DEVELOP A STOCHASTIC INVENTORY CONTROL MODEL: A CASE STURDY IN RUBBER MANUFACTURING INDUSTRY

W.A.B Wasala

(138210G)

Degree of Master of Science in Financial Mathematics.

Department of Mathematics

University of Moratuwa
Sri Lanka

September 2017

Declaration

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my thesis/dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works.

Signature: Date: 25/02/2018

The above candidate has carried out research for the Master's thesis under my supervision.

UOM Verified Signature

Signature of the supervisor: Date 25/02/18

Acknowledgement

I am using this opportunity to express my gratitude to everyone who supported me throughout the course of this MSc project. I am thankful for their aspiring guidance, invaluably constructive criticism and friendly advice during the project work. I am sincerely grateful to them for sharing their truthful and illuminating views on a number of issues related to the project.

I express my warm thanks to the project supervisor Mr. T.M.J.A Cooray for his support and guidance at department of mathematics, Faculty of Engineering, University of Mortuwa.

I would also like to thank my project external guide Mr. Kapila sooriyabandara (operations manager Engineering services),Mr.Shantha Munasinghe (Maintenance Engineer), Mr. Hasith Prematillake (country director) and Thilina Shanaka (Process Engineer) from Ansell Lanka (pvt) ltd and all the people who provided me with the facilities being required and conductive conditions for my MSc. project.

Thank you,

Wathsala Wasala

Abstract

The purpose of this research to develop a system for the evaluating and defining of inventory management parameters of widely using Purchasing models in polymer rubber manufacturing industry. This paper investigates the application of inventory models in determining stock control in a polymer rubber manufacturing organization. Developing of common data entering and analyzing software like MS excel to perform the task was particularly interested by the research. The paper starts with an overview of main types of purchasing models and also provides a user friendly system for the managing of the stock parameters of those models. It shows that there are many opportunities for using descriptive, predictive and prescriptive approaches in all areas of purchasing models by using commonly used software to apply real life situation in practical industrial level. The models were selected by focusing on the actual function from a purely operational and execution perspective in the organizational level for a strategic decision making. Introduced system was featured for easy and user friendly integration of computer aided inventory management which focused in the area of Inventory control and generates the stock management parameters easily. It can be concluded that future researches needs to explore the purchasing models evaluation systems related to enterprise resources planning in practical level which can be applied in a real life situation of an organization. It also can be acknowledged that while using empirical results to inform and improve models has advantages, but there are also drawbacks, which relate to the value, the practical relevance and the generalizability of the modelling plus software based approaches.

Key words

Economic order quantity, reorder level, Safety stock, Operation research, Anderson darling test, Normal distribution, visual Basic, Microsoft excel, Solver.

Contents

List of Figures

List of Tables

Abbreviation

AD	-	Anderson - Darling
CRM	-	Company resource management
DLT	-	Demand during the lead time
EDCF	-	Empirical cumulative distribution function
EOQ	-	Economic order quantity
EPQ	-	Economic production quantity
ERP	-	Enterprise resource planning
LT	-	Lead time
MAD	-	Mean absolute deviation
MAPE	-	Mean absolute percent error
MSD	-	Mean square deviation
OLE	-	Object linking and embedding
ROL	-	Re order level
STP	-	Ship to promise
TC	-	Total cost
VB	-	Visual basic
VBA	-	Visual basic application

Appendix

Appendix 01	-	VB User interfaces
Appendix 02	-	Stock parameter manager DVD

Chapter 01

Introduction

1.1 Operations Research

'Operations Research' was coined during the World War II, but the scientific origin of the subject dates much further back. Economist Quesnay in 1759 and Walras in 1874 have developed primitive mathematical programming models. More sophisticated economic models of a similar genre were proposed by Von Newmann in 1937 and Kantrovich in 1939. The mathematical foundations of linear models were established near the turn of the 19th century by Jordan in 1873, Minkowski in 1896 and Farkas in 1903. Many definitions of Operations Research are available. The following are a few of them. In the words of T.L Saaty, "operations research is the art of giving bad answers to problem which otherwise have worse answers". According to Fabrycky and Torgersen, "operations research is the application of scientific methods to problems arising from the operations involving integrated system by man, machine and materials. It normally utilizes the knowledge and skill of an interdisciplinary research team to provide the managers of such systems with optimum operating solutions". Churchman, Ackoff and Arnoff observe, "operations research in the most general sense can be characterized as the application of scientific methods, techniques and tools to problems involving the operations of a system to provide those in control of the operations with optimum solutions to the problems". In a nutshell, operations research is the discipline of applying advanced analytical methods to help make better decisions. The rapid growth of operations research during and after World War II stemmed from the same root with the application of mathematics to build and understand models that only approximate the reality being studied. During World War II, the military depots had the problems of maintaining their inventory such as their materials, arms, ammunition and fuel etc., and hence the optimal utilization of the same was needed with a view to minimize their costs. So, the military management called-on Scientists from various disciplines and organized them into teams to assist in solving strategic and tactic problems. Operations research as a field has always tried to maintain its multidisciplinary character and its uniqueness. Operations research comprises of various branches which includes Inventory control, Queuing theory, Mathematical Programming, Game theory and Reliability methods. In all these branches, many real-life problems are conceptualized as mathematical and stochastic models. In operations research, a model is almost always a mathematical and necessarily an approximate representation of reality. Operations research gives the executive's power to make more effective decisions and build more productive systems based on More complete data, Consideration of all available options, Careful predictions of outcomes and estimates of risk and finally on the latest decision tools and techniques. During model building in operations research, the researcher draws upon the latest analytical technologies, such as

i) Probability and Statistics for helping measure risk, mine data to find valuable connections, insights, test conclusions and make reliable forecasts.

ii) Simulation for giving the ability to try out approaches and test ideas for improvement.

iii) Optimization for narrowing choices to the best when there are virtually innumerable feasible options.

Operations researcher and computer scientists have been implementing inventory systems, while the economists have been focusing on the effect of inventories in the business cycle rather than inventory policies. Mainly, operations research provides tools to

(i) analyze the activity

(ii) assist in decision making,

(iii) Enhancement of organizations and experiences all around us.

Application of operations research involves better scheduling of airline crews, the design of waiting lines at Disney theme parks, two-person start-ups to Fortune leaders and global resource planning decisions to optimizing hundreds of local delivery routes. All benefit directly from operations research decision. Inventory control is one of the most developed fields of operations research. Many sophisticated methods of practical utility were developed in inventory management by using tools of mathematics, stochastic process and probability theory. The primary motivation of this thesis is to analyze the few inventory model from.

1.2 Inventory theory

Inventory has been defined by Monks, as idle resources that have certain economic value. Usually, it is an important component of the investment portfolio of any production system. Keeping an inventory for future sales and utilizing it whenever necessary is common in business. For example, Retail firms, wholesalers, manufacturing companies and blood banks generally have a stock on hand. Quite often, the demand rate is decided by the amount of the stock level. The motivational effect on the people is caused by the presence of stock at times. Large quantities of goods displayed in markets per seasons, motivate the customers to buy more. Either insufficient stock or stock in excess, both situations fetch loss to the manufacturer.

1.3 Inventory controlling

Inventories serve several important functions such as meeting anticipated demand, smoothing production requirements, taking advantage of quantity discounts, minimizing the effects of production and delivery disruptions, and hedging against price increases. However, inventories cost money to obtain and keep around. Therefore, two simultaneous pursuits of inventory control are to provide the right material at the right time and to minimize the cost of if service.

This Project was concerned primarily with independent demand items, which are generally finished goods. Ordering a large quantity reduces the ordering costs (sometimes called the setup cost) since orders are less frequent. Also, setup costs divided over the units produced and shipping expenses per unit are often reduced. However, ordering a small quantity will reduce the holding cost (due to the tied-up capital in the items) and the storage space required since there will be less inventory on hand. Economic order quantity (EOQ) models have been developed that balance these different costs to obtain a minimum total cost.

There are several assumptions used in the derivation of the economic order quantity:

- knowing the ordering cost and the cost of holding inventory
- instant replenishment of inventory (entire shipment comes in at one time)
- the item is not allowed to experience shortages (at least in the simple EOQ relationship)
- expressions for the ordering cost and the holding cost as a function of the order quantity are required
- the average inventory level with constant demand and instantaneous replenishment will be one-half the order quantity
- the holding cost is assumed to be directly proportional to the average inventory level
- the ordering cost is assumed to be constant for each order
- the demand rate is level and constant from one period to the next
- The number of orders per year will be the annual demand divided by the order quantity.

Inventory Control is the volitional break of the operative material flow and thus deliberately composed stocks develop. Inventory Control needs a storage that means a room, building or area to store the item. The in-pouring items are called storage input, the outpouring items storage output.

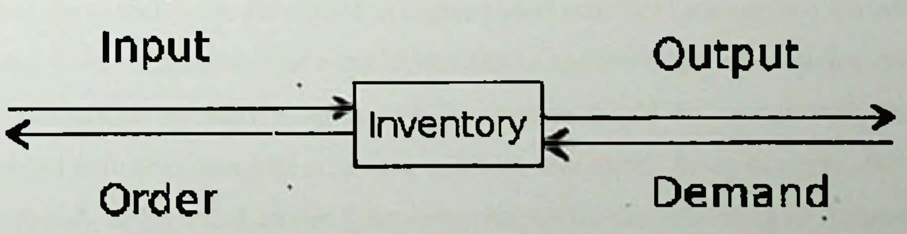


Figure 1.1: The elementary storage transaction

Therefore, inventory control contains all activities and considers all consequences, which relate to the storage of items. On the one hand, there is the mere technical and logistical aspect of inventory control, for example the storage layout. On the other hand, there are general questions, which are related to the total stock of a company. One of the most important decisions is about the quantity of inventories. Therefore, a lot of mathematical models have been developed, which are summarized under the concept of Inventory Control within the scope of Operations Research.

The project was focused on bellow mentioned purchasing models that highly applied in the polymer rubber product manufacturing industry.

01- Purchasing model with constant demand
02- Purchasing model with varying demand
03- Discount model
04- Storage limitation model
05- Limited carrying cost

1.4 Overview of Project

Inventory controlling is a critical term in the industry. It is essential to provide flexibility in operating a system or organization. An inventory models can be classified as follows

01 Purchasing model
02 Manufacturing model.

Most of the models were developed in higher ended software bases or only for educational purpose. It was difficult to find a model that can be applied in the industry that stock levels were maintained by store keepers and the system should be user-friendly as well as integrated with common data recording software like excel. As an example, the software like Minitab, SPSS, MatLab can formulate systems for the delivering of accurate figures of safety stock, Re-Order Level (ROL) & EOQ. But most of the people in the industry are not capable for the handling of those high ended software. There is a need for an accurate, robust and user friendly system that easily integrated with excel and being easily operated by the front-line supervisors of an organization.

The project is mainly focused on purchasing models that facilitates smooth functioning of a stores facility which provides the stock items for several departments.

1.5 Objective

Considering the purchasing processes of the polymer rubber products manufacturing industry there were 5 purchasing models that widely performed. Major concern of the business is it can't entertain the shortages because of the Ship to promise (STP). The system will be able to deliver accurate and optimized parameter values in the stock parameters as delivering required items without shortages.

The software can deliver bellow results with the option of checking the normality of the data set and selecting various purchasing models. Such as

01- Purchasing model with constant demand

02- Purchasing model with varying demand

03- Discount model

04- Storage limitation model

05- Limited carrying cost

The software is developed with excel and visual basic. So that the user friendliness and reliability for the further improvements is high. Same time it can be easily operated by normal data entry operator with initial training since the system is in excel.

1.6 Selected purchasing models that widely using in rubber industry

1.6.1 Purchasing model with constant demand

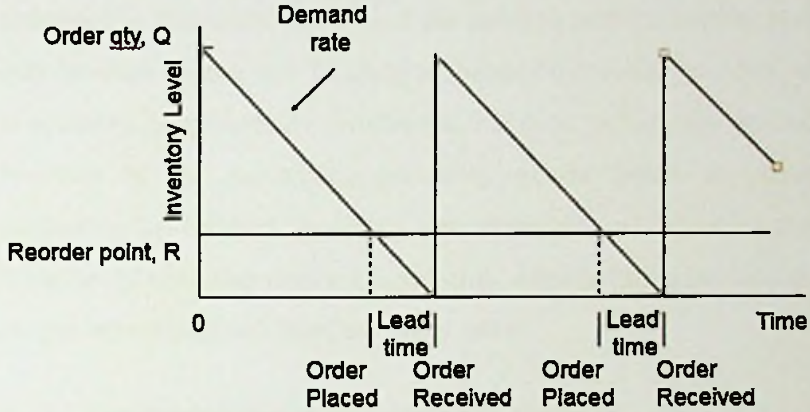


Figure 1.2: Inventory process in the purchasing model with constant demand

If the system was operated with any fluctuations in demand and lead time, we shall encounter stock out situation very often. Even the model is considered as constant demand and constant lead time, it was needed to place the order well before the end of the cycle time, so that the items are received exactly at the end of the present cycle or the beginning of the next cycle. In Polymer rubber manufacturing industry, some of the routing maintenance materials can be categorized as the uniform demand items. Most of them are periodically replacement parts of the machineries. Such as bearings, some lubricants of gear boxes, seal kits, Proximity sensors, etc.

1.6.2 Purchasing model with varying demand

The inventory models that we have discussed earlier have assumed that the demand rate is constant and deterministic throughout the year. We developed minimum-cost order quantity and reorder-point policies based on this assumption. In situations where the demand rate is not deterministic, models have been developed that treat demand as probability distribution. In this section we consider a single-period inventory model with probability demand.

In any probabilistic inventory model, the assumption about the probability distribution for demand is critical and can affect the recommended inventory decision. In the problems presented in this section, we used the uniform and the normal probability distributions may be more appropriate. In using probabilistic inventory models, we must exercise care in selecting the probability distribution that most realistically describes demand.

Majority of the purchasing processes of the items in polymer rubber product manufacturing industry including raw materials are following this purchasing model. Because the customer demand is varying, manufacturing process are changing, machine usages are varying and there are many more.

1.6.3 Purchasing model with Quantity discount

When an item is purchasing in bulk, the buyers are usually given discount in the purchase price of the item. When specifying their cost components, the preceding models have assumed that the unit cost of an item is the same regardless of the quantity in the batch. In fact, this assumption resulted in the optimal solutions being independent of this unit cost. The EOQ model with quantity discounts replaces this assumption by the following new assumption. The unit cost of an item now depends on the quantity in the batch. An incentive is provided to place a large order by replacing the unit cost for a small quantity by a smaller unit cost for every item in a larger batch, and perhaps by even smaller unit costs for even larger batches. Otherwise, the assumptions are the same as for the basic EOQ model. A quantity discount is a price discount on an item if predetermined numbers of units are ordered. Many manufacturing companies receive price discounts for ordering materials and supplies in high volume, and retail stores receive price discounts for ordering merchandise in large quantities.

The basic EOQ model can be used to determine the optimal order size with quantity discounts; however, the application of the model is slightly altered. The total inventory cost function must now include the purchase price of the item being ordered.

Purchase price was not considered as part of our basic EOQ formulation earlier because it had no impact on the optimal order size. In the preceding formula Price discount (PD) is a constant value that would not alter the basic shape of the total cost curve; that is, the minimum point on the cost curve would still be at the same location, corresponding to the same value of quantity Q. Thus, the optimal order size is the same no matter what the purchase price is. However, when a discount price is available, it is associated with a specific order size, which may be different from the optimal order size, and the customer must evaluate the trade-off between possibly higher carrying costs with the discount quantity versus EOQ cost. Thus, the purchase price does affect the order-size decision when a discount is available.

1.6.4 Multiple item Purchasing model with storage limitation

Consider the deterministic purchase model of inventory without shortages. There may be a situation where in the storage space will act as a consistent for storing deferent items. Under such circumstances, the EOQs of the items which are to be stocked in the stores may have to be modified to meet the storage space limitation.

The Economic Order Quantity (EOQ) problem is a fundamental problem in supply and inventory management. In its classical setting, solutions are not affected by the warehouse capacity. When the warehouse space is not enough the problem has to be solved under this constraint. Various approaches can be found in literature concerning the analysis of the multi-item inventory problem with a capacity constraint on a single resource. Among the classical approaches to the solution of the constrained EOQ calculation, the most widespread is based on the application of the Lagrange multipliers method. With this approach the objective is to assure that the total available capacity is not exceeded when the various products, with independent cycle times, will eventually reach a simultaneous

peak of stock. The planning problem is therefore formulated as a minimization problem with a single constraint and Lagrange multipliers are used to solve it.
In the polymer rubber products manufacturing industry there are few items related to maintenance and packaging operations that having considerable price discounts with the quantity. However those items also need to be categorized as receiving zero impact to the operation.

1.6.5 Multiple item purchasing model with carrying cost constraint

From financial standpoint, an inventory represents a capital investment and must compete with other assets within the firm's limited capital funds. Most of the classical inventory models did not take into account the effects of inflation and time value of money. This has happened mostly because of the belief that inflation and time value of money will not influence the cost and price components (i.e., the inventory policy) to any significant degree. But, during the last few decades, due to high inflation and consequent sharp decline in the purchasing power of money in the developing countries like Brazil, Argentina, India, Bangladesh, etc. In the recent decades, multi-item classical inventory problems were approached by formulating proper mathematical models that considered the factors in real world situations.

However, it is important to recognize that many inventory systems must deal simultaneously with many products, sometimes even hundreds or thousands of products. Furthermore, the inventory of each product often is dispersed geographically, perhaps even globally. With multiple products, it commonly is possible to apply the appropriate single product model to each of the products individually. However, companies may not bother to do this for the less important products because of the costs involved in regularly monitoring the inventory level to implement such a model. One popular approach in practice is the ABC control method. This involves dividing the products into three groups called the A group, B group, and C group. The products in the A group are the particularly important ones that are to be carefully monitored according to a formal inventory model. Products in the C group are the least important, so they are only monitored informally on a very occasional basis. Group B products receive an intermediate treatment. It occasionally is not appropriate to apply a single-product inventory model because of interactions between the products. Various interactions are possible. Perhaps similar products can be substituted for each other as needed. For a manufacturer, perhaps its products must compete for production time when ordering production runs. For a wholesaler or retailer, perhaps its setup cost for ordering a product can be reduced by placing a joint order for a number of products simultaneously. Perhaps there also are joint budget limitations involving all the products.

1.7 Visual Basic in Excel

VBA, or Visual Basic for Applications, is the simple programming language that can be used within Excel 2007 (and earlier versions, though there are a few changes that have been implemented with the Office 2007 release) to develop macros and complex programmers. It will facilitate below advantages

- The ability to do what you normally do in Excel, but a thousand times faster
- The ease with which you can work with enormous sets of data
- To develop, analysis and reporting programs downstream from large central data base

such as Sybase, SQL Server, and accounting, financial and production programs such as Oracle, SAP (System, Application and Products) and others

Macros save keystrokes by automating frequently used sequences of commands, and developers use macros to integrate Office with enterprise applications - for example, to extract customer data automatically from Outlook e-mails or to look up related information in (Company resource management) CRM systems or to generate Excel spreadsheets from data extracted from

enterprise resources planning (ERP) systems.

To create an Excel spreadsheet with functionality beyond the standard defaults, you write code. Microsoft Visual Basic is a programming environment that uses a computer language to do just that. Although VBA is a language of its own, it is derived from the big

Visual Basic computer language developed by Microsoft, which is now the core macro language for all Microsoft applications.

1.8 Solver in Excel

In all these situations, we want to find the best way to do something. More formally, we want to find the values of certain cells in a worksheet that optimize (maximize or minimize) a certain objective. Microsoft Office Excel Solver tool helps you answer optimization problems. An optimization model has three parts: the target cell, the changing cells, and the constraints. The target cell represents the objective or goal. In data science, many of the practices, whether that's artificial intelligence, data mining, or forecasting, are actually just some data prep plus a model-fitting step that's actually an optimization model. We'll start with a little practice with optimization now. Just a taste. In Excel, optimization problems are solved using an Add-In that ships with Excel called Solver. On Windows, Solver may be added in by going to File (in Excel 2007 it's the top left Windows button) > Options > Add-ins, and under the Manage drop-down choosing Excel Add-ins and pressing the Go button. Check the Solver Add-In box and press OK. On Mac, Solver is added by going to Tools then Add-ins and selecting Solver.xlam from the menu. A Solver button will appear in the Analysis section of the Data tab in every version.

Optimization problems are real world problems we encounter in many areas such as mathematics, engineering, science, business and economics. In these problems, we find the optimal, or most efficient, way of using limited resources to achieve the objective of the situation. This may be maximizing the profit, minimizing the cost, minimizing the total distance travelled or minimizing the total time to complete a project. For the given problem, we formulate a mathematical description called a mathematical model to represent the situation. The model consists of following components:

• Decision variables: The decisions of the problem are represented using symbols such as X1, X2, X3,.....Xn. These variables represent unknown quantities (number of items to produce, amounts of money to invest in and so on).

• Objective function: The objective of the problem is expressed as a mathematical expression in decision variables. The objective may be maximizing the profit, minimizing the cost, distance, time, etc.

• Constraints: The limitations or requirements of the problem are expressed as inequalities or equations in decision variables. If the model consists of a linear objective function and linear constraints in decision variables, it is called a linear programming model. A nonlinear programming model consists of a nonlinear objective function and nonlinear constraints. Linear programming is a technique used to solve models with linear objective function and linear constraints. The Simplex Algorithm developed by Dantzig (1963) is used to solve linear programming problems. This technique can be used to solve problems in two or higher dimensions.

1.9 Chapter overview

Chapter 2 – Literature review

Deals with the literature reviewed to get a perception to the theoretical background of the study along with an awareness onto other research where carried out in this area.

Chapter 3 – Methodology

Deeper looking at the applications of the inventory controlling models in rubber glove manufacturing organizations, identifying the assumptions and inputs to carry out the practical results and provide clear vision of the application of the software.

Chapter 4 – Calculations and results

Application and comparison of manual calculations and the calculations done by the invented system by providing realistic data taken from rubber glove manufacturing organization.

Chapter 5 – Conclusion

Compare and analyze both results and check for the deviation. Performed a sensitivity analysis for one model that used regularly to check for the behaviors of the system with realistic data as verifying the degree of accuracy. Discussed and assessed the results of the research as recommending the future improvements.

Chapter 02

Literature review

The problem of inventory control is one of the most important in organizational management. As a rule, there is no standard solution – the conditions at each company or firm are unique and include many different features and limitations. An occurring task of the mathematical models development and determining the optimal inventory control strategy is related with this problem. Features of inventory management models are that the resulting optimal solutions can be implemented in a fast-changing situation where, for example, the conditions are changed daily. There is a need for new and effective methods for modelling systems associated with inventory management, in the face of uncertainty. Uncertainty exists regarding the control object, as the process of obtaining the necessary information about the object is not always possible. The solution of such complex tasks requires the use of systems analysis, development of a systematic approach to the problem of management in general. Inventory models are distinguished by the assumptions made about the key variables: demand, the cost structure, physical characteristics of the system. These assumptions may not suit to the real environment. There is a great deal of uncertainty and variability. The research object is models of inventory control under uncertainty.

Stocks (reserves) are created to carry out the normal activities of the company. Proper and timely determination of the optimal inventory control strategy allows freeing a significant amount of assets, frozen in the form of stocks, which ultimately increases the efficiency of resource use. Even though there are literally millions of different types of products manufactured in our society, there are only two fundamental decisions that one has to make when controlling inventory:

1. How large should an inventory replenishment order be?
2. When should an inventory replenishment order be placed?

The objectives of inventory management often reduce the problem if it is more profitable to do quickly but more expensive or slower but cheaper. Such a strategy will be optimal inventory control, which minimizes the sum of milestones costs associated with the production, storage and inventory shortage per unit of time or for a specific (including infinite) amount of time.

Management models differ in the nature of the available information on the properties of the simulated system. When the value of the model parameters is well-defined, nature of the corresponding mathematical model is deterministic. If the parameters of the system are random values with a known probability, distribution models are stochastic (probabilistic). If all of the model parameters do not change over time, it is called static, otherwise – dynamic.

Static models are used when receiving a one-time decision about the level of reserves for a certain period, and dynamic – in the case of sequential decision-making about stock levels or to adjust earlier decisions, taking into account the changes taking place. When static patterns of change in system parameters cannot be installed, it is necessary to solve the problem of inventory management in the face of uncertainty.

In models of inventory management, the following characteristics are taken into account:

Single versus multiple items. This dimension considers whether a single item can be used in isolation for calculations, or whether multiple interdependent products should be taken into account, as a result of collective budget or space constraints, coordinated control or substitutability between items.

Time duration. In some inventory management situations, the selling season for products is short, and excess stock at the end of the season cannot be used to satisfy the demand of the next season. In such cases, a single period model is required. When multiple periods need to be considered, a common approach is to use a rolling horizon implementation approach. Here, decisions consider only a relatively small number of future periods and are made at the start of each period. The decisions are then implemented in the current period, and the problem resolved at the start of the subsequent period. Number of stocking points. Sometimes, it is appropriate to treat a single stocking point in isolation. In many real world cases, inventories of the same item are kept at more than one location. In multi-echelon situations, the orders generated by one location (e.g., a branch warehouse) become part or all of the demand at another location (e.g., a central warehouse).

In addition, one can have horizontal multiplicity, that is, several locations at the same echelon level (e.g., several branch warehouses) with the possibility of transshipments and redistributions. The nature of product. The product type dimension identifies and considers certain product characteristics. For instance, a product may be perishable, consumable, repairable or recoverable. Deterioration of an item in the storage period is a natural process. Therefore, it cannot be ignored in inventory policy. It may be different in different storage places due to the difference in the environment. Nature of demand. There are a number of possible choices in modelling the demand process.

Deterministic demand is exactly known, unlike the probabilistic demand. It can be of two types. One of them is static, which does not have any variation. The amount of demand known or can be computed with certainty. Second type is dynamic, which may vary. This type of demand varies with time, but the way in which the demand varies is known with certainty.

The type of demands that Stationary distribution with known parameters follows a probability distribution that is known or estimated from historical data. Commonly used distributions include normal, gamma, Poisson.

The type of demand that Non-stationary probabilistic demand behaves like a random walk that evolves over time, with regular changes in its direction and rate of growth or decline. On the basis of the demand sources, demands are divided into independent and dependent. Independent demand is the demand that consists of the individual consumers' demands, each of them feeling the need independently of the other. Dependent demand occurs when a manufacturer uses a number of components for the manufacture of finished goods, and the demand for each component is associated with other and depends on the production plan of manufacturing. Nature of supply process. The nature of the supply process refers to any restrictions or constraints that have been imposed on the inbound processes of the supply chain. Minimum or maximum order size or replenishment lead times are examples of typical factors considered in this dimension. There were three possible forms of lead-time identified. The first form is where the lead-time of each replenishment is known; the second is where replenishments arrive after a random time; and the final form is where seasonal factors may affect the time it takes for an order to be fulfilled. A supplier usually has limited capacity; therefore, order size restrictions are taken into account in this dissertation. In addition, lead-time is assumed to be a constant and known value. Any warehouse is established in order to prevent a shortage of a certain type of products handled by the system. Lack of stock at the right time leads to losses associated with downtime, unevenness of production, etc. These losses will be called a penalty for the deficit.

Any model is an abstraction of reality. The more number of dimensions to be taken into account in the model, the greater the model will meet the requirements of the real environment. It is a challenging task to obtain realistic input values for the mathematical inventory model parameters. The decision-making person performing this task is often operating in an environment, with unknown parameters. In inventory control, it is associated with the uncertainty of customer demand rates, manufacturing and delivery lead times. The models and methods of decision-making in existing theory of inventory management are usually focused on deterministic parameters and modules do not meet the full requirements of the real environment. In such cases, fuzzy models of inventory management take an important place. Fuzzy set theory suggests methods of dealing with imprecision and uncertainty in a quantitate way. Fuzzy logic is widely used in solving problems of riskology, problems of artificial intelligence as in building expert systems, and in combination with artificial neural networks. The theoretical basis of fuzzy logic constitutes the fuzzy sets has gained widespread prominence as a means to model vague data in production management applications. It was defined the uncertainty as the difference between the amount of information required to perform a task and the amount of information already possessed. In the real world, many forms of uncertainty affect production processes. There were two groups: environmental uncertainty and system uncertainty. Environmental uncertainty includes uncertainties beyond the production process, such as demand uncertainty and supply uncertainty. System uncertainty is related to uncertainties in the production process, such as operation yield uncertainty, production lead-time uncertainty, and quality uncertainty, failure of the production system and changes to product structure, to mention some. A new stage in the theory of inventory management is the emergence of models taking into account uncertainty.

For the fixed order size inventory models, the economic order quantity (EOQ) model is most well-known. 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 is derived under a set of restrictive assumptions, as follows:

- Demand is known with certainty and is constant over time.
- No shortages are allowed.
- Lead time of orders is constant.
- The order quantity is received all at once.

Economic Batch Quantity model (EBQ) determines the quantity a company or retailer should order to minimize the total inventory costs by balancing the inventory holding cost and average fixed ordering cost. This method is an extension of the EOQ model. The classical economic Batch quantity model (EBQ) has been widely used. Numerous research efforts have been undertaken to extend the basic EBQ model by releasing various assumptions or adding new so that the model conforms more closely to real-world situations. Recently, re-work activities have attracted considerable attention because of the reduction of the natural resources and the rise in the cost of raw material.

Inventory models that address issues of inventory coordination between a buyer and a seller have been extensively studied in the literature. This class of inventory models is commonly referred to as joint economic lot sizing (JELS) models. The objective of these models is the development of a jointly coordinated buyer-seller inventory strategy that is more beneficial to each member's individual non-coordinated inventory strategy. One of the first attempts was made as extending the existing model of Dolan. They applied fuzzy mathematical programming to solve the joint economic lot size problem with multiple price breaks. Single and multiple incremental price discounts are modelled as fuzzy numbers. Multi-objective joint economic lot size models are developed in both crisp and fuzzy environments. Here, the objectives are to minimize the buyer's total average cost and to maximize the seller's average revenue. A fuzzy goal programming methodology is used to solve the model. Some of the studies applied various modelling methods to manage the defective rate in an integrated vendor-buyer inventory model. Three cases are investigated: crisp defective rate, triangular fuzzy defective rate and statistic fuzzy defective rate. In these two fuzzy cases, the signed distance procedure is applied to estimate the joint total expected cost in a fuzzy sense. The newsvendor model is a single-period, probabilistic inventory model, which objective is to determine the order quantity that minimizes expected underage costs (costs due to shortage) and overage costs (costs due to holding inventory).

The main difference between the single-period model and the multi-period model is that the multi-period model may involve stock leftovers from previous periods, which makes the optimal choice of order quantities more complicated. In real-world applications, inventory and production decisions are interdependent and temporal in nature. Fuzzy logic has been useful in formulating multi-period lot sizing models.

In the past years, the efficiency of inventory management has become an area of major concern in business. New inventory models for managing the inventory levels are now available. This paper has presented a literature survey of models of inventory control under uncertainty. Most of the analytical models addressed only one type of uncertainty and assumed a simple structure of the production process. The most common dimensions to be considered as fuzzy variables are demand, the cost of acquisition. Each model, based on some assumptions, has its benefits and disadvantages, but still, many authors continue to design inventory control models using such approach as fuzzy logic. The existence of such quantity of models shows that fuzzy set theory is one of the appropriate methods, which can suppose a great advance in inventory management. The emphasis in each review was to identify how the fuzzy set theory was used in the formulation of the inventory model. The classification and review of models are quite general and can be extended.

Bill Roach explains how the origin of the Economic Order Quantity began in his article, "Origin of the Economic Order Quantity formula; transcription or transformation?" published in 2005. Roach explains that the Economic Order Quantity (EOQ) has been a well-known formula that calculates the optimal economic order quantity. He also mentions how Ford W. Harris contribution to the EOQ formula was significant. Harris was always a self-taught individual that only received formal schooling that extended throughout high school. He managed to write and publish the economic order quantity formula in 1915 as an undergraduate student. The Economic Order Quantity (EOQ) formula has been used in both engineering and business disciplines. Engineers study the EOQ formula in engineering economics and industrial engineering courses. On the other hand, business disciplines study the EOQ in both operational and financial courses. In both disciplines, EOQ formulas have practical and specific applications in illustrating concepts of cost tradeoffs; as well as specific application in inventory.

Today's leading technology, many companies are not taking advantage of the fundamental inventory models. There are various software packages in aiding companies with inventory control, but if the data inputted are inaccurate, it may lead to poor results. In order to have suitable results for any inventory model, accurate product costs, activity costs, forecasts, history, and lead times need to be in place. As a result of bad data, companies have had bad experience with some inventory models, and that is one of the reasons they do not take advantage of the EOQ model.

Another reason why a company does not take advantage of the EOQ model is because management does not know how it works. Even if a company has implemented a leading software package to help them, if they do not know how the system works it could cost more harm than good. Many times the users do not understand how the data is calculated and how the system is set up. They simply rely on the system built-in default software calculations, which in most cases, the system is "out of whack". In order to prevent the system from going "out of whack," management as well as the user, need to obtain proper knowledge of the EOQ concepts and how they are derived. The software is only design to aid and not replace the traditional way of running a business.

At times, people in the retail business or in the manufacturing industry do not know or do not understand what EOQ stands for and how it is used? In this article, "The EOQ Inventory Formula," written by James A. Cargal clearly explains the fundamental theory of the Economic Order Quantity. Cargal published this article from Troy State University Montgomery. The article is straight forward and easy to understand. Cargal does a great job explaining each variable and how it's used accordingly.

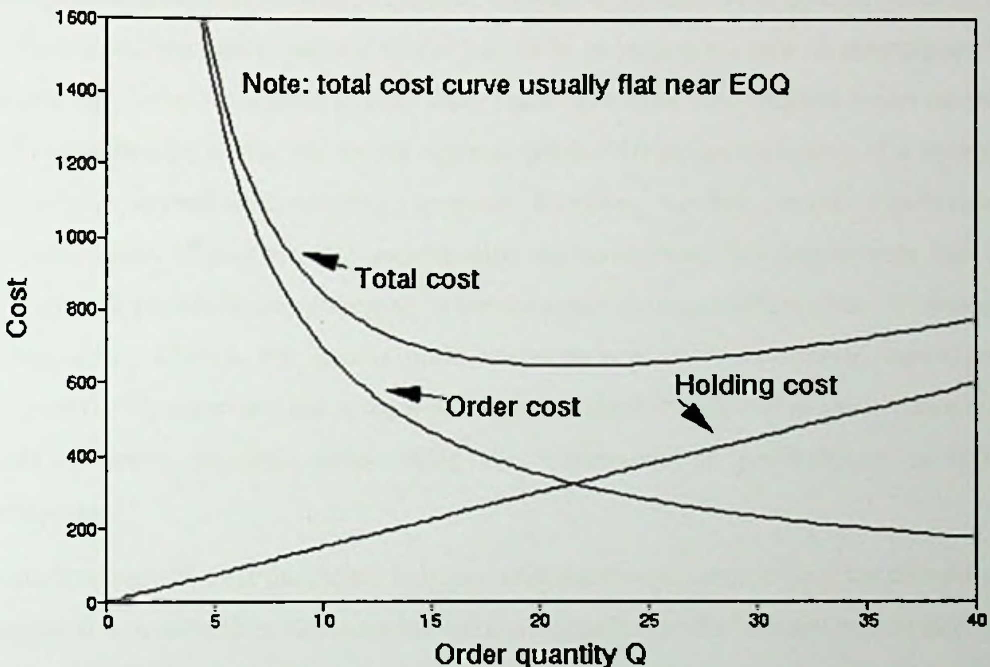


Figure 2.1: EOQ Process Graph

In summary, Cargal, describes the Economic Order Quantity as, "Determining the order quantity "Q", that balances the order cost "C" and the holding costs "H", to minimize total costs as shown in figure 2.1. The greater the Q, the order cost would decrease due to less orders placed. On the other hand, if Q increases, the holding cost would increase due to higher inventory levels." (Cargal) This is an excellent illustration of how the EOQ is used and how it benefits a company.

"Stack Them High, Let 'em Fly": Lot-Sizing Policies When Inventories Stimulate Demand" In this article, "Stack Them High, Let 'em Fly" by Anantaram Balakrishnan, Michael S Pangburn, and Euthemia Stavrulaki, introduced a revised EOQ model to help increase profit in retail. It mentions how some retails stock large quantities of inventory to drive sales and stimulate demand. By having high inventory level of a certain product, the company could create side stacks or distribute the products in different locations within the store in hence promotes impulse buying. As a result to stimulating demand, the standard economic order quantity model had to be modified in order to incorporate the demand parameter from prior cycles. They show how their new method could increase profit even though it may not be the optimal result. "Using an extension of a standard inventory-dependent demand model from the literature, we first provide a convenient characterization of products that require early replenishment. We demonstrate that the optimal cycle time is largely governed by the conventional trade-off between ordering and holding costs, whereas the reorder point relates to a promotions-oriented cost-benefit perspective. We show that the optimal policy yields significantly higher profits than cost-based inventory policies, underscoring the importance of profit-driven inventory management."

Most of the models were developed in higher ended software bases or only for educational purpose. It was difficult to find a model that can be applied in the industry that stock levels were maintained by store keepers and the system should be user-friendly as well as integrated with common data recording software like excel. As an example, the software like Minitab, SPSS, MatLab can formulate systems for the delivering of accurate figures of safety stock, ROL & EOQ. But most of the people in the industry are not capable for the using of those high ended software. There is a need for an accurate, robust and user friendly system that easily integrated with excel and being easily operated by the front line supervisors of an organization.

Visual basic is one of leading programming language that facilitate friendly user interface and the easy integration with MS excel.

There are a variety of different visual programming mediums available in the programming realm. Each of these languages has their own advantages and disadvantages. One of the most popular, long lasting, and easy to use visual programming method is visual basic. The history of visual basic stretches back decades, right to the very beginning of visual programming methods. Visual basic has a convoluted origin story that dates to the early 80's. BASIC was a programming language that was used throughout the 80's and had been developed by Microsoft. It was a somewhat cumbersome programming language to use in some ways, but its cheapness and adaptability helped push it and Microsoft to the top of the market.

Microsoft then became interested in a "form building" application that would create visual images. This was a daring idea at the time, as most computers of the time utilized crude American society of cinematographers (ASCII) based images that rarely, if ever, resembled anything. They approached a man named Alan Cooper, who had created a unique interface that seemed suited to Microsoft's needs.

Cooper's company, Tripod, developed an application called "Ruby" which did exactly what Microsoft wanted. However, it didn't have a programming language. Microsoft simply paired it up with BASIC, adapting its programming to be compatible with the language, and created Visual Basic, debuting it at a trade show in Georgia in 1991.

Visual basic was an immediately popular language and helped fuel further success for Microsoft. One of the most interesting aspects of Ruby (and Visual Basic) was that it could load new link libraries which contained controls to create your visual forms. These controls could then be utilized in future programming projects. This interface, later to be called VBX, revolutionized the industry by creating a fully adaptable programming medium.

Future editions of Visual Basic followed a nearly yearly release schedule. Visual Basic 2.0 came out in 1992. Microsoft, never known for user friendly interfaces, actually streamlined the environment. IT became a lot easier to understand and use. They also tightened up its speed and added the idea of "core objects" which later evolved into "class modules."

The history of visual basic continued with the 1993 release of version 3.0. This was the first version to include standard and professional versions. It also included the earliest edition of the Microsoft Jet Database Engine. It could read and write in Jet, making it essential for later Jet based applications.

When Visual Basic 4.0 came out in 1995, it was hailed as the best version of Visual Basic yet released. Programmers could now create 32-bit and 16-bit programs, as well as write in non-GUI (Graphical user interface) classes. The control system was updated from VBX (Visual basic extension) to OLE (Object linking and embedding), which evolved into ActiveX.

Visual Basic 5.0, released in 1997, was the first Visual Basic to offer programming only in 32-bit. This upset some fans of the older, 16-bit programming style. However, it also offered custom controls and the ability to create executable programs that could then be sold and distributed between friends and family.

The release of 6.0 in 1998 was the peak of Visual Basic's success. It let users create web based programs, and featured streamlined coding methods that made it even easier to use. Mainstream support for the programming language ended in 2005, although updated editions have been periodically released for Microsoft's own use.

Office applications like Excel have Visual Basic for Applications (VBA), a programming language that gives the ability to extend those applications.

VBA works by running macros, step-by-step procedures written in Visual Basic. Learning to program might seem intimidating, but with some patience and some examples such as the ones in this article, many users find that learning even a small amount of VBA code makes their work easier and gives them the ability to do things in Office that they did not think were possible. Once it was learned some VBA, it becomes much easier to learn a whole lot more—so the possibilities here are limitless.

By far the most common reason to use VBA in Excel is to automate repetitive tasks. For example, suppose that there have a few dozen workbooks, each of which has a few dozen worksheets, and each of those needs to have some changes made to it. The changes could be as simple as applying new formatting to some fixed range of cells or as complex as looking at some statistical characteristics of the data on each sheet, choosing the best type of chart to display data with those characteristics, and then creating and formatting the chart accordingly.

Either way, it would probably rather not have to perform those tasks manually, at least not more than a few times. Instead, it could automate the tasks by using VBA to write explicit instructions for Excel to follow.

VBA is not just for repetitive tasks though. VBA can also be used to build new capabilities into Excel (for example, new algorithms could be developed to analyze the data, then use the charting capabilities in Excel to display the results), and to perform tasks that integrate Excel with other Office applications such as Microsoft Access 2010. In fact, of all the Office applications, Excel is the one most used as something that resembles a general development platform. In addition to all the obvious tasks that involve lists and accounting, developers use Excel in a range of tasks from data visualization to software prototyping.

Chapter 03

Methodology

3.1 Purchasing model with constant demand

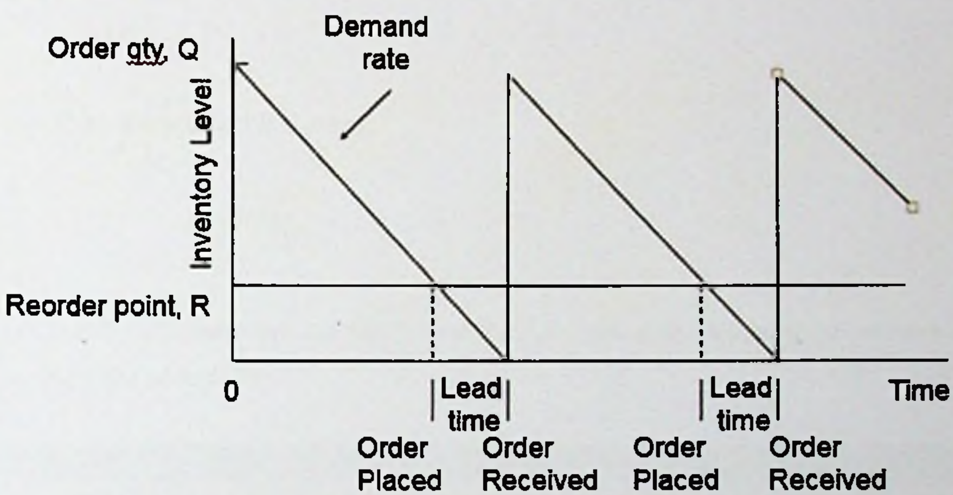


Figure 3.1: Inventory process in the purchasing model with constant demand

If the system was operated with any fluctuations in demand and lead time, we shall encounter stock out situation very often. Even the model is considered as constant demand and constant lead time, it was needed to place the order well before the end of the cycle time, so that the items are received exactly at the end of the present cycle or the beginning of the next cycle.

Let DLT be the demand during the lead time (LT). Then

DLT = Demand rate per day x Lead time period (days)

If there were no variation in lead-time and the demand then it was sufficient to have a stock of DLT at the time of placing order.

Let ROL be the stock level at which an order was placed so that the items were received against the order at the beginning of the next cycle. If the demand is not varying the reorder level (ROL) is given by

$$ROL = D_{LT}$$

Let Q* be the optimal order size

$$Q^* = \sqrt{2Co/Cc}$$

This is a straight forwarded and easily formulated in excel sheet. VB program was made for the user interface of data entry.

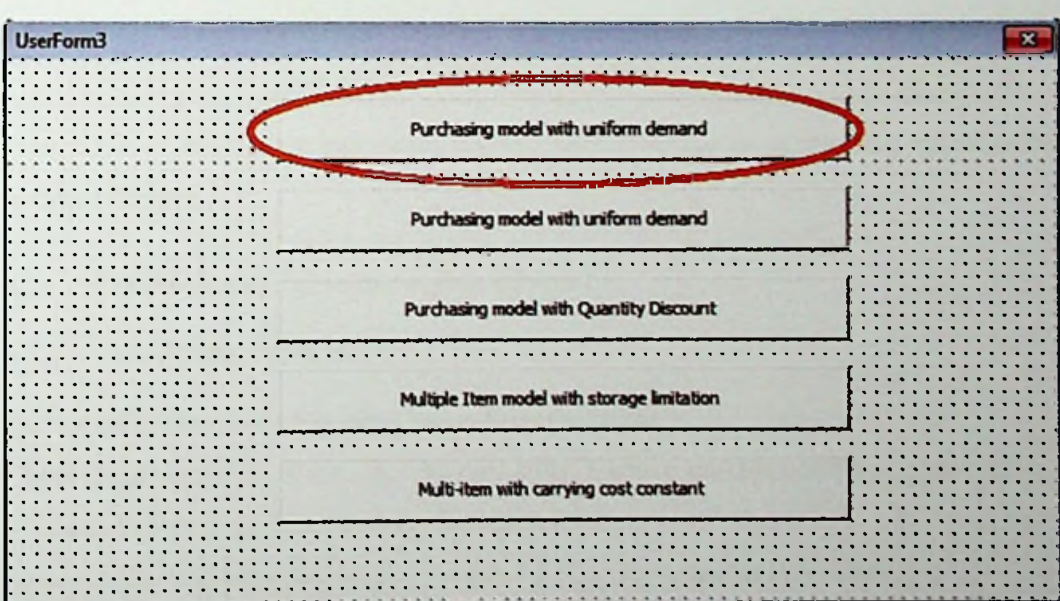


Figure 3.2: main menu for the selecting of the data entry user interface of purchasing model with constant demand

After selecting the model bellow user interface was appeared for the entering data and displaying the results.

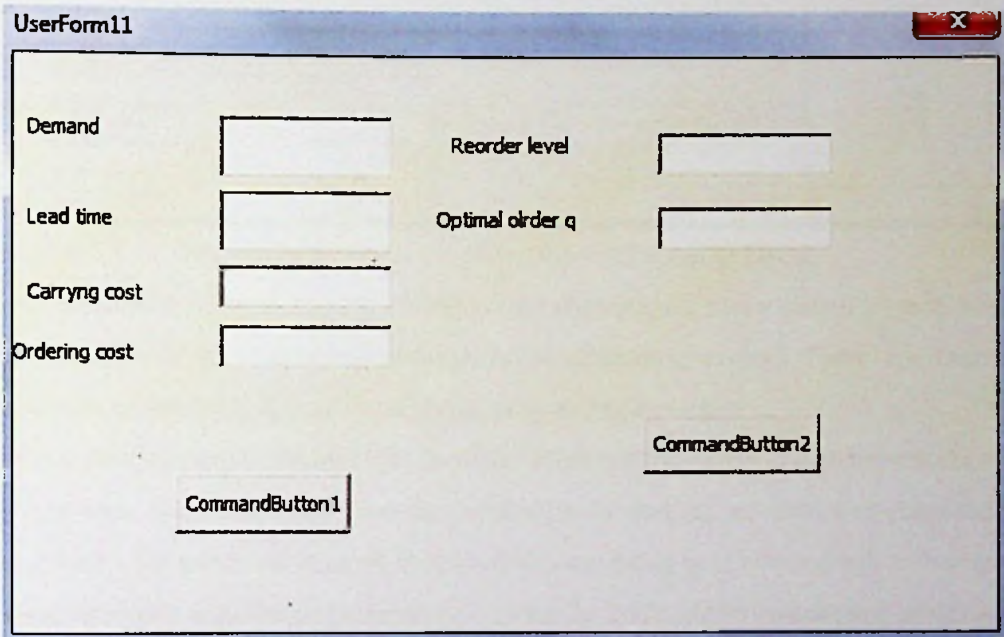


Figure 3.3: Data entry and result display user interface of purchasing model with constant demand

3.2 Purchasing model with varying demand

3.2.1 Calculating safety stock

Get the information of spare parts usage from the stores.

Check it for normality. If not, fit it for normality. Choose suitable confidence interval (Assume that 99.5%). Then develop the value for k

Safety stock (99.5% confidence) $= k\sigma$ (σ = standard deviation)

Choose suitable confidence interval

Formulated excel sheet was prepared as integrated with the with VB user interface to check the normality by using Anderson – darling test.

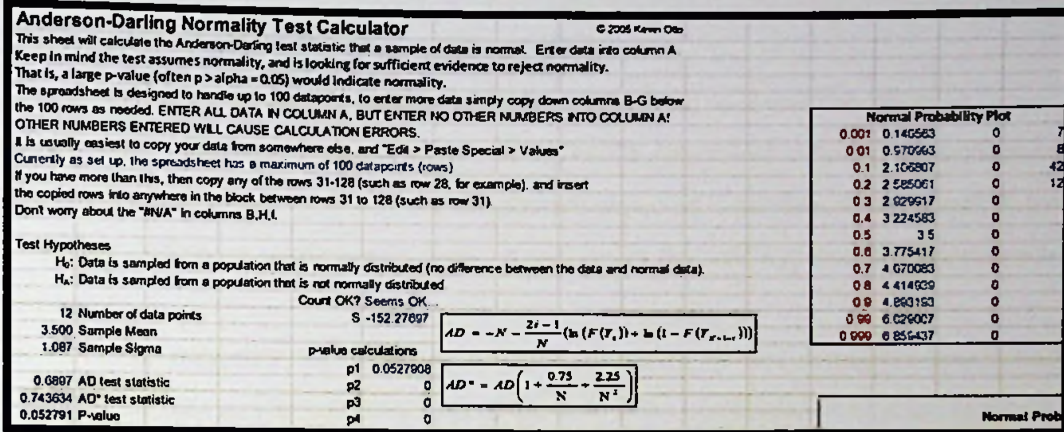


Figure 3.4: Anderson- Darling normality test work sheet in Excel

An assessment of the normality of data is a prerequisite for many statistical tests because normal data is an underlying assumption in parametric testing. There are two main methods of assessing normality as graphically and numerically.

The approaches can be divided into two main themes as relying on statistical tests or visual inspection. Statistical tests have the advantage of making an objective judgement of normality, but are disadvantaged by sometimes not being sensitive enough at low sample sizes or overly sensitive to large sample sizes. As such, some statisticians prefer to use their experience to make a subjective judgement about the data from plots/graphs. Graphical interpretation has the advantage of allowing good judgement to assess normality in situations when numerical tests might be over or under sensitive, but graphical methods do lack objectivity. If there are no any great deal of experience interpreting normality graphically, it is probably best to rely on the numerical methods.

In Minitab environment there are some methods to define normality of a data set. The path is as bellow

Choose Stat > Basic Statistics > Normality Test.

The test results indicate whether you should reject or fail to reject the null hypothesis that the data come from a normally distributed population. The normality test can be done and produce a normal probability plot in the same analysis. The normality test and probability plot are usually the best tools for judging normality, especially for smaller samples.

3.2.1.1 Types of normality tests

The following are types of normality tests that can be used to assess normality.

Anderson-Darling test: This test compares the ECDF (empirical cumulative distribution function) of the sample data with the distribution expected if the data were normal. If the observed difference is adequately large, it will reject the null hypothesis of population normality.

Ryan-Joiner normality test: This test assesses normality by calculating the correlation between the data and the normal scores of the data. If the correlation coefficient is near 1, the population is likely to be normal. The Ryan-Joiner statistic assesses the strength of this correlation; if it is less than the appropriate critical value, you will reject the null hypothesis of population normality. This test is similar to the Shapiro-Wilk normality test.

Kolmogorov-Smirnov normality test: This test compares the ECDF (empirical cumulative distribution function) of the sample data with the distribution expected if the data were normal. If this observed difference is adequately large, the test will reject the null hypothesis of population normality. If the p-value of this test is less than the chosen α, then it can reject the null hypothesis and conclude that the population is no normal.

3.2.1.2 Comparison of Anderson-Darling, Kolmogorov-Smirnov, and Ryan-Joiner normality tests

Anderson-Darling and Kolmogorov-Smirnov tests are based on the empirical distribution function. Ryan-Joiner (similar to Shapiro-Wilk) is based on regression and correlation.

All three tests tend to work well in identifying a distribution as not normal when the distribution is skewed. All three tests are less distinguishing when the underlying distribution is a t-distribution and nonmorality is due to kurtosis. Usually, between the tests based on the empirical distribution function, Anderson-Darling tends to be more effective in detecting departures in the tails of the distribution. Usually, if departure from normality at the tails is the major problem, many statisticians would use Anderson-Darling as the first choice.

The focus was to integrate the normality test with excel environment by applying one of above methods.

Software will generate a report by itself by checking the normality of the data set. If the data set is not normal then the operator need to go through the data set and check for the outliers.

These tests can be easily done by the software like minitab, SPSS, MATLab, etc. but those are higher ended software that cannot be integrated with conventional data entering software and would be difficult to handle by the front line supervisory levels like store keepers.

The system was developed in Visual Basic environment which was easily integrated with excel for the checking normality of the data set using Anderson darling test.

3.2.1.3 Anderson Darling test

The Anderson-Darling Test was developed in 1952 by Theodore Anderson and Donald Darling. It is a statistical test of whether or not a dataset comes from a certain probability distribution, e.g., the normal distribution. The test involves calculating the Anderson-Darling statistic. Anderson-Darling statistic can be used to compare how well a data set fits different distributions.

The two hypotheses for the Anderson-Darling test for the normal distribution are given below:

H0: The data follows the normal distribution

H1: The data do not follow the normal distribution

The null hypothesis is that the data are normally distributed; the alternative hypothesis is that the data are non-normal.

In many cases (but not all), it can be determined a "P" value for the Anderson-Darling statistic and use that value to help you determine if the test is significant are not. That is P ("probability") value is the probability of getting a result that is more extreme if the null hypothesis is true. If the P value is low (e.g., <=0.05), it can be concluded that the data do not follow the normal distribution.

The Anderson-Darling Test will determine if a data set comes from a specified distribution, in our case, the normal distribution. The test makes use of the cumulative distribution function. The Anderson-Darling statistic is given by the following formula:

$$AD = -n - \frac{1}{n}\sum_{i=1}^{m}(2i-1)\left[\ln F(X_i) + \ln\left(1 - F(X_{n-i+1})\right)\right]$$

$$AD^* = AD\left(1 + \frac{0.75}{N} + \frac{2.25}{N^2}\right)$$

Where n = sample size, F(X) = cumulative distribution function for the specified distribution and i = the i^{th} sample when the data is sorted in ascending order.

The calculation of the p value is not straightforward. The reference most people use is R.B. D'Augostino and M.A. Stephens, Eds., 1986, Goodness-of-Fit Techniques, Marcel Dekker. There are different equations depending on the value of AD*. These are given by:

- If $AD^* \geq 0.6$, then $P = \exp\left(1.2937 - 5.709\left(AD^*\right) + 0.0186\left(AD^*\right)^2\right)$
- If $0.34 \leq AD^* \leq 0..6$, then $P = \exp\left(0.9177 - 4.279\left(AD^*\right) - 1.38\left(AD^*\right)^2\right)$
- If $0.2 \leq AD^* \leq 0.34$,then $P = 1 - \exp\left(-8.318 + 42.796\left(AD^*\right) - 59.938\left(AD^*\right)^2\right)$
- If $AD^* \leq 0.2$, then $P = 1 - \exp\left(-13.436 + 101.14\left(AD^*\right) - 223.73\left(AD^*\right)^2\right)$

The Anderson-Darling test is used to determine if a data set follows a specified Involves calculating the Anderson-Darling statistic and then determining the p value for the statistic. It is often used with the normal probability plot.

3.2.2 Calculating re order level

D_{LT} = Demand per day*lead time (Days)

Reorder level = D_{LT} + safety stock

3.2.3 Calculate the economic order quantity

Carrying cost $-c_c$

Ordering cost $-c_o$

Total cost = carrying cost + ordering cost

$$\text{Totalcost} = \frac{DC_0}{Q} + \frac{QC_c}{2}$$

Partial differentiate w.r.t

$$\frac{\partial Tc}{\partial Q} = \frac{-DC_0}{Q^2} + \frac{C_c}{2}$$

In the minimum total cost,

$$\partial Tc/\partial Q = 0$$

$$\frac{\partial Tc}{\partial Q} = 0$$

$$0 = \frac{-DC_0}{Q^2} + \frac{C_c}{2}$$

$$Q_{opt} = \sqrt{\frac{2DC_0}{C_c}}$$

It was required that all the data be recorded and the calculations need to be straight forward and accurate as well as the system should be user-friendly.

So that the developed system need to be facilitate user friendly data entering and recording, normality checking and indicating the outliers, defining accurate and clear parameters (safety stock, Reorder level, Economic order quantity) and recording those in particular raw data sheet.

The formulated sheet was prepared for the extraction of the results of above equations with respected to the data entered in VB user interface.

Figure 3.5: VB user interface of Purchasing model with varying demand

3.3 Purchasing model with Quantity discount

When an item is purchasing in bulk, the buyers are usually given discount in the purchase price of the item. Let i be the percent of the purchase price accounted for carrying cost / unit/ period. The discount may be a step function of purchase quantity as shown bellow

Quantity	Purchase price per unit
$0 \le Q1 \le b1$	P1
$b1 \le Q2 \le b2$	P2
$b2 \le Q3 \le b3$	P3
....	....
$bn\text{-}1 \le Qn$	Pn

Table 3.1: General illustration of discount scenarios

Bellow procedure is needed to follow for the computing of optimum order size

Step 1: Find the EOQ of last (nth) price break

$$Q_n^* = \sqrt{\frac{2C_0D}{iP_n}}$$

If it is greater than or equal to b_{n-1} then optimal order size Q^* is equal to Q^*_n otherwise go to step 2

Step 2: Find the EOQ for the (n-1) th price break.

$$Q^*_n = \sqrt{\frac{2C_0D}{iP_{n-1}}}$$

If it is greater than or equal to b_{n-2}, then compute the following and select the least cost. Purchase quantity as the optimal order size. Otherwise go to step 3.

(i) Total cost $TC(Q_{n-1})$

(ii) Total cost $TC(b_{n-1})$

Step 03: Find the EOQ for the $(n-2)^{th}$ price break.

$$Q^*_{n-2} = \sqrt{\frac{2C_0D}{iP_{n-2}}}$$

If it is greater than or equal to b_{n-3} then compute the following and select the least cost purchase quantity as the optimal order size. Otherwise go to step 04

(i) Total cost $TC(Q^*_{n-2})$

(ii) Total cost $TC(b_{n-2})$

(iii) Total cost $TC(b_{n-1})$

Step 04: Continue in this manner until $Q^*_{n-i} \geq b_{n-i-1}$. Then compute total costs $TC(Q^*_{n-i})$, $TC(b_{n-i+1})$... $TC(b_{n-1})$ corresponding to purchase quantity with respect to the minimum total cost can be taken as the optimal order size.

There was a provision in main menu to open the data entry of the quantity discount model.

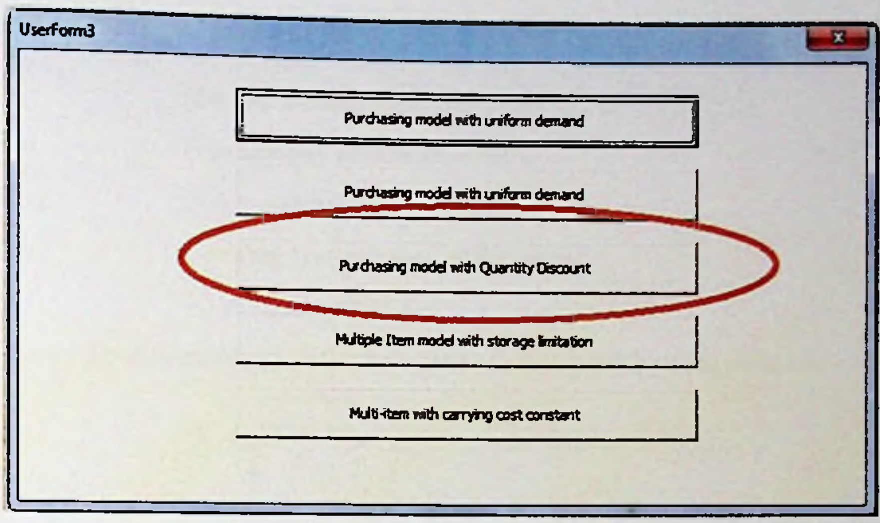


Figure 3.6: VB main user interface of selecting purchasing model with quantity discount data entry user interface

That is asking number of products and other parameters. Then there was a macro recorded to define the formulated sheets according to above scenario in separate sheets.

The calculations were made as comparing all the results delivered in each work sheet that was performed by the VB program as delivering optimum parameters. Before that there is a combo for selecting the number of price breaks

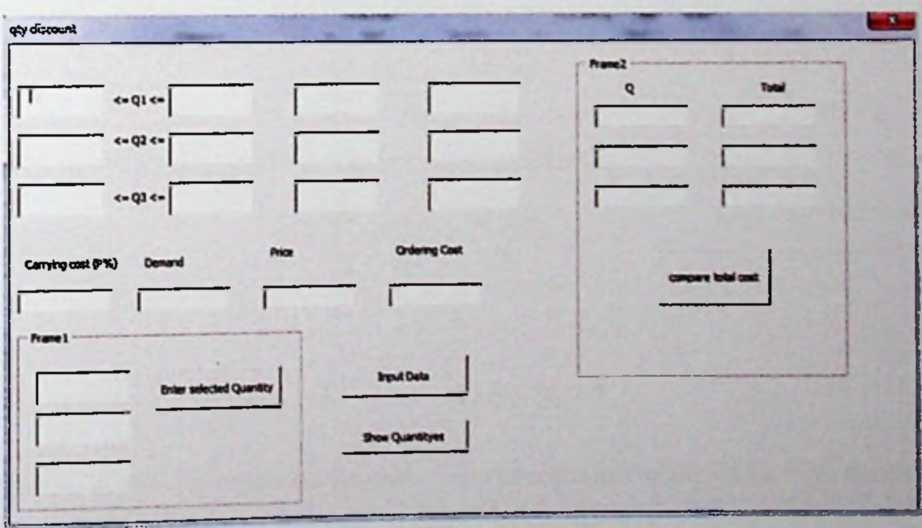


Figure 3.7: VB user interface of purchasing model with quantity discount data entry and calculation

3.4 Multiple item Purchasing model with storage limitation

n	-	Number of items stocked in the stores
Di	-	Demand per year of the item i
Coi	-	Order cost per order of item i
Cci	-	Carrying cost per unit of the item i
K	-	Total space available

Based on above definition the formula to find the EOQ of the item i is

$$Q_i^* = \sqrt{\frac{2C_{0i}D_i}{C_{ci}}}, \qquad \{i = 1,2,3\ldots\}$$

If the store has unlimited space, then the EOQ of the items need no modification. Otherwise the best combination of the order quantities of the n item is to be determined such that the total space requirement is equal to the available space.

Let the space constraint is

$$\sum_{i=1}^{n} S_i Q_i \leq K$$

The objective function of this problem consists of two cost components, those are ordering cost and carrying cost that represented as

$$C = \sum_{i=1}^{n} \left(\frac{D_i C_{0i}}{Q_i} + \frac{Q_i C_{ci}}{2}\right)$$

The mathematical model of the proposed problem as

Minimize $$C = \sum_{i=1}^{n} \left(\frac{D_i C_{0i}}{Q_i} + \frac{Q_i C_{ci}}{2}\right)$$

Subjected to $\sum_{i=1}^{n} S_i Q_i \leq K$ Where $Qi > 0$

In this model, the objective function finds the optimal values of Qi such that the constraint is satisfied in equality sign. The model is translated in to Lagrangian function.

$$L(\mu, Q_1, Q_2, \ldots, Q_n) = C(Q_1, Q_2, \ldots, Q_n) - \mu\left(\sum_{i=1}^{n} S_i Q_i - K \right)$$

Where μ is the Lagrange multiplier and it is less than zero. The partial derivatives of the Lagrangian function with respect to Qi and μ are

$$\frac{\partial L}{\partial \mu} = -\frac{D_i C_{0i}}{Q_i^2} + \frac{C_{ci}}{2} - \mu S_i, \qquad (i = 1,2,3,\ldots,n)$$

And

$$\frac{\partial L}{\partial \mu} = -\left(\sum_{i=1}^{n} S_i Q_i - K \right)$$

$$\frac{\partial L}{\partial \mu} = -\sum_{i=1}^{n} S_i Q_i + K$$

The second equation shows that the total space requirement for all the items is equal to K.

The formula for Q* is obtained by equating $\frac{\partial L}{\partial \mu}$ to zero as shown below,

$$Q_i^* = \sqrt{\frac{2 C_{0i} D_i}{(C_{ci} - 2\mu^* S_i)}} \qquad i = 1,2,3,\ldots,n$$

In the above equation Q* depends on μ. The optimal value for μ can be obtained by trial and error method such that the space constraint is satisfied.

Here also the model was selected from the main menu.

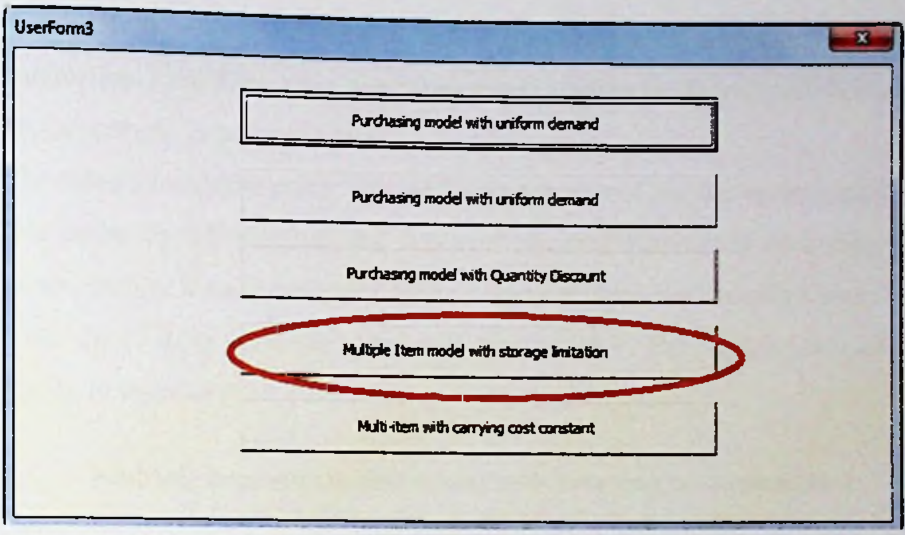


Figure 3.8: VB main user interface of selecting multiple item purchasing model with storage limitation

Once the selection was made for the multiple item purchasing model with storage limitation bellow user interface was appeared for the data entry. Before that there is a combo for selecting number of items

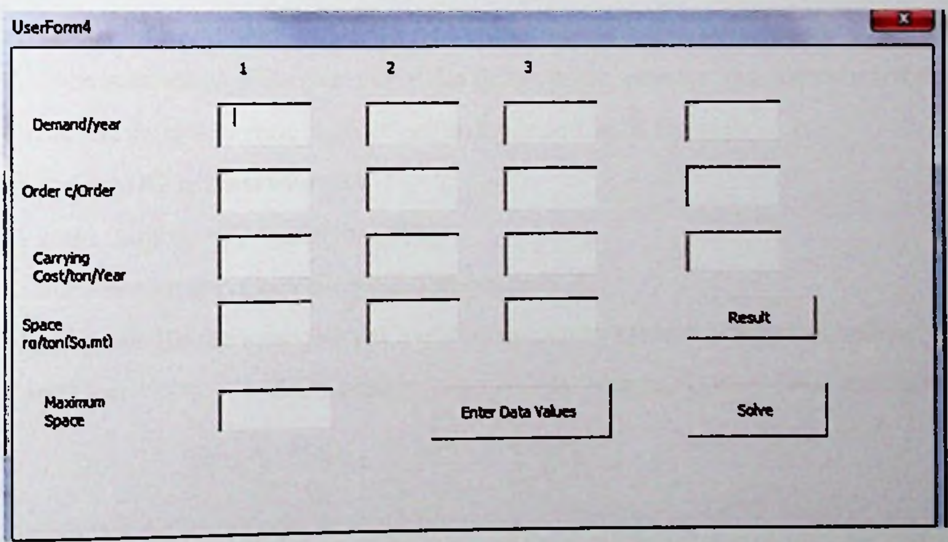


Figure 3.9: VB user interface of multiple item purchasing model with storage limitation

Same scenario was performed to detail the number of products and other required parameters. Then there was a macro recorded to define the formulated sheets according to above scenario in separate sheets.

The calculations were made base on Excel solver tool for the optimization. Solver tool was called by VB program and delivered accurate parameters according to the given parameters for the automatically defined objective function and constrains

After the clicking solve the solver tool was called by the VB program and display the results in separate excel tab.

3.5 Multiple item purchasing model with carrying cost constraint

Consider the purchase model of inventory with multi item with a constraint on the inventory carrying cost, K. The variables involved in the purchased model of inventory with inventory carrying cost constraint are listed below. In this model shortages are not permitted.

C_{oi} is the ordering cost of the item i

D_i is the annual demand in units of the item i

P_i is the purchasing price per unit of the item i in the group of the items ordered.

C_{ci} be the inventory carrying cost per unit per period of the item i

Q_j is the EOQ in units of item i

M is the number of items in the group

K is the utmost inventory carrying cost per period

The formula for the total cost (TC) of this inventory system is given as bellow,

Total Cost = Total ordering cost + Total carrying cost + Total purchase cost

$$TC = \sum_{i=1}^{m} \frac{D_i C_{oi}}{Q_i} + \sum_{i=1}^{m} \frac{Q_i C_{ci}}{2} + \sum_{i=1}^{m} D_i P_i$$

As per the problem statement, there is a constraint on the total carrying cost whose utmost value is K. The Lagràngian function with the above constraint is

$$TC = \sum_{i=1}^{m} \frac{D_i C_{oi}}{Q_i} + \mu\left(\sum_{i=1}^{m} \frac{Q_i C_{ci}}{2} - K\right) + \sum_{i=1}^{m} D_i P_i$$

Where μ is Lagrange multiplier. Differentiating the function L with respect to Qi, we get

$$\frac{\partial L}{\partial Q_i} = -\frac{D_i C_{0i}}{Q_i^2} + \mu \frac{C_{ci}}{2} \qquad (i = 1,2,3,\ldots,m)$$

Then by differentiating the function L by μ and equating it to zero, we get,

$$\frac{\partial L}{\partial \mu} = \sum_{i=1}^{m} \frac{Q_i C_{ci}}{2} - K, \qquad (i = 1,2,3,\ldots,m)$$

The second equation gives the condition that the total carrying cost is restricted to utmost K. Equating the first equation to zero, the formula for Qi is as given bellow

$$Q_i^* = \sqrt{\frac{2 C_{0i} D_i}{C_{ci} \mu}} \qquad i = 1,2,3,\ldots,m$$

Subjected to $\frac{Q_i C_{ci}}{2} \leq K$

Here also the model was selected from the main menu.

Once the selection was made for the multiple item purchasing model with storage limitation bellow user interface was appeared for the data entry.

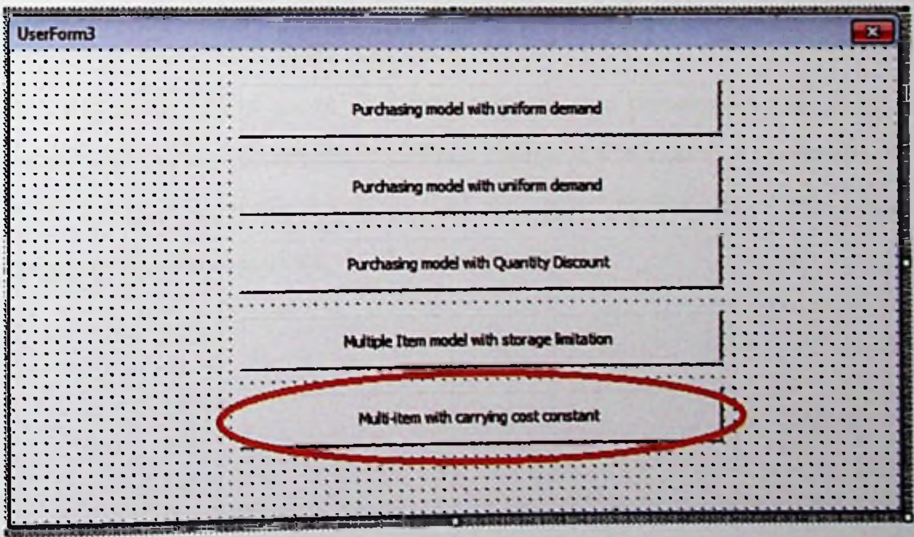


Figure 3.10: VB user interface of main menu to select data entry user interface of multiple item purchasing model with carrying cost constraint

Same scenario was performed to detail the number of products and other required parameters. Then there was a macro recorded to define the formulated sheets according to above scenario in separate sheets. Before there is a combo to select the number of items

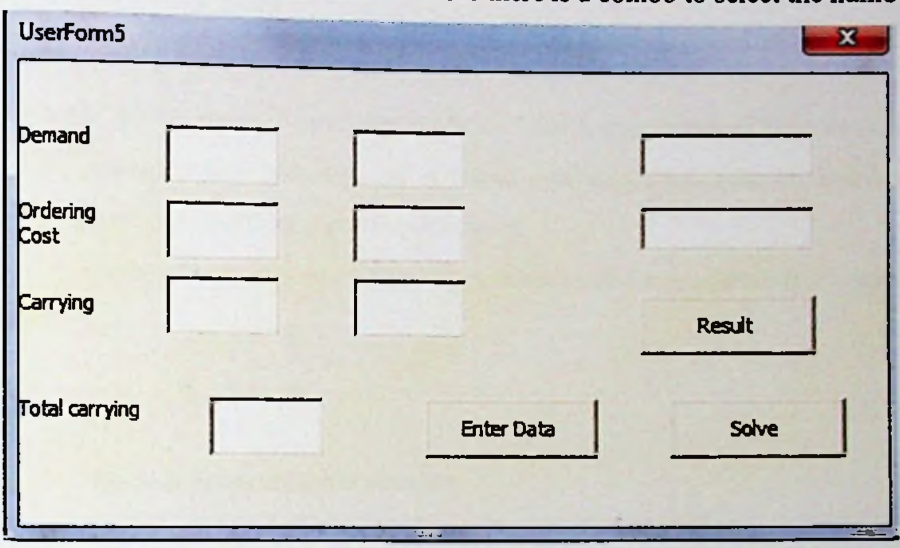


Figure 3.11: Data entry user interface of multiple item purchasing model with carrying cost constraint

The calculations were made base on Excel solver tool for the optimization. Solver tool was called by VB program and delivered accurate parameters according to the given parameters for the automatically defined objective function and constrains

After the clicking solve the solver tool was called by the VB program and display the results in separate excel tab.

Chapter 04

Calculations and Results

4.1 Purchasing model with constant demand

Periodic Robot gear oil consumption is 12 bottles per month. This robots were used in glove manufacturing industry and expected performance is zero breakdown or repairs. Only scheduled maintenance was performed.

Let the demand of the item is 12 units per month and the lead time is 15 days.

C_c = Rs. 100.00

C_0 = Rs. 500.00

4.1.1 System generated parameters

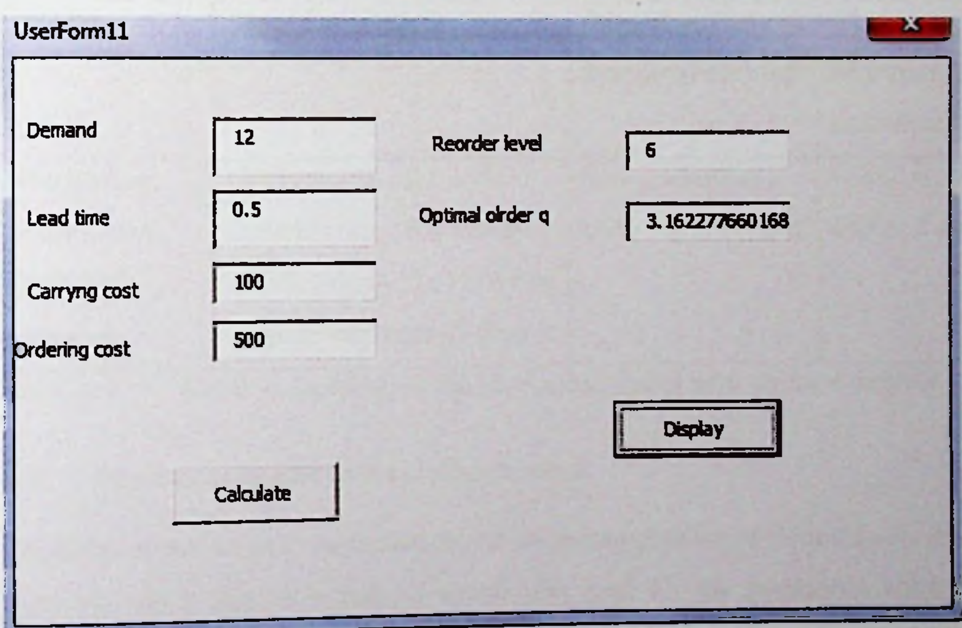


Figure 4.1: System generated results of the purchasing model with uniform demand

4.1.2 Parameters from manual calculations

Since the model is in uniform demand

D_{LT} = Demand rate per day x Lead time (days)

If the demand is not varying the reorder level (ROL) is given by

ROL = D_{LT}

ROL = 12 x 0.5

= 6 units

Let Q* be the optimal order size

$$Q = \sqrt{2Co/_{C_c}}$$

$$Q^* = \sqrt{2 \times 500/_{100}}$$

= 3.16 units.

Comparing with fig 4.1 that can be committed that the system generated parameters and manually calculated parameters are same.

Model	Input Parameters	Output parameters	
		System generated	Manually calculated
Purchasing model with uniform demand	Carrying cost : Rs. 100.00 Ordering cost : Rs. 500.00 monthly demand : 12 bottles supplier lead time 15 days	ROL : 6 bottles EOQ : 3.16 bottles	ROL : 6 bottles EOQ : 3.16 bottles

Table 4.1 Result comparison of the purchasing model with uniform demand

4.2 Purchasing model with varying demand

The data set was taken from the centrlized Engineering stores of Ansell lanka (Pvt) Ltd. Particular stock item is a seal kit which was used for the pneumatic actutors. The maintenance of those actuators are periodic but with the envioranmantal conditions (Tempurature, humidity, vibration, dust, etc.) and the chemicl influences, there are some break down repairs also performed. Hence the demand can't be predicted and can be categorized as varying demand. The data set was analysed in manual calculation and using invented software. Bellow data were taken from the supplier order history which can be committed as actual data parameters.

Ordering cost	Rs. 28.50
Monthly Holding cost (0.05% from the ordering cost)	Rs. 0.01425
Lead time	0.5 months

Table 4.2 Cost and lead time data of the selected item

Month	Demand
Jan	10
Feb	11
Mar	13
Apr	12
May	11
Jun	10

Month	Demand
Jul	9
Aug	8
Sep	15
Oct	16
Nov	4
Dec	13

Table 4.3 Monthly consumption of Engineering stock item no 5544014 item within 2015 year period

4.2.1 System generted parameters

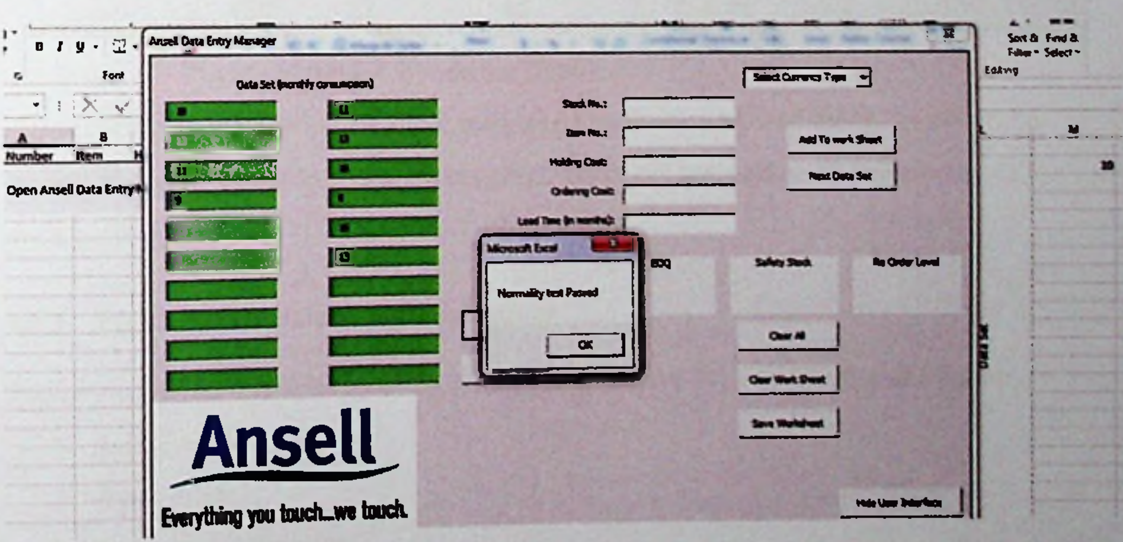


Fig 4.2 Normality check result of the data set

It was observed no any outliers in the data set.

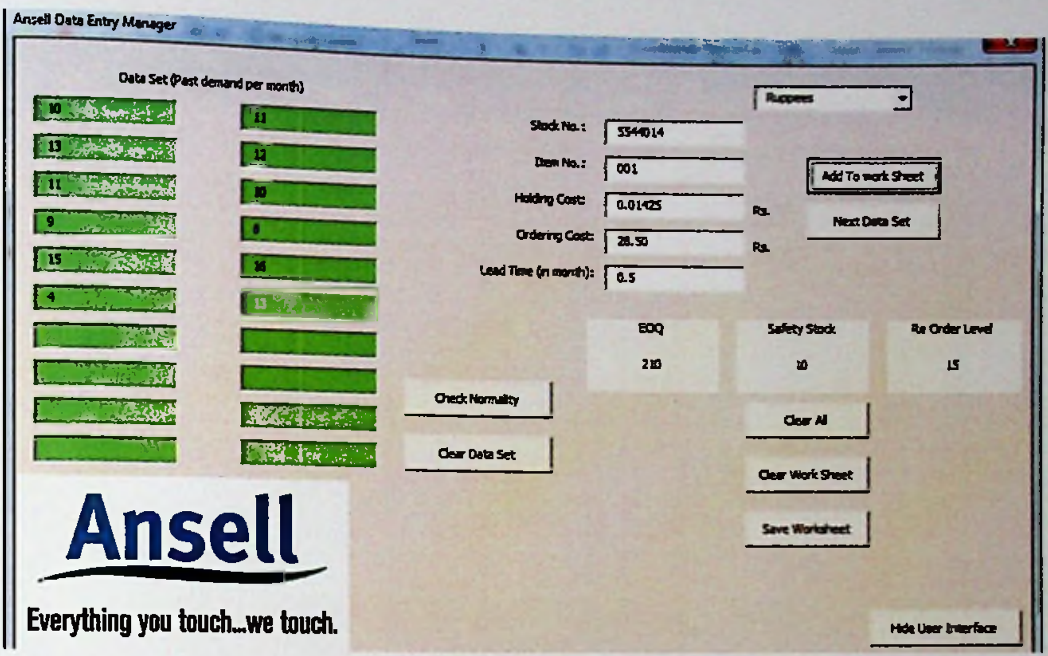


Fig 4.3 Defined parameters by the system

Stock Number	Item	Holding cost	Ordering cost	Lead Time / months	Demand	EOQ	Safety Stock	Re order Level	P Value
5544014	1	0.01425	28.5	0.5	11	209.7617696	9.915321477	15.41532148	0.798546967

Table 4.4 Results of stock item number 5544014

The results were recorded in the excel work sheet as above table and the 'p' value of the Anderson darling test at 99.5% confident level was 0.798 that can be claimed as the data set is normal.

4.2.2 Parameters from manual calculations

The normality test was done by using Minitab. There were three techniques in Minitab.

1- Anderson darling test
2- Ryan Joiner
3- Kolmogorov Smirnov

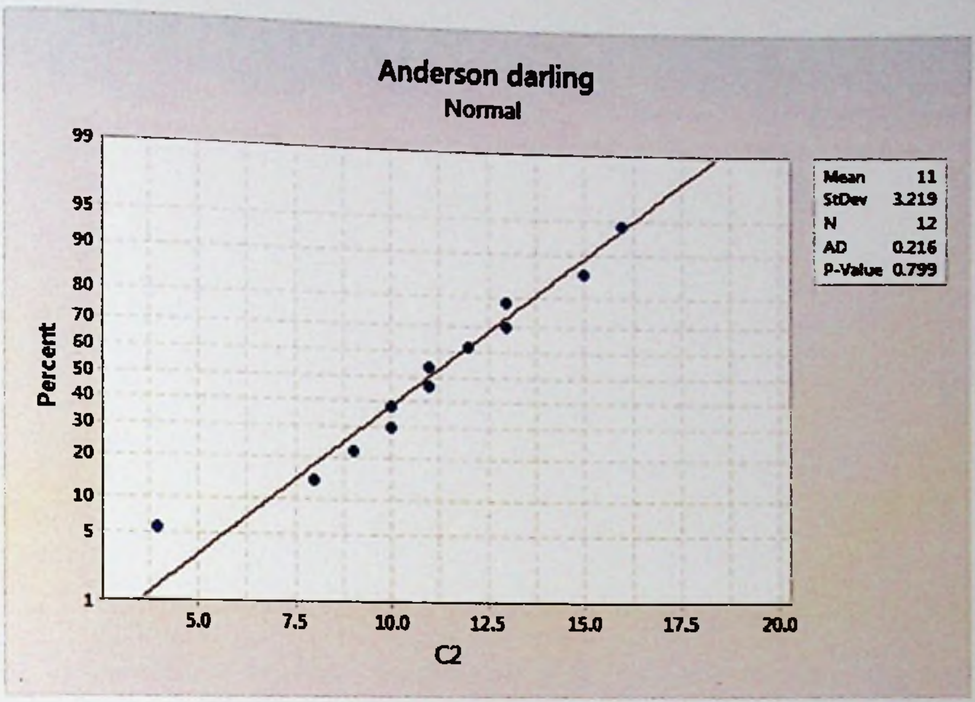


Fig 4.4 Normality check by Anderson darling test

According to AD statictics the P cvalue of the test is well greater (0.798) than the test stastistic (0.05) it can be claimed that the data series is normal. Compairing with table 4.3 it can be claim that The 'p' value was same with the invented system 'p' value.

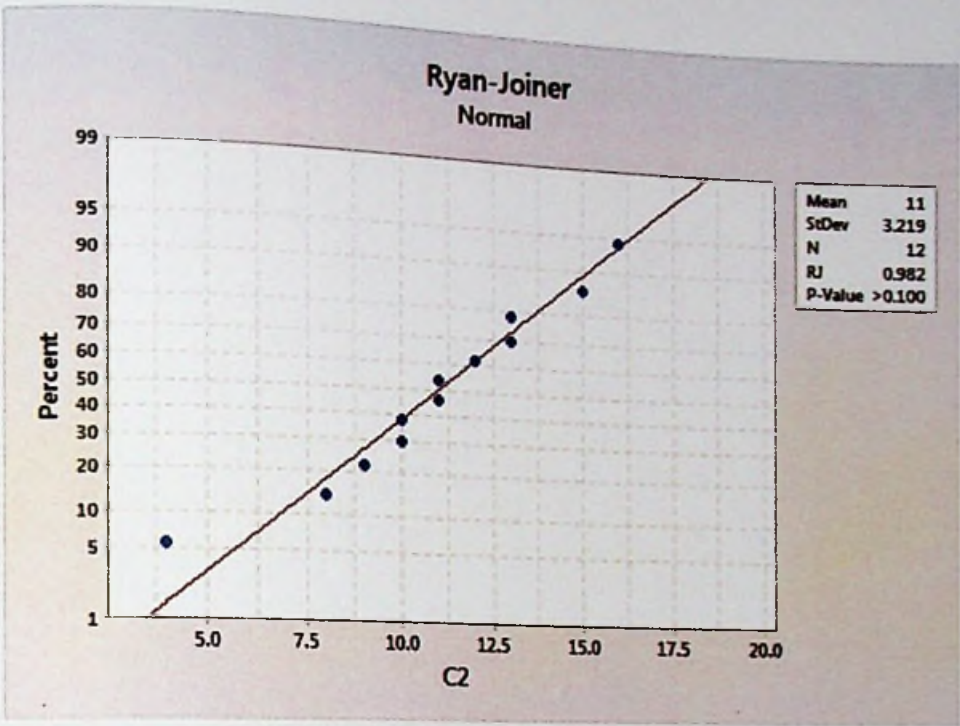


Fig 4.5 Normality check by Ryan - Joiner test

Ryan Joiner test also deliver the result as P- value is greater than 0.1 which reconfirms the data set is normal.

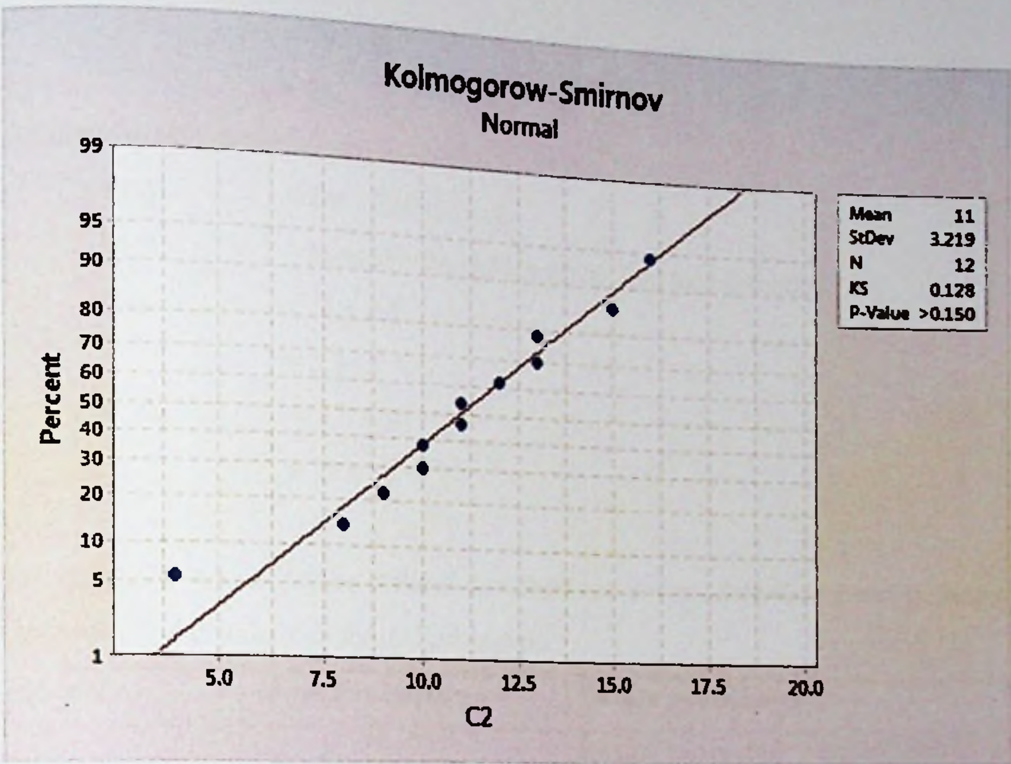


Fig 4.6 Normality check by Kolmogorov - Smirnov test

It was resulted as the P value is greater than 0.15 that is the data set is normal by Kolmogorov – Smirnov test also.

Based on above results the safety stock calculation was made.

Bellow parameters of the data set was calculated by using Minitab.

Variable	Mean	StDev	Minimum	Q1	Median	Q3	Maximum	Range
C2	11.000	3.219	4.000	9.250	11.000	13.000	16.000	12.000

Applying

K = 3.08 (at 99.5% confidence interval)

Safety stock = kσ

Safety stock = 3.08 x 3.219

= 9.91

~ 10

EOQ = √ (2DC0 / Cc)

EOQ = √ (2 x 11 x 28.50 / 0.01425)

= 209 .76

~ 210

Reorder level,

ROL = Dlt + Safety stock

D_{LT} = Monthly demand x supplier lead time (Months)

D_{LT} = 11 x 0.5

= 5.5

ROL = 5.5 + 10

= 15.5

~ 16

Recalling fig 4.3, it can be claimed that there are no any deference between system generated and manually calculated parameters.

Model	**Input Parameters**	**Output parameters**	
		System generated	**Manually calculated**
Purchasing model with varying demand	Holding cost : Rs.0.01425 Ordering cost : Rs. 28.50 supplier lead time 15 days 12 months' demand data were given	Average D: 11 P value: 0.798 Standard dev: 3.22 Safety stock: 10 EOQ: 210 ROL: 16	Average D: 11 P value: 0.799 Standard dev: 3.22 Safety stock: 10 EOQ: 210 ROL: 16

Table 4.5 Result comparison of the purchasing model with varying demand

4.3 Purchasing model with Quantity discount

For the item was a packaging Polybag used for the glove waste bundling for the dumping the supplier is offering some quantity discounts for the item. It was noted that the item consumes less space, low cost item and not make critical impact on continues deliveries of finished products. It was given that

Annual demand - 2500 units

Ordering cost - Rs. 20 per order

Inventory carrying cost - 20% of the purchase price/unit/year

The price breakups are as bellow

Quantity	Purchase price per unit
0 ≤ Q1 ≤ 1500	2
1500 ≤ Q2 ≤ 2500	1.94
2500≤ Q3	1.9

Table 4.6: Parameters of discount scenario

4.3.1 System generated parameters

The data was entered to the user frame and then the Qi values will be displayed. Need to select the range satisfying point manualy and enter those for the TC calculation.

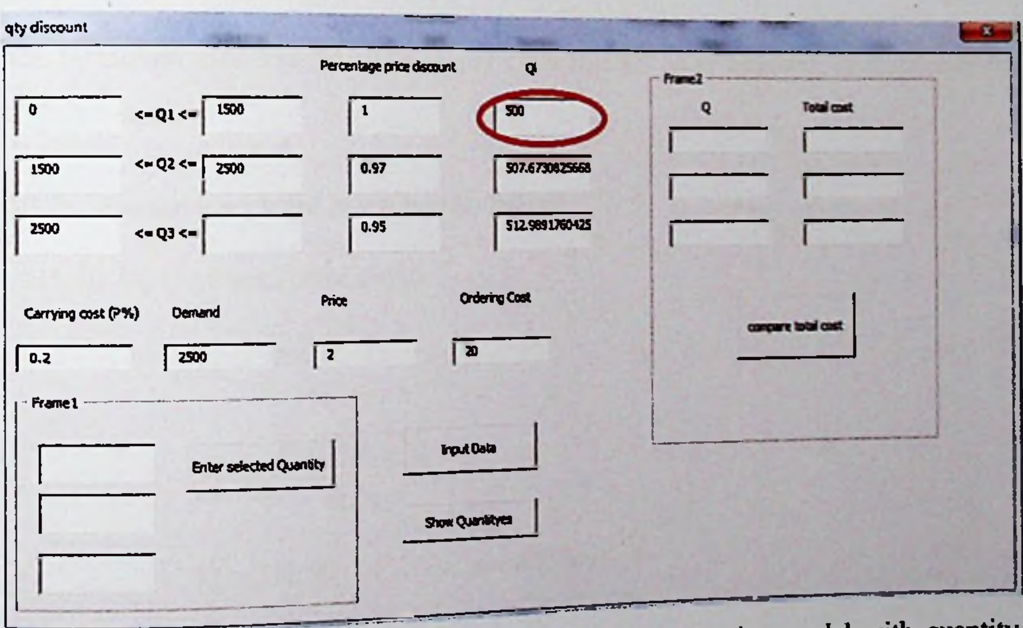


Figure 4.7: system generated results for Q of the purchasing model with quantity discount

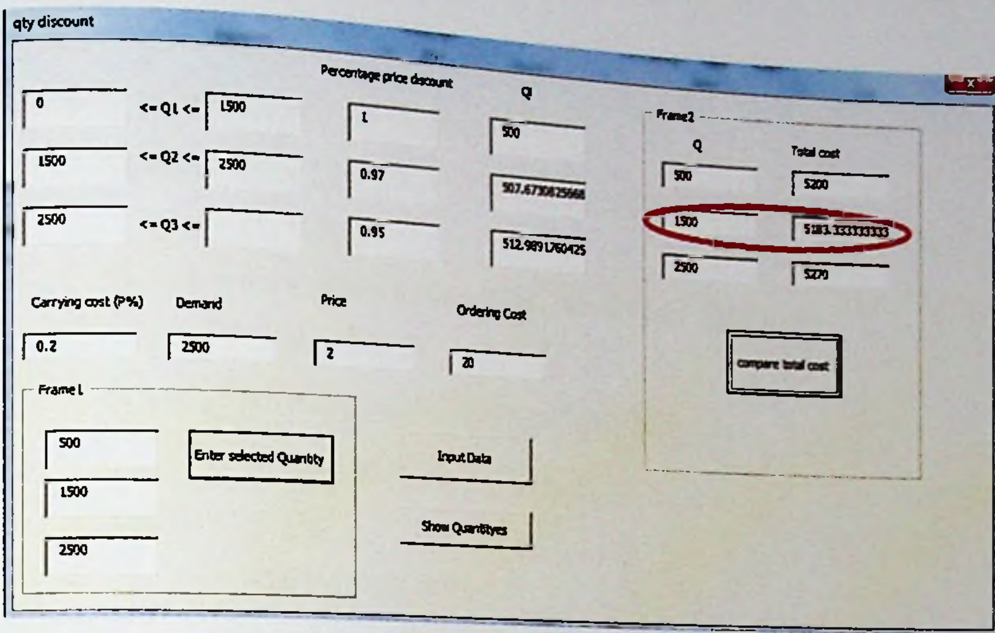


Figure 4.8: system generated results of the purchasing model with quantity discount

The minimum total cost Rs. 5183.33 was given in 1500 order quantity. So that the EOQ is 1500 units.

4.3.2 Parameters from manual calculations

Find the EOQ of three price breaks

$$Q_n^* = \sqrt{\frac{2C_0D}{iP_n}}$$

$$Q_3^* = \sqrt{\frac{2 \times 2500 \times 20}{0.38}}$$

$$Q_3^* = 512.99 \quad (<2500; \text{not satisfied})$$

$$Q_2^* = \sqrt{\frac{2 \times 2500 \times 20}{0.388}}$$

$$Q_2^* = 507.67 \quad (<1500; \text{not satisfied})$$

$$Q_1^* = \sqrt{\frac{2 \times 2500 \times 20}{0.4}}$$

$$Q_1^* = 500 \qquad (=500;\ \text{Satisfied})$$

Compute TC (b_3), TC (b_2) and TC (Q^*)

$$TC(b_3) = 0.5 \times 2500 \times 0.38 + 2500 \times 20/2500 + 2500 \times 1.9$$
$$= Rs.\ 5270.00$$
$$TC(b_2) = 0.5 \times 1500 \times 0.388 + 2500 \times 20/1500 + 2500 \times 1.94$$
$$= Rs.\ 5183.33$$
$$TC(Q^*) = 0.5 \times 500 \times 0.4 + 2500 \times 20/500 + 2500 \times 2$$
$$= Rs.\ 5200.00$$
$$\text{Min } TC = TC(b_2)$$

So that Q = 1500 units per order

Referring fig 4.8 the system has provided the minimum total cost Rs. 5183.33 was given in 1500 order quantity. So that the EOQ is 1500 units which is same with manual calculation.

Model	**Input Parameters**	**Output parameters**	
		System generated	**Manually calculated**
Multiple item model with quantity discount	Demand: 2500 / year Unit price: Rs.2.00 ordering cost: Rs. 20.00 carrying cost: 20% of purchase price /unit/annum 3 discount price breakups were given	EOQ: 1500 units Min TC: Rs.5183.33	EOQ: 1500 units Min TC: Rs.5183.33

Table 4.7 Result comparison of the purchasing model Quantity discount

4.4 Multiple item purchasing model with storage limitation

Consider three item model for limited storage model. Those items are chemicals that used for the enhance polymer latex stability. Those items need to be placed in conditioned space. So that the space is limited in the case. Let availavle space is 500 square meters and details of the items as below.

	Item number		
	1	2	3
Demand / year (Ton)	1000	1500	750
Ordering cost / order (Rs.)	500	700	300
Carrying cost/ton/year (Rs.)	50	80	100
Space requirement / ton (Sq. m)	2	1	3

Table 4.8: Parameters of Multiple item model with limited storage

4.4.1 System generated parameters

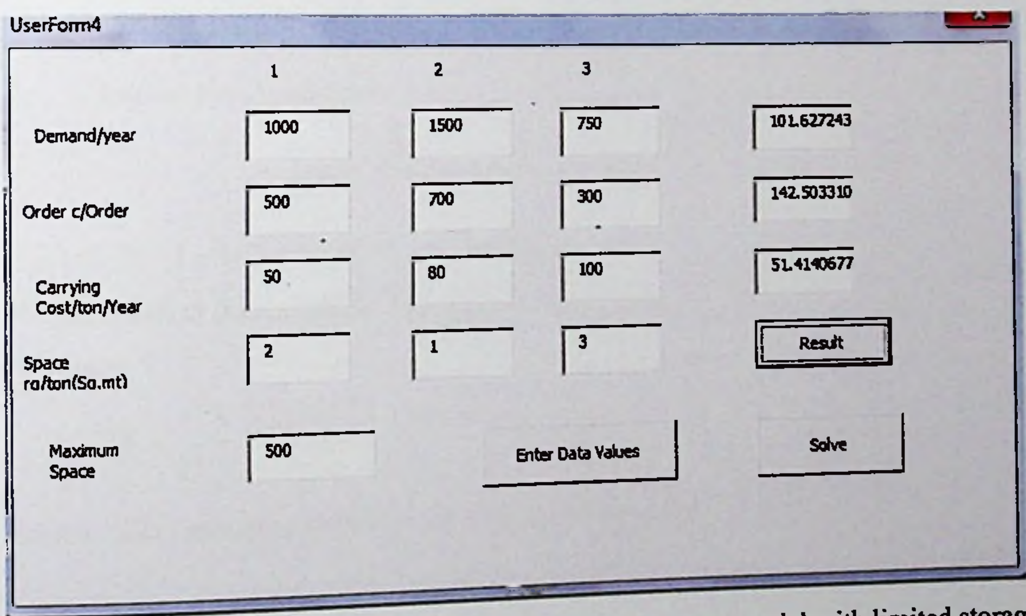


Fig 4.9 System generated parameters of multiple item model with limited storage

4.4.2 Parameters from manual calculations

Assuming unlimited storage and estimate the Q_1, Q_2 and Q_3

$$Q_i = \sqrt{\frac{2C_{oi}D_i}{C_{ci}}}$$

$$Q_1 = \sqrt{\frac{2 \text{ x } 1000 \text{ x } 500}{50}}$$

Q_1 = 141.42 units

$$Q_2 = \sqrt{\frac{2 \text{ x } 1500 \text{ x } 700}{80}}$$

Q_2= 162 units

$$Q_3 = \sqrt{\frac{2 \text{ x } 750 \text{ x } 300}{100}}$$

Q_3= 67 units

For the space constraint

$$\sum_{i=1}^{n} S_i Q_i \leq K$$

2 x 141.42 + 1 x 162 + 3 x 67 = 645.84

Which is higher than available 500 square meters' space.

Applying

$$Q_i^* = \sqrt{\frac{2C_{oi}D_i}{(C_{ci} - 2\mu^* S_i)}} \qquad i = 1,2,3$$

Bellow table was prepared for the calculating optimum "μ"

μ	Q1	Q2	Q3	∑Si Qi
0	141.4214	162.0185	67.08204	646.1073
-5	119.5229	152.7525	58.83484	568.3028
-10	105.4093	144.9138	53.03301	514.8313
-15	95.34626	138.1699	48.66643	474.8617
-11	103.1421	143.486	52.06576	505.9675
-12	101.0153	142.0996	51.14958	497.5789
-11.1	102.9234	143.3455	51.97192	505.108
-11.2	102.706	143.2055	51.87858	504.2533
-11.3	102.49	143.0658	51.78575	503.4031
-11.4	102.2754	142.9266	51.69341	502.5576
-11.5	102.0621	142.7878	51.60157	501.7166
-11.6	101.8501	142.6494	51.51021	500.8802
-11.7	101.6395	142.5113	51.41934	500.0482
-11.8	101.4301	142.3737	51.32894	499.2207

Table 4.9: Total space calculation by varying μ

Optimum value of μ is -11.8

Respective ordering quantities are

Q_1 = 101 units

Q_2 = 142 units

Q_3 = 51 units

Referring Fig 4.9 it can be concluded that there are no any differences between system generated parameters and the manually calculated parameters

Model	Input Parameters	Output parameters	
		System generated	Manually calculated
Multiple item model with limited storage	3 items model was entered available space 500 square meters	EOQ 1: 101.617 EOQ 2: 142.503 EOQ 3: 51.41	EOQ 1: 101.617 EOQ 2: 142.503 EOQ 3: 51.41 optimum μ: (-11.8)

Table 4.10 Result comparison of the purchasing model with limited storage

4.5 Multiple item purchasing model with carrying cost constraint

Consider two item purchasing model with carrying cost was constrained on Rs. 4000.00 Those items refers needles and needle holder of the knitting machines that used for the knitting operation of supported glove manufcturing. Those are periodic replacement part that consumes special enviorenmental conditions to prevent internal cracking.

The details of the two items are as bellow

	Item number	
	1	2
Annual Demand (units)	12000	18000
Ordering cost / order (Rs.)	500	400
Carrying cost/unit/year (Rs.)	5	8

Table 4.11: Parameters of Multiple item model with carrying cost constraint

4.5.1 System generated parameters

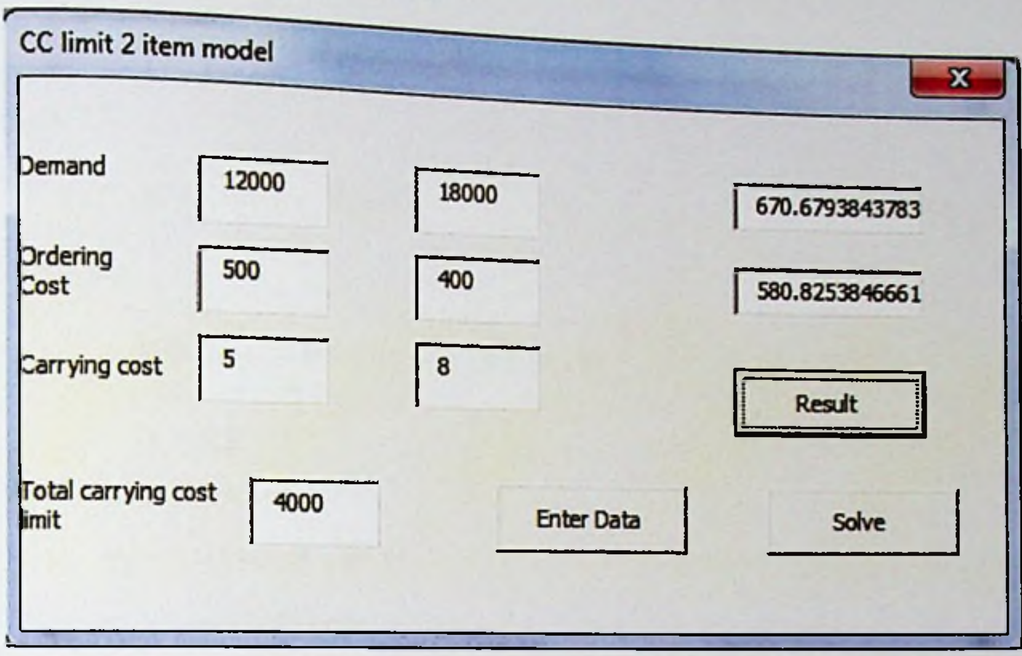


Fig 4.10 System generated parameters of multiple item model with limited carrying cost

4.5.2 Parameters from manual calculations

Assuming unlimited carring cost and estimate the Q_1 and Q_2

$$Q_i = \sqrt{\frac{2 C_{0i} D_i}{C_{ci}}} \qquad i = 1,2$$

$$Q_1 = \sqrt{\frac{2 \times 12000 \times 500}{5}}$$

$Q_1 = 1549.19$ units

$$Q_2 = \sqrt{\frac{2 \times 18000 \times 400}{8}}$$

$Q_2 = 1341.64$ units

Applying Carrying cost constraint

$$Q_i^* = \sqrt{\frac{2C_{0i}D_i}{C_{ci}\mu}} \qquad i = 1,2$$

And

$$K = \frac{Q_1C_{c1}}{2} + \frac{Q_2C_{c2}}{2}$$

Applying

$$4000 = \frac{1}{2}\times\frac{1}{\mu}(1549.19\times5+1341.64\times8)$$

$$\mu = 5.33$$

Optimum order values

$$Q_1 = 1549.19 / \sqrt{5.33}$$

$$= 670.94 \text{ units}$$

$$Q_2 = 1341.64 / \sqrt{5.33}$$

$$= 580.85 \text{ units}$$

Refering Fig 4.10 it can be concluded that there are no any differences in system generated calculations and manually calculated results.

Model	Input Parameters	Output parameters	
		System generated	Manually calculated
Multiple item model with Carrying cost constraint	2 items model was entered available fund was Rs. 4000.00	EOQ 1: 670.68 EOQ 2: 580.82	EOQ 1: 670.94 EOQ 2: 580.85 optimum μ: 5.33

Table 4.12 Result comparison of the purchasing model with limited carrying cost

Chapter 05

Conclusion

5.1 Results analysis

Model	Input Parameters	Output parameters	
		System generated	Manually calculated
Purchasing model with uniform demand	Carrying cost: Rs. 100.00 Ordering cost: Rs. 500.00 monthly demand: 12 bottles supplier lead time: 15 days	ROL: 6 bottles EOQ: 3.16 bottles	ROL: 6 bottles EOQ: 3.16 bottles
Purchasing model with varying demand	Holding cost: Rs.0.01425 Ordering cost: Rs. 28.50 supplier lead time 15 days 12 months demand data were given	Average D: 11 P value: 0.798 Standard dev: 3.22 Safety stock: 10 EOQ=210, ROL = 15	Average D: 11 P value: 0.799 Standard dev: 3.22 Safety stock: 10 EOQ=210, ROL=16
Multiple item model with quantity discount	Demand: 2500 / year Unit price: Rs.2.00 ordering cost: Rs. 20.00 carrying cost: 20% of purchase price /unit/annum 3 discount price breakups were given	EOQ: 1500 units Min TC: Rs.5183.33	EOQ: 1500 units Min TC: Rs.5183.33
Multiple item model with limited storage	3 items model was entered available space 500 square meters	EOQ 1: 101.617 EOQ 2: 142.503 EOQ 3: 51.41	EOQ 1: 101.617 EOQ 2: 142.503 EOQ 3: 51.41 optimum μ: (-11.8)
Multiple item model with Carrying cost constraint	2 items model was entered available fund was Rs. 4000.00	EOQ 1: 670.68 EOQ 2: 580.82	EOQ 1: 670.94 EOQ 2: 580.85 optimum μ: 5.33

Table 5.1: Parameters analysis of system generated vs. manually calculated

5.2 Interpretation of the results

Based on realistic data that extracted from real life situations, it can be concluded that the system is providing accurate data with proper justifications for the inventory parameters.

Purchasing Model	**Deviation in system generated vs. manual calculation**	
	Yes	No
Purchasing model with uniform demand		√
Purchasing model with varying demand		√
Quantity discount model		√
Multiple item model with limited storage		√
Multiple item model with limited carrying cost		√

Table 5.2: Parameters comparison of system generated vs. manually calculated

5.3 Sensitivity analysis of the results in real life situation

Implemented system was applied for the most relating real life situation. That is purchasing model with varying demand.

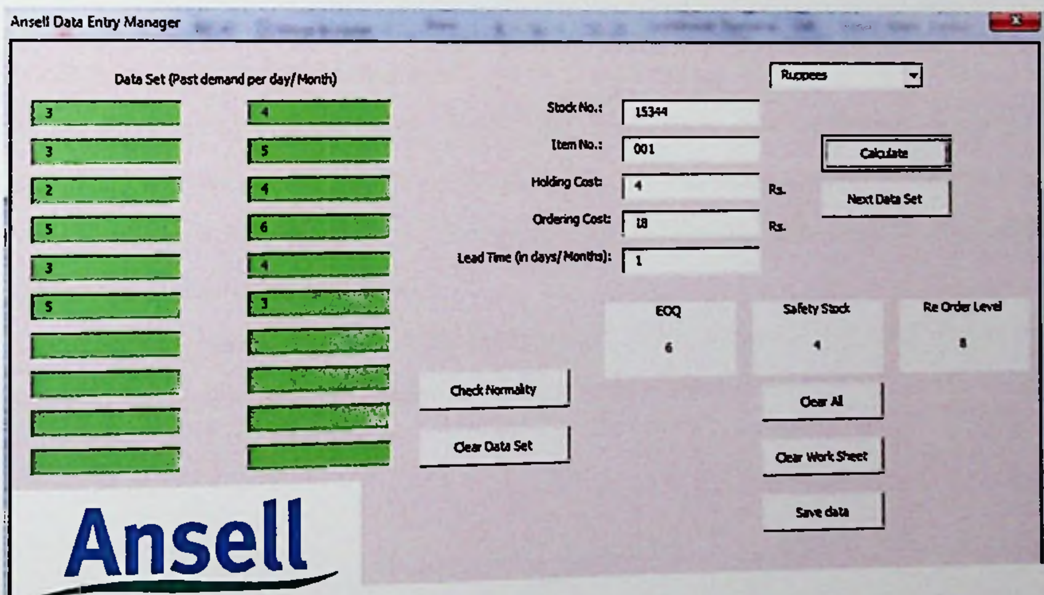


Fig 5.1 System generated parameters in real life situation (varying demand)

Consumpsion information is as table 5.3

Date	Days from last delivery	Consumption / units	Stock level / units	Remarks
01-Jan	191		9	Starting stock / last order 50 units placed on June 24, 2016
03-Jan	193	1	8	ROL Achieved and order placed
08-Jan	198	2	6	
17-Jan	207	1	5	
25-Jan	215	1	4	
09-Feb	230	2	2	Supplier lead time 36 days against 30 days target
10-Feb	1		8	ROL Achieved and order placed
15-Feb	6	1	7	
26-Feb	17	1	6	
07-Mar	26	1	5	
18-Mar	37	1	4	Items received in supplier lead time 36 days
19-Mar	1		12	
30-Mar	12	2	10	
05-Apr	18	1	9	
20-Apr	33	1	8	ROL Achieved and order placed
05-May	48	2	6	
21-May	64	1	5	
02-Jun	76		13	Items received in supplier lead time 43 days
10-Jun	8	2	11	
21-Jun	19	1	10	

Table 5.3: Stock level status report

As per the stock level status report, there were no any short stock situation experienced. But after the receiving of the items of ordered on 03rd Jan there is another order placed because of the achieving of ROL. Main root cause of this is higher supplier lead time against the documented lead time.

Including the consumption data after January 2017 when the stores was subjected to be operated by the invented system, bellow results were experienced.

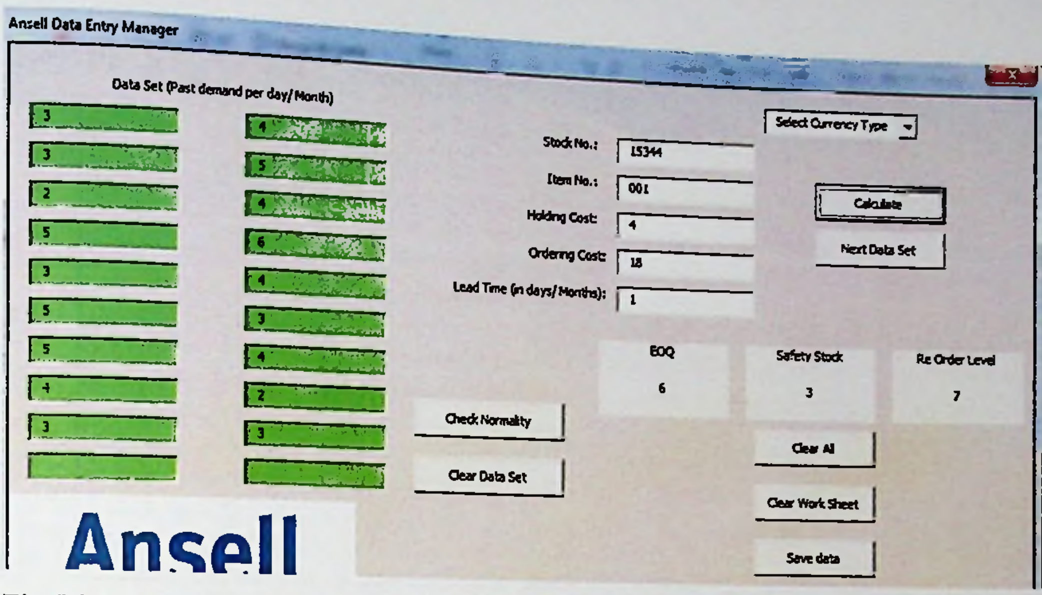


Fig 5.2 System generated parameters after refreshing with reacent data

It was observed that there is a deviation in all 3 parameters after the refreshing whole data set by adding status.

If we use the parameters of the figure 5.1 then the confusion occurred on 10th February will not be appeared. Below hypothetical table 5.4 will illustrate the operation of the stocks.

Date	Days from last delivery	Consumption / units	Stock level / units	Remarks
01-Jan	191			
03-Jan	193		9	Starting stock / last order 50 units placed on June 24, 2016
08-Jan	198	1	8	
17-Jan	207	2	6	ROL Achieved and order placed
25-Jan	215	1	5	
09-Feb	230	1	4	
13-Feb	234	2	2	
15-Feb	2		8	Supplier lead time 36 days against 30 days target
26-Feb	13	1	7	ROL Achieved and order placed
07-Mar	22	1	6	
18-Mar	33	1	5	
19-Mar	1	1	4	Items received in supplier lead time 36 days
30-Mar	12		11	
05-Apr	18	2	9	
20-Apr	33	1	8	
05-May	48	1	7	ROL Achieved and order placed
21-May	64	2	5	
02-Jun	76	1	4	
10-Jun	8		11	Items received in supplier lead time 43 days
21-Jun	19	2	9	
		1	8	

Table 5.4: Stock level status report with most recent data

It was observed that the stock parameters calculations are more accurate when the system is operating with most recent data.

5.4 Analysis with Forecasting

The Last six month's data of item were forecasted with respected to last year data by decomposition method.

By observing the data series, it shows some seasonality whereas showing some sinusoidal behavior. Hence the data set was tested in various forecasting methods that preferred decomposition method. The method was applied by changing model as multiplicative and additive as well as changing seasonal type and seasonal length. Bellow table illustrate the summary of the analysis.

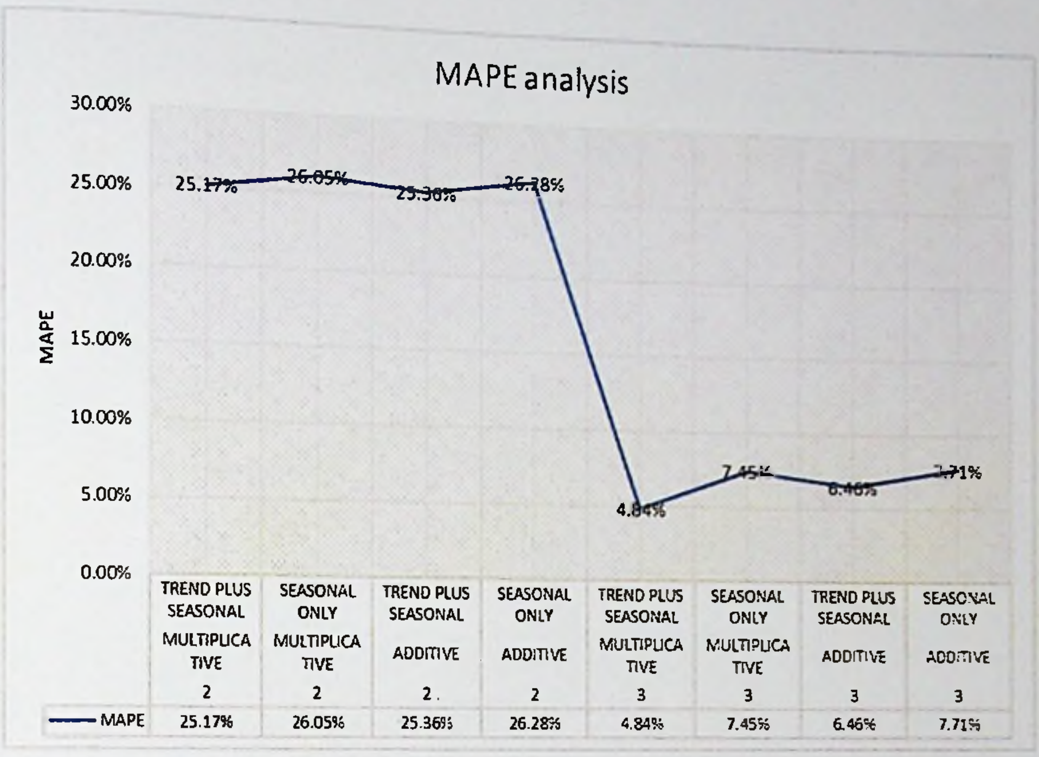


Fig 5.3 last 6 months data forecast analysis of MAPE

According to the fig 5.3 it can be claimed that the data series is follows Additive model with trend plus seasonality as the seasonal length is 3. Recalling the Minitab work sheet of above scenario. The model was given lowest MAPE (mean absolute percentage error).

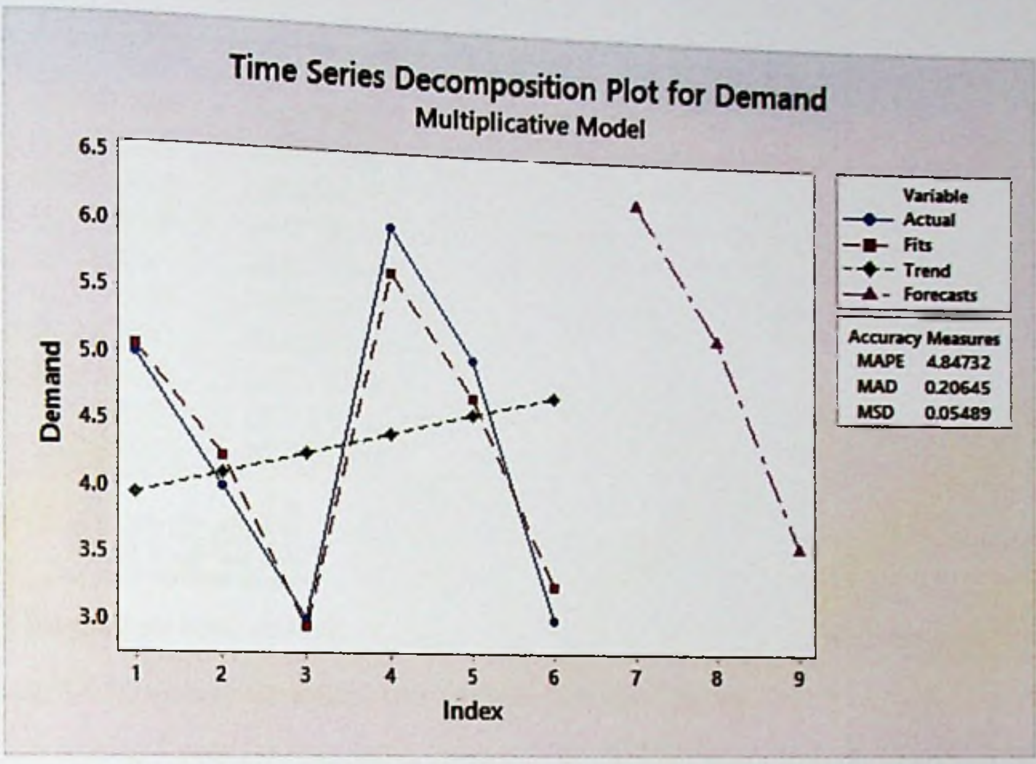


Fig 5.4 Best forecasting model in decomposition

Applying forecasted figeres in to the system to generate the parameters.

Month	Forecasts
17-Jan	6.25353
17-Feb	5.1989
17-Mar	3.58297

Table 5.5: Forecasted parameters by decomposition method

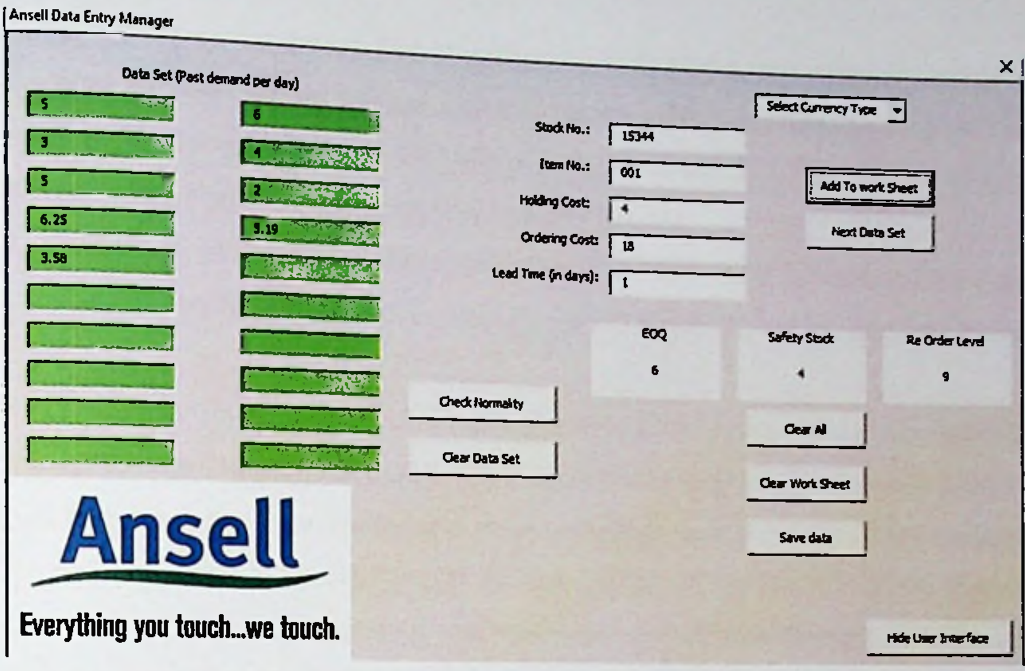


Fig 5.5 Parameters calculation after applying forecasted figures

Comparing figure 5.5 with figure 5.2 it can be claimed that there is no any deference between EOQ. But there are some deference can be observed in ROL and SS figures. Those were higher than actuals. So, that we can claim that the short stock situations won't be occurred against the forecasted figures over actual stock behavior.

5.5 Recommendations

Based on the results of the system there were some space changes experienced and some of nonmoving items were also identified and eliminated. As well as the system can be more developed to cover all the inventory models that covers manufacturing models also. It was unable to find any system that easily integrated with MS excel, statistical & numeric optimization calculations and friendly user interface in the academic level as well as industrial level. So that it can be concluded that this particular system was introduced in 1st time for the world.

Same time generally the bellow observed considerations need to be must in the applying inventory theories for the real-life situations.

1. If it is assumed that the unit cost of an item is constant throughout time independent of the batch size, the unit cost does not appear in the optimal solution for the batch size. This result occurs because no matter what inventory policy is used, the same number of units is required per unit time, so this cost per unit time is fixed.

2. The analysis of the EOQ models assumed that the batch size Q is constant from cycle to cycle. The resulting optimal batch size Q* minimizes the total cost per unit time for any cycle.

3. The optimal inventory level at which inventory should be replenished can never be greater than zero under these models. Waiting until the inventory level drops to zero (or less than zero when planned shortages are permitted) reduces both holding costs and the frequency of incurring the setup cost K. However, if the assumptions of a known constant demand rate and the order quantity will arrive just when desired (because of a constant lead time) are not completely satisfied, it may become prudent to plan to have some "safety stock" left when the inventory is scheduled to be replenished. This is accomplished by increasing the reorder point above that implied by the model.

4. The basic assumptions of the EOQ models are rather demanding ones. They seldom are satisfied completely in practice. For example, even when a constant demand rate is planned, interruptions and variations in the demand rate still are likely to occur. It also is very difficult to satisfy the assumption that the order quantity to replenish inventory arrives just when desired. Although the schedule may call for a constant lead time, variations in the actual lead times often will occur. Fortunately, the EOQ models have been found to be robust in the sense that they generally still provide nearly optimal results even when their assumptions are only rough approximations of reality. This is a key reason why these models are so widely used in practice. However, in those cases where the assumptions are significantly violated, it is important to do some preliminary analysis to evaluate the adequacy of an EOQ model before it is used. This preliminary analysis should focus on calculating the total cost per unit time provided by the model for various order quantities and then assessing how this cost curve would change under more realistic assumptions.

Reference

01 A Revision on Cost Elements of the EOQ Model, Mehdi Rajabi, Business School, University of New South Wales, Canberra, Australia, 2016

02 A Stochastic modeling with varying demand distributions in inventory control, Thisis submition by Dowlath Fathima under Dr. P.H Shaik Uduman, Department of mathematics, University of B.S Abdur Rahaman, Vandalur, Chennai-600048, 2014

03 Analysis of an Economic Order Quantity and Reorder Point Inventory Control Model for Company XYZ , Jose L. Gonzalez and Daniel González, California Polytechnic State University, San Luis Obispo, 2010 March

04 Business Systems and Economics, Vol. 5 (1), 2015.
Serhii Ziukov, Yurii Fedkovych Chernivtsi National University, 2 Kotsjubynskyi str., Chernivtsi 58012, Ukraine

05 Computarized inventory control applications in operational research techniques, A. Dassanayake, MSc research paper, Department of mathematics, university of moratuwa, Sri Lanka (2009)

06 Dynamic version of the economic lot size model, H.M. Wagner, T.M. Whitin, , Manage. Sci. 5 (1958)

07 Economic order quantity (EOQ) Model: Inventory management models, Cecil Bozarth, Ph.D, Jan 28 2011, *www.scm.ncsu.edu/scm-articles/article*

08 Economic order Quantity and Types, Shashank Shekhar, Apr 01 2012, *www.slideshare.net/ShashankV7/economic-order-quantity-models*

09 Evaluating the Anderson-Darling Distribution, George Marsaglia, the Florida State University, John C. W. Marsaglia, Western Oregon University, Page 1-5
05 Excel VBA made easy, Dr. Liew Voon Kiong, 2009

10 Fuzzy Sets. Information and Control, Zadeh, L.A. (1965). 8: 338-353.

11 Introduction Theory of Inventory Control, Research paper, Prof. Dr. Ingo Morgenstern, Faculty of Physics, University of Regensburg, Copyright by Markus Zizler, May 2007

12 Inventory Management and Production Planning and Scheduling E.A. Silver, D.F. Pyke, R. Peterson, , John Wiley and Sons Inc., New York, 1998.

13 Inventory Management: Non-classical View, Jaber, M.Y. (2009).. Boca Raton: CRC Press.

14 Inventory models-quantitative methods for business, Anderson, Sweeney and Williams, 1st ed. Kundali, India, Thompson Southwest, pp.135-185, 2009.

15 The lead time and Inventory control problem, Cawdery M.N, Operational Research Quarterly, Vol. 27, pp.971–982, 1976.

16 Learn Visual Basic 6.0, Lou Tylee, KIDware 15600 NE 8th, Suite B1-314 Bellevue, 1998.

17 Operations Management, 6th edition, J. Heizer, B. Render, Prentice-Hall, Englewood Cliffs, NJ, 2000, p. 436.

18 Operations Management Models and Principles, D. Chhajed and T.J. Lowe (eds.) Building Intuition, 2008, Chapter 08

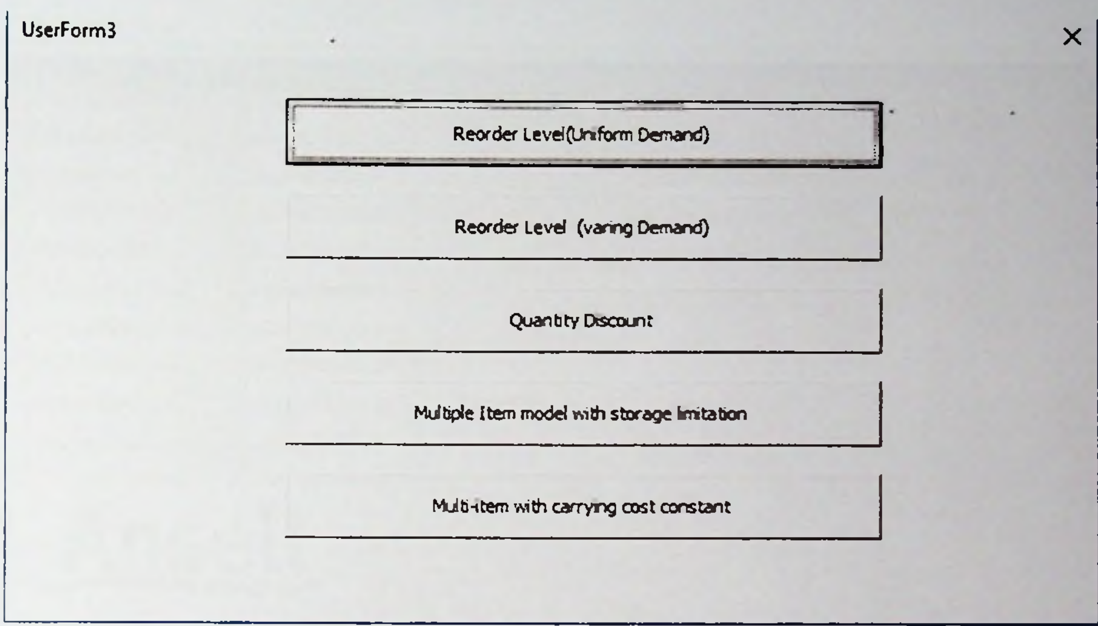
19 Optimal inventory policy, Arrow K.J, Harris and Marschak, Econometrica, Vol.19, pp.250-272, 1951.

20 Principles of Inventory Management: When You Are Down to Four, J.A. Muckstadt and A. Sapra, Springer Series in Operations Research and Financial Engineering, 2010

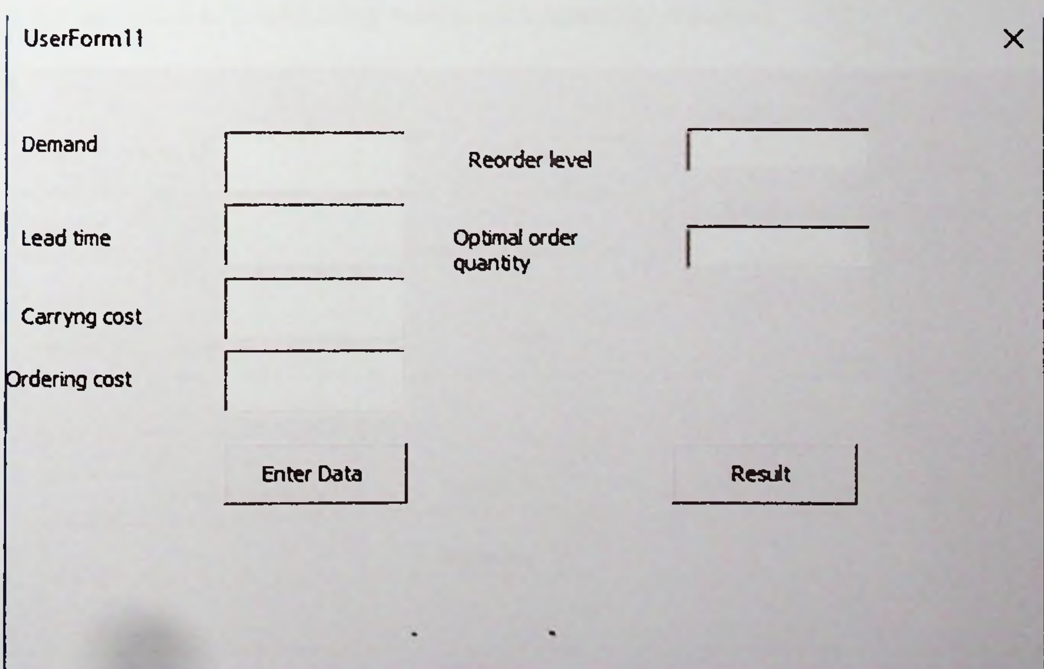
21 Using Excel Solver in Optimization Problems, Leslie Chandrakantha John Jay College of Criminal Justice of Cuny Mathematics and Computer Science Department, 445 West 59th Street, New York,

Appendix 01

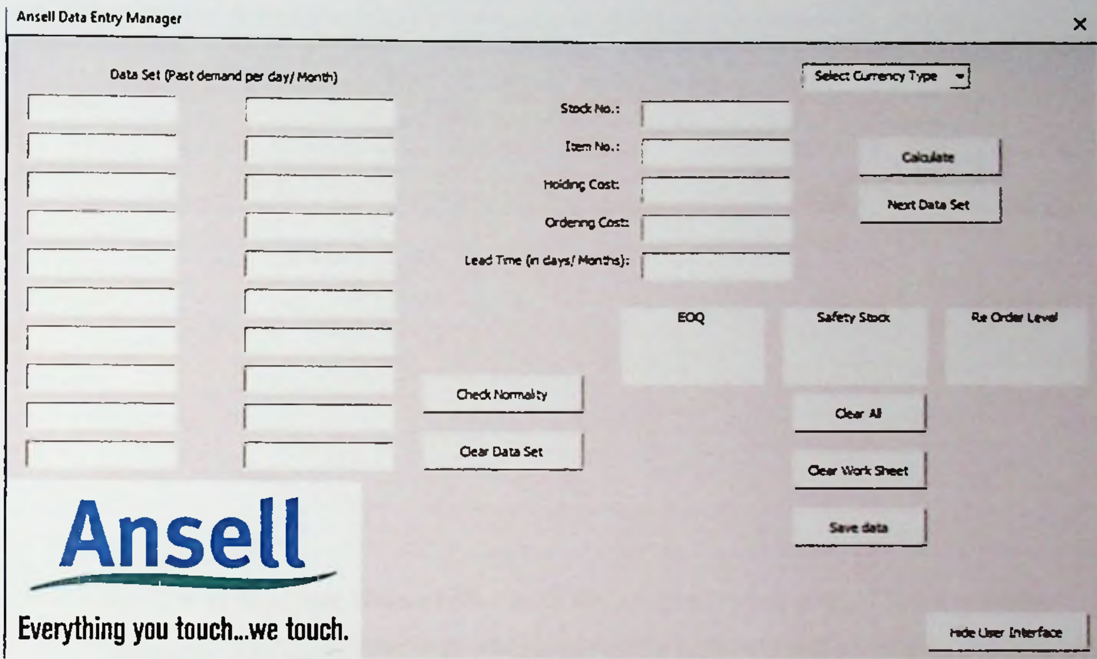
Main menu user interface



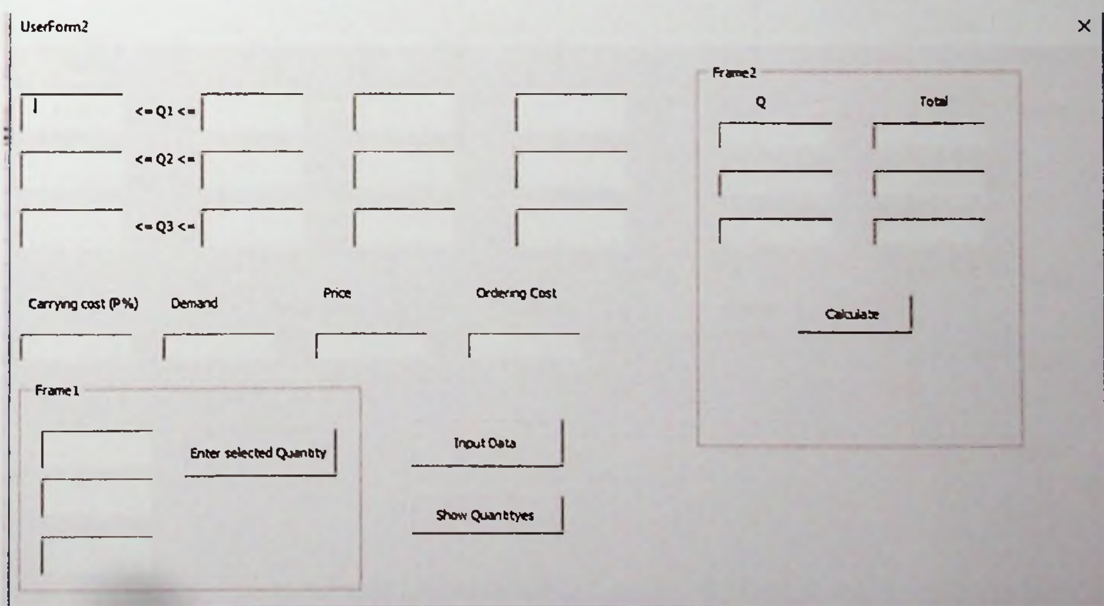
User interface of purchasing model with constant demand



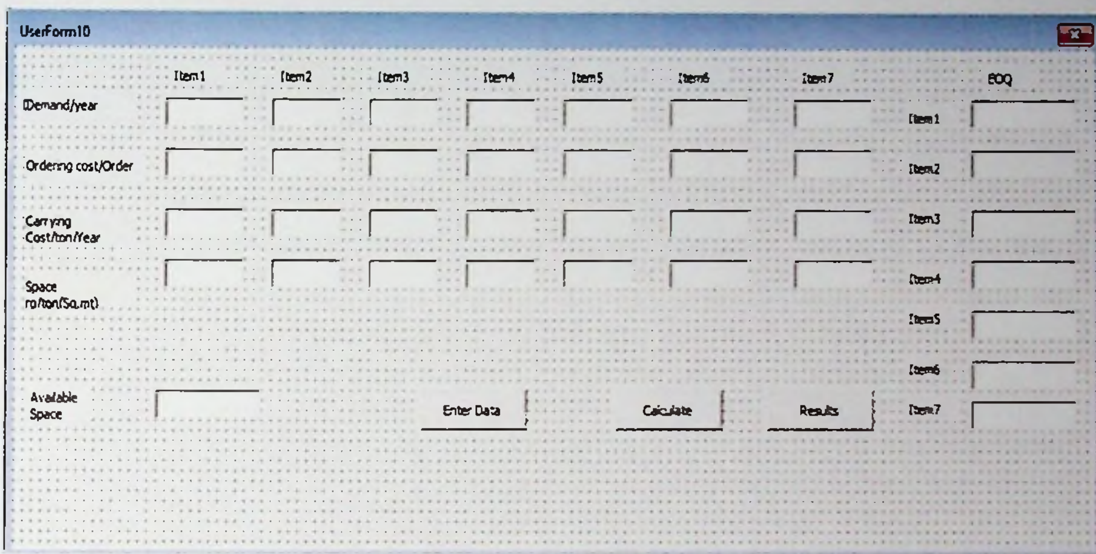
User interface of purchasing model with varying demand



User interface of purchasing model with quantity discount



User interface of multiple item model with limited storage (7 Item model)



User interface of multiple item model with limited carrying cost (7 item model)