordering cost curve. This enables us to determine the optimal value of Q* by equating the two cost functions and solving for Q: $\frac{\text{Co x D}}{\text{Q}} = \frac{\text{Cc x Q}}{2}$, from this equality equation we can get the optimal value of quantity.

$$Q^* = \sqrt{\frac{2Co \times D}{Cc}}$$

Alternatively, the optimal value of Q*can be determined by differentiating the total cost curve with respect to Q*, setting the resulting function equal to zero (the slope at the minimum point on the total cost curve), and solving for Q*:

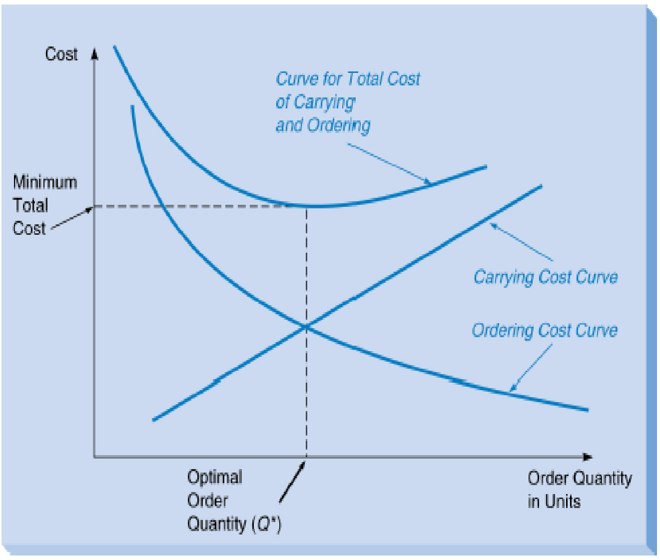

Figure 1: Economic order quantity model of total cost

The total minimum cost is determined by substituting the value for the optimal order size, Qopts, into the total cost equation:

$$Tcmin = \frac{Co \times D}{Q^*} + \frac{Cc \times Q^*}{2}$$

The optimal order quantity, determined in this example, and in general, is an approximate value, since it is based on estimates of carrying and ordering costs as well as uncertain demand (although all of these parameters are treated as known, certain values in the EOQ model). In practice it is acceptable to round the Q values off to the nearest whole number. The precision of a decimal place is generally not necessary. In addition, because the optimal order quantity is computed from a square root, errors or variations in the cost parameters and demand tend to be dampened. Variations in both inventory costs will tend to offset each other, since they have an inverse relationship. As a result, the EOQ model is relatively resilient to errors in the cost estimates and demand, or is robust, which has tended to enhance its popularity.

3.5. Minitab statistical software and micro soft excel

This statistical software is used for analysis, which spare parts are needed close control by sketching Pareto graph. Microsoft excel is also used to sketching different type of statistical graphs and used to arrange the data from descending to ascending order or vice versa is also right.

3.6. Designs for the optimum solution

Design the optimal solution based on these inventory controlling techniques which are ABC classification analysis, HLM classification analysis, VED classification analysis, SDE classification analysis and FSN classification analysis. From those classification analyses most of the time ABC and HLM classifications are related to costs. In the Messobo cement factory there are high inventory costs, especially in spare parts. This problem is happening due to the lack of well inventory control management and prioritization of items. Since ABC and HLM classification analysis are related to cost we select these classifications in order to minimize total inventory costs in the Messobo cement factory.

4. Result and Discussion

4.1. Current practice of inventory control in the company

In the Messobo cement factory there are different inventory control practices such as ERP (enterprise resource planning, straight line method, physical inventory control system, and periodic inventory control practices. According to the information gotten from the company straight line method is putting materials in a straight line, for easy to visualize and identified that the materials or other things. Enterprise resource planning, controlling system is used to indicate how many materials are left in the warehouse, but it can't analysis when to order, how much to order, the time between orders and number of orders. For inventory control and planning these methods are not enough, it may be used as the supportive methods. In addition to these methods the company should use HML, ABC and EOQ inventory control classifications and analysis in order to maximize its profit and for well inventory control and planning. By using the existing data, we analysis the existing total mechanical spare parts inventory costs by using EOQ. Messobo cement factory is working for 300 days per year and the lead time for receiving and replacing for the following mechanical spare parts is eight months that means ordering date is 26/5/2011; receiving date is 26/01/2012 E.C.

The following table indicates costs per order of these mechanical spare parts during ordering process that means until they reach the Messobo cement factory.

Table 2
Inland charges:

Insurance cost (local)	12,574.97birr
Bank service charge	117,439.57birr
Freight charges (sea/air)	51,076.10birr
Customs duty (less vat)	448,322.28birr
Clearance (transit) costs & port handling	11,430.66birr
Inland transport	-
Loading & unloading	-
Storage cost	-
Currency fluctuation	-
Other overhead, if any	-
Ordering cost per order (Co)	640,843.58birr

4.2. Existing data of spare parts taken from the company

All these spare parts are ordered at once in one ordering batch and this data is taken from the company which shows list of different spares with their quantity per order and costs. In the following table total cost per year per item is calculated by multiplying the annual demand per item with its unit cost per item.

Table 3
Items cost with their quantity per order and costs:

No	Description	Quantity per order	Unit cost in birr	Annual demand	Total cost per year
1	Bearing T309	8	201.4913	14	2820.88
2	Bearing F310	8	216.6988	13	2817.08
3	Bearing T311	8	288.9313	14	4045.04
4	Bearing FY508M	8	507.5313	10	5075.31
5	Bearing FY505M	8	288.9313	3	866.79
6	Bearing SY508M	8	326.9488	16	5231.18
7	Bearing FL207	8	195.7888	6	1174.73
8	Bearing F311	8	332.6513	16	5322.42
9	Bearing T312	8	368.7675	4	1475.07
10	Bearing K209	8	380.1725	14	5322.42
11	Bearing FC211	8	216.6988	6	1300.12
12	Bearing UCF310	8	1,267.8763	12	15,214.52
13	Bearing UCF311	8	1,446.5575	8	11,572.46
14	Bearing UCK309	8	610.1775	10	6,101.78
15	Bearing UCK311	8	849.6863	8	6,797.49
16	Bearing 6211	8	469.5138	5	2,347.57
17	Bearing 22315	8	4,562.0738	8	36,496.59
18	Bearing P308	8	180.5825	8	1,444.66
19	Bearing P310	8	216.6988	7	886.89
20	Bearing 22228cc/w33/c3	8	6,672.0325	6	40,032.20
21	Bearing DGBB144	8	171.0775	6	1,026.47
22	Bearing seat SNK211	8	541.7463	8	4,333.97
23	Bearing DGBB118	8	456.2075	5	2,281.04
24	Bearing oscillating bearingGE120ES-2RS	8	10,777.8988	8	86,223.19
25	GearboxSBD65-P-B-Φ50,speed rated=44,2.2kw	1	9,162.1600	1	9,162.16
26	Gearbox SBD65-P-B-Φ50,speed rated=284,2.2kw	1	9,162.1600	1	9,162.16
27	Gearbox SBD65-P-B-Φ50,speed rated=317,2.2kw	1	9,067.1200	1	9,067.12
28	Gearbox SBD65-P-B-Φ50,speed rated=68,3kw	1	9,618.3700	1	9,618.37
29	Gearbox XWD5-29-5.5,5.5kw	1	12,093.3000	1	12,093.30
30	Gearbox DCY180-50-1N	1	25,923.9800	1	25,923.98
31	Gearbox YKF272-180-II,2.2kw	1	40,767.8300	1	40,767.83
32	Gearbox XWD8-71-7.5,7.5kw	1	19,369.8000	1	19,369.80
33	Gearbox Flender Sr No..4501155687.01.001,B3SH12D	1	604,474.7200	1	604,474.72
34	Gearbox FlenderSr No..4501155687.04.001,B3SH14D	1	928,762.1100	1	928,762.11
35	Gearbox FlenderSr No..45o1141774.04.001,B3DH9D	1	370,668.4600	1	370,668.46
36	Gearbox DCY160-40-1T,7.5kw	1	25,887.8700	1	25,887.87
37	YOX400 liquid coupling	1	16,651.5700	1	16,651.57
38	YOX II Z405 liquid coupling	1	17,069.7600	1	17,069.86
39	YOX500 liquid coupling	2	17,297.8600	2	34,595.72
40	YOX560 liquid coupling	1	17,487.9500	1	17,487.95
41	YOX360 liquid coupling	1	16,157.3400	1	16,157.34
42	Chain for travel motor16A-1	100	361.1641	100	36,116.41
43	Sprocket tooth form 16A,number of teeth13	8	1,045.4750	5	5,227.38
44	Big sprocket tooth form 16A,number of teeth27	8	1,254.5700	7	8,781.99
45	Big sprocket tooth form 12A,number of teeth38	8	1,330.6050	10	13,306.05
46	Driven sprocket tooth form 12A,number of teeth25	8	1,330.6050	13	17,297.87
47	Chain 12A-1	100	361.1641	100	36,116.41
48	Hydraulic liquid coupling ML6-55X112/42X112-MT6B	1	570.2600	1	570.26
49	Hydraulic liquid coupling MLL5-I-200-48X112/40X112-MT5	1	475.2200	1	475.22
50	Hydraulic liquid coupling ML38X82/25X62MT3B	1	494.2200	1	494.22
51	Hydraulic liquid coupling ML4-42X112/30X82-MT4B	1	513.2300	1	513.23
52	Pump PGH4-2X/040RE11VE4	1	32,580.8100	1	32,580.81
53	High pressure pump 10-5 CY14-1D	1	12,678.7600	1	12,678.76
	TOTAL	448pcs	1,863,497.074 birr	474pcs	2,563,991.009birr

4.3. Assumption costs as a percent of inventory value per unit

This assumption is differing from company to company because they have their own strategies. Before assuming this assumption costs, I have distributed questionnaire papers to the company in order to simplify for my assumption. Based on these questionnaires the assumptions are written on the table 4. For Messobo cement factory I will take the assumption based on this existing situation. According Chase, Richard B., et al. (2004) the summation of all these costs is not above 26%.

Table 4
Assumption of holding or carrying cost per unit

Category	Assumption Cost as a percent of inventory value per unit
Cost of capital (either the local money-market interest rate or the company's return on investment target)	6%
Material handling cost (equipment leases or depreciation, power, operating cost)	5%
Labor cost (receiving, warehousing, security)	5%
Obsolescence, pilferage, & space	5%
Housing cost (building rent or depreciation, taxes, insurances)	4%
Total carrying cost per unit(c)	25%

4.4. Existing cost analysis by using economic order quantity

Since, the ordering spare parts are different items the average unit cost (i) must be need to analysis annual holding cost.

Average unit cost (i) = $\frac{\sum(\text{each unit cost})}{\text{Number of items}}$

Average unit cost = $\frac{1,863,497.07}{53}$

i =35,160,32birr/unit

Holding cost per unit per year (**Cc**) = average unit cost **x** percentage of carrying cost

= i x c

= 35,160.32 x 0.25

Cc=**8,990.08birr/pcs**

Annual holding cost (**H**) = (Q/2) x (Cc)

= (448pcs/2) **x** (8,990.08birr/pcs)

= (228) x (8,973.97)

H = 2,013,777.92birr/year

Annual setup cost(**S**) = (D/Q) x (Co)

= (474/448) x (640,843.58)

S = 678,035.31birr/year

Average inventory (**I**) = Q/2

= 448pcs/2

I = 224pcs

Expected number of order (N) = D/Q

= 474pcs/448pcs

N ≈ 1times/year

Expected time between order (**T**) = $\frac{\text{Number of working days per year}}{\text{N}}$

= 300days/1

T = 300days/year

Inventory turns = annual demand/ average inventory

= 474pcs/224pcs

Inventory turns = 2

Reorder point (**Rop**) = (demand per day) x (lead time for a new order in day)

Where, demand per day (**d**) = demand per year/number of working days in a year

= 474pcs/300days

d = 2pcs/day

Reorder point = **d** x **L**

= 2pcs/day x 240days

Rop = 480pcs

Total existing annually inventory cost (**TICe**) = (Annual holding cost) + (Annual setup cost) = [((Q/2) x (Cc)) + ((D/Q) x (Co))] = (2,013,777.92birr/year) + (678,035.31birr/year)

TICe = 2,691,813.23birr/year

4.5. Proposed inventory cost analysis by using HML, ABC classification and optimal economic order quantity.

Because of the large number of the spare parts, it is essential to use inventory control technique to classify the spare parts. I have used two inventory control techniques HML classification (according to unit price), ABC (according to annual consumption value), and optimal economic order quantity which is used to analysis annual inventory costs and answer the question when to order and how much to order for this case study which simplify the controlling mechanism.

4.5.1. Classification of spare parts by using HML classification method

This classification method is used to classify spare parts based on their unit costs. Classifying spare parts in high (H), medium (M), low (L) prices is the pre-condition of inventory control planning. After we classify these spare parts, it is easy to identify which spare parts need periodic review or not. Based on the given data spare parts are classified into H, M, and L as the following analysis

Step 1: arrangement of unit price of spare parts from maximum to minimum unit price

Table 5
Shows descending order of unit price of spare parts

No	Description	Quantity per order	Unit cost in birr	Annual demand	Total cost per year
34	GearboxFlenderSr No..4501155687.04.001,B3SH14D	1	928,762.1100	1	928,762.11
33	GearboxFlenderSr No..4501155687.01.001,B3SH12D	1	604,474.7200	1	604,474.72

35	GearboxFlenderSrNo..45o1141774.04.001, B3DH9D	1	370,668.4600	1	370,668.46
31	Gearbox YKF272-180-II,2.2kw	1	40,767.8300	1	40,767.83
52	Pump PGH4-2X/040RE11VE4	1	32,580.8100	1	32,580.81
30	Gearbox DCY180-50-1N	1	25,923.9800	1	25,923.98
36	Gearbox DCY160-40-1T,7.5kw	1	25,887.8700	1	25,887.87
32	Gearbox XWD8-71-7.5,7.5kw	1	19,369.8000	1	19,369.80
40	YOX560 liquid coupling	1	17,487.9500	1	17,487.95
39	YOX500 liquid coupling	2	17,297.8600	2	34,595.72
38	YOX II Z405 liquid coupling	1	17,069.7600	1	17,069.86
37	YOX400 liquid coupling	1	16,651.5700	1	16,651.57
41	YOX360 liquid coupling	1	16,157.3400	1	16,157.34
53	High pressure pump 10-5 CY14-1D	1	12,678.7600	1	12,678.76
29	Gearbox XWD5-29-5.5,5.5kw	1	12,093.3000	1	12,093.30
24	Bearing oscillating bearingGE120ES-2RS	8	10,777.8988	8	86,223.19
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25	GearboxSBD65-P-B-Φ50,speed rated=44,2.2kw	1	9,162.1600	1	9,162.16
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27	Gearbox SBD65-P-B-Φ50,speed rated=317,2.2kw	1	9,067.1200	1	9,067.12
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13	Bearing UCF311	8	1,446.5575	8	11,572.46
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46	Driven sprocket tooth form 12A,number of teeth25	8	1,330.6050	13	17,297.87
12	Bearing UCF310	8	1,267.8763	12	15,214.52
44	Big sprocket tooth form 16A,number of teeth27	8	1,254.5700	7	8,781.99
43	Sprocket tooth form 16A,number of teeth13	8	1,045.4750	5	5,227.38
15	Bearing UCK311	8	849.6863	8	6,797.49
14	Bearing UCK309	8	610.1775	10	6,101.78
48	Hydraulic liquid coupling ML6-55X112/42X112-MT6B	1	570.2600	1	570.26
22	Bearing seat SNK211	8	541.7463	8	4,333.97
51	Hydraulic liquid coupling ML4-42X112/30X82-MT4B	1	513.2300	1	513.23
4	Bearing FY508M	8	507.5313	10	5075.31

50	Hydraulic liquid coupling ML38X82/25X62MT3B	1	494.2200	1	494.22
49	Hydraulic liquid coupling MLL5-I-200-48X112/40X112-MT5	1	475.2200	1	475.22
16	Bearing 6211	8	469.5138	5	2,347.57
23	Bearing DGBB118	8	456.2075	5	2,281.04
10	Bearing K209	8	380.1725	14	5322.42
9	Bearing T312	8	368.7675	4	1475.07
42	Chain for travel motor16A-1	100	361.1641	100	36,116.41
47	Chain 12A-1	100	361.1641	100	36,116.41
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5	Bearing FY505M	8	288.9313	3	866.79
2	Bearing F310	8	216.6988	13	2817.08
11	Bearing FC211	8	216.6988	6	1300.12
19	Bearing P310	8	216.6988	7	886.89
1	Bearing T309	8	201.4913	14	2820.88
7	Bearing FL207	8	195.7888	6	1174.73
18	Bearing P308	8	180.5825	8	1,444.66
21	Bearing DGBB144	8	171.0775	6	1,026.47
	TOTAL	448pcs	1,863,497.074birr	474pcs	2,563,991.009birr

Step 2: determine annual consumption value of spare parts. Annual consumption value of spare part is calculated by multiplying annual demand of each spare part with unit cost per unit.

Table 6
Shows descending order of unit prices and annual consumption value of spare parts

No	Description	Unit cost in birr	Annual demand	Annual consumption value
34	GearboxFlenderSr No..4501155687.04.001,B3SH14D	928,762.1100	1	928,762.1100
33	GearboxFlenderSr No..4501155687.01.001,B3SH12D	604,474.7200	1	604,474.7200
35	GearboxFlenderSr No..45o1141774.04.001,B3DH9D	370,668.4600	1	370,668.4600
31	Gearbox YKF272-180-II,2.2kw	40,767.8300	1	40,767.8300
52	Pump PGH4-2X/040RE11VE4	32,580.8100	1	32,580.8100
30	Gearbox DCY180-50-1N	25,923.9800	1	25,923.9800
36	Gearbox DCY160-40-1T,7.5kw	25,887.8700	1	25,887.8700
32	Gearbox XWD8-71-7.5,7.5kw	19,369.8000	1	19,369.8000
40	YOX560 liquid coupling	17,487.9500	1	17,487.9500
39	YOX500 liquid coupling	17,297.8600	2	34,595.72
38	YOX II Z405 liquid coupling	17,069.7600	1	17,069.7600
37	YOX400 liquid coupling	16,651.5700	1	16,651.5700

41	YOX360 liquid coupling	16,157.3400	1	16,157.3400
53	High pressure pump 10-5 CY14-1D	12,678.7600	1	12,678.7600
29	Gearbox XWD5-29-5.5,5.5kw	12,093.3000	1	12,093.3000
24	Bearing oscillating bearingGE120ES-2RS	10,777.8988	8	86,223.1904
28	Gearbox SBD65-P-B-Φ50,speed rated=68,3kw	9,618.3700	1	9,618.3700
25	GearboxSBD65-P-B-Φ50,speed rated=44,2.2kw	9,162.1600	1	9,162.1600
26	Gearbox SBD65-P-B-Φ50,speed rated=284,2.2kw	9,162.1600	1	9,162.1600
27	Gearbox SBD65-P-B-Φ50,speed rated=317,2.2kw	9,067.1200	1	9,067.1200
20	Bearing 22228cc/w33/c3	6,672.0325	6	40,032.195
17	Bearing 22315	4,562.0738	8	36,496.5904
13	Bearing UCF311	1,446.5575	8	11,572.46
45	Big sprocket tooth form 12A,number of teeth38	1,330.6050	10	13,306.050
46	Driven sprocket tooth form 12A,number of teeth25	1,330.6050	13	17,297.865
12	Bearing UCF310	1,267.8763	12	15,214.5156
44	Big sprocket tooth form 16A,number of teeth27	1,254.5700	7	8,781.99
43	Sprocket tooth form 16A,number of teeth13	1,045.4750	5	5,227.375
15	Bearing UCK311	849.6863	8	6,797.4904
14	Bearing UCK309	610.1775	10	6,101.775
48	Hydraulic liquid coupling ML6-55X112/42X112-MT6B	570.2600	1	570.2600
22	Bearing seat SNK211	541.7463	8	4,333.9704
51	Hydraulic liquid coupling ML4-42X112/30X82-MT4B	513.2300	1	513.2300
4	Bearing FY508M	507.5313	10	5075.313
50	Hydraulic liquid coupling ML38X82/25X62MT3B	494.2200	1	494.2200
49	Hydraulic liquid coupling MLL5-I-200-48X112/40X112-MT5	475.2200	1	475.2200
16	Bearing 6211	469.5138	5	2,347.569
23	Bearing DGBB118	456.2075	5	2,281.0375
10	Bearing K209	380.1725	14	5,322.415
9	Bearing T312	368.7675	4	1,475.07
42	Chain for travel motor16A-1	361.1641	100	36,116.41
47	Chain 12A-1	361.1641	100	36,116.41
8	Bearing F311	332.6513	16	5,322.4208
6	Bearing SY508M	326.9488	16	5,231.1808
3	Bearing T311	288.9313	14	4,045.0382
5	Bearing FY505M	288.9313	3	866.7939
2	Bearing F310	216.6988	13	2,817.0844
11	Bearing FC211	216.6988	6	1,300.1928
19	Bearing P310	216.6988	7	1,516.8916
1	Bearing T309	201.4913	14	2,820.8782
7	Bearing FL207	195.7888	6	1,174.7328
18	Bearing P308	180.5825	8	1,444.66
21	Bearing DGBB144	171.0775	6	1,026.465
	Total			2,580,918.75

Step 3: Accumulate value and add up number of items, calculate percentage on total inventory in value and in number.

Cumulative percentage of item = $\frac{\text{item number grouped in one category}}{\text{total number of items}}$

Annual consumption value percentage = $\frac{\text{annual consumption value of item}}{\text{total annual consumption value}}$

Table 7
Shows percentage of items and annual consumption value.

No	Cumulative percentage of items	Unit price in birr	Annual consumption value	Percentage of annual consumption value	Percentage cumulative of annual consumption value
34	1.89	**928,762.1100**	928,762.1100	35.99	35.99
33	3.77	**604,474.7200**	604,474.7200	23.42	59.43
35	5.66	**370,668.4600**	370,668.4600	14.36	73.79
31	7.55	**40,767.8300**	40,767.8300	1.58	75.37
52	9.43	**32,580.8100**	32,580.8100	1.26	76.63

30	11.32	**25,923.9800**	25,923.9800	1.004	77.634
36	13.21	**25,887.8700**	25,887.8700	1.003	78.637
32	15.09	**19,369.8000**	19,369.8000	0.751	79.388
40	16.98	**17,487.9500**	17,487.9500	0.678	80.066
39	18.87	**17,297.8600**	34,595.72	1.340	81.406
38	20.75	**17,069.7600**	17,069.7600	0.661	82.067
37	22.64	**16,651.5700**	16,651.5700	0.645	82.712
41	24.53	**16,157.3400**	16,157.3400	0.626	83.338
53	26.42	**12,678.7600**	12,678.7600	0.491	83.829
29	28.30	**12,093.3000**	12,093.3000	0.469	84.298
24	30.19	**10,777.8988**	86,223.1904	3.341	87.639
28	32.08	**9,618.3700**	9,618.3700	0.373	88.012
25	33.96	**9,162.1600**	9,162.1600	0.355	88.367
26	35.85	**9,162.1600**	9,162.1600	0.355	88.722
27	37.74	**9,067.1200**	9,067.1200	0.351	89.073
20	39.62	**6,672.0325**	40,032.195	1.551	90.624
17	41.51	**4,562.0738**	36,496.5904	1.414	92.038
13	43.40	**1,446.5575**	11,572.46	0.448	92.486
45	45.28	**1,330.6050**	13,306.050	0.516	93.002
46	47.17	**1,330.6050**	17,297.865	0.670	93.672
12	49.06	**1,267.8763**	15,214.5156	0.589	94.261
44	50.94	**1,254.5700**	8,781.99	0.340	94.601
43	52.83	**1,045.4750**	5,227.375	0.203	94.804
15	54.72	**849.6863**	6,797.4904	0.263	95.067
14	56.60	**610.1775**	6,101.775	0.236	95.303
48	58.49	**570.2600**	570.2600	0.022	95.325
22	60.38	**541.7463**	4,333.9704	0.168	95.493
51	62.26	**513.2300**	513.2300	0.020	95.513
4	64.15	**507.5313**	5,075.313	0.197	95.710
50	66.04	**494.2200**	494.2200	0.019	95.729
49	67.92	**475.2200**	475.2200	0.018	95.747
16	69.81	**469.5138**	2,347.569	0.091	95.838
23	71.70	**456.2075**	2,281.0375	0.088	95.926
10	73.58	**380.1725**	5,322.415	0.206	96.132
9	75.47	**368.7675**	1,475.07	0.057	96.189
42	77.36	**361.1641**	36,116.41	1.399	97.588
47	79.25	**361.1641**	36,116.41	1.399	98.987
8	81.13	**332.6513**	5,322.4208	0.206	99.193
6	83.02	**326.9488**	5,231.1808	0.203	99.396
3	84.91	**288.9313**	4,045.0382	0.157	99.553
5	86.79	**288.9313**	866.7939	0.034	99.587
2	88.68	**216.6988**	2,817.0844	0.109	99.696
11	90.57	**216.6988**	1,300.1928	0.050	99.746
19	92.45	**216.6988**	1,516.8916	0.059	99.805
1	94.34	**201.4913**	2,820.8782	0.109	99.914
7	96.23	**195.7888**	1,174.7328	0.040	99.954
18	98.11	**180.5825**	1,444.66	0.040	99.994
21	100	**171.0775**	1,026.465	0.040	100
	Total		**2,580,918.75**		

Step 4: classified these spare parts into H, M and L category

Table 8

Shows categories of HML and which category is firstly need action.

Category	**Items**	**Percentage of items**	**Percentage of annul consumption value**	**Action**
Class H	30,31,33,34,35, 36, 52	13%	78.62%	To be stored in warehouse
Class M	32,40,39,38,37, 41,53,29,24,28, 25,26,27,20,17,	39.6%	16.16%	The medium one
Class L	13,45,46,12,44, 43 15,14,48,22,51,4,50,49, 16,23,10,9, 42,47,8,6,3, 5,2,11,19,1,7,18,21	47.17%	5.23%	It may not be store it in warehouse

From the above table we conclude that spare parts which are classified under H classification are stored in cupboard in order to facilitate the production process. This classification also analyzed by the following graph.

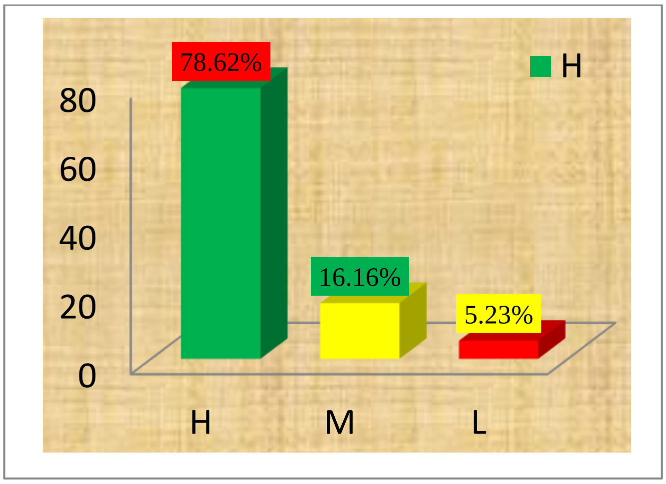

Figure 2: shows HML classification of mechanical spare

As we have seen from the above graph the manager focuses on the H classification. From all spare parts H group spares are 78.62% of annual consumption value based on its unit price. M group of spare parts are 16.16% of total spare parts then this group need medium consideration and spare parts which are classified under L classification are not that much consider.

4.5.2. Classification of spare parts by using ABC classification method

This classification method is used to classify items or spare parts based on their annual consumption value. It is similar with **HML** classification but the difference is, **HML** classification is based on items unit price. The advantages of classifying spare parts into **ABC** classification are:

Easily understand cycle counting time of spare parts that means used to understand when the spare parts are counting, to identify the number of items or spare parts are counted per day and which spare parts are required close control, regular review and infrequent review in order to minimize inventory costs of the company. Spare parts are classified into **A**, **B** and **C** based on their annual consumption value as the following analysis.

Step 1: Multiply the unit cost by the estimated annual usage to obtain the net value.

Table 9

Annual consumption values of mechanical spare parts.

No	Description	Unit cost in birr	Annual demand	Annual consumption value
1	Bearing T309	201.4913	14	2,820.8782
2	Bearing F310	216.6988	13	2,817.0844
3	Bearing T311	288.9313	14	4,045.0382
4	Bearing FY508M	507.5313	10	5075.313
5	Bearing FY505M	288.9313	3	866.7939
6	Bearing SY508M	326.9488	16	5,231.1808
7	Bearing FL207	195.7888	6	1,174.7328
8	Bearing F311	332.6513	16	5,322.4208
9	Bearing T312	368.7675	4	1,475.07
10	Bearing K209	380.1725	14	5,322.415
11	Bearing FC211	216.6988	6	1,300.1928
12	Bearing UCF310	1,267.8763	12	15,214.5156
13	Bearing UCF311	1,446.5575	8	11,572.46
14	Bearing UCK309	610.1775	10	6,101.775
15	Bearing UCK311	849.6863	8	6,797.4904
16	Bearing 6211	469.5138	5	2,347.569
17	Bearing 22315	4,562.0738	8	36,496.5904
18	Bearing P308	180.5825	8	1,444.66
19	Bearing P310	216.6988	7	1,516.8916
20	Bearing 22228cc/w33/c3	6,672.0325	6	40,032.195
21	Bearing DGBB144	171.0775	6	1,026.465
22	Bearing seat SNK211	541.7463	8	4,333.9704
23	Bearing DGBB118	456.2075	5	2,281.0375
24	Bearing oscillating bearingGE120ES-2RS	10,777.8988	8	86,223.1904
25	GearboxSBD65-P-B-Φ50,speed rated=44,2.2kw	9,162.1600	1	9,162.1600
26	Gearbox SBD65-P-B-Φ50,speed rated=284,2.2kw	9,162.1600	1	9,162.1600
27	Gearbox SBD65-P-B-Φ50,speed rated=317,2.2kw	9,067.1200	1	9,067.1200
28	Gearbox SBD65-P-B-Φ50,speed rated=68,3kw	9,618.3700	1	9,618.3700
29	Gearbox XWD5-29-5.5,5.5kw	12,093.3000	1	12,093.3000
30	Gearbox DCY180-50-1N	25,923.9800	1	25,923.9800
31	Gearbox YKF272-180-II,2.2kw	40,767.8300	1	40,767.8300
32	Gearbox XWD8-71-7.5,7.5kw	19,369.8000	1	19,369.8000
33	Gearbox Flender Sr No..4501155687.01.001,B3SH12D	604,474.7200	1	604,474.7200
34	Gearbox FlenderSr No..4501155687.04.001,B3SH14D	928,762.1100	1	928,762.1100
35	Gearbox FlenderSr No..45o1141774.04.001,B3DH9D	370,668.4600	1	370,668.4600
36	Gearbox DCY160-40-1T,7.5kw	25,887.8700	1	25,887.8700
37	YOX400 liquid coupling	16,651.5700	1	16,651.5700
38	YOX II Z405 liquid coupling	17,069.7600	1	17,069.7600
39	YOX500 liquid coupling	17,297.8600	2	34,595.72
40	YOX560 liquid coupling	17,487.9500	1	17,487.9500
41	YOX360 liquid coupling	16,157.3400	1	16,157.3400

42	Chain for travel motor16A-1	361.1641	100	36,116.41
43	Sprocket tooth form 16A,number of teeth13	1,045.4750	5	5,227.375
44	Big sprocket tooth form 16A,number of teeth27	1,254.5700	7	8,781.99
45	Big sprocket tooth form 12A,number of teeth38	1,330.6050	10	13,306.050
46	Driven sprocket tooth form 12A,number of teeth25	1,330.6050	13	17,297.865
47	Chain 12A-1	361.1641	100	36,116.41
48	Hydraulic liquid coupling ML6-55X112/42X112-MT6B	570.2600	1	570.2600
49	Hydraulic liquid coupling MLL5-I-200-48X112/40X112-MT5	475.2200	1	475.2200
50	Hydraulic liquid coupling ML38X82/25X62MT3B	494.2200	1	494.2200
51	Hydraulic liquid coupling ML4-42X112/30X82-MT4B	513.2300	1	513.2300
52	Pump PGH4-2X/040RE11VE4	32,580.8100	1	32,580.8100
53	High pressure pump 10-5 CY14-1D	12,678.7600	1	12,678.7600
	Total			2,580,918.75

Step 2: List out all the items and arrange them in the descending value of annual consumption value.

Table 10
Descending value of mechanical spare parts.

No	Description	Unit cost in birr	Annual demand	Annual consumption value
34	Gearbox FlenderSr No..4501155687.04.001,B3SH14D	928,762.1100	1	**928,762.1100**
33	Gearbox Flender Sr No..4501155687.01.001,B3SH12D	604,474.7200	1	**604,474.7200**
35	Gearbox FlenderSr No..45o1141774.04.001,B3DH9D	370,668.4600	1	**370,668.4600**
24	Bearing oscillating bearingGE120ES-2RS	10,777.8988	8	**86,223.1904**
31	Gearbox YKF272-180-II,2.2kw	40,767.8300	1	**40,767.8300**
20	Bearing 22228cc/w33/c3	6,672.0325	6	**40,032.195**
17	Bearing 22315	4,562.0738	8	**36,496.5904**
42	Chain for travel motor16A-1	361.1641	100	**36,116.41**
47	Chain 12A-1	361.1641	100	**36,116.41**
39	YOX500 liquid coupling	17,297.8600	2	**34,595.72**
52	Pump PGH4-2X/040RE11VE4	32,580.8100	1	**32,580.8100**
30	Gearbox DCY180-50-1N	25,923.9800	1	**25,923.9800**
36	Gearbox DCY160-40-1T,7.5kw	25,887.8700	1	**25,887.8700**
32	Gearbox XWD8-71-7.5,7.5kw	19,369.8000	1	**19,369.8000**
40	YOX560 liquid coupling	17,487.9500	1	**17,487.9500**
46	Driven sprocket tooth form 12A,number of teeth25	1,330.6050	13	**17,297.865**
38	YOX II Z405 liquid coupling	17,069.7600	1	**17,069.7600**
37	YOX400 liquid coupling	16,651.5700	1	**16,651.5700**
41	YOX360 liquid coupling	16,157.3400	1	**16,157.3400**
12	Bearing UCF310	1,267.8763	12	**15,214.5156**
45	Big sprocket tooth form 12A,number of teeth38	1,330.6050	10	**13,306.050**
53	High pressure pump 10-5 CY14-1D	12,678.7600	1	**12,678.7600**
29	Gearbox XWD5-29-5.5,5.5kw	12,093.3000	1	**12,093.3000**
13	Bearing UCF311	1,446.5575	8	**11,572.46**
28	Gearbox SBD65-P-B-Φ50,speed rated=68,3kw	9,618.3700	1	**9,618.3700**
25	GearboxSBD65-P-B-Φ50,speed rated=44,2.2kw	9,162.1600	1	**9,162.1600**
26	Gearbox SBD65-P-B-Φ50,speed rated=284,2.2kw	9,162.1600	1	**9,162.1600**
27	Gearbox SBD65-P-B-Φ50,speed rated=317,2.2kw	9,067.1200	1	**9,067.1200**
44	Big sprocket tooth form 16A,number of teeth27	1,254.5700	7	**8,781.99**
15	Bearing UCK311	849.6863	8	**6,797.4904**
14	Bearing UCK309	610.1775	10	**6,101.775**
8	Bearing F311	332.6513	16	**5,322.4208**
10	Bearing K209	380.1725	14	**5,322.415**
6	Bearing SY508M	326.9488	16	**5,231.1808**
43	Sprocket tooth form 16A,number of teeth13	1,045.4750	5	**5,227.375**
4	Bearing FY508M	507.5313	10	**5075.313**
22	Bearing seat SNK211	541.7463	8	**4,333.9704**
3	Bearing T311	288.9313	14	**4,045.0382**
1	Bearing T309	201.4913	14	**2,820.8782**
2	Bearing F310	216.6988	13	**2,817.0844**
16	Bearing 6211	469.5138	5	**2,347.569**
23	Bearing DGBB118	456.2075	5	**2,281.0375**

19	Bearing P310	216.6988	7	**1,516.8916**
9	Bearing T312	368.7675	4	**1,475.07**
18	Bearing P308	180.5825	8	**1,444.66**
11	Bearing FC211	216.6988	6	**1,300.1928**
7	Bearing FL207	195.7888	6	**1,174.7328**
21	Bearing DGBB144	171.0775	6	**1,026.465**
5	Bearing FY505M	288.9313	3	**866.7939**
48	Hydraulic liquid coupling ML6-55X112/42X112-MT6B	570.2600	1	**570.2600**
51	Hydraulic liquid coupling ML4-42X112/30X82-MT4B	513.2300	1	**513.2300**
50	Hydraulic liquid coupling ML38X82/25X62MT3B	494.2200	1	**494.2200**
49	Hydraulic liquid coupling MLL5-I-200-48X112/40X112-MT5	475.2200	1	**475.2200**
	Total			2,580,918.75

Step 3: Accumulate value and add up number of items and calculate percentage on total inventory in value and in number.

Cumulative percentage of item = $\frac{\text{item number grouped in one category}}{\text{total number of items}}$

Annual consumption value percentage = $\frac{\text{annual consumption value of item}}{\text{total annual consumption value}}$

Table 11
Shows cumulative items % age and %age of annual consumption value.

No	Cumulative percentage of items	Unit price in birr	Annual consumption value	Percentage of annual consumption value	Percentage cumulative of annual consumption value
34	**1.89**	**928,762.1100**	**928,762.1100**	**35.99**	**35.99**
33	**3.77**	**604,474.7200**	**604,474.7200**	**23.42**	**59.43**
35	**5.66**	**370,668.4600**	**370,668.4600**	**14.36**	**73.79**
24	**7.55**	**10,777.8988**	**86,223.1904**	**3.341**	**87.639**
31	**9.43**	**40,767.8300**	**40,767.8300**	**1.58**	**75.37**
20	**11.32**	**6,672.0325**	**40,032.195**	**1.551**	**90.624**
17	**13.21**	**4,562.0738**	**36,496.5904**	**1.414**	**92.038**
42	**15.09**	**361.1641**	**36,116.41**	**1.399**	**97.588**
47	**16.98**	**361.1641**	**36,116.41**	**1.399**	**98.987**
39	**18.87**	**17,297.8600**	**34,595.72**	**1.340**	**81.406**
52	**20.75**	**32,580.8100**	**32,580.8100**	**1.26**	**76.63**
30	**22.64**	**25,923.9800**	**25,923.9800**	**1.004**	**77.634**
36	**24.53**	**25,887.8700**	**25,887.8700**	**1.003**	**78.637**
32	**26.42**	**19,369.8000**	**19,369.8000**	**0.751**	**79.388**
40	**28.30**	**17,487.9500**	**17,487.9500**	**0.678**	**80.066**
46	**30.19**	**1,330.6050**	**17,297.865**	**0.670**	**93.672**
38	**32.08**	**17,069.7600**	**17,069.7600**	**0.661**	**82.067**
37	**33.96**	**16,651.5700**	**16,651.5700**	**0.645**	**82.712**
41	**35.85**	**16,157.3400**	**16,157.3400**	**0.626**	**83.338**
12	**37.74**	**1,267.8763**	**15,214.5156**	**0.589**	**94.261**
45	**39.62**	**1,330.6050**	**13,306.050**	**0.516**	**93.002**
53	**41.51**	**12,678.7600**	**12,678.7600**	**0.491**	**83.829**
29	**43.40**	**12,093.3000**	**12,093.3000**	**0.469**	**84.298**
13	**45.28**	**1,446.5575**	**11,572.46**	**0.448**	**92.486**
28	**47.17**	**9,618.3700**	**9,618.3700**	**0.373**	**88.012**
25	**49.06**	**9,162.1600**	**9,162.1600**	**0.355**	**88.367**
26	**50.94**	**9,162.1600**	**9,162.1600**	**0.355**	**88.722**
27	**52.83**	**9,067.1200**	**9,067.1200**	**0.351**	**89.073**
44	**54.72**	**1,254.5700**	**8,781.99**	**0.340**	**94.601**
15	**56.60**	**849.6863**	**6,797.4904**	**0.263**	**95.067**
14	**58.49**	**610.1775**	**6,101.775**	**0.236**	**95.303**
8	**60.38**	**332.6513**	**5,322.4208**	**0.206**	**99.193**
10	**62.26**	**380.1725**	**5,322.415**	**0.206**	**96.132**
6	**64.15**	**326.9488**	**5,231.1808**	**0.203**	**99.396**
43	**66.04**	**1,045.4750**	**5,227.375**	**0.203**	**94.804**
4	**67.92**	**507.5313**	**5,075.313**	**0.197**	**95.710**
22	**69.81**	**541.7463**	**4,333.9704**	**0.168**	**95.493**
3	**71.70**	**288.9313**	**4,045.0382**	**0.157**	**99.553**
1	**73.58**	**201.4913**	**2,820.8782**	**0.109**	**99.914**
2	**75.47**	**216.6988**	**2,817.0844**	**0.109**	**99.696**
16	**77.36**	**469.5138**	**2,347.569**	**0.091**	**95.838**

23	**79.25**	**456.2075**	**2,281.0375**	**0.088**	**95.926**
19	**81.13**	**216.6988**	**1,516.8916**	**0.059**	**99.805**
9	**83.02**	**368.7675**	**1,475.07**	**0.057**	**96.189**
18	**84.91**	**180.5825**	**1,444.66**	**0.050**	**99.994**
11	**86.79**	**216.6988**	**1,300.1928**	**0.040**	**99.746**
7	**88.68**	**195.7888**	**1,174.7328**	**0.040**	**99.954**
21	**90.57**	**171.0775**	**1,026.465**	**0.040**	**100**
5	**92.45**	**288.9313**	**866.7939**	**0.034**	**99.587**
48	**94.34**	**570.2600**	**570.2600**	**0.022**	**95.325**
51	**96.23**	**513.2300**	**513.2300**	**0.020**	**95.513**
50	**98.11**	**494.2200**	**494.2200**	**0.019**	**95.729**
49	**100**	**475.2200**	**475.2200**	**0.018**	**95.747**
	Total		**2,580,918.75**		

Step 4: Draw a curve of percentage items and percentage value by using Pareto diagram.

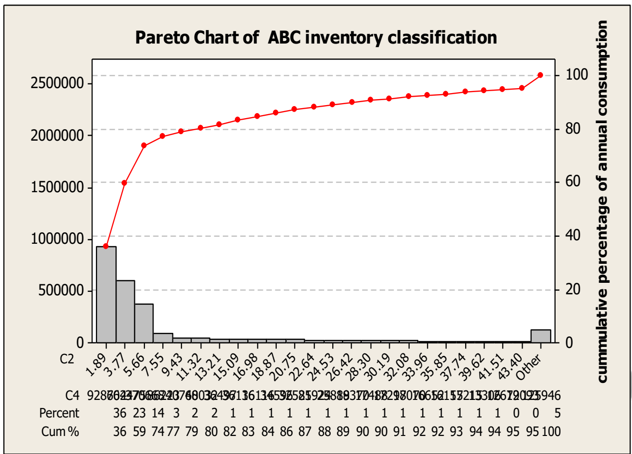

Figure 3: shows which spare part is required close control or not.

Based on Pareto's Law: "the vital few and the trivial many" of spare parts are easily identified. As we have seen in the above diagram the first four items have maximum annual consumption value. To minimizing total spare part inventory costs the company should minimizing inventory costs of the first four items by using different inventory control system.

Step 5: classified these spare parts into A, B, and C category

Table 12

Shows mechanical spare parts category and which category is firstly need action.

Category	Items	Percentage of items	Percentage of annul consumption value	Action
Class A	34,33,35,24, 31, 20	12%	80%	Close control
Class B	17,42,47,39, 52,30,36,32, 40,46,38,37, 41,12,45,53, 29,13	34%	15.4%	Regular review
Class C	28,25,26,27, 44,15,14,8,1 0,6,43,4,22,3 ,1,2,16,23,19 ,9,18,11,7,21 ,5,48,51,50,4 9	54%	4.6%	Infrequent review

According to the above table from all these spare parts 12% of spare parts are consumed 80% annually. For minimizing total inventory cost of spare parts, the management of inventory planning will be focused on **A** classification and required close control. Spare parts which are classified under **B** and **C** are required regular review and infrequent review respectively. Additional to this the analysis is described graphically as the following.

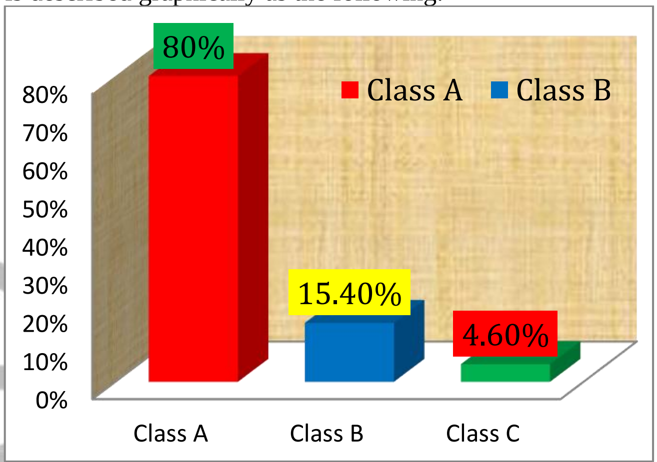

Figure 4: Mechanical spare parts classification in A, B and C classis by their annual % age

NOTE: Classifying spare parts by using HML and ABC classification methods are not enough for minimizing inventory costs of these spare parts. It is using as a precondition for inventory planning and controlling of the spare parts. After classifying those spare parts by using these methods we have analyzed their costs through optimal economic order quantity (Q*) as the following analysis.

4.5.3. Proposed cost analysis by using optimal economic order quantity

This method is used to analysis or used to answer the question when to order, how much to order and the detail analyses are:

$$Q^* = \sqrt{\frac{2DCo}{Cc}}$$

$$= \sqrt{\frac{2 \text{ x } 474 \text{ x } 640{,}843.58}{8{,}990.08}}$$

$$= \sqrt{67{,}576.675}$$

Q*=<u>260pcs</u>

Annual holding cost (**H**) = (Q*/2) x (Cc)

= (260pcs/2) x (8,990.08birr/pcs)

=130 x 8,990.08birr/pcs

H = <u>1,168,710.4birr/year</u>

Annual setup cost (S) = (D/Q*) x (Co)

= (474pcs/260pcs) x (640,843.58birr)
= (1.823) x (640,843,58birr)

S = 1,168,307.14birr/year

Optimal average inventory (**I**) = Q*/2
= 260/2

I = **130pcs**

Expected number of order (N) = D/Q*
= 474pcs/260pcs

N = **2times**

$$\text{Expected time between order } (\mathbf{T}) = \frac{\text{Number of working day per year}}{\text{N}}$$

= 300days/2

T = **150days**

$$\text{Inventory turns} = \frac{\text{Annual demand}}{\text{optimal average inventory}}$$

= 474pcs/130pcs

Inventory turns = 4

Reorder point = demand per day x lead time
= 2pcs x 240 days

Reorder point = 480 pcs

Total annually proposed inventory cost (**TICp**) = annual holding cost + annual setup cost = **H** + **S**
= 1,168,710.4birr + 1,168,307.14birr

TICp = 2,337,017.54birr/year

Therefore, the different between existing and proposed total inventory cost is:

TICe – TICp
2,691,813.23birr – 2,337,017.54birr

= 354,795.69birr/year

Based on the above analysis the company should order two times per year rather than one times. Total existing inventory costs of these mechanical spare parts can be reduced from 2691813.23birr to2337017.54birr by using economic order quantity. This cost minimization is formed by increasing annual setup costs of spare parts from the existing one.

5. Conclusion and recommendation

5.1. Conclusion

This research presents a literature review on inventory management of mechanical spare parts at inventory control and planning department. From this investigation and analysis, we can conclude that ABC classification of spare parts in categories is an important tool to prioritize inventory management efforts and when the spares are counted, which spare parts are need close control or not. The **HML** analysis is useful for keeping control over consumption at departmental levels, for deciding the frequency of physical verification, and for controlling purchases. The existing total spare part inventory costs minimizing by using different inventory control methods as we have seen in the above analysis.

The maximum inventory cost that become due to the lack well of inventory management system, communication between inventory control and planning department and maintenance department will be solved as the above analysis. If the company is used to practice this case study in practical, it might increase its profit by minimizing its total existing inventory costs to the proposed total inventory costs. This existing cost is decreased from **2,691,813.23birr/year** to **2,337,017.54birr/year** that means the company can save **354,795.69birr/year**. Generally, this study is used to make close control in order to avoid the gap in operation, protecting inventories from deterioration and increasing the productivity of the company.

5.2. Recommendation

As an output of my study, I would like to recommend to the company;
The company should identify which spare parts required close control, regular review and infrequent review. The company should apply economic order quantity model and ABC and HML inventory classification system in its inventory management. The company should check the standard code of spare parts during purchase and the relationship inventory planning and control (IPC) department and maintenance department. The company should know when and how many spare parts are ordered. The company also should apply this inventory control analysis in its all-inventory department, i.e. this case study is not limited only on mechanical spare parts it can applied in all inventory types.

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