Development of an Optimal Inventory Management System in Khulna Shipyard Limited- A Case Study.

by

Md. Safiq Uzzaman

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Engineering in Industrial Engineering and Management

Khulna University of Engineering & Technology
Khulna 920300, Bangladesh

December 2019

Declaration

This is to certify that the thesis work entitled *"Development of an Optimal Inventory Management System in Khulna Shipyard Limited- A Case Study"* has been carried out by *Md. Safiq Uzzaman* in the Department of *Industrial Engineering and Management*, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above thesis work or any part of the work has not been submitted anywhere for the award of any degree or diploma.

Signature of Supervisor

Dr. Azizur Rahman
Associate Professor
Department of IEM
KUET, Khulna-9203

Signature of Candidate

Md. Safiq Uzzaman
Roll no.- 0811554
Master of Science in IEM
Department of IEM, KUET

Approval

This is to certify that the project work submitted by *Md. Safiq Uzzaman* entitled *"Development of an optimal Inventory Management System in Khulna shipyard Limited- A Case Study "* has been approved by the Board of Examiners for the partial fulfillment of the requirements for the degree of *Master of Science* in *Industrial Engineering and Management* in the department of *Industrial Engineering and Management,* Khulna University of Engineering & Technology, Khulna, Bangladesh in December 2019.

BOARD OF EXAMINERS

1.	22.12.19 Dr. Azizur Rahman Associate Professor Department of Industrial Engineering and Management Khulna University of Engineering & Technology, Khulna	Chairman (Supervisor)
2.	Head of the Department Department of Industrial Engineering and Management Khulna University of Engineering & Technology, Khulna	Member
3.	Dr. Md. Kutub Uddin Professor Department of Mechanical Engineering Khulna University of Engineering & Technology, Khulna	Member
4.	22.12.19 Md. Mahbubur Rahman Assistant Professor Department of Industrial Engineering and Management Khulna University of Engineering & Technology, Khulna	Member
5.	22/12/19 Dr. Md. Mosharraf Hossain Professor Department of Industrial and Production Engineering Rajshahi University of Engineering & Technology, Rajshahi	Member (External)

ACKNOWLEDGMENT

Foremost, the author wishes to convey his gratitude to the Almighty Allah for accomplishing the thesis work.

Afterwards, the author would like to express his extreme gratitude to the respected thesis supervisor Dr. Azizur Rahman, Associate Professor, Department of IEM, KUET for his encouragement, valuable comments, suggestions, and intellectual supervision in developing this research work. The author could not be capable to prepare it in the absence of his deepest scrutiny and strong support. He has always been generous with his time, knowledge and ideas. The author would also forwarded his heartfelt thanks to Dr. Kazi Arif-Uz-Zaman, Assistant professor, IEM, KUET for his valuable advices, cordial support, contribution and inspiration. The author has learnt a lot from him. Furthermore, the author feels gratefulness to Dr. Rafiquzzaman, Assistant professor, Head of IEM, KUET for supporting all kinds of facilities throughout this work.

The author is highly grateful to the managing director of khulna shipyard limited for giving the permission of MSc studies. He is also thankful to the employees of this shipyard for their cordial assistance and providing all the information and data required in the thesis work.

The author makes an effort to pay his heartfelt satisfaction to his parents and wife for the motivation and relentless patience over the years.

Finally, the author would deliver his thankfulness to all the people mentioned or not but associated with this thesis work for their hospitality, assistance and collaboration. Last but no means least, I apologize to all who helped me and whose names could not be individually acknowledged.

December 2019 The Author

ABSTRACT

Inventory, the key component of any organization is the stock of any goods or asset that are required for manufacturing or assembly of the product to maintain the plant. The fundamental function of an inventory system is to keep track of and maintain the inventory levels, determine both the order size and replenishing period. Inventory is directly related with the manufacturing cost. As a result, Inventories influence the most essential portion of current resources of a greater numbers of companies. Thus, sufficient amount of capital is tied up due to maintaining the inventories in bulk by the organization. Poor inventory management may cause under-stocking or over-stocking including higher operating cost of the items. Thus, a firm ignoring the control and monitoring of inventories might be at risk of its ultimate profitability and may collapse in the long run. As a result, it is clearly necessary to manage inventories effectively and properly for the avoidance of unnecessary investment.

In the study it was found that Khulna Shipyard Limited frequently fails to maintain inventory level/ stock for the regular consumption of raw materials to meet the lead time of the demand. Demand for replenishment of inventory items are placed when it is required. The shipyard follows the traditional method of purchasing the raw materials and other items. As a result, the shipyard is unable to maintain delivery schedule of the project due to shortages of required materials and also due to the late delivery of proper materials from the suppliers. On the contrary, the plant also faces over stocking of materials in the warehouse. Both these situations act as a catalyst to increase the total inventory expenditure of the shipyard. Besides, the workers have to work in extra time (overtime) to finish the job quickly. Ultimately, the shipyard can not maintain the desire quality of the finished product and production cost also increases. As the ship cannot undock within the schedule time and the construction yard is engaged, the shipyard cannot dock the ship under pipeline within predetermined schedule. As a result, customer dissatisfaction may raise due to inferior quality, late delivery, failure to dock and high production cost of ships/ product. Moreover, this shipyard may lose their customer day by day. Thus the above discussion stated that, there is a room for improvement to identify the procedure of managing and maintaining inventory at khulna shipyard limited.

One of the most important goals in inventory management decision is how much inventory should be made and when to submit an order. If a firm procures higher quantities of inventory, carrying cost also increases. On the other hand, if the firm purchases less quantities, more orders to be placed which increases ordering cost. Therefore, the order quantity at a particular time should be controlled by balancing the ordering and carrying cost. Considering both the costs, EOQ model is applied to decide the optimal order quantity to be replenished at a specific order time for the optimization of carrying and ordering cost and also confirming the availability of material when required. In addition, ROP model provides information when to order the item. Safety stock policy can be adopted for providing protection against the variation and uncertainty in both lead time and demand.

It was observed that managing inventory at ship construction and repairs industry is more complicated due to the distinctive and uncertainty nature of demand. In this thesis, a sample for inventory items from a major workshop of khulna shipyard limited was identified and demand data for these items was collected. Accordingly, required data for cost calculation was gathered to implement EOQ, ROP and safety stock for the selected inventory items. Finally, the thesis work has been completed with several specific recommendations for the management of Khulna Shipyard Limited and suggestions for carrying out future research.

Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

GLOSSARY

KSY	Khulna Shipyard Limited
EOQ	Economic Order Quantity
ERP	Enterprise Resource Planning
BDT	Bangladesh Taka
PO	Purchase Order
ROP	Reorder Point
SKU	Stock Keeping Unit
SS	Safety Stock
SD	Standard Deviation
M	Mean
LT	Lead Time

C H A P T E R 1

Introduction

1.1 General

Pursuant to chase et al [1], inventory refers to the stock of any goods or assets served in a business organization to continue the uninterrupted production. The word inventory was initially documented in the year of 1601. The French terminology inventaire, or "detailed of goods" originated in 1415. In simple terms, inventory is comprised of resources which are ready for selling in next time in the usual way of business operations.

An inventory system is the policy to keep track of inventory levels and maintain the levels, determine both the order size and replenishing period. Inventory control implies the availability of inventory items when and where it is necessary by stocking sufficient number and types of inventories. The summation of these relevant activities required for the purchase, stock piling, sales, removal or utilization of items is considered as inventory management.

This chapter emphasizes on the background of the shipyard, the objectives of the research, problem statement, justification and is finally concluded with the limitations of the study.

1.2 Background of Khulna Shipyard Limited

This thesis pertains to inventory management in khulna shipyard limited, the largest shipyard in Bangladesh. The shipyard is located at khulna on the western bank of river Rupsha. Approximately one thousand and five hundred employees are working in this shipyard. Khulna shipyard generally builds, renovates and repairs all types of inland, coastal and sea going vessels including war craft. Generally it provides the services for Bangladesh Navy, Bangladesh Coast Guard as well as other government and civil organizations throughout the country. About seventy ships per year are constructed and repaired here. Among these twenty ships are being newly constructed and the remaining are being repaired. Moreover, the company has a glorious history to provide technical support in manufacturing of engineering parts for sugar mills, paper mills, electric power stations, cement factory, jute mills, etc.

The shipyard was started his glorious journey in manufacturing steel boat in the year of 1957. Upto 1967 from the very beginning it was engaged with the collaboration of M/S. stulcken shoon, Humburg; M/S. burness corlett, England and M/S. maieform, Geneva. Afterwards all the control was vested with its own expert engineers under the ministry of Industry. At last this shipyard was handed over to Bangladesh Navy under the ministry of Defence since 1999 [2].

Khulna shipyard owns one warehouse named KSY Main Store. From the warehouse data base, it was obtained that the store owns nearly two thousands of inventory items.

1.3 Objectives of the Thesis

The objectives of the thesis are discussed below:

i) To determine an optimal order quantity of inventory items to ensure continuous supply of materials during production.
ii) To measure the total inventory costs optimizing inventory carrying and ordering costs.
iii) To identify an optimal re-order level and safety stock of inventory items.

1.4 Problem Statement

Inventory management is performed from the smallest company to bigger industries. Effective inventory management enables a firm to decrease the total costs through gaining the scale operational efficiencies. It assists the organization improving product availability and buffering against daily uncertainties the organizations faces.

Khulna shipyard limited, over the years, has been improved into a prominent shipbuilding industry by offering the commitments which are quality, timely delivered and competitive price to the customers. As a result, a good number of ships for building and repairing are increasing day by day. But, now a days it is observed that the schedule of ship building and repairing becomes difficult to maintain due to unavailability of material during production. It was found that this shipyard follows the traditional method of purchasing for inventory items. Demand for replenishment of inventory items are placed when required. Sufficient additional stock is not maintained to meet the lead time demand. Therefore, shortage of materials frequently occurs during production. Besides, it appeared that the management does not follow analytical procedure in setting reorder points. As a result, the shipyard faces over stocking of materials in the warehouse. Hence the total expenditure of the shipyard is increased. Based On the average, around 40% of current resources involved with the inventory items of this shipyard.

Those problems can be avoided by ordering optimal quantities of inventory items at right time and the minimum safety stock is maintained in order to meet customer demand during lead time. EOQ (economic order quantity) and ROP (reorder level) models can be effective to find out the optimum quantity to order and when to order respectively. Determination of safety stock can be useful to avoid uncertainties in demand and lead time.

The varieties of items required for repairing each ship make the demand is difficult to estimate. Consequently, managing inventories in the shipyard is also so challenging due to variation and uncertainty of demand. However, Theories, equations, models and best logistic practices gathered throughout the thesis work makes it possible for the shipyard to minimize its levels of inventories to a significant extent without any undesirable impact on production. It carries a beneficial effect on shipyard's profitability.

1.5 Justification

Many companies including khulna shipyard limited have not any proper method to manage their inventories. A few number of studies was done on inventory ordering models, but these models were not yet developed to implement inventory management systems in khulna shipyard limited. As a consequence, it is expected that the outcome of the study becomes useful for the shipyard to establish an effective inventory management system. This could help the shipyard to determine when to order for required items without shortage of required inventory level.

1.6 Requirements for Effective Inventory Management

Basically management has to perform two functions regarding inventory. One is to control and monitor the inventory levels and another is to decide how much and when to replenish. For managing the inventory effectively, the manager has to meet the following requirements.

i. A method of monitoring inventory items for both available in the firm and on procurement.
ii. A effective system of forecasting of demand indicating probable forecasting error.
iii. Understanding of lead time and its variability.
iv. Reliable determination of total inventory cost.
v. A realistic classifying system of inventory.

1.7 Functions of Inventory

The functions [2] of inventory are described as follows:

i. A reasonable level of inventory is normally carried out to satisfy anticipated or expected customer or user demand.
ii. Demand is usually unknown with certainty. As a result, extra amounts of inventory named safety or buffer stocks are often held available to fulfil unexpected variations in demand.
iii. Additional stocks of inventories are occasionally accumulated to satisfy seasonal or cyclical demand in nature.
iv. Inventory is held to accept the benefit of price changes. A company frequently orders additional amounts of inventory to take advantage of price discounts as a hedge to avoid anticipated price increase in the future or get a lower price by procuring in volume.

1.8 Scope of Inventory Management

Inventory management performs the following scopes.

i. The items are achieved in the optimum quantity at the lower cost at the right time to meet the uninterrupted production.
ii. Minimum inventories holds according to the market conditions.
iii. Market and economic conditions of supply and availability of materials can forecast.
iv. New materials are found from the potential supplier.
v. Product research and development may be improved.
vi. Maintaining of proper documents
vii. It minimizes company cost and time.

1.9 Symptoms of Poor Inventory Management

Lambert et al. [3] stated the following factors to analyze poor inventory management.

i. Increasing number of back orders.
ii. Increasing dollar investment in inventory with back orders remaining constant.
iii. High customer turnover.
iv. Increasing number of orders neglected.
v. Periodic lack of enough storage- space.
vi. Large variance in inventory turnover among distribution centers and among major inventories items.
vii. Obsolesce of materials in enormous quantities.

1.10 Limitations of the Study

Some limitations have been faced during the study of this research. The limitations are as follows:

i. All the inventory items had not been taken into consideration due to limited time frame.
ii. The study was conducted with the available limited data and time period.

iii. Most of the data was collected and there was no scope for gathering the entire information as being confidential.

C H A P T E R 2

Literature Review

2.1 Concept of Inventory Management

Inventory management [4] is a continuation method of planning, executing, organizing and monitoring the inventories which focuses on minimizing the capital investment in inventory that balances supply and demand. Precisely, inventory management is the process to make sure sufficient supply without additional oversupply by means of supervision of supply, stockpiling and accessibility of materials on order [5].

For the both of operational and financial points of view, inventory management acts as an essential function in continuous production. A good inventory management decreases the holding costs, ordering costs and related operational expenditures of a company and thereby, increases total profit. Flow of funds develops by saving on procurement and storage of the items that may be spent for other project. In addition, effective inventory management ensures satisfying the customer demand and regular production. L.R. Howard [6] detected that a good inventory management and control overcomes the acute problem of liquidity along with improvement of the yearly profit margin and considerable minimization in the running capital of the company.

Inventory management deals with the determination of the optimum level of funds for each unit of inventory and also concerns with the effective utilization of the inventory and the operation of an appropriate control and review system. The management of inventory needs precise planning to avoid the excess and shortage of inventory.

It is a matter of advantages to take the attention of higher management and to make the decision of the planning and the executive workforces. Moreover, the personnel concerned with production, sales, forecasting, inventory planning, marketing, material handling, finance, product designing, etc. is to be sincerely focused on inventory management and control problem.

2.2 Classification of Inventory

Depending on the process stage, inventory are classified as follows:

i. **Raw materials:** Raw materials are the basic inputs that are converted into finished product through the manufacturing process.

ii. **Work-in-progress:** work-in-progress is the semi-manufactured products that need some more work before they become finished goods for sale.

iii. **Finished goods:** Finished goods are completely manufactured products ready for sale.

Stock et al. [3] demonstrated the classification of inventory as following six categories depending on purpose of uses:

i. **Cycle stock:** Cycle stock is inventory that results from the replenishment of inventory sold or used in production. It requires to meet demand under conditions of certainty, that is when a firm can predict demand and replenishment times perfectly.

ii. **In-transit inventory:** In-transit inventories are items that routes from one location to another. They may be considered part of cycle stock even though they are not readily available for sale and/ or shipment until after they arrive at the destination.

iii. **Safety or buffer stock:** Safety or buffer stock is held in excess of cycle stock because of uncertainty in demand or lead time.

iv. **Speculation stock:** Speculation stock is inventory held for reasons other than satisfying current demand. For example, materials may be purchased in volumes larger than necessary in order to receive quantity discounts, because of a forecasted price increase, materials shortages or protect against the possibility of a strike.

v. **Seasonal stock:** Seasonal stock is a form of speculation stock that involves the accumulation of inventory before a season begins in order to maintain a stable labor force and stable production runs.

vi. **Dead stock:** Dead stock is inventory that no one wants, at least immediately.

2.3 Demand Management

2.3.1 Types of Demand

The demand is the system's output. It is usually a physical outflow. The demand is most critical and uncontrollable. Again, without demand there are no need to maintain inventory. Kinds of demand [7] may be categorized as shown in Figure 2.1.

Deterministic demand is exactly known where probabilistic demand is not known with time. Deterministic demand is of two types. Among them, static demand does not vary and the amount of demand is known with certainty. Another type is dynamic, which may have variation with time, but in the direction of variation, it is known with certainty.

Stationary distribution follows a probability distribution such as normal, gamma and Poisson with known parameters of demands. It is known or estimated from historical data. Non-stationary probabilistic demand performs as random that varies over time with regular changes in its direction.

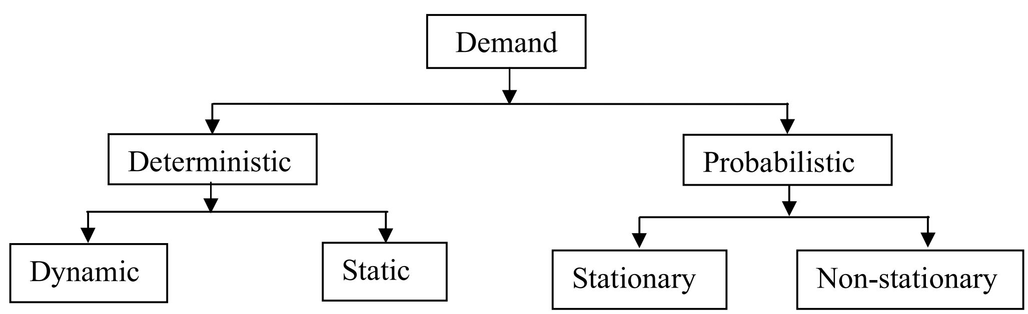


Figure 2.1: Demand classification

Besides, there are two types of demand based on the demand sources. One is independent demand which is finished goods delivered as end items to customers. The other is dependent demand which is a number of parts used to produce finished goods and the demand for each parts depends on production.

2.3.2 Demand Forecast

Adequate data result is required for efficient and effective forecasts. The traditional method to demand forecast is associated with the historical data of demand. All forecasting procedures are considered as the fact that if the more data are collected, the more estimation along with more accurate of the average demand and demand variability are obtained [8].

2.4 Inventory Costs

Following three basic costs related to inventories must be taken into consideration to adopt any decision having effects on inventory size: holding, ordering and shortage costs.

In general, inventories are roughly 50% of total investment of an organization and 70% of the price of items sold.

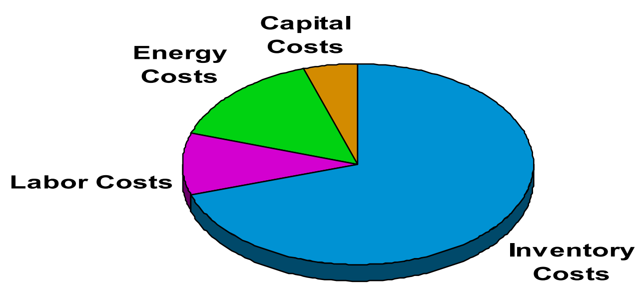


Figure 2.2: Inventory cost of organization.

2.4.1 Product Cost

Item cost refers to the cost of purchasing or manufacturing for single goods. In case of offered quantity discounts, the item cost acts as an important consideration. Supplier or vendor generally provides item cost.

2.4.2 Inventory Carrying Cost

Holding or carrying costs of inventory [9] are associated with physically presence of items in stock. Costs associated with insurance, interest, taxes, deterioration, depreciation, obsolescence, damage, wastage, pilferage, and warehousing costs (heat, light, rent, security). It also holds opportunity costs related to the investment occupied in inventory which can be used in other services. The cost to hold goods in inventory is computed in accordance with length of time, normally a year.

Carrying costs are expressed as a rate of unit cost or as an amount of money per item. Generally annual carrying costs varies from 20 % to 40 % of individual item price.

Annual holding or carrying cost, H = $\frac{Q}{2}H$ (2.1)

Where, Q = Order quantity in units

H= Holding cost per unit per year

2.4.3 Ordering Cost

The costs incurs for ordering and receiving of raw materials are termed as ordering costs [9]. It includes the total costs of inventories obtained by means of requisition purchases ordering, transportation, receiving, inspecting and storing. If the firm maintains inventories at more frequently, they have to place more orders and higher ordering cost incurs. Conversely, the large amount of inventory levels is required to place few orders and thus, ordering cost is found comparatively lower. As a result, ordering cost reduces with increasing the levels of inventories. Ordering costs are usually denoted as fixed amount of money per order, irrespective of order size.

Annual ordering cost = $\frac{D}{Q}S$ (2.2)

Where, Number of orders per year= $\frac{D}{Q}$ (2.3)

D= Demand in units per year

Q= Order size

S= Ordering cost

Following table 2.1 provides summary on ordering and carrying cost factors [10].

Table 2.1: Inventory cost factors

Ordering Cost	**Carrying Cost**
Producing and placing purchase orders	Capital cost
Processing and inspection of received inventory	Taxes
Supplier's Bill payment	Insurance
Inventory queries	Wastage
Utilities, telephone bills, etc. for commercial department	Obsolescence
Employees' salaries and wages for purchasing department	Employees' salaries and wages for warehouse
Stationary items- documents and papers for purchasing department	Warehouse costs regarding utilities and building.
	Stationary items- documents and papers for warehouse

Figure 2.3 illustrates the general relationship between carrying cost and ordering cost. The costs are inversely proportional to each other. Different order sizes have a substantial effect on total cost. The minimum total inventory cost is achieved by balancing carrying and ordering costs. Optimum order quantity (EOQ) is addressed at the lowermost point of total cost curve. This happens when ordering cost equals to holding or carrying cost. Anyway, the other costs such as transportation, shortage or in-transit inventory carrying costs may have an effect on total cost subject to various logistic processes.

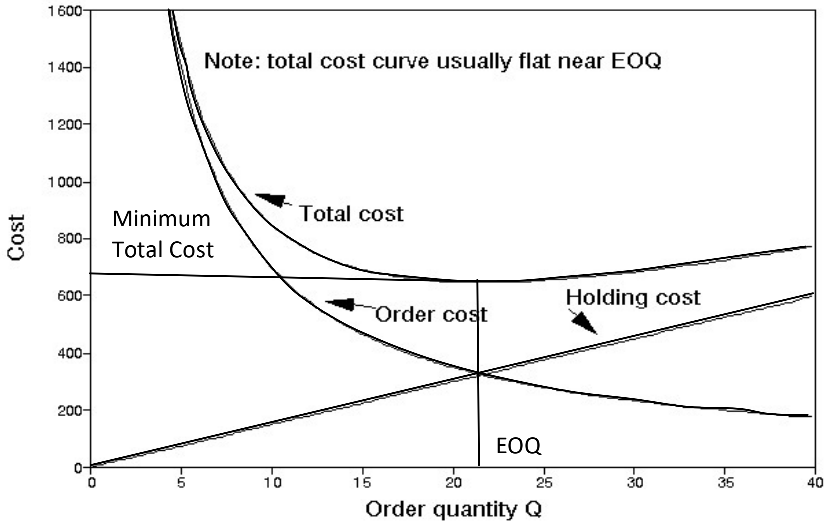


Figure 2.3: Cost minimization goal

2.5 Basic Inventory Terms

2.5.1 Lead Time

Lead time indicates to the time period between placing and receiving an order.

2.5.2 Safety Stock

Safety stock is the additional units of inventory used to protect against probable stock-outs during lead time. The safety stock should be carried out in case of uncertainty in the demand of the item and/ or the lead time.

The amount of safety stock depends on the following issues.

i. The average demand rate and average lead time.
ii. Demand and lead time variability.
iii. The expected service level.

Figure 2.4 illustrates the safety stock.

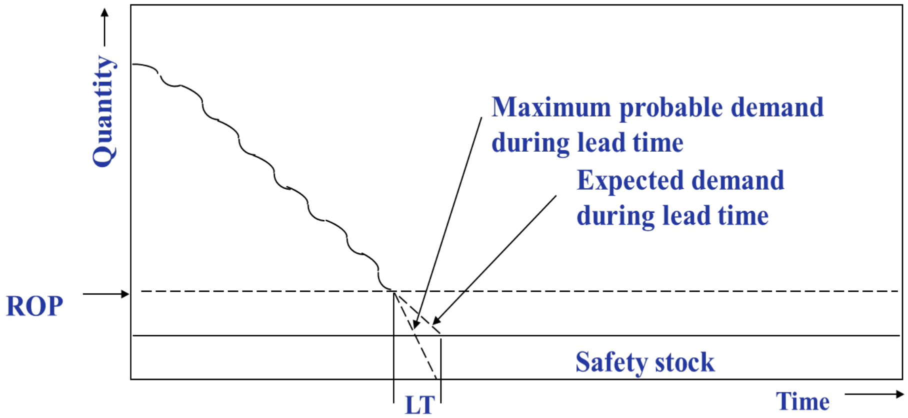


Figure 2.4: Safety stock.

2.5.3 Reorder Point

A reorder point (ROP) is the unit quantity available in hand which initiates the replenishment of inventory in a predetermined amount. This amount usually contains expected demand during lead time along with buffer stock which decrease the probability of stockout during lead time.

Factors to determine the Reorder Point:

i. Demand rate
ii. Lead time
iii. Variability of demand and/or lead time
iv. Stockout risk

Figure 2.5 shows the ROP with the safety stock.

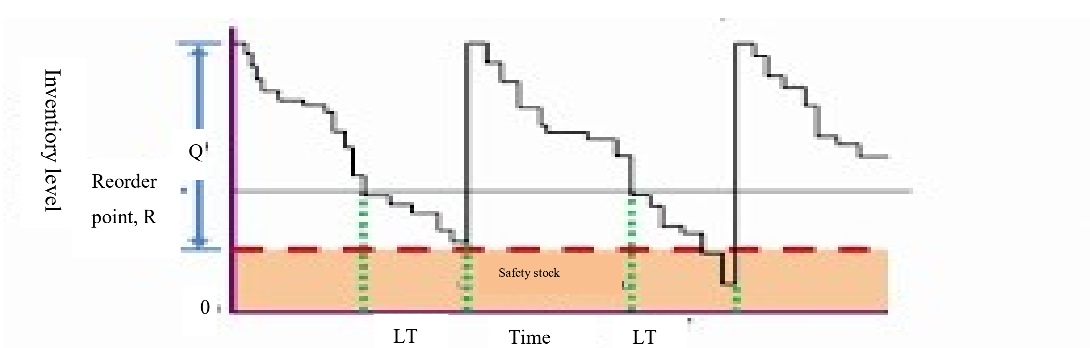


Figure 2.5: Reorder point.

2.5.3 Service Level

Service level refers to the probability of demand that does not exceed the supply during lead time. In the figure 2.6, it is shown clearly.

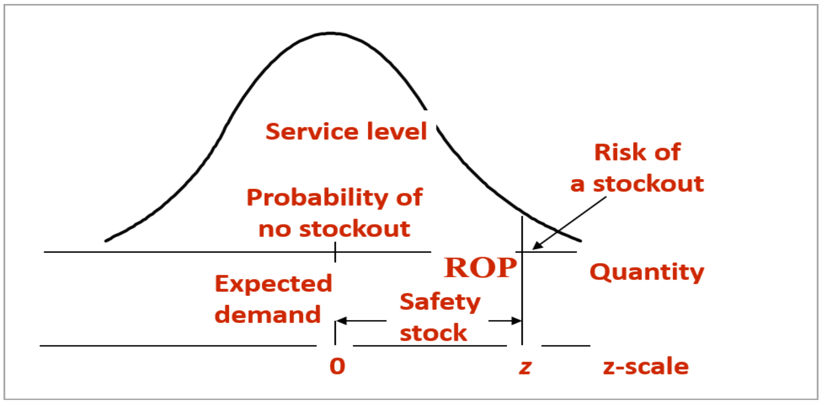


Figure 2.6: Service level for normal distribution

2.6 Inventory Control Systems (ABC analysis)

inventory classification systems contributes to assign the time and investment in inventory management. It enables firms to consider number of product lines and significant amount of stock-keeping units (SKU). The most commonly used classification system is ABC analysis.

As stated by Onwubolu and Dube [10], ABC analysis applied to an inventory system, identifies the importance of inventory items and the level of control employed on inventories. The outcome of classifying importance is achieved by the factors of the usage rate for individual item and its unit cost. Annual usage value for each item is determined by multiplying both of these two factors. The larger annual usage value, the higher top ranking is the item. Hence, tight monitoring is most essential for fast moving items with a high unit price. On the other hand, for slow moving items with less unit price, convenient process of control should be applied. Because, the expenses of the stock monitor system may be excessive comparing to the advantages to be achieved. While conducting ABC analysis, the annual usage value of inventory items is positioned in the descending order with the maximum usage value at topmost. Based on importance and the annual usage vale, a firm's inventory is divided into three classifications-A, B, or C. Afterwards, a cumulative curve indicating in Figure 2.7 is found putting this data in the graph.

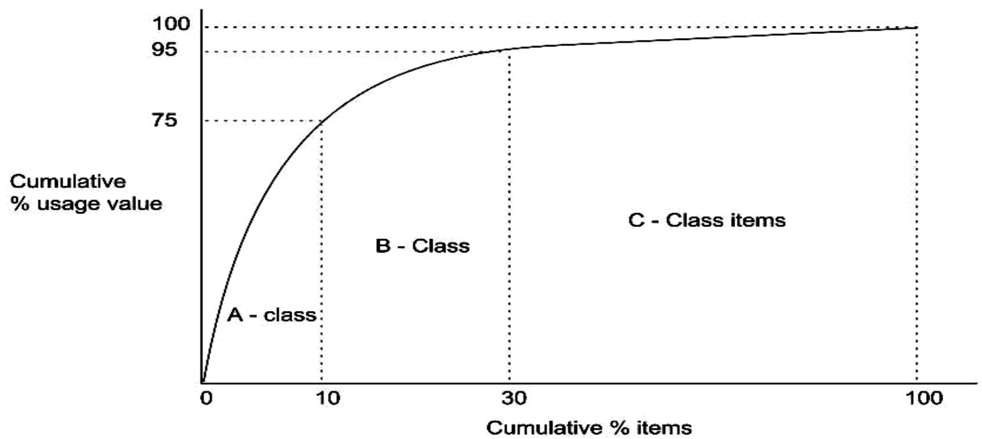


Figure 2.7: ABC curve

According to Fuerst [11], 'A' items usually contain about 10 percent of inventory which include approximately 50 percent of annual dollar volume. The classification 'B' items contain roughly 40 percent of inventory items which include nearly 40 percent of annual dollar volume. The rest items, C items, account for only 10 percent of annual dollar volume, yet account for about 50 percent of the items.

Figure 2.8 depicts on the conception of ABC analysis.

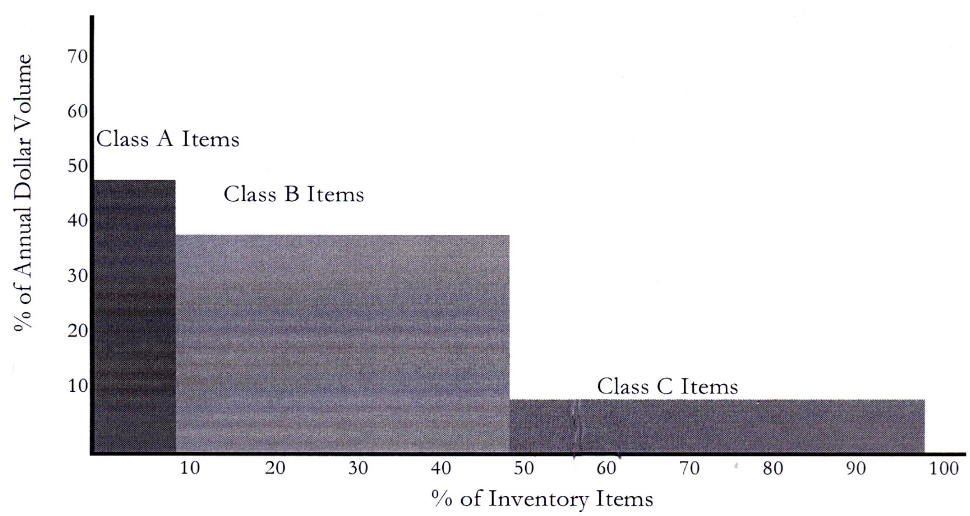


Figure 2.8: Basic illustration of ABC classification

A class items requires most strict inventory control applying strongly related inventory model for ordering decisions. Precise demand forecasting, major steps in calculating inventory costs, continuous monitoring of the stock level, proper record keeping and daily monitoring of the inventory turnover ratios of A items are the scopes for development.

On the other hand, B class items includes a simple, considerable inventory models, considerable forecasting method and periodic review of stock (loose control) for monitoring the inventory level and rough estimation of lead times.

C class items need not any inventory model, demand forecasting and estimation of inventory cost. Heuristic rules on practical decision is sufficient. It may be allowed more safety stocks and large order quantities.

2.7 Concept of Inventory Model and Inventory Policy

An inventory model tries to define the decision making policy regarding inventory management problem. Basically, the inventory model determines (a) what amount of inventory to purchase and (b) when to purchase. With a view to addressing these questions, it is a prerequisite to establish an inventory model which includes decision variables. The variables are demand, lead time, inventory costs, item purchase cost and any uncertainties related to demand and lead times. In addition, it may involve any specific approach especially quantity discounts, inflation, fund, space limitations, etc.

Naddor [12] represented inventory model as a mathematical expression which includes inventory carrying cost, ordering cost and shortage cost in which minimum two of these costs can be controlled.

Furthermore, Inventory policy is an operating process to apply an inventory model. Undoubtedly, the inventory model depends on the selection of inventory policy adopted. Usually, an inventory policy results in an inventory graph as a function of time period. Practically, three inventory policies described as follows are usually involved in inventory management.

2.7.1 (Q, R) Policy

Based on (Q, R) policy, the inventory level is continuously monitored. When the inventory level comes across the reorder level (ROP), a replenishment order of fixed amount of inventory called economic order quantity (EOQ) is submitted. In this way, EOQ (Q) and ROP (R) are the two decision variables involved in solving the problem of how much to purchase and when to purchase. Figure 2.9 represents (Q, R) policy.

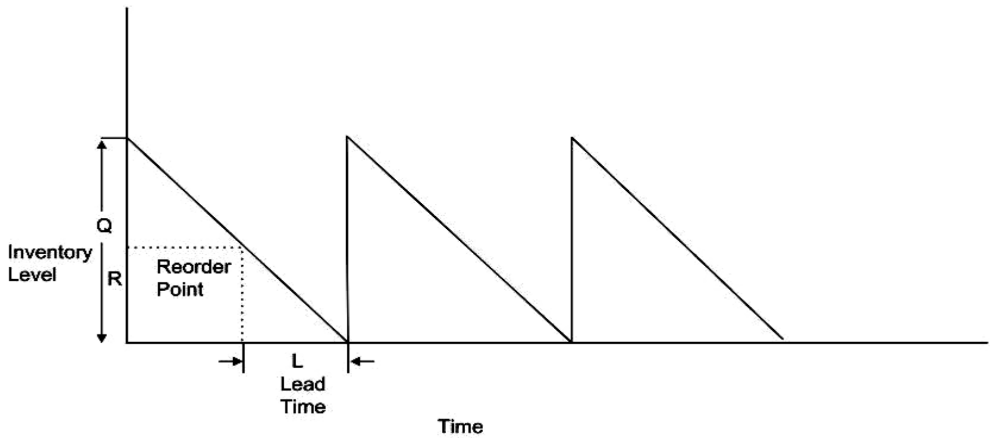


Figure 2.9: (Q, R) policy

As this policy needs continuous monitoring of the inventory stock levels, both computerized and manual inventory control are employed. Computerized monitoring system is easy while in manual systems, its operational expenses are higher. To simplify the manual system, a conventional process “two-bin” policy has been developed. For this two-bin policy, whole stock is held in two bins. The second bin is used to hold the stock for lead time demand and the first bin holds the items which is obtained by deducting the stock of second bin from the fixed amount of inventory Q. After total consumption of first bin, the reorder point is considered to have been reached and a replenishment order of size (Q) is placed.

Obviously, with the computerization system, the stock level is continuously monitored easily, while in the two-bin policy someone has to keep two storage units for each item.

2.7.2 Periodic Review Inventory Policy

In the periodic review inventory policy, stock level is periodically reviewed after a fixed time interval, T. Whenever the review period is arrived, the order quantity, Q is placed which is calculated by subtracting the stock available on hand during review, X from maximum stock level, S. Thus, Order quantity, Q = S- X

Figure 2.10 depicts the periodic review policy in graphical form.

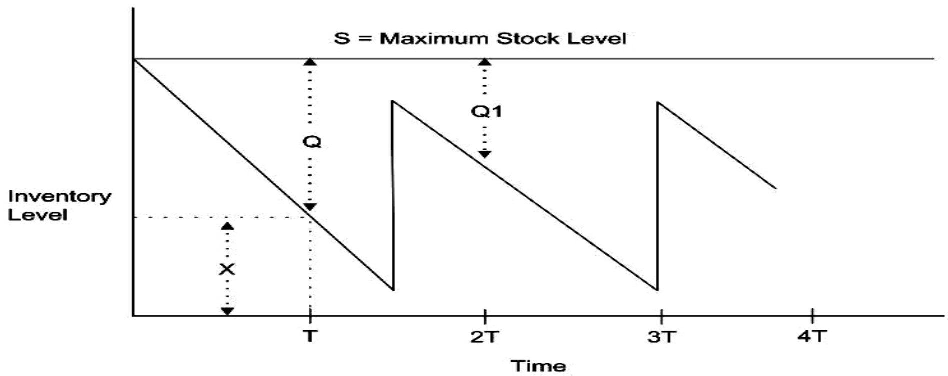


Figure 2.10: Periodic review inventory policy

In this policy, S and T are the two decision variables for optimization. For that reason, it is also known as (S, T) policy. Operation of this policy is comparatively easy due to monitoring the inventory level only after a fixed time period. On the contrary, this policy is relatively risky to the consumption at the time of review cycle. An order has to be compulsorily placed even though stock level on hand is much higher at the review period than the order quantity for the next period.

2.7.3 Optional Replenishment Policy

Optional replenishment policy varies from periodic review inventory policy in which two levels of inventory as S (maximum stock level) and s (minimum stock level) are detected. The stock levels are periodically inspected at fixed time interval T. Though the stock levels are higher than the minimum level (s) at the time of review, the replenishment decision is deferred to the next review cycle. As a result, no order is placed due to the sufficient existing stock until the next review cycle. If the stock level (X) is less than or equal to (s) during review, the order quantity Q is placed so that it raises the stock level to S. So, the mathematical relationships are considered as follows:

$Q = S - X$ if $X \leq s$

$= 0$ if $X > s$

Figure 2.11 represents the policy as graphically.

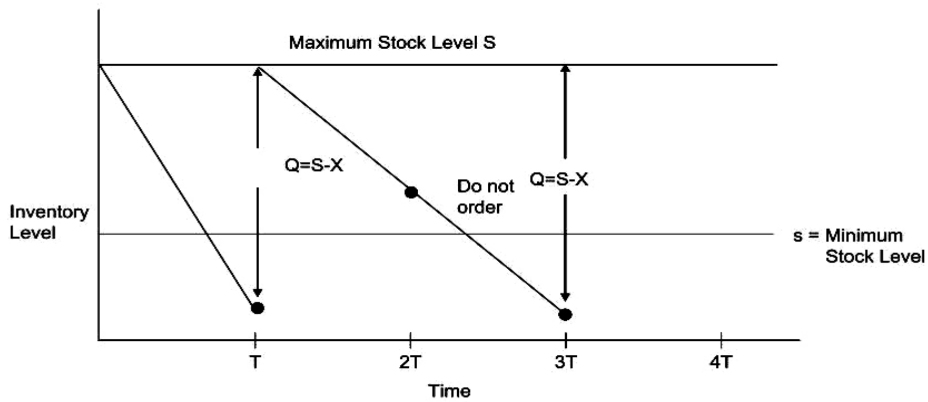


Figure 2.11: (s, S) inventory policy

This policy is also identified as minimum-maximum stock level policy or (s, S) policy. Here the decision variables are s, S, and T. This is also referred to as optional replenishment policy. Because, the opportunity of the replenishment decision skips to the next review period for higher current stock on hand than the prescribed minimum stock level. Thus, intuitively, this policy performs as better comparing to (S, T) policy while (s, S) and T are optimized.

It has been viewed in the inventory control research that if (s, S, T) are optimized, the optional replenishment policy is the best among the three policy mentioned above. Practically, (Q, R) policy is a good option for high usage value items, while (S, T) policy is good for low usage value items. (s, S) policy may be employed for very high usage value items.

2.8 Economic Order Quantity and its Assumptions

Undoubtedly, The Economic Order Quantity (EOQ) model of inventory management is the most widely spoken policy in relevant literature and most basic inventory decision model of inventory control. The EOQ formula was created by Ford W. Harris in 1915.

EOQ model is applied to take a decision on the optimal order quantity and the minimization of total costs of investments in inventories. EOQ model is a method which determines the optimal amount of inventory to order each time to reduce the inventory of that item [15]. It considers as the balancing between ordering cost and storage cost to decide the quantity to be used in replenishing inventories. A larger amount of order decreases ordering frequency and hence ordering cost, but needs to carrying more average inventory which rises carrying costs. On the contrary, a lower amount of order decreases average inventory, but involves in higher numbers of orders and hence, higher ordering costs.

Economic order quantity employed in a firm maintains a daily inventory of items which have a constant demand [13]. It is usually used in deterministic model which assumes that the demand rate for an item is constant and continuous. The lead time and carrying cost are also assumed to be known and uniform. The following assumptions [9] are demonstrated to satisfy the basic economic order quantity model.

i. Only one item is considered.
ii. The annual demand is known.
iii. Demand is uniform all over the year so that the demand rate is rationally constant.
iv. Lead time is known with certainty.
v. Every order quantity is received in one time delivery.
vi. Quantity discounts are not allowed.

2.9 Economic Order Quantity (EOQ) Related Empirical Studies

Several study had been accomplished until now in the area of inventory management are stated as follows.

Several numbers of articles relevant to inventory management had been published since the mid-1990s. Some researchers [14] performed such corresponding research in many regards. At first, most of logistics journals are about traditional inventory control models. These documents determined traditional inventory control models under specific conditions or combined further considerations into established models. Other familiar topic was about improving technics to decrease the amount of inventory usually required a warehouse, which indicates lowering the safety stock by combination of warehouse locations.

Piasecki [15] represented an inventory model for determining optimum order quantity that applied to the procedure of economic order quantity. He mentioned that many firms were not using the EOQ method due to poor outcomes received obtained from incorrect data input. He explained that various errors resulted in the determination of EOQ in the software were due to the unsuccessful of the users in considering how the data inputs and system setup control the output. He assumed that the EOQ was an accounting formula that calculated the order costs and inventory cost which are the least. Then, he pointed out that the EOQ method did not conflict with the Just in Time (JIT) concept. In fact, he clarified that JIT was essentially used to reduce wasted steps, wasted material, wasted labor and other costs. In this situation, EOQ method was used to calculate which items were included in JIT model and what level was economically profitable for the operation.

Piasecki [15] further explained the EOQ formula that contained the factors such as annual usage, ordering cost and carrying cost. At last, he suggested some techniques to follow in applying the EOQ method. These concerned the testing of the formula by inspecting the result obtained, run a simulation by using a sampling of goods, and maintained the EOQ formula by reviewing the interest rates, storage costs and operational cost periodically.

Liberatore [16] represented an EOQ model, with a few changes to the assumptions on the basis of which the traditional EOQ model had been developed. Typically, demand always followed a pattern that could be traced by probability distribution for analysis. The basic

EOQ model, however, expected that this demand was deterministic to simplify the calculations involved.

Silver [17] elongated the classical EOQ model to include supply uncertainty. Two problems were analyzed; one of them standard deviation of quantity received was independent of quantity ordered and the other was proportional to the quantity ordered. For both situations the optimum order quantity was viewed to be a simple modification of the EOQ.

CHAPTER 3

Methodology

3.1 Collection of Data

Required data and information for the research workwasstudied and collectedfrom various sources through interviews, observations, literature studies and databases. All these methods areclassified into two approaches which refers to primary data and secondary data.

3.1.1 Primary Data

Primary data are all forms of new data and information that could be collected by interviews, test or observationsconnectedwith the research. This data iscontinuouslyadjusted for the purpose as the research work is carried out for the particular project.

3.1.2 Secondary Data

Secondary data is obtained from historical data which has not been gathered to the particular project and the information is gained by every other user than the researchers.

3.2Sources of Data Collection

3.2.1 Interviews

Interviews are typically primary data. It is aneffective and simple method of data collectionto get a well understanding and to adjust the questions to specificpeople. This type of data is exactly related with a specific research work having lots of similarities between a normal conversations and an interviews. Time interval of conducting and summarizing the result of the interviewcould be more.

Interviews are usuallyof three types- structured, semi-structured and unstructured. In a structured interviews, the investigatorhaslots of control over the inquiries and the form of the answers. But in a semi-structured interview, the investigator still has a list of questions that should be answered and permits the answers in depthbeyond their planning.

Unstructured interviews are the conversation where the interviewer just begins the questions and the answers need tobe more like reasoning.

3.2.2 Databases

Information collected from the database particularly for a research is similarly a primary data. Databases is a digital form of planned data and now a daysdatabase system is employed almost in everyorganization to maintaina great numbers of transactions, information,etc.

3.2.3 Literature Studies

Literature is typically classed as a secondary data.This type of method is very fast and simple for the collection of information and knowledge of a particularsubject. Literature contains all types of written informationrecorded in the books, journals,texts, newspapers, etc. which is accurately written by an objective oriented author.The researchershave to ensurethat the information of the literature is up to date.

3.2.4 Data from Previous Research

Old data from earlierresearch is also a secondary data. This type of information such as quantities measurement of performance, previous tests, analysis, etc. may be used by another investigator.

3.3Sources of Data used in thisThesis

Several methods for data collection had been taken into consideration to perform this research. A wide range of data and information was taken from different sources in combination with theliterature and the shipyard. The major portion of the data had been collected from software and then studied. Khulna shipyard used an inventory related software named Inventory Expert. The software only works on the receiving of items and the remaining stock of that item.

Interviews in several ways and methods had been done for the understanding of the shipyard, present condition and approaches of working. During the thesis work, there had been continuingdiscussions with concerned managers onoperating procedure.Different data and information achieved from these conversations/interviews performsasasupplementary source for the present situation analysis. The interview was also beneficial to understand the operation of the existing databases and how performed the data collected.

3.4 SampleSelection

Selection of sample is the process used for categorizing the samples available in the selected case and can be either probabilistic or non-probabilistic. The shipyard belongs twelve in number workshops that are related with raising demand of materials. Different materials demand and replenishment policy is almost similar for all the workshops of Khulna shipyard limited. As a result, all the shops of the shipyard were not taken into consideration while carrying out the project work.

Data and information was collected from the four individual department of the organization: Plater shop, Costing departments, Commercial departments and Main store. To accomplish the thesis work, demand for six in numbers gases (*Argon*, CO_2, LPG, Acetylene, Liquid O_2 and Compressed dry air) placed by plater shop are taken.Plater shop uses about five hundred items for the construction and repairing of ships.

In the material consumption record it was found that the major items are different gases, various types of welding rod, different sizes of plates, angles, safety equipment, pipe, nut-bolt, gasket, window glass, port hole, zinc anode, bar, doors, etc. Among these list, the gases is most essential for the shipyard and undoubtedly shortage of the gases breaks downstheproduction line entirely. Since, based on importance of the shipyard, all types of gases were considered in this thesis work.

3.5 ABC Analysis

The inventory was grouped by the following ways:

i. To multiply the annual number of individual items with the price of per item, annual usage value for each is determined.
ii. The annual usage value of an item was added with succeeding usage value to get cumulative usage.
iii. Annual usage value of all items were added.
iv. Total annual usage value cumulative usage for each itemwere transformed into the cumulative percentage of total usage.
v. Every item was included in the list as per descending order based on annual usage value.
vi. A SKU tablewas created to include the usage value and the number of items and divided up into A, B and C classes.

3.6 Model Development

3.6.1 StatisticalData Processing

Statistical data can be presented in different ways. Two statistical measures of probabilistic data are: mean and standard deviation.

Mean wasdetermined by the following ways.

i. A frequency table was constructed from the statistical data table.
ii. Mean, $M = \frac{\Sigma fX}{\Sigma f}$ is used for a frequency distribution.

Following sequences were involved to determine the standard deviation.

i. A frequency table was constructed similar to mean calculation.

ii. The difference of each number, d and the number of frequency, fwas calculated.

iii. Squared toall differences.

iv. The interval of demand or lead time, C was calculated.

v. Standard deviation, SD = $C\sqrt{\{\frac{\Sigma fd^2}{\Sigma f} - (\frac{\Sigma fd}{\Sigma f})^2\}}$ was used for a frequency distribution.

3.6.2Notations

EOQ: Economic order quantity

D: annual demand (unit/year)

K: ordering cost (BDT/order)

Q: order size (unit)

H: inventory carrying cost (%/year)

C: unit purchase cost (BDT)

3.6.3 EOQModel Formulation

The basic model of EOQ [18]is explained in the figure 3.1.

Where,D is constant demand rate which represents the negative sloping lines.

T is the order cycle of length which refers to time between orders or arrivals.

L is the lead time which statesthe durationof the products to arrive.

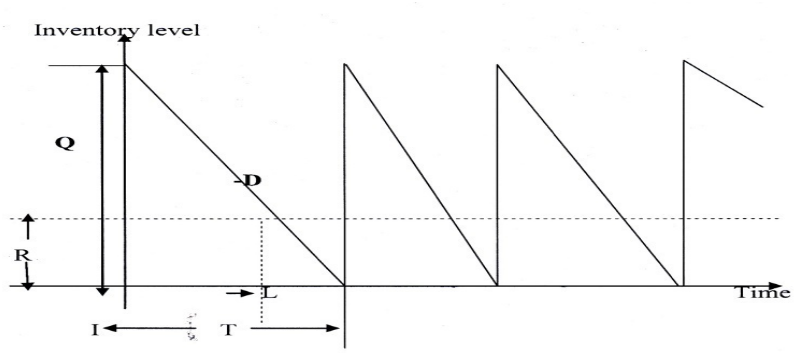


Figure 3.1:Basic inventory model

As, the inventory level variesfrom a minimum level (zero)to a maximum level (Q units), the average inventory in anorder cycle is indicatedbelow.

Average inventory= $\frac{(Q+O)}{2} = \frac{Q}{2}$ (3.1)

The total annual inventory cost is the summation of carrying cost, purchase cost and order cost.

The annual purchase cost is the annual cost for the item paid by the purchaser. Thus, annual purchase cost is the purchase cost per unit (C) times the total procured unit (Q).
The cost incurred for placing an order is the order cost during each cycle (K).
The holding cost during each cycleis the holding cost per unit time say (H) times T, the average inventory $\frac{Q}{2}$.

Total inventory cost = purchase cost + order cost + holding cost

$$\text{TC (Q)} = \text{CQ+K+HT}\frac{\text{Q}}{2} \qquad (3.2)$$

Thus, the total cost per unit time TCU is equal to $\frac{\text{TC(Q)}}{\text{T}}$

Therefore, TCU (Q) = $\frac{\text{CQ}}{\text{T}} + \frac{\text{K}}{\text{T}} + \frac{\text{HT}}{\text{T}}\frac{\text{Q}}{2}$ (3.3)

But, the optimum number of order per unit time, N= $\frac{1}{\text{T}}$ and D= $\frac{\text{Q}}{\text{T}}$

Hence, TCU (Q) = CD + $\frac{\text{KD}}{\text{Q}} + \frac{\text{HQ}}{2}$ (3.4)

The required condition for minimum TCU (Q) was calculated by the first derivative of the total inventory cost with respect to Q and setting it equal to zero.

As a result, $\frac{dTCU\ (Q)}{dQ} = 0$

$$\frac{dTCU\ (Q)}{dQ} = 0 = -\frac{\text{KD}}{\text{Q}^2} + \frac{\text{H}}{2} = 0$$

After solving for Q, it yields the EOQ(Q^*).

$$\frac{\text{KD}}{\text{Q}^2} = \frac{\text{H}}{2}$$

$$\text{Q}^2 = \frac{2\text{KD}}{\text{H}}$$

$$Q^{*}= \sqrt{\frac{2KD}{H}} \qquad (3.5)$$

3.6.4Total Inventory Cost Formulation

The minimum total cost per unit time was achieved by replacing Q* for Q in the total inventory cost equation.

TCU (Q*) = CD + $\frac{HQ^{*}}{2} + \frac{KD}{Q^{*}}$

Where, Q*= $\sqrt{\frac{2K}{H}}$

Optimum order quantity (Q*) is to be minimum when carrying costs and ordering costs are equal. Thus, $\frac{HQ^{*}}{2} = \frac{KD}{Q^{*}}$

TCU (Q*) = CD+$\frac{2KD}{Q^{*}}$

TCU (Q*) = CD+2K$\frac{D}{\sqrt{\frac{2KD}{H}}}$

Minimum total cost, TCU (Q*) = CD+$\sqrt{2KDH}$ (3.6)

3.7 Formulation of Safety Stock and Reorder Point

In case of (Q, R) policy, reorder point,R and order quantity,Q as discussed before wherecorrect level of Rwas determined. The level of the reordering point at a specific certainty protects the demand during the lead time, LT. Itwascalculated by the average demand, $\bar{X}$ and the safety stock, SS.

Reorder Point = $\bar{x}$ LT + $k\sigma_{dLT}$ (3.7)

where, $\bar{x}$ LT = average forecasted demand during the lead time

$k\sigma_{dLT}$ = Safety stock

k = safety factor

σ_{dLT} = standard deviation of demand forecasts and lead time, in units.

$\bar{x}$ = Average demand during the lead time.

σ_d = standard deviation of lead time.

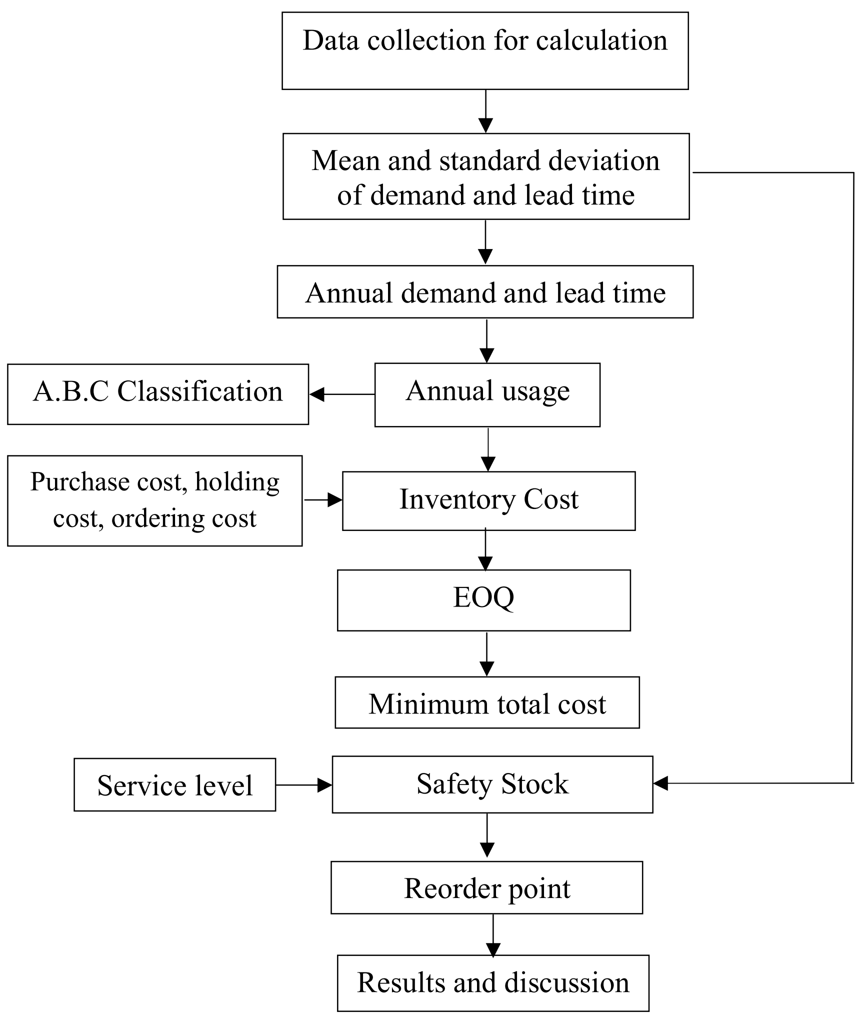
σ_{LT} = standard deviation of demand

Safety stock= $k\sigma_{dLT} = k\sqrt{\{\text{Average LT x } \sigma_d^2 + \bar{x}^2 (\sigma_{LT})^2\}}$ (3.8)

This equation assumes that both demand and lead times are normally distributed.
The safety stock depends on the service level.

3.8Structure of the Study

In this chapter different procedure for the calculation of demand, lead time, inventory cost, ABC classification, EOQ, minimum total cost, safety stock and reorder point was described. The process is shownbelow in the following flow chart 3.2.



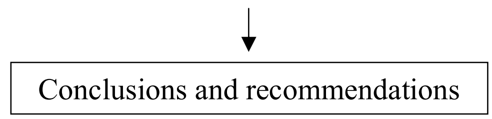


Figure 3.2:Structure of the study

CHAPTER 4

Datacollection and calculation

4.1General

This section coverdthe discussion of sample data of the shipyard. This data was collected from theplatter shop, main store, commercial and costing departmentof the shipyard. At first, some important sample of items was collected from plater shop of the shipyard. As there was no existing classification in the corporation database, the selected items were organized in relation to the ABC classification model.Then optimum order quantity of the items and reorder level was determined applying economic order quantity model. Six gases (Argon, CO2, LPG, Acetylene, Liquid $O_2$and Compressed dry air) discussed earlier in methodology chapterwere selected to perform the thesis work.

4.2Types of Data used

In this study, secondary data from the shipyard databasewas collected for the period of 2016 to 2018. The collected data and information from the companyhelped to determinecarrying cost, order cost, item purchase cost and annual demand of six gases.

4.3 Calculation of Item Price and Average Demand

To calculate the annual usage,annual demand (D) and the unit price (c)were required. Annual demandwasdetermined from the calculated mean by multiplying 12 (a year)associating the data from January 2016 to December 2018.

For the calculation of item price, the average price was taken from thepurchase order over the years. A similar price with less variation was obtained amongthe files.

4.3.1 UnitPrice Calculation of Items

The average unit price of the itemsin the list of the sample was calculated according to the dataobtainedfrom the purchase order file. All the values of Appendix A were averaged out for the years from 2016 to 2018. Table 4.1 shows the average unit priceas determined in Appendix A.

Table4.1: Unit price calculation

Serial No.	Product Description	Unit measure	Average unit price(c) (BDT)
1	Argon	each cylinder	2702.00
2	CO_2	each cylinder	1110.00
3	LPG	each cylinder	996.00
4	Acetylene	each cylinder	3163.00
5	Liquid O_2	Liter	27.00
6	Compressed dry air	each cylinder	72.00

4.3.2 Average Demand Calculation

Monthly average demand was determined through Appendix B and Appendix C. Table 4.2 shows the average monthly demand for the selected 6 gases.

Table4.2: Monthly demand and standard deviation of demand.

Product No.	Name	Unit measure	Average monthly demand	Annual demand (D)	Monthly St. Dev.
1	Argon	No. of cylinder	91	1092	39
2	CO_2	No. of cylinder	21	252	9
3	LPG	No. of cylinder	165	1980	26
4	Acetylene	No. of cylinder	6	72	2
5	Liquid O_2	Liter	10,167	1,22,004	1,857
6	Compressed dry air	No. of cylinder	14	168	9

4.4 Item Classification

The data of six in number items (Argon, CO_2, LPG, Acetylene,Liquid O_2 and Compressed dry air)was collected from plater shop of the shipyard for the thesis work. It was found that this workshop uses about five hundred items for the construction and repairs of ships. The material consumption record shows that different types of gases, various types of welding rod, different sizes of plates, angles, safety equipment, pipe, nut-bolt, gasket, window glass, port hole, zinc anode, bar, doors, etc.are regular consumption items. Among these list, the gases are the lifeline of the shipyard and in case of any shortage,entire production line interrupts. In view of the fact that all types of gases were considered in this thesis workbased on importance of the shipyard.

With the demand and value information, the annual usage was calculated from the annual demand and itemprice.Then the items were divided upby means of ABC classification. The achieved result through calculation is listed in Table 4.3 and organized in descending order.

Table 4.3: Listing of sample SKUs by descending BDT usage.

Ser. No.	SKU Name	Cum. Percent SKU	Annual Usage (D) (BDT)	Cumulative Usage (BDT)	Cum. Per. of total usage	Item Class
1	Liquid O_2	17%	32,94,108	32,94,108	38%	A
2	Argon	34%	29,32,056	62,26,164	72%	B
3	LPG	50%	19,73,076	81,99,240	94%	B
4	CO_2	67%	2,73,504	84,72,744	97%	C
5	Acetylene	84%	2,07,000	86,79,744	99%	C
6	Compressed dry air	100%	11,808	86,91,552	100%	C

Table 4.3 shows that the most important inventories (class A) were placed in position 1, because the item covered17% of total SKU which accounted for 38% of total annual usage.

The second most important Class B itemscomparing to Class A items were positioned in the row 2 to 3 of the SKU table. These B items represented33% of total SKU which accounted for 56% of BDT usage.

Lastly, the least important Class C items were positioned in the row 4 to 6 of the SKU table. These B items represented50% of the total SKU which accounted for only 6% of the total annual usage.

4.5 Lead Time Calculation

For the calculation of lead time, the purchase order file was employed. All purchase orders replenished for an item was studied and the lead time was represented in Appendix D whichwas obtained by deductingthe date of placing an order to the supplier from the item receiving date. It was observed that lead time from suppliers have a regular time frame. Average lead time and standard deviation of lead time for the items were calculated in Appendix E and is shown in table 4.4.

Table 4.4: Calculation of lead times per unit per item.

Item	Name	Unit	Average Lead Time (LT)	Std. Dev. Lead Time
1	Argon	Days	10	6
2	CO_2	Days	15	7
3	LPG	Days	15	5
4	Acetylene	Days	20	7
5	Liquid O_2	Days	8	3
6	Compressed dry air	Days	14	6

4.6 InventoryCost Calculation

4.6.1 Holding Cost per Unit

Inventory carrying costs incurred by the Corporation in order to hold the items in the warehouse. It includes the opportunity cost of using the investment to purchase inventory instead of utilizing somewhere in interest-earning financial investments. In calculating the holding or carrying costs, required data was collected from Khulna Shipyard financial magazine [19] and also other related documents, in which the warehousing costs were estimated.

It was calculated according to the procedure mentioned in table 2.1.

		BDT
Average Inventory Value	:	34,20,45,000
Warehousing cost	:	1,00,30,978
Materials Handling and others expenditures	:	1,04,03,240
Tax 4.5%	:	1,53,92,055
Vat 2.5%	:	85,51,142
Annual Cost	:	4,43,77,415

Average warehousing cost= $\frac{4,43,77,415}{34,20,45,000}$ = .13 = 13%

The average warehousing cost,13% was obtained by dividing annual holding cost and the average annual value of total inventory. The opportunity cost was found by the ninety days deposit certificate interest rate used in KSY financial investment which was 10.8%. Hence, the total carrying or holding cost was gained by the summation of these two percentages which makes 23.8%. This percentage was multiplied to the unit cost of each item to obtain the carrying cost per unit per year. Table 4.5represents the carrying cost calculation per unit per item.

Table 4.5: Calculation of holding cost per unit per item.

No.	Name	Unit Measure	Unit cost (c) (BDT)	Holding rate (I)	Holding Cost (H) (BDT) (c.I)
1	Argon	No. of cylinder	2702.00	0.238	644.00
2	CO_2	No. of cylinder	1110.00	0.238	265.00
3	LPG	No. of cylinder	996.00	0.238	238.00
4	Acetylene	No. of cylinder	3163.00	0.238	753.00
5	Liquid O_2	Liter	27.00	0.238	6.00
6	Compressed dry air	No. of cylinder	72.00	0.238	18.00

4.6.2 Fixed Cost per Order

Determination of fixed order cost for purchasing inventory was determined as follows according to the procedure as discussed in table 2.1.

		working hour
Raising demand from the section	:	1
Raising indent from main store	:	0.5
Entering cost from costing section	:	0.2
Checking budget from finance dept.	:	0.5
Approval from Managing Director	:	0.1
Floating tender from commercial	:	0.4
Preparing CST from commercial	:	0.5
Taking approval from managers and Managing Director	:	0.8
Purchase order from commercial	:	0.2
Contracting and expediting the supplier by commercial	:	0.2
Unloading of inventory by main store	:	0.2
Inventory received by main store	:	0.2
Quality inspection by managers and section	:	0.2
Inventory transfer	:	0.1
Payment of supplier by cash section	:	0.2
Total labor	:	5.3

Hence, Total labor cost: 5.3 X BDT 350 = BDT 1855.

		BDT
Cost of paper and print out from section	:	6
Cost of indent paper from main store	:	2
Cost of paper and print out for CST	:	10
Cost of paper and print out for purchase order	:	12
Cost of phone call, fax and tender schedule	:	25
Total	:	55

Total cost for executing a purchase process (K) = BDT 1855 + 55 = BDT 1910

4.7Calculation of EOQ

The following EOQ formuladiscussed earlierwas applied.

EOQ= Q* = $\sqrt{\frac{2K}{H}}$

Optimal orders per year, N= $\frac{D}{Q*}$

EOQ of the items and the required variables were calculated in Appendix F. Table 4.6 shows the economic order quantity.

Table 4.6: Economic order quantity (EOQ)

No.	Product Name	Unit Measure	Annual Demand (D)	Fixed Cost per Order (K) (BDT)	Holding Cost (H) (BDT)	EOQ	Optimal orders per year
1	Argon	No. of cylinder	1092	1910	644	81	13
2	CO2	No. of cylinder	252	1910	265	61	4
3	LPG	No. of cylinder	1980	1910	238	178	11
4	Acetylene	No. of cylinder	72	1910	753	20	4
5	Liquid O2	Liter	1,22,004	1910	6	8813	13
6	Compressed dry air	No. of cylinder	168	1910	18	188	1

4.8 Calculation of Total Annual Cost

The minimum total cost was calculated by the following equation.

$$TCU\ (Q^*) = CD + \frac{HQ^*}{2} + \frac{KD}{Q^*}$$

EOQ of the items and the required variables were calculated in Appendix G and Appendix H. Table 4.7, 4.8 and 4.9 shows the total annual cost after and before applying EOQ and total cost comparison.

Table 4.7:Total annual cost after applying EOQ

	Argon	CO_2	LPG	Acetylene	Liquid O_2	Compressed dry air
Unit Measure	cylinder	cylinder	cylinder	cylinder	Liter	cylinder
Annual Demand (D)	1092	252	1980	72	1,22,004	168
Unit cost price (C) BDT	2702	1110	996	3163	27.00	72
Holding Cost (BDT) (H)	644	265	238	753	6.00	18
Fixed Cost per Order (BDT) (K)	1910	1910	1910	1910	1910	1910
EOQ= Q*	81	61	178	20	8813	188
Optimal orders	13	4	11	4	13	1
Annual holding cost	25,852	7970	21182	6850	26439	3357

(BDT)						
Annual order cost (BDT)	25,852	7970	21182	6850	26439	3357
Total purchase cost (BDT)	2932056	273504	197208 0	207000	3294108	11808
Total annual cost	2983760	289444	201444 4	220700	3346986	18522

Table 4.8: Total annual cost calculation before employing EOQ

	Argon	CO_2	LPG	Acetyle ne	Liquid O_2	Compressed dry air
Time ordered	13	13	13	12	13	6
Annual Demand (D)	1092	252	1980	72	1,22,004	168
Unit cost price (C) BDT	2702	1110	996	3163	27.00	72
Holding Cost (BDT) (H)	644	265	238	753	6.00	18
Fixed Cost per Order (BDT) (K)	1910	1910	1910	1910	1910	1910
Q (Demand/Number times order)	84	20	153	6	9385	28
Annual holding cost (BDT)	27048	2650	18207	2059	28155	252
Annual order cost (BDT)	24830	24066	24718	22920	24830	11460
Total purchase cost (BDT)	2950584	279720	1972080	227736	3294108	12096
Total annual cost (BDT)	3002462	306436	2015005	252715	3347093	23808

Table 4.9: Total cost comparison

	Argon	CO_2	LPG	Acetyle ne	Liquid O_2	Compressed dry air
Total annual cost before EOQ (BDT)	3002462	306436	2015005	252715	3347093	23808
Total annual cost after EOQ(BDT)	2983760	289444	2014444	220700	3346986	18522
Total savings (BDT)	18702	16992	561	32015	107	5286
Total savings = BDT 73663.00						

4.9 Comparison of Orders

Table 4.10 is a comparison of the numbers of orders between order placed by the company before applying the EOQ model and after applying the EOQ model.

Table 4.10: Numbers of orders before and after applying the EOQ model.

Item name	Numbers of orders before applying EOQ	Numbers of orders after applying EOQ
Argon	13	13
CO2	13	4
LPG	13	11
Acetylene	12	4
Liquid O_2	13	13
Compressed dry air	6	1

Table 4.10denotes thatthe number of orders before applying the EOQ model wasfound much highercomparing to the number of orders after applying the EOQ model. Higher number of orders increases the order costs of the shipyard, hence increasing the annual inventory cost.On the contrary, higher number of orders minimizes the number of stock outs.

4.10 Calculation of Safety Stock and Reorder Point

Assuming 95% service levelconsidered by the shipyard, the reorder point and safety stock of inventorieswasdetermined by applying the following equation.

Reorder point = $\bar{x}$ LT + $k\sigma_{dLT}$

Table 4.11 shows the safety stock and reorder point which had been calculated inAppendix I.

Table4.11: Reorder point (ROP) and safety stock

Item name	Safety stock	ROP
	cylinder	cylinder
Argon	24	54
CO_2	7	17
LPG	27	110
Acetylene	2	5
Liquid O_2	1151	3863
Compressed dry air	6	13

CHAPTER 5

Results and Discussion

5.1Results

In the earlier chapter, it was obtained the result of EOQ, total cost, safety stock and reorder point for six in number gases which is the important raw material for Khulna Shipyard Limited. The achieved results are represented in the table5.1.

Table 5.1: Obtained result of the research.

Item name / Parameter	Argon	CO_2	LPG	Acetyle-ne	Liquid O_2	Compr-essed dry air
Unit Measure	cylinder	cylinder	cylinder	cylinder	Liter	cylinder
Annual Demand (D)	1092	252	1980	72	1,22,004	168
Optimum order quantity (EOQ)	81	61	178	20	8813	188
Quantity orders before EOQ	84	20	153	6	9385	28
Numbers of orders before EOQ	13	13	13	12	13	6
Optimal orders per year	13	4	11	4	13	1
Total annual cost before EOQ (BDT)	3002462	306436	2015005	252715	3347093	23808
Total annual cost after EOQ (BDT)	2983760	289444	2014444	220700	3346986	18522
Total savings (BDT)	18702	16992	561	32015	107	5286
Safety stock	24	7	27	2	1151	6
ROP	54	17	110	5	3863	13

5.2 Discussion

Table 5.1illustrates the optimal order quantity for each gas. The optimal order quantity wasfound larger compared to their current quantity ordered. This result helps Khulna Shipyard limited to minimize the number of stock outs, thus meeting the customer demand.

The number of order placed by the shipyard before applying the EOQ model was much higher. The frequency of the orders contributed to high rate of increase in ordering cost and consequently increasing the annual total cost of inventory. The result shown that the number of orders after applying the EOQ model was found much lower. Fewer numbers of orders decreases ordering costs, hence decreasing the annual cost of inventory.

A comparison with their current inventory cost showed a decrease of BDT 73663. This was an indicative of the significant benefits derived from the use of the model by the shipyard.

The achieved resultindicated that the optimal reorder point and safety stock help the shipyard to minimize the number of stock outs with a view to meeting the lead time demand.

CHAPTER 6

Conclusions and Recommendations

6.1Conclusions

In this thesis work, an optimum order quantity (EOQ) model was implemented in which the significance of cost minimization was evaluatedto enhancethe profitability of Khulna Shipyard Limited.It was found that the carrying cost and the order cost reduced considerablyby using EOQ model.It helped the shipyard to decrease the total priceof six selected gases.The application of this model contributed the shipyard to identifythe optimumamount of gases to order in one year as well as when to order for the specific gases.Safety stock policy also assisted to protect the variation and uncertainty in both lead time and demand.

6.2Recommendations

i. It is recommended for khulna shipyard limited that applyingof economic order quantity model will assist to obtain optimal ordered quantities, reorder level and number of orders for the gases. This model may also be implemented forother materials which are not considered in the research work.

ii. It is recommended to communicate with its clientsfor better decisions ondemand and replenishment. It will facilitate the shipyard to developforecasts on inventory items for repair. It will also assist to avoidfrom over-ordering of materials whileit is not required.

iii. Another suggestion for the shipyard is to establish the Enterprise resource planning (ERP) software which willreduce the requirementof keeping inventories. A more effective system containing good data resource will also decrease theinaccuracy in forecasts and demand calculations.

iv. Agreements and communicationswiththeir suppliers will be improved for making better decisions and better information sharing process on a timelier manner.Itwill assistthe shipyard significantly to reducelead time, lead time variability and operating costs of inventory management.

v. Shipyard management may reviewonthe requirements of items based on ships coming for repair instead ofdemand forecasting.

REFERENCES

[1] Chase R.B. Jacobs F.R. and Aquilano N.J (2004). Operations management for competitive advantage, 10th edition. Mc Graw-Hill, New York.

[2] Khulna Shipyard Limited website, www.khulnashipyard.com.

[3] Stock J.R and lambert D.M. (2001). Strategic Logistics management, 4th edition. Mc Grawn Hill. Investigational edition.

[4] Ali, A.K., ″Inventory Management in Pharmacy Practice: A Review of Literature. Archives of Pharmacy Practice″, 2011. 2(4): p. 151-156.

[5] Miller, R. (2010). Inventors Control: Theory and Practice. New Jersey: Prentice Hall.

[6] L.R. Howard, (1971). ″Working Capital – Its Management and Control″, London: Macdonald & Evan Ltd.

[7] Silver, E.A. (2008). Inventory Management: An Overview, Canadian Publications, Practical Applications and Suggestions for Future Research. *INFOR*, 46(1): 15-28.

[8] Simchi-Levi et al.,(2004) . Inventory Management: 52, (1), 243-269.

[9] William, J.S.; Operations Management. 8th ed. McGraw-Hill, 2009-2010.

[10] Onwubolu, G.C., & Dube, B.C. (2006) Implementing an Improved Inventory Control system in a small company, A case study. Production planning and control, 17 (1), 67-76.

[11] Fuerst, W.C. (1981). Small Business Get A new look at ABC Analysis for Inventory control. Journal of small Business Management, 19 (3), 39-44.

[12] Naddor E (1966) Inventory systems. Wiley, New York.

[13] Tersine, R.J. (1982), Principles of inventory and material management. 2nd edition,New York, North Holland.

[14] Williams, B.D. and T. Tokar, (2008). ″A review of inventory management research in major logistics journals. International Journal of Logistics Management: Themes and future directions″, 19(2): p. 212-232.

[15] Dari Piasecki (2001). "Optimizing Economic order quantity (EOQ) solution magazine, January 2001 issues.

[16] Liberatore (1979), "The EOQ Model under stochastic lead time", operation reasharch vol.27.

[17] Silver, E.A (1976), "Establishing the order quantity when the amount receive is uncertain". In for, vol.14, PP 32-39.

[18] Chambers, D. & Lacey, N. (2011). Modern Corporate Finance, Sixth Edition, Michigan: Hayden McNeil Publishing.

[19] Annual reports 2016, Khulna Shipyard Limited.

Appendix A. Average unit price yearly from purchase order data file of commercial department for 6 gases.

Description of gases:

Ser. No.	Item name	Capacity of each cylinder	Total numbers of cylinder exists	Supplier name	Purposes
1	Argon	7 m^3	96	Linde Bangladesh	Aluminium/ SS materials cutting
2	CO_2	30 kg	37	Linde Bangladesh	MS materials MAG welding
3	LPG	12 kg	370	Omera	MS materials cutting and preheating
4	Acetylene	5.5 m^3	18	Linde Bangladesh	Gas welding/ Brazing
5	Liquid O_2	5000 liter	01	Linde Bangladesh	MS materials cutting and preheating
6	Compressed dry air	6 m^3	11	Linde Bangladesh	Aluminium/ SS materials cutting

Item price as per order

Product Description	(1) Argon	(2) CO_2	(3) LPG	(4) Acetylene	(5) Liquid O_2	(6) Compressed dry air
Year	BDT/ cylinder	BDT/ cylinder	BDT/ cylinder	BDT/ cylinder	BDT/ liter	BDT/ cylinder
2016	2695.00	990.00	960.00	-	27.00	72.00
2017	2695.00	1140.00	996.00	3163.00	27.00	72.00
2018	2716.00	1200.00	1020.00	-	28.00	72.00
Average unit price	2702.00	1110.00	992.00	3163.00	27.00	72.00

Appendix B. Historical data of monthly consumption from store out (SR) data file of Main store for 6 gases.

Product Description	(1) Argon	(2) CO_2	(3) LPG	(4) Acetylene	(5) Liquid O_2	(6) Compressed dry air
Date (MM/YY)	m^3	Kg	Kg	m^3	liter	m^3
Jan- 2016	790	300	2000	25	6000	100
Feb- 2016	620	320	2100	35	7000	120
Mar- 2016	455	280	1750	25	8500	120
Apr- 2016	570	200	1600	30	9500	80
May- 2016	690	270	1600	5	8500	98
Jun- 2016	800	150	1750	35	11100	25
Jul- 2016	770	350	2000	5	10000	65
Aug- 2016	580	580	2300	8	9900	44
Sep- 2016	600	720	2250	25	11000	40
Oct- 2016	800	830	2460	40	13200	70
Nov- 2016	580	810	2280	40	8800	35
Dec- 2016	960	370	2140	50	9900	82
Jan- 2017	903	90	2280	40	7300	96
Feb- 2017	483	90	1800	35	9800	12
Mar- 2017	273	90	1536	25	10000	132
Apr- 2017	364	135	1560	22	9900	12
May- 2017	175	270	1620	17	8500	24
Jun- 2017	84	90	1680	25	10300	18
Jul- 2017	273	360	1920	28	9700	12
Aug- 2017	441	585	2280	35	11900	12
Sep- 2017	539	810	2400	35	12000	48
Oct- 2017	735	855	2550	37	12100	30
Nov- 2017	616	810	2280	40	14300	24

Dec- 2017	525	180	1920	45	13700	30
Jan- 2018	686	315	1440	40	14000	102
Feb- 2018	378	1620	2160	28	13900	120
Mar- 2018	903	540	2400	30	12800	138
Apr- 2018	1001	900	2340	30	13100	144
May- 2018	686	135	2112	25	11750	162
Jun- 2018	371	315	2160	40	11900	174
Jul- 2018	1267	1260	2280	48	12100	132
Aug- 2018	693	1395	1560	45	12300	90
Sep- 2018	987	1980	2424	50	11900	156
Oct- 2018	1169	1755	1644	45	13600	156
Nov- 2018	868	1530	1872	50	13200	150
Dec- 2018	840	1260	1320	25	11000	180

Appendix C. Frequency distribution of monthly demand datafor 6 gases.

Product 1. *Argon*

Demand	Frequency f	Midpoint X	$d = \frac{X - A}{C}$	fd	fd^2
0-200	2	100	-3	-6	18
200-400	5	300	-2	-10	20
400-600	9	500	-1	-9	9
600-800	11	700(A)	0	0	0
800-1000	6	900	1	6	6
1000-1200	2	1100	2	4	8
1200-1400	1	1300	3	3	9
C= 200	$\sum f = 36$			$\sum fd = -12$	$\sum fd^2 = 70$

Mean (Average), M= $\frac{\sum fX}{\sum f} = \frac{200+1500+4500+7700+5400+2200+130}{36}$

= 633 m^3

= 91 cylinders.

Standard deviation, SD= $C\sqrt{\{\frac{\sum fd^2}{\sum f} - (\frac{\sum fd}{\sum f})^2\}} = 200\sqrt{\{\frac{70}{36} - (\frac{-12}{36})^2\}}$

= $200\sqrt{\{1.94 - 0.11\}}$

= 270 m^3

= 39 cylinders.

Product 2. CO_2

Demand	Frequency f	Midpoint X	$d = \frac{X - A}{C}$	fd	fd^2
0-300	13	150	-3	-39	117
300-600	9	450	-2	-18	36
600-900	7	750	-1	-7	7
900-1200	0	1050 (A)	0	0	0
1200-1500	3	1350	1	3	3
1500-1800	3	1650	2	6	12
1800-2100	1	1950	3	3	9
C= 300	$\sum f = 36$			$\sum fd = -52$	$\sum fd^2 = 184$

Mean (Average), M= $\frac{\sum fX}{\sum f} = \frac{1950+4050+5250+0+4050+4950+1950}{36}$

= 616 Kg

= 21 cylinders.

Standard deviation, SD= $C\sqrt{\{\frac{\sum fd^2}{\sum f} - (\frac{\sum fd}{\sum f})^2\}} = 300\sqrt{\{\frac{184}{36} - (\frac{-52}{36})^2\}}$

$= 300\sqrt\{5.11 - 4.28\}$

$= 273$ Kg

$= 9$ cylinders.

Product 3. *LPG*

Demand	Frequency f	Midpoint X	$d = \frac{X-A}{C}$	fd	fd^2
1300-1550	3	1425	-2	-6	12
1550-1800	10	1675	-1	-10	10
1800-2050	5	1925 (A)	0	0	0
2050-2300	12	2175	1	12	12
2300-2550	6	2425	2	12	24
C= 250	$\sum f = 36$			$\sum fd = 8$	$\sum fd^2 = 58$

Mean (Average), $M = \frac{\sum fX}{\sum f} = \frac{4275+16750+9625+26100+14550}{36}$

$= 1981$ Kg

$= 165$ cylinders.

Standard deviation, $SD = C\sqrt\{\frac{\sum fd^2}{\sum f} - (\frac{\sum fd}{\sum f})^2\} = 250\sqrt\{\frac{58}{36} - (\frac{8}{36})^2\}$

$= 250\sqrt\{1.61 - 0.05\}$

$= 313$ Kg

$= 26$ cylinders.

Product 4. *Acetylene*

Demand	Frequency f	Midpoint X	$d = \frac{X-A}{C}$	fd	fd^2
0-10	3	5	-2	-6	12
10-20	1	15	-1	-1	1
20-30	13	25 (A)	0	0	0
30-40	12	35	1	12	12
40-50	7	45	2	14	28
C= 10	$\sum f = 36$			$\sum fd = 19$	$\sum fd^2 = 53$

Mean (Average), $M = \frac{\sum fX}{\sum f} = \frac{15+15+325+420+31}{36}$

$= 30\ m^3$

$= 6$ cylinders.

Standard deviation, $SD = C\sqrt\{\frac{\sum fd^2}{\sum f} - (\frac{\sum fd}{\sum f})^2\} = 10\sqrt\{\frac{53}{36} - (\frac{19}{36})^2\}$

$= 10\sqrt\{1.47 - 0.28\}$

$= 11\ m^3$

$= 2$ cylinders.

Product 5. Liquid O_2

Demand	Frequency f	Midpoint X	$d = \frac{X-A}{C}$	fd	fd^2
6000-7000	2	6500	-4	-8	32
7000-8000	1	7500	-3	-3	9
8000-9000	3	8500	-2	-6	12
9000-10000	9	9500	-1	-9	9
10000-11000	3	10500 (A)	0	0	0
11000-12000	6	11500	1	6	6
12000-13000	4	12500	2	8	16
13000-14000	7	13500	3	21	63
14000-15000	1	14500	4		
C= 1000	∑f = 36			∑fd = 9	$\sum fd^2 = 147$

Mean (Average), M= $\frac{\sum fX}{\sum f} = \frac{13000+7500+25500+85500+31500+69000+25000+94500+14500}{36}$

$= 10167$ liter

Standard deviation, SD= $C\sqrt{\{\frac{\sum fd^2}{\sum f} - (\frac{\sum fd}{\sum f})^2\}} = 1000\sqrt{\{\frac{147}{36} - (\frac{9}{36})^2\}}$

$= 1000\sqrt{\{4.08 - 0.63\}}$

$= 1857$ Liter

Product 6. Compressed dry air

Demand	Frequency f	Midpoint X	$d = \frac{X-A}{C}$	Fd	fd^2
0-20	5	10	-4	-20	80
20-40	7	30	-3	-21	63
40-60	2	50	-2	-4	8
60-80	3	70	-1	-3	3
80-100	5	90 (A)	0	0	0
100-120	4	110	1	4	4
120-140	3	130	2	6	12
140-160	4	150	3	12	36
160-180	3	170	4	12	48
C= 20	∑f = 36			∑fd = -14	$\sum fd^2 = 254$

Mean (Average), M= $\frac{\sum fX}{\sum f} = \frac{50+210+100+210+450+440+390+600+51}{36}$

$= 82m^3$

$= 14$ cylinders.

Standard deviation, SD= $C\sqrt{\{\frac{\sum fd^2}{\sum f} - (\frac{\sum fd}{\sum f})^2\}} = 20\sqrt{\{\frac{254}{36} - (\frac{-14}{36})^2\}}$

$= 20\sqrt{7.06 - 0.15}$

$= 53m^3$

= 9 cylinders.

Appendix D. Historical data of lead time for 6 gases.

Product Description		Argon	CO_2	LPG	Acetylene	Liquid O_2	Compressed dry air
Date (YY)	Order no.	Days	Days	Days	Days	Days	Days
2016	1	15	32	22	8	7	20
	2	13	23	17	17	8	13
	3	12	20	14	30	2	14
	4	8	12	24	26	5	24
	5	10	14	11	27	7	8
	6	20	15	22	6	4	8
	7	25	26	18	6	9	10
	8	25	28	10	28	10	25
	9	9	19	20	25	12	
	10	7		13	19	14	
	11	24		15	23	5	
	12	25		25	28	8	
2017	1	3	12	20	29	10	6
	2	8	16	11	25	11	6
	3	7	14	10	30	15	16
	4	6	10	15	22	9	13
	5	21	18	16	27	8	25
	6	15	9	21	14	7	15
	7	11	8	1	14	11	17
	8	8	9	19	21	12	7
	9	6	25	9	25	15	9
	10	6		25	16	14	
	11	9		17	16	12	
	12	18		20	10	13	
2018	1	8	11	14	22	6	22
	2	5	13	12	25	5	14
	3	7	13	14	17	12	12
	4	7	10	11	20	13	25
	5	11	8	9	27	9	14
	6	10	9	22	30	10	14
	7	9	25	12	14	12	
	8	8	22	10	19	9	
	9	4	19	8	26	5	
	10	3	14	15	14	6	
	11	5	16	17	14	9	
	12	4	12	8	15	12	
	13	12	8	19	-	8	

Appendix E. Frequency distribution of lead time for 6 gases.

Product 1. Argon

Lead time	Frequency f	Midpoint X	d= (X-A)/C	fd	fd^2
0-5	6	2.5	-2	-12	24
5-10	17	7.5	-1	-17	17
10-15	7	12.5 (A)	0	0	0
15-20	2	17.5	1	2	2
20-25	5	22.5	2	10	20
C= 5	$\sum f = 37$			$\sum fd = -17$	$\sum fd^2 = 63$

Mean (Average), M= $\frac{\sum \mathbf{fX}}{\sum \mathbf{f}} = \frac{15+127.5+87.5+35+112.5}{37}$ = 10 days

SD= $\mathbf{C}\sqrt{\{\frac{\sum \mathbf{fd^2}}{\sum \mathbf{f}} - (\frac{\sum \mathbf{fd}}{\sum \mathbf{f}})^2\}} = \mathbf{5}\sqrt{\{\frac{\mathbf{63}}{\mathbf{37}} - (\frac{\mathbf{-17}}{\mathbf{37}})^2\}}$

= 6 days

Product 2. CO_2

Lead time	Frequency f	Midpoint X	d= (X-A)/C	fd	fd^2
0-5	0	2.5	-3	0	0
5-10	8	7.5	-2	-16	32
10-15	10	12.5	-1	-10	10
15-20	6	17.5 (A)	0	0	0
20-25	4	22.5	1	4	4
25-30	2	27.5	2	4	8
30-35	1	32.5	3	3	9
C= 5	$\sum f = 31$			$\sum fd = -15$	$\sum fd^2 = 63$

Mean (Average), M= $\frac{\sum \mathbf{fX}}{\sum \mathbf{f}} = \frac{0+60+125+105+90+55+\quad .5}{31}$ = 15 days

SD= $\mathbf{C}\sqrt{\{\frac{\sum \mathbf{fd^2}}{\sum \mathbf{f}} - (\frac{\sum \mathbf{fd}}{\sum \mathbf{f}})^2\}} = \mathbf{5}\sqrt{\{\frac{\mathbf{63}}{\mathbf{31}} - (\frac{\mathbf{-15}}{\mathbf{31}})^2\}}$

= 7 days

Product 3. LPG

Lead time	Frequency f	Midpoint X	d= (X-A)/C	fd	fd^2
0-5	1	2.5	-2	-2	4
5-10	7	7.5	-1	-7	7
10-15	12	12.5 (A)	0	0	0
15-20	10	17.5	1	10	10
20-25	7	22.5	2	14	28
C= 5	$\sum f = 37$			$\sum fd = 15$	$\sum fd^2 = 49$

Mean (Average), M= $\frac{\sum fX}{\sum f} = \frac{2.5+52.5+150+175+157.5}{37}$ = 15 days

SD= $\mathbf{C}\sqrt{\{\frac{\sum fd^2}{\sum f} - (\frac{\sum fd}{\sum f})^2\}} = \mathbf{5}\sqrt{\{\frac{49}{37} - (\frac{15}{37})^2\}}$

= 5 days

Product 4. Acetylene

Lead time	Frequency f	Midpoint X	d= (X-A)/C	fd	fd^2
0-5	0	2.5	-2	0	0
5-10	4	7.5	-1	-4	4
10-15	6	12.5 (A)	0	0	0
15-20	7	17.5	1	7	7
20-25	8	22.5	2	16	32
25-30	11	27.5	3	33	99
C= 5	$\sum f = 36$			$\sum fd = 52$	$\sum fd^2 = 142$

Mean (Average), M= $\frac{\sum fX}{\sum f} = \frac{0+30+75+122.5+180+302.5}{36}$ = 20 days

SD= $\mathbf{C}\sqrt{\{\frac{\sum fd^2}{\sum f} - (\frac{\sum fd}{\sum f})^2\}} = \mathbf{5}\sqrt{\{\frac{142}{36} - (\frac{52}{36})^2\}}$

= 7 days

Product 5. Liquid O_2

Lead time	Frequency f	Midpoint X	d= (X-A)/C	fd	fd^2
0-3	1	1.5	-2	-2	4
3-6	7	4.5	-1	-7	7
6-9	12	7.5 (A)	0	0	0
9-12	11	10.5	1	11	11
12-15	6	13.5	2	12	24
C= 3	$\sum f = 37$			$\sum fd = 14$	$\sum fd^2 = 46$

Mean (Average), M= $\frac{\sum fX}{\sum f} = \frac{1.5+31.5+90+115.5+8}{37}$ = 8 days

SD= $C\sqrt{\{\frac{\sum fd^2}{\sum f} - (\frac{\sum fd}{\sum f})^2\}} = 3\sqrt{\{\frac{46}{37} - (\frac{14}{37})^2\}}$

= 3 days

Product 6. Compressed dry air

Lead time	Frequency f	Midpoint X	d= (X-A)/C	fd	fd^2
0-5	0	2.5	-2	0	0
5-10	7	7.5	-1	-7	7
10-15	6	12.5 (A)	0	0	0
15-20	5	17.5	1	5	5
20-25	5	22.5	2	10	20
C= 5	$\sum f = 23$			$\sum fd = 8$	$\sum fd^2 = 32$

Mean (Average), M= $\frac{\sum fX}{\sum f} = \frac{0+52.5+75+\quad .5+112.5}{23}$ = 14 days

SD= $C\sqrt{\{\frac{\sum fd^2}{\sum f} - (\frac{\sum fd}{\sum f})^2\}} = 5\sqrt{\{\frac{32}{23} - (\frac{8}{23})^2\}}$

= 6 days

Appendix F. EOQ calculation for 6 gases.

No.	Product Name	Unit Measure	Annual Demand (D)	Fixed Cost per Order (BDT) (K)	Holding Cost (BDT) (H)	EOQ	Optimal orders per year
1	Argon	No. of cylinder	1092	1910	644	81	13
2	CO_2	No. of cylinder	252	1910	265	61	4
3	LPG	No. of cylinder	1980	1910	238	178	11
4	Acetylene	No. of cylinder	72	1910	753	20	4
5	Liquid O_2	Liter	1,22,004	1910	6	8813	13
6	Compressed dry air	No. of cylinder	168	1910	18	188	1

Product 1. Argon

EOQ= $Q^* = \sqrt{\frac{2\ KD}{H}} = \sqrt{\frac{2\ X\ 1910\ X\ 1092}{644}}$ = 81cylinders

Number of orders per year, N= $\frac{D}{Q*} = \frac{1092}{81} = 13$ (Avg. order frequency)

Time between consecutive order, T = $\frac{1}{N} = \frac{1}{13} = 28\ days$

Product 2. CO_2

EOQ= $Q^* = \sqrt{\frac{2\ KD}{H}} = \sqrt{\frac{2\ X\ 1910\ X\ 252}{265}}$ = 61cylinders

Number of orders per year, N= $\frac{D}{Q*} = \frac{252}{61} = 4$ (Avg. order frequency)

Time between consecutive order, T = $\frac{1}{N} = \frac{1}{4} = 91\ days$

Product 3. LPG

EOQ= Q* = $\sqrt{\frac{2\ \text{KD}}{H}} = \sqrt{\frac{2\ \text{X}\ 1910\ \text{X}\ 1980}{238}}$ = 178 cylinders

Number of orders per year, N= $\frac{D}{Q*} = \frac{1980}{178} = 11$ (Avg. order frequency)

Time between consecutive order, T = $\frac{1}{N} = \frac{1}{11} = 33\ days$

Product 4. Acetylene

EOQ= Q* = $\sqrt{\frac{2\ \text{KD}}{H}} = \sqrt{\frac{2\ \text{X}\ 1910\ \text{X}\ 72}{753}}$ = 20 cylinders

Number of orders per year, N= $\frac{D}{Q*} = \frac{72}{20} = 4$ (Avg. order frequency)

Time between consecutive order, T = $\frac{1}{N} = \frac{1}{4} = 91\ days$

Product 5. Liquid O_2

EOQ= Q* = $\sqrt{\frac{2\ \text{KD}}{H}} = \sqrt{\frac{2\ \text{X}\ 1910\ \text{X}\ 122004}{6}}$ = 8813Liters

Number of orders per year, N= $\frac{D}{Q*} = \frac{122004}{8813} = 13$ (Avg. order frequency)

Time between consecutive order, T = $\frac{1}{N} = \frac{1}{13} = 28\ days$

Product 6. Compressed dry air

EOQ= Q* = $\sqrt{\frac{2\ \text{KD}}{H}} = \sqrt{\frac{2\ \text{X}\ 1910\ \text{X}\ 168}{18}}$ = 188 cylinders

Number of orders per year, N= $\frac{D}{Q*} = \frac{168}{188} = 1$ (Avg. order frequency)

Time between consecutive order, T = $\frac{1}{N} = \frac{1}{1} = 1\ year$

Appendix G. Total annual cost calculation after applying EOQ.

	Argon	CO_2	LPG	Acetyle ne	Liquid O_2	Compressed dry air
Unit Measure	cylinder	cylinder	cylinder	cylinder	Liter	cylinder
Annual Demand (D)	1092	252	1980	72	1,22,004	168
Unit cost price (C) BDT	2702	1110	996	3163	27.00	72
Holding Cost (BDT) (H)	644	265	238	753	6.00	18
Fixed Cost per Order (BDT) (K)	1910	1910	1910	1910	1910	1910
EOQ= Q*	81	61	178	20	8813	188
Optimal orders	13	4	11	4	13	1
Annual holding cost (HQ*/2)	25,852	7970	21182	6850	26439	3357
Annual order cost (KD/Q*)	25,852	7970	21182	6850	26439	3357
Total purchase cost (CD)	2932056	273504	1972080	207000	3294108	11808
Total annual cost $(CD + \frac{HQ^*}{2} + \frac{KD}{Q^*})$	2983760	289444	2014444	220700	3346986	18522

Appendix H. Total annual cost calculation before employing EOQ.

	Argon	CO_2	LPG	Acetylene	Liquid O_2	Compressed dry air
Time ordered	13	13	13	12	13	6
Annual Demand (D)	1092	252	1980	72	1,22,004	168
Unit cost price (C) BDT	2702	1110	996	3163	27.00	72
Holding Cost (BDT) (H)	644	265	238	753	6.00	18
Fixed Cost per Order (BDT) (K)	1910	1910	1910	1910	1910	1910
Q (Demand/Number times order)	84	20	153	6	9385	28
Annual holding cost (HQ/2)	27048	2650	18207	2059	28155	252
Annual order cost (KD/Q)	24830	24066	24718	22920	24830	11460
Total purchase cost (CD)	2950584	279720	1972080	227736	3294108	12096
Total annual cost $(CD + \frac{HQ}{2} + \frac{KD}{Q})$	3002462	306436	2015005	252715	3347093	23808

Appendix I. Calculation of safety stock and reorder point.

	Argon	CO_2	LPG	Acetylene	Liquid O_2	Compressed dry air
Unit Measure	m3	Kg	Kg	m3	Liter	m3
Monthly Demand ($\bar{x}$)	91	21	165	6	10,167	14
Monthly Demand St. dev. (σ_d)	39	9	26	2	1,857	9
Average daily demand, $\bar{x}$	21	21	66	1	339	3
Daily St. Dev. of demand, σ_d	49	49	56	2	334	10
Avg lead time (LT) in days	10	15	15	20	8	14
lead time st. dev. (σ_{LT}) in days	6	7	5	7	3	6
Service level, SL	0.95	0.95	0.95	0.95	0.95	0.95
Safety Factor (k)	0.8289	0.8289	0.8289	0.8289	0.8289	0.8289
Safety stock (cylinder)	24	7	27	2	1151	6
ROP (cylinder)	54	17	110	5	3863	13

Average daily demand, $\bar{x}$= (Monthly average demand) X $\frac{1}{30}$

Daily St. Dev. of demand, σ_d = (Monthly St. Dev.) X $\sqrt{\frac{1}{30}}$

The safety factor, k is obtained from Appendix B, Table B [9] for the assumed service level 95%.

Finally,

Safety stock= $k\sigma_{dLT} = k\sqrt{\{\text{Average LT x } \sigma_d^2 + \bar{x}^2 (\sigma_{LT})^2\}}$

ROP = $\bar{x}$ LT + $k\sigma_{dLT}$

Product 1. Argon

Safety stock= $k\sigma_{dLT} = k\sqrt{\{\text{Average LT x } \sigma_d^2 + \bar{x}^2 (\sigma_{LT})^2\}}$

$= (0.8289) \sqrt{\{(10 \text{ x } 49^2) + (21^2 \text{ x } 6^2)\}} = 166 \text{ m}^3 = 24$ cylinders

ROP = $\bar{x}$ LT + $k\sigma_{dLT}$

= (21)(10) + 166

$= 376m^3 = 54$ cylinders

Product 2. CO_2

Safety stock= $k\sigma_{dLT} = k\sqrt{\{\text{Average LT x } \sigma_d^2 + \bar{x}^2 (\sigma_{LT})^2\}}$

$= (0.8289) \sqrt{\{(15 \times 49^2) + (21^2 \times 7^2)\}} = 198$ Kg = 7 cylinders

ROP = $\bar{x}$ LT + $k\sigma_{dLT}$

$= (21)(15) + 198$

$= 513$Kg = 17 cylinders

Product3. LPG

Safety stock= $k\sigma_{dLT} = k\sqrt{\{\text{Average LT x } \sigma_d^2 + \bar{x}^2 (\sigma_{LT})^2\}}$

$= (0.8289) \sqrt{\{(15 \times 56^2) + (66^2 \times 5^2)\}} = 327$ Kg = 27 cylinders

ROP = $\bar{x}$ LT + $k\sigma_{dLT}$

$= (66)(15) + 327$

$= 1317$Kg = 110 cylinders

Product 4. Acetylene

Safety stock= $k\sigma_{dLT} = k\sqrt{\{\text{Average LT x } \sigma_d^2 + \bar{x}^2 (\sigma_{LT})^2\}}$

$= (0.8289) \sqrt{\{(20 \times 2^2) + (1^2 \times 7^2)\}} = 9\ m^3 = 2$ cylinders

ROP = $\bar{x}$ LT + $k\sigma_{dLT}$

$= (1)(20) + 9$

$= 29m^3 = 5$ cylinders

Product 5. Liquid O_2

Safety stock= $k\sigma_{dLT} = k\sqrt{\{\text{Average LT x } \sigma_d^2 + \bar{x}^2 (\sigma_{LT})^2\}}$

$= (0.8289) \sqrt{\{(8 \times 334^2) + (339^2 \times 3^2)\}} = 1151$Liters

ROP = $\bar{x}$ LT + $k\sigma_{dLT}$

$= (339)(8) + 1151$

$= 3863m^3$

Product 6. Compressed dry air

Safety stock= $k\sigma_{dLT} = k\sqrt{\{\text{Average LT x } \sigma_d^2 + \bar{x}^2 (\sigma_{LT})^2\}}$

$= (0.8289)\sqrt{\{(14 \text{ x } 10^2) + (3^2 \text{ x } 6^2)\}} = 34 \text{ m}^3 = 6$ cylinders

ROP = $\bar{x}$ LT + $k\sigma_{dLT}$

= (3)(14) + 34

= 76m^3 = 13 cylinders