Examination Roll No: 1893721

Project Report

On

"To forecast the demand and determine an optimal procurement policy for raw materials based on annual demand"

Submitted By

Aditi

In

Partial fulfillment of the requirements of the

Degree of Master of Science

In

Operational Research

To

Department of Operational Research

Faculty of Mathematical Sciences

New Academic Block

University of Delhi

Delhi-110007

(2020)

DEPARTMENT OF OPERATIONAL RESEARCH

FACULTY OF MATHEMATICAL SCIENCES

NEW ACADEMIC BLOCK

UNIVERSITY OF DELHI, DELHI-110007

Name of Student : Aditi

Date of commencement of Project : 26th February, 2020

Date of Submission of the Project : 31st May, 2020

Project title : To forecast the demand and determine the optimal procurement policy for raw material based on the annual demand

Supervisors from the teaching faculty: Prof. Pankaj Gupta
Prof. Chandra K. Jaggi
Prof. Prakash C. Jha
Prof. Preeti Wanti Srivastava
Prof. K.K. Aggarwal
Prof. Anu Gupta Aggarwal
Dr. Ompal Singh
Dr. Mukesh Kumar Mehlawat
Dr. Vandana Khaitan
Dr. Adarsh Anand
Mr. Kaushal Kumar

DECALARTION

This is to certify that this project entitled **“To forecast the demand and determine an optimal procurement policy for raw materials based on annual demand”** is my original work carried out in the year 2020, and has been submitted for partial fulfillment of the requirements of the course M.Sc. Operational Research. This project report has not been submitted earlier in full or in part for any other diploma or degree to any other university or institute to the best of my knowledge.

Aditi

M.Sc. Operational Research (Semester-IV)

Department of Operational Research

University of Delhi, Delhi-110007

Professor Pankaj Gupta

Head

Department of Operational Research

Faculty of Mathematical Sciences

University of Delhi, Delhi-110007

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to the Faculty members of Department of Operational Research, University of Delhi for their invaluable guidance, support and co-operation at various levels during the project study.

The project would not be a success without the constant support and valuable guidance of **Dr.C.K Jaggi**, my internal guide for the project, who is rendering all sorts of help as and when required.

Aditi

M.Sc. Operational Research (Semester-IV)

Department of Operational Research

University of Delhi, Delhi-110007

INDEX

OPERATION RESEARCH

The Operational Research Society of U.K. defines OR as:

"Operational Research is the application of the methods of science to complex problems arising in the direction and management of large systems of men, machines, materials and money in industry, business, government and defense. The distinctive approach is to develop a scientific model of the system, incorporating measurements of factors, such as chance and risk, with which to compare the outcome of alternative decisions, strategies and controls. The purpose is to help management determine its policies and actions scientifically."

As its name implies, operation research involves "research on operations". Thus, operations research is applied to problems that concern how to conduct and coordinate the operations (i.e. the activities) within an organization. The nature of organization is essentially immaterial, and, in fact, or has been applied extensively in such diverse areas as manufacturing, transportation, construction, telecommunications, financial planning, healthcare, the military and public services, to name just a few. The "research" part of the name that operations research uses that resembles the way research is conducted in established scientific (typically mathematical) model that attempts to abstract the essence of the real problem. It is then hypothesized that this model is sufficiently precise representation of the essential features of the situation that the conclusions (solution) obtained from the model are also valid for the real problem. An additional characteristic is that O.R. frequently attempts to find a best solution (optimal solution) for the problem under consideration. During the year, 1950O.R. achieved recognition as a subject worthy of academic study in the universities Operations Research Society of America was formed in 1950 and 1957 the international federation of O.R. Societies was established.

Operations research encompasses a wide range of problem-solving techniques and methods applied in the pursuit of improved decision-making and efficiency, such as simulation, mathematical optimization, queuing theory, Markov decision processes, economic methods, data analysis, statistics, neural networks, expert systems, and decision analysis. Nearly all of these techniques involve the construction of mathematical models that attempt to describe the system. Operational Research in practice is a team effort, requiring close cooperation among the decision-makers, the skilled OR analyst and the people who will be affected by the management action. Organizations may seek a very wide range of operational improvements - for example, greater efficiency, better customer service, higher quality or lower cost. Whatever the business engineering aim, OR can offer the flexibility and adaptability to provide objective help. Most of the problems OR tackles are messy and complex, often entailing considerable uncertainty. OR can use advanced quantitative methods, modeling, problem structuring, simulation and other analytical techniques to examine assumptions, facilitate an in -depth understanding and decide on practical action. Operations research is the science of decision-making. OR methods involve identifying business problems and possible scenarios for solving them. These variables are modeled using various forms of applied mathematics implemented as software algorithms. On a more granular level, the OR professional collects the relevant data to instantiate the model, optimizes it, and then evaluates the results, which provide business professionals with a suggested course of action. OR can help the following kinds of business questions:

− How should the fleet of delivery trucks be allocated to meet customer needs while making the best use of drivers? − How should inventory be kept to maintain smooth functioning of the organization while minimizing its carrying cost? − Where warehouses should be located to minimize transportation costs? − What is the impact of faster machinery on the factory-production process?

HISTORY OF OPERATIONAL RESEARCH

As a discipline, operational research originated in the efforts of military planners during World War I (convoy theory and Lanchester's laws). In the decades after the two world wars, the techniques were more widely applied to problems in business, industry and society. Since that time, operational research has expanded into a field widely used in industries ranging from petrochemicals to airlines, finance, logistics, and government, moving to a focus on the development of mathematical models that can be used to analyse and optimize complex systems, and has become an area of active academic and industrial research.

The encouraging results achieved by the British operations research teams motivated the United States military management to start on similar activities. Successful applications of the U.S. teams included the study of complex logistical problems, invention of new flight patterns, planning sea mining, and effective utilization of electronic equipment. Following the end of the war, the success of the military teams attracted the attention of industrial managers who are seeking solutions to their complex executive type problems. Such problems were becoming more acute because of the introduction of functional specialization into business organizations, despite the fact that specialized functions are established primarily to serve the overall objective of the organization; the individual objectives of these functions may not be always consistent with the goals of the organization. This has resulted in complex decision problems, which ultimately have forced business organizations to seek the utilization of the effective tools of the operational research. Today, the impact of operation research can be seen in many areas. The number of academic institutions that are offering this field at all degree levels indicates this. A large number of management consultancy firms are currently engaged in operational research activities. The activities have gone beyond military and business applications to include hospitals, financial institutions, libraries, city planning, transportation system,

IMPORTANCE OF O.R

In order to facilitate business decision-making, OR plays a huge part of planning. The decision-making we are referring to in this specific context has to do with optimization. Therefore, we can say that OR is very important because it enables businesses to "do things best under the given circumstances". But that's too broad of an answer. To get a better picture of the scenario let us consider the following points:

- **OR simplifies the business environment**. In a business environment, numbers and figures often provide the most reliable information. Quantification gives more room for objectivity, so business decisions can be made objectively, since there numbers say so.
- **OR maximizes the usefulness of data**. Depending on the size of the business operations, there are a lot of data that have to be dealt with on a daily basis. Larger operations are faced with millions of bits of information, and going through each and every piece of data can be tedious, time-consuming and, therefore, counter-productive. Through the use of OR techniques and analytical methods, there is a way to handle all those volumes and volumes of data in significantly less time. Obviously, this will lead to being able to make better decisions, faster.
- **OR aids in the optimization of resources**. Resources are scarce, so businesses have to find ways to make the best use of the resources that are currently available to them, while ensuring that they are of high quality or, at least, with quality that meets the expectations of the end users.
- **OR ensures effective and efficient delivery of products or services to the end users**. By applying OR in decision-making, the process becomes more systematic, so that you are able to provide the high quality products or services to the customers or end users when and where they are needed. Having high-quality products will be of no use if you are unable to deliver them to the end users when you're supposed to.

Step 1. Orientation

OR is not a one-man activity. It takes a team, with members equipped with various skills and specializations assigned with various tasks and functions, depending on their strengths or the areas they excel at. Therefore, there are two things that must be done in this step.

- **Form the team that will conduct the OR study**. Take into account the multifunctional nature of OR when choosing the members of the team. It is advised that the areas or divisions that are directly or even indirectly affected by, or related to, the OR be represented in the team. If the OR is on product design, then include the engineering, assembly and quality control divisions to be represented, along with someone from finance and marketing, specifically those that are involved in customer and market research. Install a team leader who will be able to steer the team in the right direction, and one with the ability to manage both the work and the members of the OR team.

- **Ensure that all members of the team fully understand the issues at hand**, specifically on the matter regarding the OR. What are they supposed to study, and what should they pay attention to? For what reason are they conducting this specific activity, and how will it benefit the organization? These are only a few of the primary questions that you must address before the members of the team so that they won't be "flying blind".
  Bringing them into the loop will also motivate them to do the best they could in the OR study. It is also important that you are able to instill an appreciation within the team for the objectives of the activity and for what have been done so far (if there are).

Step 2. Problem Definition

Most processes – even the scientific method – puts this on the first step, and it is ***considered by most to be the most difficult part of the entire process***, since it will set the tone for the rest of the activities or tasks that will follow. If we don't know what the problem is, then we will simply be spinning your wheels and going nowhere.

If, on the other hand, we were able to identify a problem, but it's not the actual or real problem, then we will also end up wasting a lot of time and resources, and consequently we might even end up making the wrong decisions.

In defining the problem, we ***have to clearly identify its scope and the results that you desire or expect to have at the end.*** This time, we will be more specific. Instead of saying that we want to improve the company's product design system, we will have a more targeted objective, such as "to lower the unit production cost of the product".

Once we've identified the specifics, delve deeper into it.

- **Identify the specific factors that will affect your objective**, clearly distinguishing those that are within our control from those that are not, and determine all possible alternative courses of action that may be taken. Say that you want to lower the unit production cost of the product, so the factors may include the flexibility of product design, factors of production used (e.g. direct materials, direct labor, and overhead).

- **Identify the constraints on the courses of action**. There are bound to be limits that all decision-makers in business have to operate within. It is possible that the nature of the product and even government regulations and legislation do not provide enough room for flexibility in product design. Availability of resources – especially the alternative resources should you decide to change some of the inputs into the product – is also another constraint.

Step 3. Data Collection

In this step, there are two things we should take note of before you can go about successful data collection. Of course, ***<u>this is under the assumption that you already know what type of data you should collect</u>***.

- **Sources of data.** There are many identifiable sources of data, depending on the data type you need. Generally, we look to existing standards, such as current and historical trends and set values. Another source is the system or process that is being studied, particularly on how it works in actuality.

- **Methods and tools for data collection.** Observation remains to be one of the most commonly used methods of data collection and, thanks to automation and computerization, combined with the flexibilities brought on by the internet, data collection is greatly facilitated. What used to take businesses years to collect data and process it into valuable information is now doable in just a matter of hours, days even.

Step 4. Model Formulation

Modeling is what sets OR apart from other decision-making processes. Where other approaches would directly look into the system and analyze it, OR goes about it by formulating a model, or a representation of the system, and using that model for its analysis.

Modeling allows the researchers to simplify the system while maintaining its accuracy and faithfulness to the original. Besides, it is much easier – and less costly – to analyze the model instead of the actual system.

The team conducting OR may create different types of models, and there are four general types of models that are often formulated and employed.

- **Analog models.** These are models with physical properties that are significantly smaller than the actual system being studied, and having similar characteristics with the latter. These similarities make the model and the original analogous, even if they are not identical.

- **Simulation models.** This involves the approach where the behavior of individual elements within the system is mimicked or mirrored. In other words, a model of a real-life situation is created, and that's where techniques such as sampling and experimentation, if need be, are conducted. This method is usually favored as it allows testing for future improvement. Through simulation, you can analyze even complex systems by coming up with estimates of statistical measures. Values are inputted and, with every replication, you can observe the response of the system. In this day and age, when technology plays a very important role in almost all businesses, computer simulation is often applied. This allows you to look for areas of improvement, specifically in an automated business environment.

- **Mathematical models.** OR is considered one of the many branches of mathematics, so do not be surprised when you find yourself having to apply many mathematical methods in your OR. Without going into the most intricate details, let us list down the various logical methods employed in OR. The preference for usage of mathematical models is how they effectively map out all the variables and describe their relationships with each other.

- **Physical models.** As the name implies, this is a tangible model, which is basically a copy of the original system, but scaled down appropriately. Unlike the analogic models, which are simply made to be analogous to the original system, these scaled down versions are smaller replicas of the original. Among the four model categories, this is the hardest to pull off, especially in the case of complex systems.

Step 5. Model Solution

This is where you will attempt to solve the problem; in other words, it's the analysis stage. Needless to say, this is the part where the OR team will spend the most amount of time and resources, employing a variety of analytical methods and techniques on the models formulated in the previous step.

Briefly, the most commonly used techniques are:

- **Simulation techniques, for the analysis of simulation models.** These techniques often come part and parcel with several statistical techniques. That's right. If you though that resorting to simulation will save you from dealing with numbers, you can't fully get away from it, since statistical computations will still hound you.

- **Mathematical analysis techniques**, which dominantly utilizes statistical methods, such as regression analysis, variance analysis, queuing, and statistical inference.

- **Optimization techniques**, where you will try to determine the best values or the optimum levels that will affect decision-making. That involves the application of various mathematical programs and statistical methods. Mathematical programming techniques often used include linear and non-linear programming, integer programming and network theory.

At the end of this step, you should have obtained a solution, after considering the results of the analytical tasks you used.

Step 6. Validation and Output Analysis

the process does not end once solution is obtained. We still have to make sure that the model you used in your analysis is, indeed, an accurate representation of the system. This is the validation part.

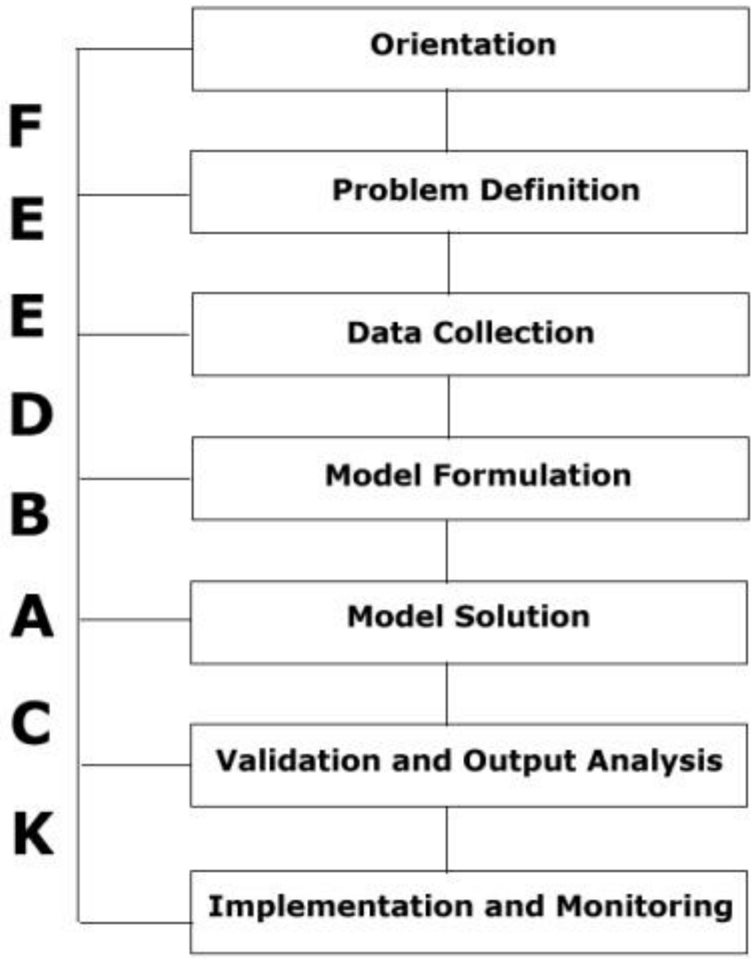
And that's not all. If you thought you're done with the analysis bit, there's still more analysis to be done. In this case, you'll be going over various "what if" scenarios, where you will consider the possible outcomes if the solutions obtained are implemented.

Step 7. Implementation and Monitoring

Finally we settled on the best solution or recommendation and made a decision. It is time to implement that decision.

Of course, you need to still have control over the implementation, which is why there should be a team in place to be in charge of the implementation. It is highly recommended that you place some members of the OR team in the implementing team.

Monitoring is a must, since we want to ensure that the solution decided upon is the one actually being implemented. This is also a way to remain on our toes, since unforeseen circumstances might lead to some aspects of the solution needing some tweaking along the way.



APPLICATIONS OF OR

1.4. APPLICATION OF OPERATIONAL RESEARCH

There are certain areas where Operation Research Techniques are effectively used. Some of them

are:

1. Production and Inventory Control

(a) Scheduling and sequencing the production by proper allocation of machine

(b) Decision on optimum product mix.

(c) Raw material control.

2. Product Design and Development

(a) Redesigning assemblies to simplify use.

(b) Scheduling design project.

3. Purchasing

(a) Designing Economic Order Quality.

(b) Setting up areas where alternative source should be planned

(c) Identifying low cost shipment pattern.

4. Marketing

(a) Determining the optimal budget, which should spent on personal selling,

(b) Advertising and sale promotion.

(c) Decision for choice of different media of advertising.

(d) Allocation the advertising budget in the most effective manner.

(e) Introduction of the new project.

5. Distribution

(a) Suggesting best locations for agents, warehouses.

(b) Minimizing the transportation cost.

6. Personnel

(a) Finding skilled person at a minimum cost.

(b) Determining the optimum of sequencing personnel to variety of jobs.

INVENTORY

Inventory- An idle resource that a firm holds in stock with the intent (anticipation of future demand) of selling it or transforming it into a more valuable state. (An idle resource of any kind provided such a resource has economic value)

The control and maintenance of inventories of physical goods is a problem common to all enterprises in any sector of a given economy. There are many reasons why organizations should maintain inventories of goods. The fundamental reason in doing so is that it is either physically impossible or economically unsound to have goods arrive in a given system precisely when demand arrives for them. For example, inventories must be maintained in agriculture, industry, retail establishments and the military. Without inventories customer would have to wait until there orders were fulfilled from a source or where manufactured. In general, however customer will not wait for long period. There are other reasons too for holding inventories. For example, the price of some raw materials used by manufacturer may exhibit considerable seasonal fluctuations. When the price is, low it is profitable for him to procure a sufficient quantity of it to last through a high priced season and to keep in inventory to be used as needed in production. In the case of retail establishments, the sale and profit could be increased if one has the inventories of goods display to customers.

Two fundamental questions that must be answered in controlling the inventory of any physical goods are, ***<u>when to replenish the inventory and how much to order for replenishment.</u>***

BASIC CHARACTERISTICS OF INVENTORY SYSTEM

The costs incurred in opening an inventory system play the major role in determining what the operating doctrine should be:

Fundamentally, there are five such costs:

Set up cost: This cost originates from expenses of placing a purchases order to an outside supply or from an internal production setup. This cost is usually assumed to vary directly with the number of orders or setups and not in the size of the order.

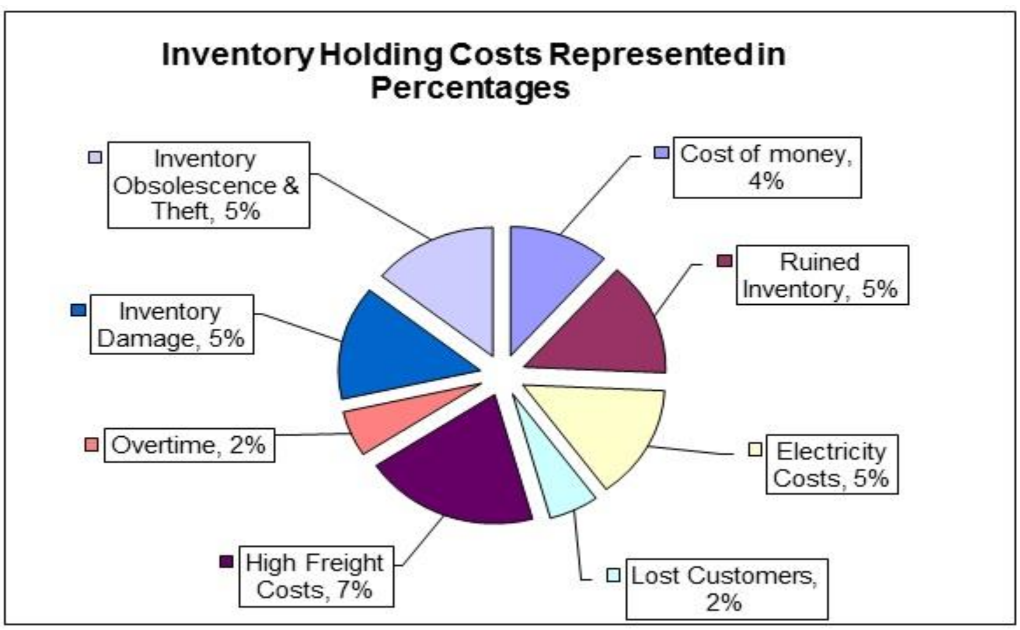
<u>In case of procurement</u>, this cost includes such as making requisition, analyzing vendors, writing purchase cost, securing material and transportation cost, inspecting materials, following up orders, and doing the paper work necessary for making transactions.

In case of production, set up cost includes cost of changing over production process; produce the order item, preparing shop orders, scheduling the work, pre-production set up, expediting and quality acceptance.

Unit production cost or unit purchase price: Such a cost is of special interest when “quantity discounts” can be availed for orders above certain quantity or large production runs may result in a decrease in the production cost. Under these conditions, the order quantity must be adjusted to take advantage of these rebates.

Selling price: In some inventory situations, the demand of the commodity may be affected by the quantity stocked. In such case the decisions model is based on a profit maximization criterion, which includes the revenue from selling the commodity. Unit selling price may be constant or variable, depending on various factors, for example, whether quantity discount are allowed or not.

Inventory holding cost: This cost includes real out of pocked cost such as costs of insurance, taxes, breakage and pilferage at the storage side, warehouse rental if the management does not own warehouse, and the cost of operating the warehouse such as light, heat, night watchman etc. It also includes opportunity cost, which is an important component of this cost. This is the incurred by having capital tied up in inventory rather than having it invested elsewhere, and it is equal to the largest rate of return which the system could obtain from alternative investments. By having funds invested in inventory, one forgoes this rate of return and hence, it represents a cost of carrying inventory. The cost is assumed to be varying directly with the level of inventory as well as the length of time the item is held in stock. A brief break up of the Inventory holding cost is given below:



Shortage cost: These are the costs, which are incurred by having demand when the system is out of stock. These are inherently extremely difficult to measure since they can include such as loss of customer goodwill and potential loss in income. Other parts include cost of notifying a customer than an item is not in stock and will be back ordered plus the cost of attempting to find out when the customers' orders can be filled and giving him this information. If the system uses the part, the back order cost may simply be the cost of keeping a machine idle for lack of parts.

In case where unfilled demand for the commodity can be, satisfy at a later date (***backlog case)These costs are assumed to be usually varying directly with both the shortage quantity and delayed time***. On the other hand, if the unfilled demand is lost (***lost sale case), the shortage cost becomes proportional to shortage quantity only***.

The demand pattern: is the next major characteristic of any inventory system. The demand pattern of commodity may be either deterministic or probabilistic. In the deterministic case, it is assumed that the quantity needed over subsequent period is known with certainty. This may be expressed over equal period in term of known constant demand or in term of known variable of demand.

The two cases are referred to as ***static and dynamic demand***, respectively.

The *probabilistic demand* occurs when the demand occurs when the *demand over certain period is not known with certainly but its pattern can be described by a known probability distribution*. In this case, ***probability distribution*** may be ***either stationary or non-stationary over time.*** These two cases are referred to as ***static and dynamic demand*** respectively.

The ordering cycle: This is concerned with the measurement of inventory situation. An ordering cycle may be identified by the time between two successive placements of order. The ordering cycle depend on the type of review undertaken.

Continuous review: Where a record of inventory level is updated continuously until a certain lower limit is reached. At the point when new order is placed.

Periodic review: Where orders are placed usually at equally spaced interval of time.

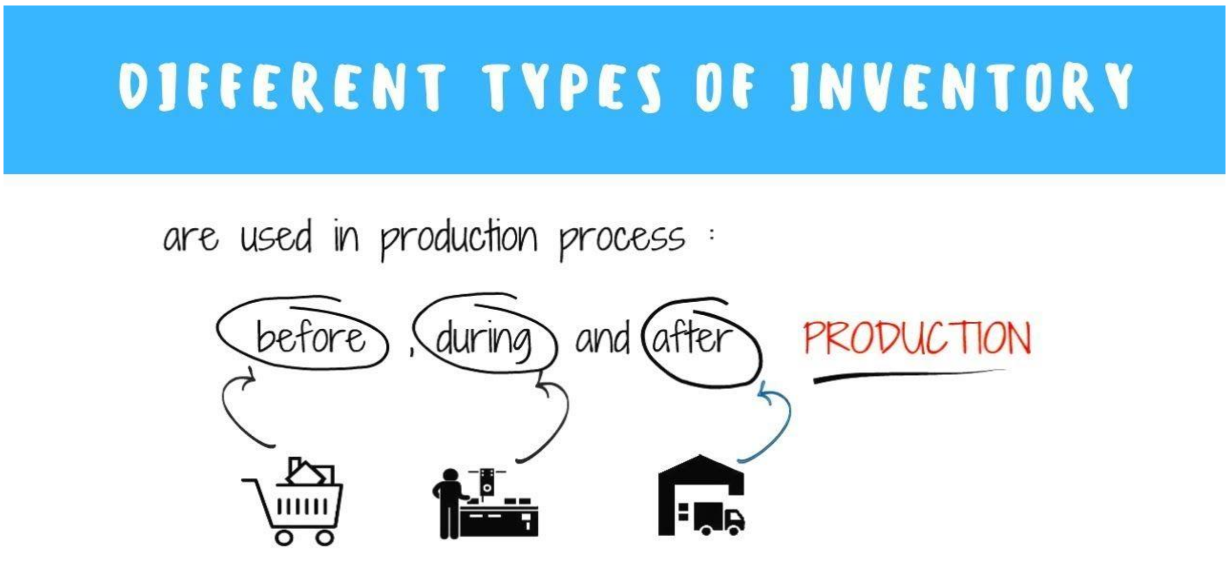
Delivery lag or lead-time: Lead-time for an inventory system is defined as the interval between the time when the stocking point placing an order for replenishment and the time when the order arrives and is on the shelves available to customers. Often the procurement lead-time will not be constant, since, the time to fill the order at the source, the shipping time and time required to carry out paper work etc. can vary from one order to another. Sometimes the variation in the ***lead-time will be small enough so that the lead-time can be assumed absolutely constant***. In other cases it will exhibit sufficient ***unpredictable variability that it is necessary to assume that the lead-time is a stochastic random variable.***

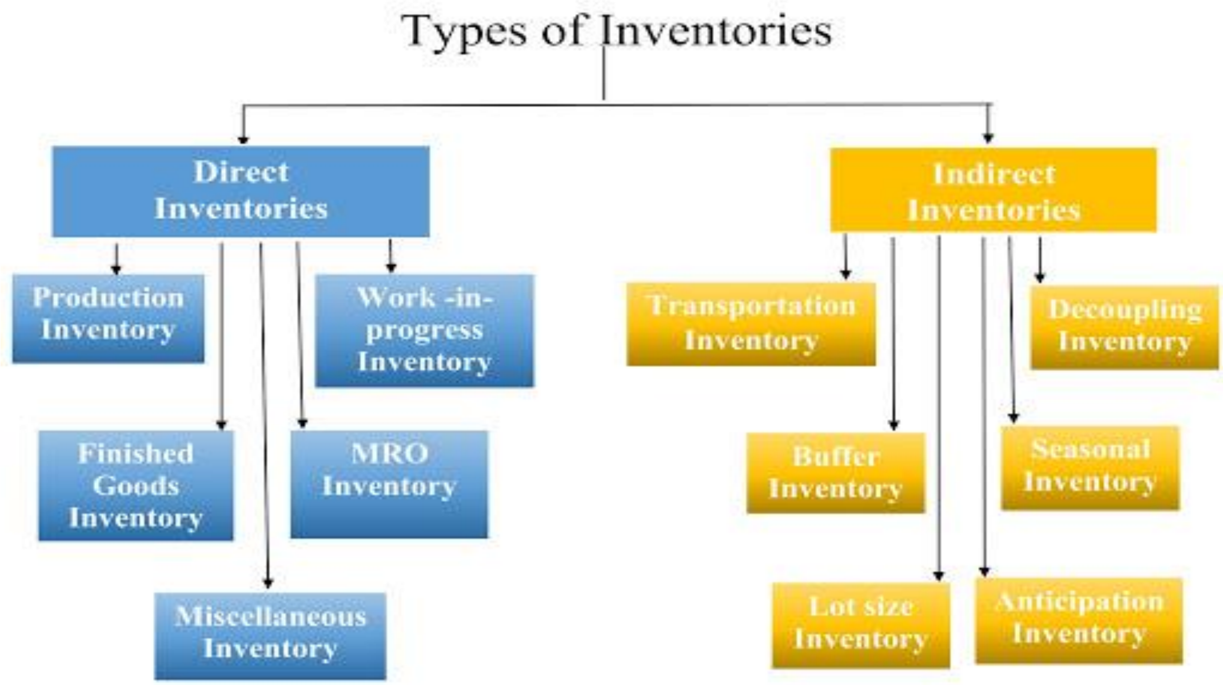
Stock replenishment: They can occur either instantaneously or uniformly over time. Instantaneous replenishment occurs in case the stock is purchased from outside sources. On the other hand, uniform replenishment may occur when the product is manufactured locally within the organization. This means that a system may operate with positive deliver lags and with uniform stock replenishment. This case, however, is not generally considered while developing inventory models.

Time horizon: It defines the time over which the inventory level will be controlled. This horizon may be finite or infinite depending on the nature of the demand for the commodity.

Limited floor space: An inventory system may include more than one item or the commodity. This case will be of interest only if some kind of interaction exists between the different items. For example, the item may compete for limited floor space and limited total capital. Such an interaction must lead to a special formulation of the inventory model.

TYPES OF INVENTORY





RAW MATERIALS

Raw materials are inventory items that are used in the manufacturer's conversion process to produce components, subassemblies, or finished products. These inventory items may be commodities or extracted materials that the firm or its subsidiary has produced or extracted. They also may be objects or elements that the firm has purchased from outside the organization. Even if the item is partially assembled or is considered a finished good to the supplier, the purchaser may classify it as a raw material if his or her firm had no input into its production. Typically, raw materials are commodities such as ore, grain, minerals, petroleum, chemicals, paper, wood, paint, steel, and food items. However, items such as nuts and bolts, ball bearings, key stock, casters, seats, wheels, and even engines may be regarded as raw materials if they are purchased from outside the firm.

The bill-of-materials file in a material requirements planning system (MRP) or a manufacturing resource planning (MRP II) system utilizes a tool known as a product structure tree to clarify the relationship among its inventory items and provide a basis for filling out, or "exploding," the master production schedule. Consider an example of a rolling cart. This cart consists of a top that is pressed from a sheet of steel, a frame formed from four steel bars, and a leg assembly consisting of four legs, rolled from sheet steel, each with a caster attached. Generally, raw materials are used in the manufacture of components. These components are then incorporated into the final product or become part of a subassembly. Subassemblies are then used to manufacture or assemble the final product. A part that goes into making another part is known as a component, while the part it goes into is known as its parent. Any item that does not have a component is regarded as a raw material or purchased item. From the product structure tree it is apparent that the rolling cart's raw materials are steel, bars, wheels, ball bearings, axles, and caster frames.

WORK-IN-PROCESS

Work-in-process (WIP) is made up of all the materials, parts (components), assemblies, and subassemblies that are being processed or are waiting to be processed within the system. This generally includes all material—from raw material that has been released for initial processing up to material that has been completely processed and is awaiting final inspection and acceptance before inclusion in finished goods.

Any item that has a parent but is not a raw material is considered to be work-in-process. A glance at the rolling cart product structure tree example reveals that work-in-process in this situation consists of tops, leg assemblies, frames, legs, and casters. Actually, the leg assembly and casters are labeled as subassemblies because the leg assembly consists of legs and casters and the casters are assembled from wheels, ball bearings, axles, and caster frames.

FINISHED GOODS

A finished good is a completed part that is ready for a customer order. Therefore, finished goods inventory is the stock of completed products. These goods have been inspected and have passed final inspection requirements so that they can be transferred out of work-in-process and into finished goods inventory. From this point, finished goods can be sold directly to their final user, sold to retailers, sold to wholesalers, sent to distribution centers, or held in anticipation of a customer order.

Any item that does not have a parent can be classified as a finished good. By looking at the rolling cart product structure tree example one can determine that the finished good in this case is a cart.

Inventories can be further classified according to the purpose they serve. These types include **transit inventory**, **buffer inventory, anticipation inventory, decoupling**

inventory, cycle inventory, and MRO goods inventory. Some of these also are know by other names, such as speculative inventory, safety inventory, and seasonal inventory.

TRANSIT INVENTORY

Transit inventories result from the need to transport items or material from one location to another, and from the fact that there is some transportation time involved in getting from one location to another. Sometimes this is referred to as pipeline inventory. Merchandise shipped by truck or rail can sometimes take days or even weeks to go from a regional warehouse to a retail facility. Some large firms, such as automobile manufacturers, employ freight consolidators to pool their transit inventories coming from various locations into one shipping source in order to take advantage of economies of scale. Of course, this can greatly increase the transit time for these inventories, hence an increase in the size of the inventory in transit.

BUFFER INVENTORY

As previously stated, inventory is sometimes used to protect against the uncertainties of supply and demand, as well as unpredictable events such as poor delivery reliability or poor quality of a supplier's products. These inventory cushions are often referred to as safety stock. Safety stock or buffer inventory is any amount held on hand that is over and above that currently needed to meet demand. Generally, the higher the level of buffer inventory, the better the firm's customer service. This occurs because the firm suffers fewer "stock-outs" (when a customer's order cannot be immediately filled from existing inventory) and has less need to backorder the item, make the customer wait until the next order cycle, or even worse, cause the customer to leave empty-handed to find another supplier. Obviously, the better the customer service the greater the likelihood of customer satisfaction.

ANTICIPATION INVENTORY

Oftentimes, firms will purchase and hold inventory that is in excess of their current need in anticipation of a possible future event. Such events may include a price increase, a seasonal increase in demand, or even an impending labor strike. This tactic is commonly used by retailers, who routinely build up inventory months before the demand for their products will be unusually high (i.e., at Halloween, Christmas, or the back-to-school season). For manufacturers, anticipation inventory allows them to build up inventory when demand is low (also keeping workers busy during slack times) so that when demand picks up the increased inventory will be slowly depleted and the firm does not have to react by increasing production time (along with the subsequent increase in hiring, training, and other associated labor costs). Therefore, the firm has avoided both excessive overtime due to increased demand and hiring costs due to increased demand. It also has avoided layoff costs associated with production cut-backs, or worse, the idling or shutting down of facilities. This process is sometimes called "smoothing" because it smoothes the peaks and valleys in demand, allowing the firm to maintain a constant level of output and a stable workforce.

DECOUPLING INVENTORY

Very rarely, if ever, will one see a production facility where every machine in the process produces at exactly the same rate. In fact, one machine may process parts several times faster than the machines in front of or behind it. Yet, if one walks through the plant it may seem that all machines are running smoothly at the same time. It also could be possible that while passing through the plant, one notices several machines are under repair or are undergoing some form of preventive maintenance. Even so, this does not seem to interrupt the flow of work-in-process through the system. The reason for this is the existence of an inventory of parts between machines, a decoupling inventory that serves as a shock absorber, cushioning the system against production irregularities. As such it "decouples" or disengages the plant's dependence upon the sequential requirements of the system (i.e., one machine feeds parts to the next machine).

The more inventories a firm carries as a decoupling inventory between the various stages in its manufacturing system (or even distribution system), the less coordination is needed to keep the system running smoothly. Naturally, logic would dictate that an infinite amount of decoupling inventory would not keep the system running in peak form. A balance can be reached that will allow the plant to run relatively smoothly without maintaining an absurd level of inventory. The cost of efficiency must be weighed against the cost of carrying excess inventory so that there is an optimum balance between inventory level and coordination within the system.

CYCLE INVENTORY

Those who are familiar with the concept of economic order quantity (EOQ) know that the EOQ is an attempt to balance inventory holding or carrying costs with the costs incurred from ordering or setting up machinery. When large quantities are ordered or produced, inventory holding costs are increased, but ordering/setup costs decrease. Conversely, when lot sizes decrease, inventory holding/carrying costs decrease, but the cost of ordering/setup increases since more orders/setups are required to meet demand. When the two costs are equal (holding/carrying costs and ordering/setup costs) the total cost (the sum of the two costs) is minimized. Cycle inventories, sometimes called lot-size inventories, result from this process. Usually, excess material is ordered and, consequently, held in inventory in an effort to reach this minimization point. Hence, cycle inventory results from ordering in batches or lot sizes rather than ordering material strictly as needed.

MRO GOODS INVENTORY

Maintenance, repair, and operating supplies, or MRO goods, are items that are used to support and maintain the production process and its infrastructure. These goods are usually consumed as a result of the production process but are not directly a part of the finished product. Examples of MRO goods include oils, lubricants, coolants, janitorial supplies, uniforms, gloves, packing material, tools, nuts, bolts, screws, shim stock, and key stock. Even office supplies such as staples, pens and pencils, copier paper, and toner are considered part of MRO goods inventory.

MANAGING AND CONTROLLING INVENTORY

Inventory models give answers to two questions. When should an order be placed or a new lot be manufactured? Moreover, how much should be ordered or purchased?

REASONS FOR HOLDING INVENTORY

To meet anticipated customer demand with large fluctuations.

- To protect against shortages.
- To take advantage quantity discounts.
- To maintain independence of operations.
- To smooth production requirements.
- To guard against price increases.
- To take advantage of order cycles.
- To overcome the variations in delivery times.
- To guard against uncertain production schedules.

- To count for the possibility of large number of defects.
- To guard against poor forecasts of customer demand.

GUIDELINES FOR BETTER INVENTORY MANAGEMENT

- **1. Prioritize your inventory.**
  Categorizing your inventory into priority groups can help you understand which items you need to order more of and more frequently, and which are important to your business but may cost more and move more slowly. Experts typically suggest segregating your inventory into A, B and C groups. Items in the A group are higher-ticket items that you need fewer of. Items in the C category are lower-cost items that turn over quickly. The B group is what's in between: items that are moderately priced and move out the door more slowly than C items but more quickly than A items.

- **2. Track all product information.**
  Make sure to keep records of the product information for items in your inventory. This information should include SKUs, barcode data, and suppliers, countries of origin and lot numbers. You might also consider tracking the cost of each item over time so you're aware of factors that may change the cost, like scarcity and seasonality

- **3. Audit your inventory.**
  Some businesses do a comprehensive count once a year. Others do monthly, weekly or even daily spot checks of their hottest items. Many do all of the above. Regardless of how often you do it, make it a point to physically count your inventory regularly to ensure it matches up with what you think you have.

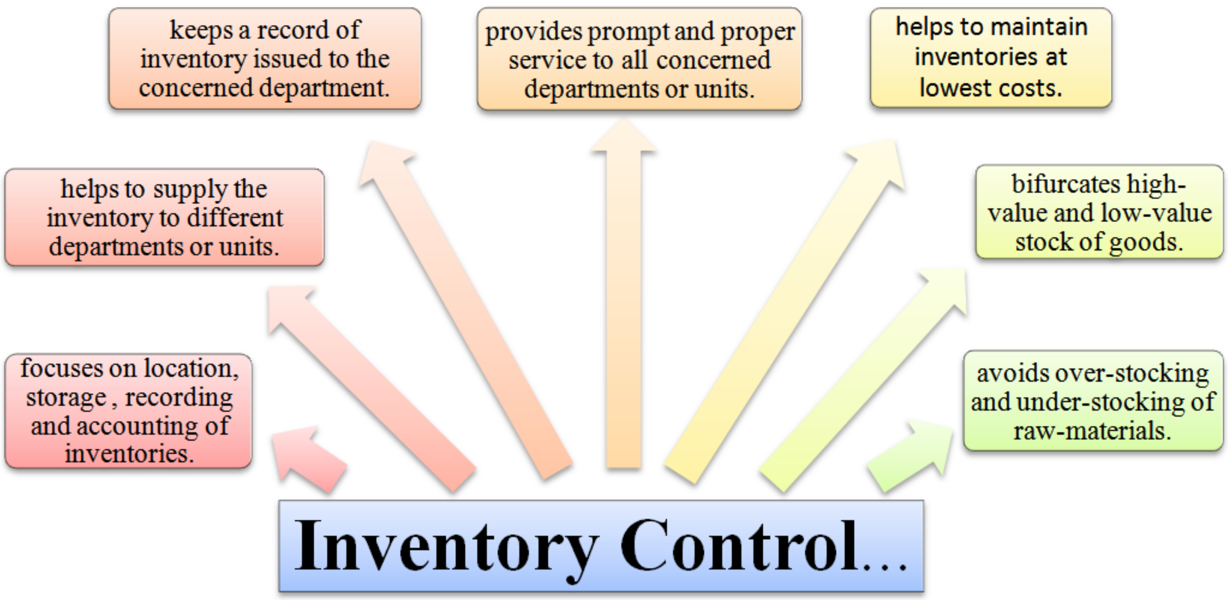
- **4. Analyze supplier performance.**
  An unreliable supplier can cause problems for your inventory. If you have a supplier that is habitually late with deliveries or frequently shorts an order, it's time to take action. Discuss the issues with your supplier and find out what the problem is. Be prepared to switch partners, or deal with uncertain stock levels and the possibility of running out of inventory as a result.

- **5. Practice the 80/20 inventory rule.**
  As a general rule, 80% of your profits come from 20% of your stock. Prioritize inventory management of this 20% of items. You should understand the complete sales lifecycle of these items, including how many you sell in a week or a month, and closely monitor them. These are the items that make you the most money; don't fall short in managing them.

- **6. be consistent in how you receive stock.**
  It may seem like common sense to make sure incoming inventory is processed, but do you have a standard process that everyone follows, or does each employee receiving and processing incoming stock do it differently? Small discrepancies in how new stock is taken in pile up at the end of the month or year, wondering why your numbers don't align with your purchase orders. Make sure all staff that receives stock does it the same way, and that all boxes are

verified, received and unpacked together, accurately counted, and checked for accuracy.

- **7. Track sales.**
  One should keep a track, on a daily basis, what items you sold and how many, and update your inventory totals. But beyond that, you'll need to analyze this data. Do you know when certain items sell faster or drop off? Is it seasonal? Is there a specific day of the week when you sell certain items? Do some items almost always sell together? Understanding not just your sales totals but the broader picture of how items sell is important to keeping your inventory under control.
- **8. Order restocks yourself.**
  Some vendors offer to do inventory reorders for you. On the surface, this seems like a good thing – you save on staff and time by letting someone else manage the process for at least a few of your items. But remember that your vendors don't have the same priorities you do. They are looking to move their items, while you're looking to stock the items that are most profitable for your business. Take the time to check inventory and order restocks of all your items yourself.
- **9. Invest in inventory management technology.**
  If you're a small enough business, managing the first eight things on this list manually, with spreadsheets and notebooks, is doable. But as your business grows, you'll spend more time on inventory than you do on your business, or risk your stock getting out of control. Good inventory management software makes all these tasks easier. Before you choose a software solution, make sure you understand what you need, that it provides the analytics important to your business and that it's easy to use.
  10. Other factors include: close inspection of
- Interest on loans to purchase inventory or opportunity costs because of funds tied in the inventory.
- Taxes, and insurance costs.
- Ordering and setup costs.
- Costs of holding an item in inventory.
- Cost of funds tied up in inventory.
- Transportation & shipping cost.
- Receiving and inspection costs.
- Handling & storage cost.
- Accounting and auditing cost.
- Storage costs such as rent, heating, lighting, and security.
- Depreciation cost



PROS AND CONS OF EXCESSIVE INVENTORY

Pros to holding excess inventory

Quicker response time

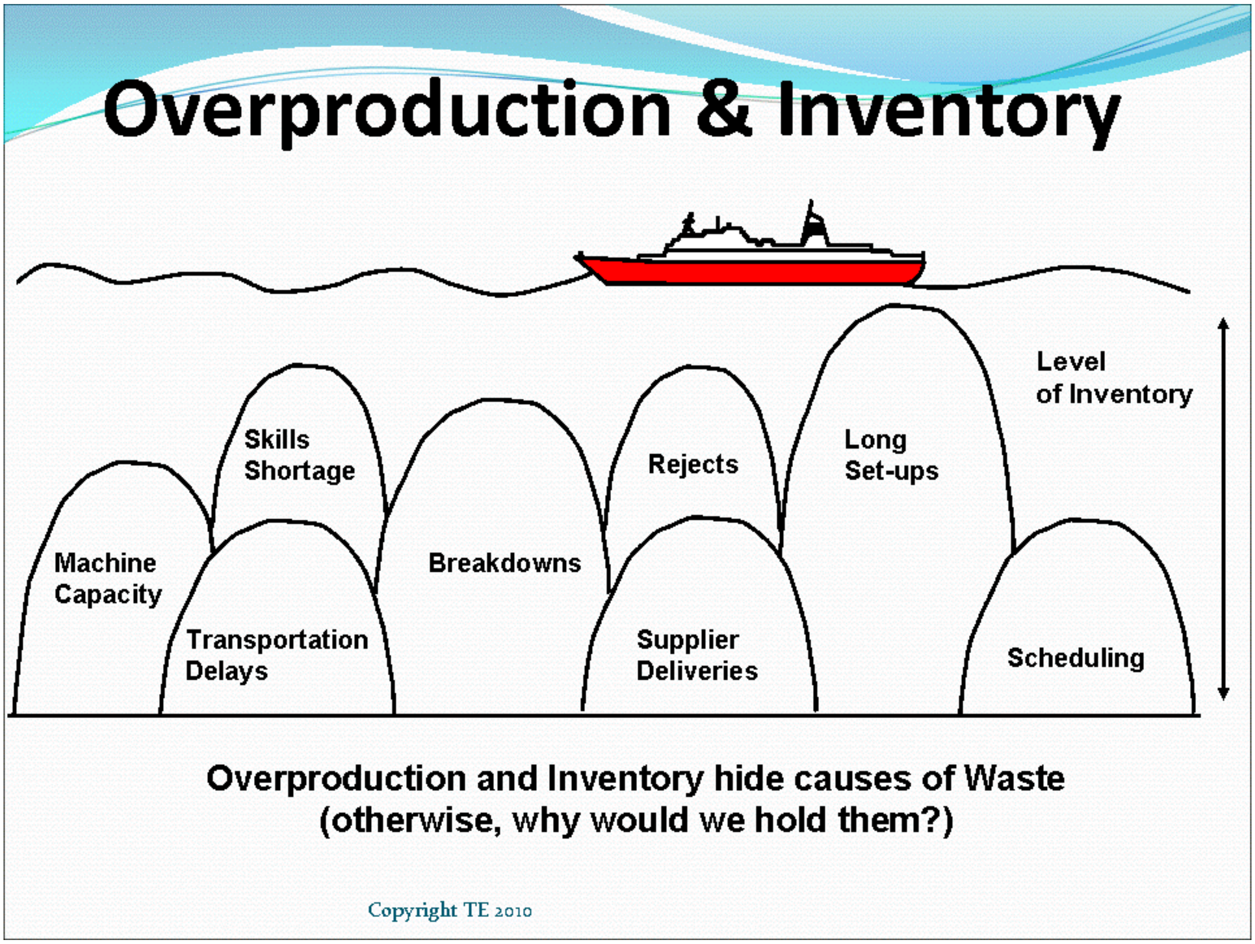
You are able to easily and quickly fill all customer orders as soon as they come in, without having to worry about waiting on your stock to come in to ship their order out. Customers can be lost if you can't ship an order quickly.

Decreased risk of shortages

By keeping stock on hand, you are able to guarantee, up to a certain point, that you will not run out of a particular item, and you have less to worry about if a product is discontinued. Should there be a shift in the demand for your product, you are more able to meet (or even beat) the competition; you will be more likely to be able to sell your excess inventory at an ideal price.

Quick replenishment-

By keeping excess inventory, you are able to work to make sure that your shelves are always full, and that your store always has a neat and tidy appearance.



Cons of holding excess inventory

Tying up Cash flow-The more inventory you have on hand, the greater the amount of the business' capital is tied up. You will risk slowing down your business' cash flow.

Risk of inventory becoming obsolete

The value and quality of your product decreases the longer you keep it on stock. You have to make it a priority to sell your inventory while they're new to the market. Smart phones, for example, are updated almost every six months, so you have to sell your stock before new versions arrive. You might end up having to sell them at a smaller price because it has become outdated or obsolete. Similarly, if you are selling perishable goods, you would have to sell them at a much lower price the nearer it gets to its expiration date. You would potentially lose money on the item if it must be sold below cost in order to clear it out.

Risk of item not selling

By keeping excess inventory on hand, it’s possible that you have misjudged what will and what will not sell, and in doing so, you could end up with a large quantity of items on hand that people do not wish to purchase. Again, you might have to sell at a steep discount, or sell below cost to move the inventory out of your warehouse.

Higher storage costs

Excess inventory means extra space needed for storage. Extra space also means extra costs, and since you have to include those extra costs in your price, you might end up losing to competition with other sellers because your price is too high. Even if you have your own warehouse, you would still be having extra costs in maintenance, and you also risk not having enough space for new items.

Risk of natural disasters

Any type of stock is always at a risk of being destroyed or damaged by fires, floods, or other natural disasters. Having less of it in excess, however, would incur smaller losses should these natural disasters happen.

Higher insurance premiums

The more inventory you keep and the longer you keep it, the more insurance you pay on it.

SELECTIVE INVENTORY CONTROL

Every organization consumes several items of store. Since all the items are not of equal importance, a high degree control on inventories of each item in neither applicable nor useful. So is becomes necessary to classify the items in-group depending upon their ***utility importance***. Such type of classification is named as the principal of selective control, which is applied to control the inventories.

ABC Analysis:

ABC analysis is a basic tool, which helps the management to place their efforts where the results would be useful to the greatest possible extent. This technique involves the classification of inventory items into three categories A, B and C in descending order of annual consumption and annual monetary value of each item. The ABC analysis is based on Pareto‘s law that a few high usage value items constitute a major part of the capital invested in inventories, whereas bulk of items in inventory having low value constitute insignificant part of the capital. This concept is based on selective control. If there are large no. of items of be analyzed, then sampling technique may be used for ABC analysis. In ABC analysis the items are classified in three main categories based on their respective usage value:

A – Class items: Costlier and valuable items are classified as —A. Such items have large investments but not much in number, for example say, 10% of items account for 75% of the total capital invested in inventory. So more careful and closer control is needed for such items. The items of this category should be ordered frequently but in small no. A periodic review policy should be followed to minimize the shortage percentage of such items and top inventory staff should control these items. These items have a high carrying cost and frequent orders of small size for these items can results in enormous savings.

B – Class items: The items having average consumption value are classified as —B. nearly 15% of items in an inventory account of 15% of the total investment. These items have less importance than a class items, but are much costly to pay more attention on their use. These items cannot be over looked and require less degree of control than those in category A. Statistical sampling is generally useful to control them.

C – Class items: The items having low consumption value are put in class —C. nearly 75% of the inventory items account only for 10% of the total invested capital. Such items can be stocked at an operative place where people can help themselves with any requisition formality. These items can be charged to an overhead account. In fact, lose control of C class items increase their investment cost and expenditure on itself wear, obsolescence and wasteful use, but this will not be so much offset for the saving and recording costs.

XYZ Analysis:

XYZ analysis is calculated by dividing an item's current stock value by the total stock value of the stores. The items are first sorted on descending order of their current stock value. The values are then accumulated till values reach say 60% of the total stock value. These items are grouped as 'X'. Similarly, other items are grouped as 'Y' and 'Z' items based on their accumulated value reaching another 30% & 10% respectively. The XYZ analysis gives, you an immediate view of which items are expensive to hold. Through this analysis, you can reduce your money locked up by keeping as little as possible of these expensive items.

SOS Analysis:

Seasonal, Off Seasonal Report helps you to view seasonal required items.

S- For seasonal Materials

OS - For non-seasonal Materials

Purchase planning has to be done if the material is seasonal as material shall be available for a particular time period of the year.

Seasonal Items can be further classified into two groups:

1. Mango is seasonal fruit which is available only for one month in year. If any Juice and pulp company wants to buy this fruit then the procurement department shall have to plan in advance the requirement and procurement job becomes concentrated only for one month. Other than this issue, shelf life and storage is also a big problem as the plan is consume is throughout the year while the buying time available is only one month.

2. Some materials are seasonal but are available throughout the year such as grains, and other non-perishable items. These items are bought during season and these items are cheaply available during season. The company can take the advantage of

economies of scale in buying these materials in bulk. But at the same time the inventory carrying cost should not go beyond the profit margins while holding the large inventory

Non-seasonal materials are available throughout the year without any significant price variation.

Non seasonal items can be Plastics, Metals etc. The prices of these materials are independent of the season.

HML Analysis

This analysis is done for classifying the materials based on their prices

<u>H -High Price Materials</u>

<u>M-Medium Price Material</u>

<u>L - Low price materials</u>

Procurement department is more concerned with prices of materials so this analysis helps them to take them the decisions such as, who will procure what based on the hierarchy and price of material.

Some of the other objective can be as under Helps in taking the decision such as whether to procure in exact requirement or opt for EOQ or purchase only when needed, when it is desired to evolve purchasing policies then also HML analysis is carried out i.e. whether to purchase in exact quantities as required or to purchase in EOQ or purchase only when absolutely necessary When the objective is to keep control over consumption at the department level then authorization to draw materials from the stores will be given to senior staff for H item, next lower level in seniority for M class item and junior level staff for L class items cycle counting can also be planned based on HML analysis.

H class items shall be counted very frequently, M class shall be counted at lesser frequency and L class shall be counted at least frequency as compared to H & M class.

SDE Analysis:

S-Scarce Material i.e. hardly available.

D-Difficult material i.e. difficult in sourcing.

E-Easy materials i.e. materials available easily.

SDE analysis is done based on purchasing problems associated with items on day to-day basis. Some of the purchasing problems are as under: -

-Long Lead Times.

-Scarcity and hardly available

-Sourcing the same material from many geographically scattered sources

-Uncertain and unreliable sources of supply

Purchasing department classifies these materials and formulates the strategy and policy of procurement of these items accordingly. So classification of materials is done based on level of difficulty in sourcing

S Class Materials: These materials are always in shortage and difficult in procurement. These materials sometimes require government approvals, procurement through government agencies. Normally one has to make the payment in advance for sourcing these materials. Purchase policies are very liberal for such materials

D Class Materials: These materials though not easy to procure but are available at a longer lead times and source of supply may be very far from the consumption. Procurement of these materials requires planning and scheduling in advance. Particular OEM spares of the machinery may fall under this category as that OEM may be very far from the ordering or consumption location.

E Class Materials: These materials are normally standard items and easily available in the market and can be purchased anytime.

GOLF Analysis:

Government, Ordinary, Local, and Foreign Report help you to do material analysis based on location and type of organization.

G -Government suppliers

O- Ordinary or non-government suppliers

L - Local suppliers

F - Foreign suppliers

FSN Analysis:

Classification of materials based on movement i.e. Fast Moving, Slow Moving and Non Moving. Sometimes it is also called as FNS (Fast Moving, Normal Moving and slow moving). By doing FSN analysis materials can be classified based on their movement from inventory for a specified period. Items are classified based on consumption and average stay in the inventory. Higher the stay of item in the inventory, the slower would be the movement of the material.

F- Fast moving

S-Slow Moving

N-Non Moving

VED Analysis:

By using this analysis for material we classify materials according to their criticality to the production i.e. how and to what extent the material M1 is going to effect the production if the material M1 is not available.

V- Vital,

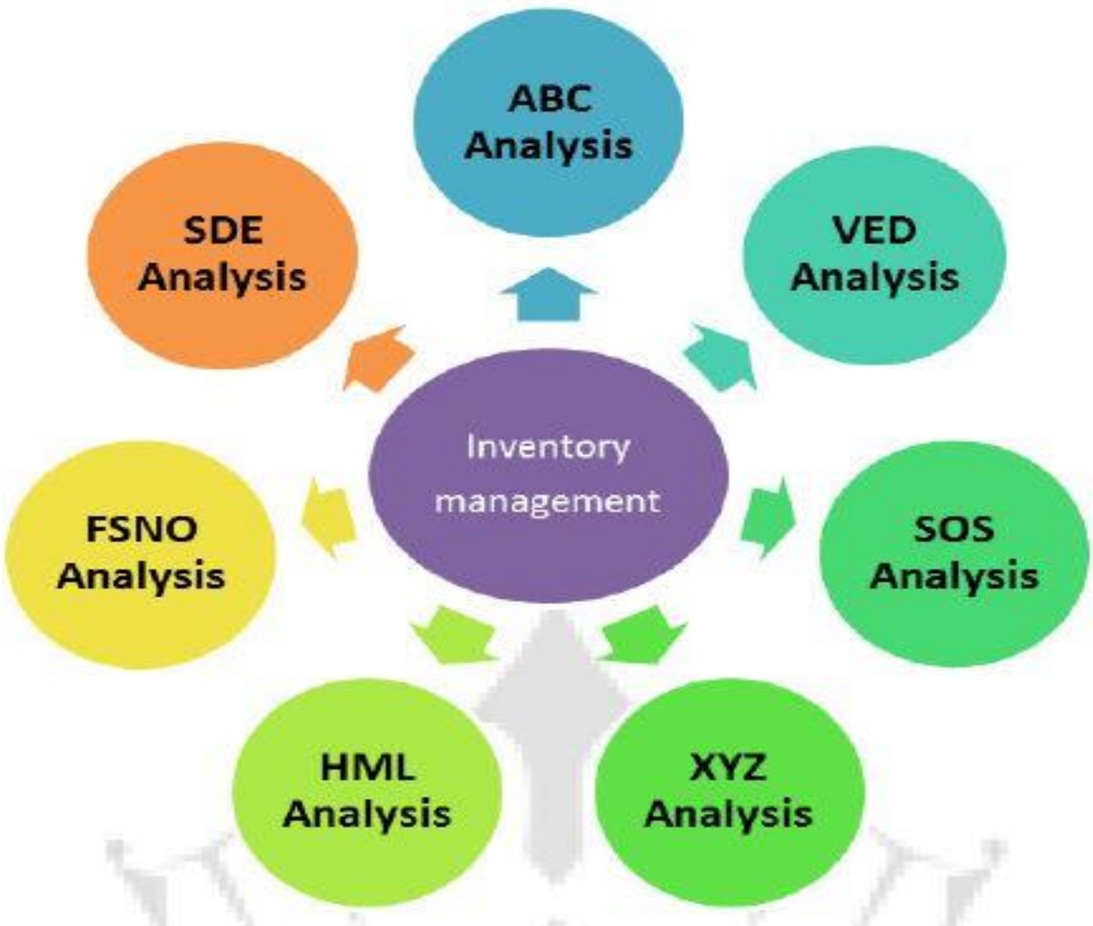
E- Essential,

D- Desirable.

V class item is the item, if not issued, then the production stop shall result, Water, Power, Compressed Air are some the Vital class Items

Essential Class of items- If these items are not available then stock out cost is very high.

Desirable Class of items- If these items are not available then there is not going to be immediate production loss; stock out cost is very less.



FORECASTING

Forecasting helps a company to set inventory targets in order to ensure that their inventory allows them to maximize their operations and output. It also aids companies in optimizing the deployment of their inventory, deal with uncertainties, limitations, and difficulties within their supply chain.

Why Forecasting is needed?

Forecasting has long been associated with processes that impacts on stock. Such process includes production, procurement and sales. Irrespective of the industry type, whether"make to sell" or "buy to sell" elements of forecasting springs up. This is because the driving phenomenon of "demand" is inevitable.

In industry, the producer can't wait for orders to be received before the production process is initiated. In like manner, the buy to sell; entrepreneur can't wait for customers to request for an item before he procures the item. However, these behaviors might be practicable for special order. From the foregoing, it is evident that some level of inventory must exist at any point in time. It can be raw materials for production and/or finished goods. The crux of the matter then becomes, what should be the relative inventory level at a particular point in time. In objectively answering this question, some form of forecasting must be made. Inventory forecasting in my opinion is a proactive and futuristic strategy aimed at providing estimated stock level to meet demand at a particular point in time. Proactiveness can be interpreted as a step taken, prelude to a known event. Forecasting involves estimating what will be needed based on certain assumptions. It can also be viewed as projections of some sort.

A number of factors can determine the turn of demand for a particular product. They include but not limited to price, availability of close substitutes, market trends, season and advertising strategy. My concern in this posting is not to emphasize demand as a concept but the perception of inventory forecasting as a tool that can either make or mar an entrepreneur.

In analyzing the subject matter, it is worthy to briefly mention two important concepts namely over stocking and under stocking. Inventory forecasting can give rise to the duo especially when it is faulty and the consequences can be grave as asserted in a prior posting titled: Increasing Profitability through Inventory and Financial Reports

4.2 Forecasting Techniques

Planning for the future is the essence of any business. Businesses need estimates of future values of business variables. Commodities industry needs forecasts of supply, sales and demand for production planning, sales, marketing and financial decisions. Some businesses need forecasts of monetary variables - costs or price, for example. Financial institutions face the need to forecast volatility in stock prices. There are macro-economic factors that have to be predicted for policy-making decisions in Governments. The list is endless and forecasting is a key-decision-making practice in most organizations.

Managers should always keep themselves abreast of forecasting methods, whether they already have a forecasting package, have built models themselves or plan to invest in one. Most forecasting packages boast of having a variety of models built into them, but then ask the user to choose the model he or she thinks would be most relevant. There are plenty of forecasting models available and choosing the right one is not an easy task.

A common, erroneous perception is that complex forecasting models always give better results than simple ones. Since forecasting play an important role in decision-making, it is crucial to use the best available technique to minimize the forecast inaccuracy. However, there is no unique method, which can always guarantee the best result, as a natural consequence of the increased emphasis placed on the systematic management, the area of forecasting has been studied extensively and the methods of making predictions with objectivity and reliability have been developed. These techniques vary considerably, according to their sophistication and usefulness.

<u>Following are some of the important method of forecasting</u>:

- Time series analysis
- Regression analysis
- Arithmetic average
- Moving average
- Exponential smoothing

The selection of an appropriate method depends on many factors-the context of the forecast, the relevance and availability of historical data, the degree of accuracy desired, the time period for which forecasts are required, the cost of forecast to the company and the time available for making the analysis.

Time Series Analysis

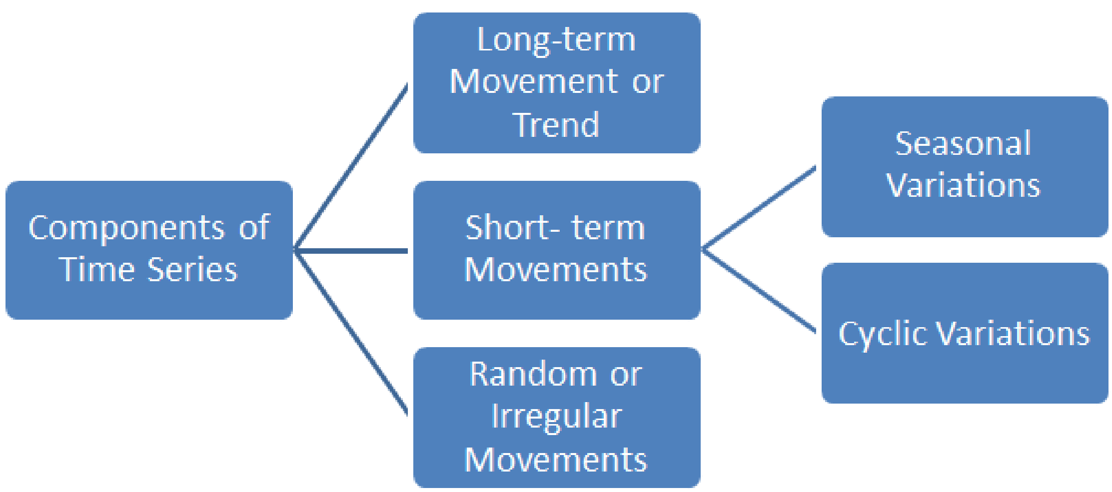
A time series is a set of observations taken at specific time usually at equal intervals: Here the observations are taken in chronological order (in accordance with time).

Examples for time series are:

1. Annual productions of steel in a particular factory over a no. of years from 1990-2004.
2. Daily closing price of shares in stock exchange.
3. The hourly temperature of a city recorded by weather bureau.
4. Total monthly receipts pertaining to sales in a departmental store.

There are 4 components of Time – Series.

- **Secular trend (long-term movements)**
- **Seasonal variation (periodic changes)**
- **Cyclical variation (or short-term evaluations)**
- **Irregular variation (random movement)**

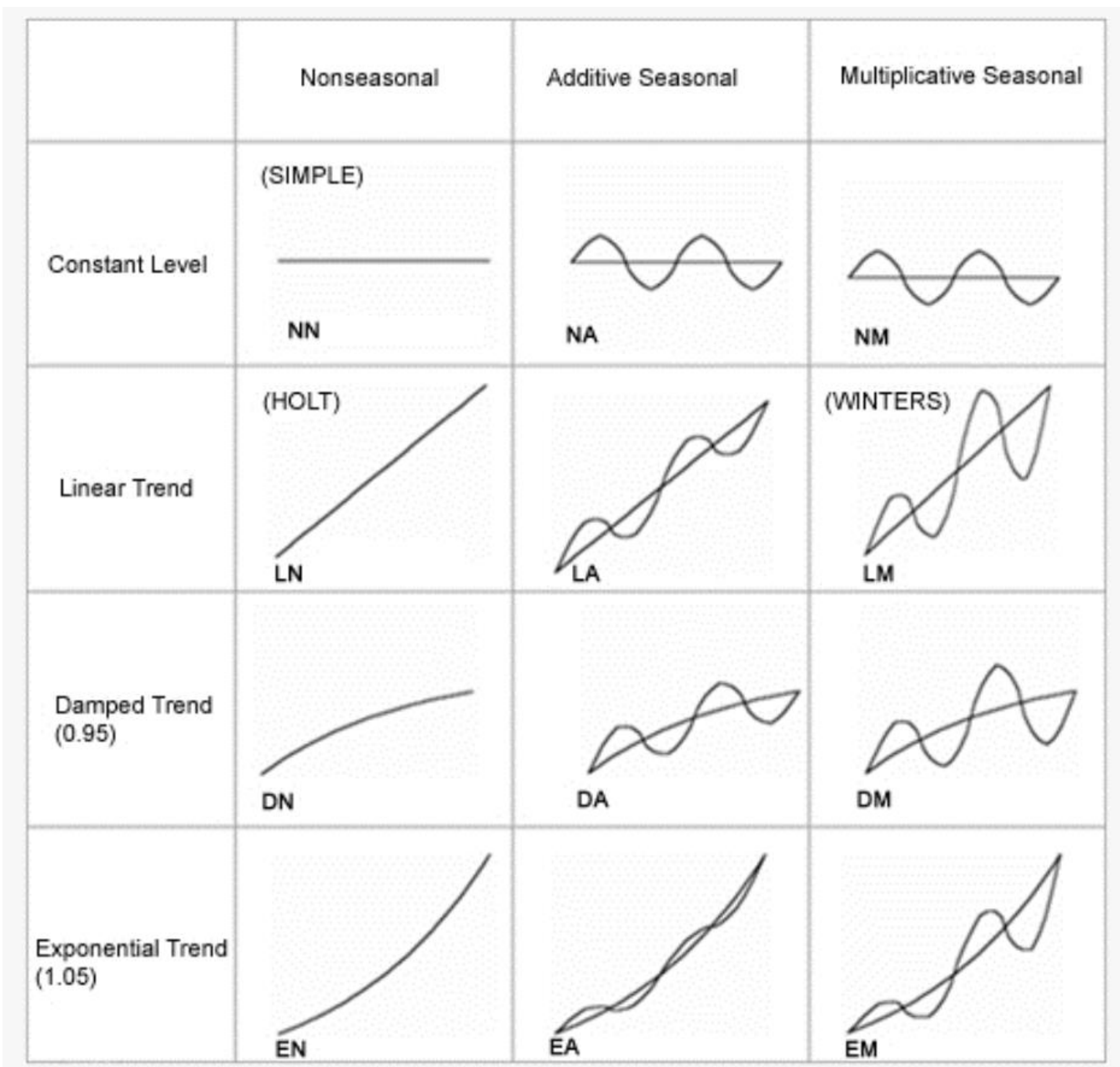


TREND:

The ABS trend is defined as the long term movement in a time series without calendar related and irregular effects, and is a reflection of the underlying level. It is the result of influences such as population growth, price inflation and general economic changes.

Types of Trend

The trend is the consistent behavior of the series to move in a specified direction, towards new highs or towards new lows.



WHAT IS SEASONALITY?

The seasonal component consists of effects that are reasonably stable with respect to timing, direction and magnitude. It arises from systematic, calendar related influences such as:

 Natural Conditions-weather fluctuations that are representative of the season

(Uncharacteristic weather patterns such as snow in summer

Would be considered irregular influences)

 Business and Administrative procedures-start and end of the school term

 Social and Cultural behavior-Christmas.

It also includes calendar related systematic effects that are not stable in their annual timing or are caused by variations in the calendar from year to year, such as:

 Trading Day Effects-the number of occurrences of each of the day of the week in a

given month will differ from year to year

- There were 4 weekends in March in 2000, but 5 weekends in

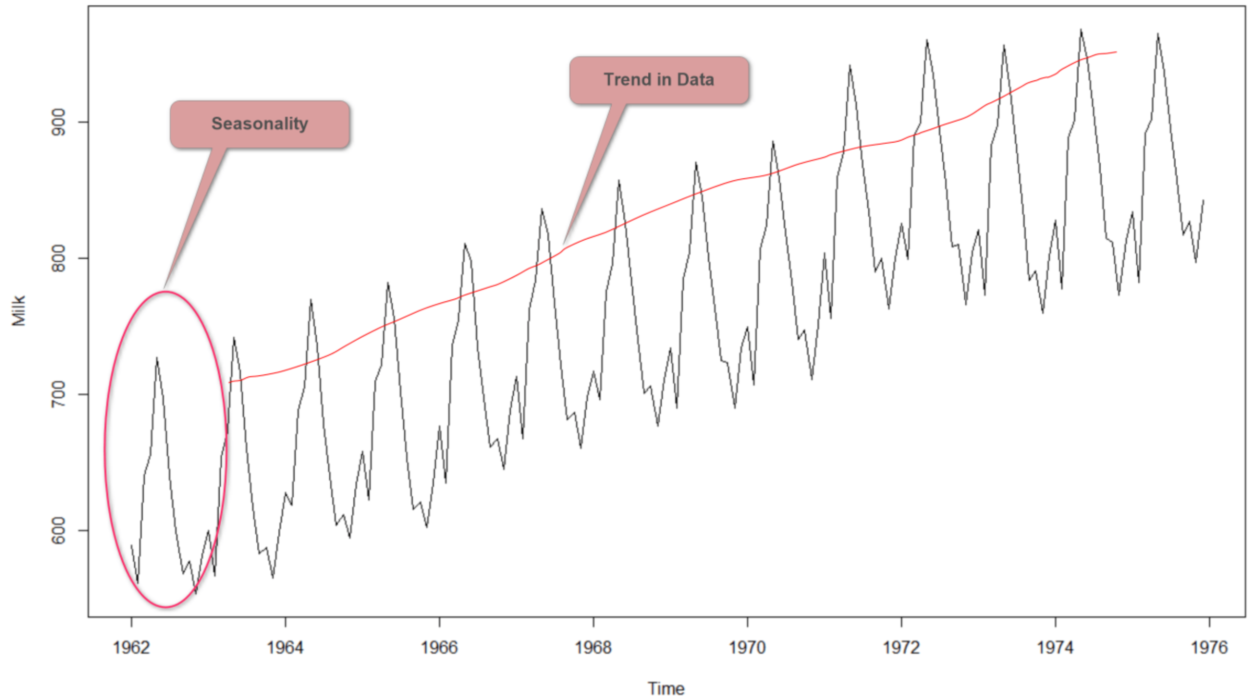
March of 2002

 Moving Holiday Effects- holidays which occur each year, but whose exact timing shifts

- Easter, Chinese New Year

HOW DO WE IDENTIFY SEASONALITY?

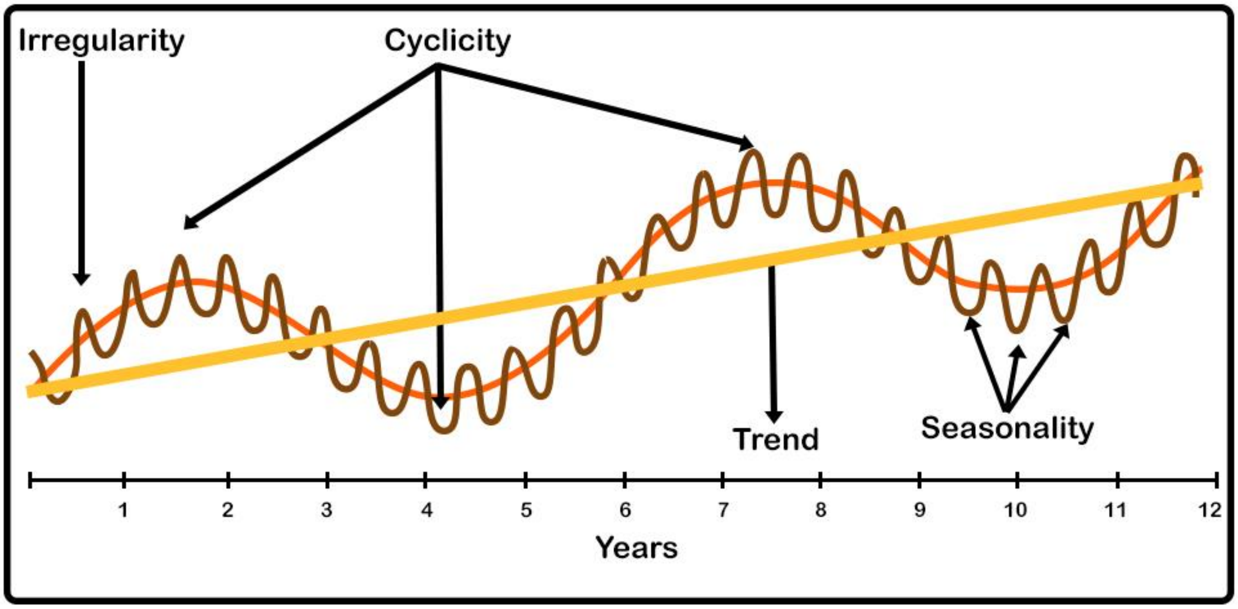
Seasonality in a time series can be identified by regularly spaced peaks and troughs which have a consistent direction and approximately the same magnitude every year, relative to the trend. The following diagram depicts a strongly seasonality as well as trend line is depicted



.

WHAT IS AN IRREGULAR?

The irregular component (sometimes also known as the residual) is what remains after the seasonal and trend components of a time series have been estimated and removed. It results from short term fluctuations in the series which are neither systematic nor predictable. In a highly irregular series, these fluctuations can dominate movements, which will mask the trend and seasonality. The following graph is of a highly irregular time series:



Cyclical Variations (Fluctuation)

The oscillatory in a time series with period of oscillation that last for 7 to 11 years and recurs with no known period. The cyclical are recurrent but not periodic. The cyclical movement in a time series is generally attributed with so-called business cyclic, which may also be referred to four, base cycle composed of prosperity and normally lasts for 7 to11 years. The upswing and downswings in business depends upon the cumulative nature of the economic forces effecting

Measurement of Trend:

I. **Graphical Method**: This method is very subjective.

II. **Method of Curve Fitting**

The following curves can be fitted using Method of Least Squares (MLS)

a) A straight line

$$Y_t = a + bt$$

b) Second-degree parabola

$$Y_t = a + bt + ct^2$$

c) Kth degree parabola

$$Y_t = a_0 + a_1 t + a_2 t^2 + ...a_k t^k$$

d) Exponential curve

$$Y_t = ab^t$$

e) Second degree curve fitted to logarithms

$$Y_t = ab^t c^{t^2}$$

Fitting of these curves are then done as follows

1) **Fitting Straight line** $Y_t = a + bt$

Let curve fit obtained be $\hat{Y}_t = \hat{a} + \hat{b}t$

$$S = \sum_{t=1}^{n} (Y_t - \hat{Y}_t)^2 = \sum (Y_t - \hat{a} - \hat{b}t)^2$$

The normal equation for estimates $\hat{a}$ and $\hat{b}$

$$\frac{\partial S}{\partial \hat{a}} = 0 \Rightarrow \sum_{t=1}^{n} Y_t = n\hat{a} + \hat{b}\sum_{t=1}^{n} t$$

$$\frac{\partial S}{\partial \hat{b}} = 0 \Rightarrow \sum_{t=1}^{n} tY_t = \hat{a}\sum_{t=1}^{n} t + \hat{b}\sum_{t=1}^{n} t^2$$

These equations are then solved for the estimates $\hat{a}$ and $\hat{b}$

2) **Fitting Second Degree Parabola** $Y_t = a + bt + ct^2$

Let the curve fit obtained be $\hat{Y}_t = \hat{a} + \hat{b}t + \hat{c}t^2$

The normal equations for estimation for $\hat{a}$, $\hat{b}$, $\hat{c}$

$$\sum Y_t = n\hat{a} + \hat{b}\sum t + \hat{c}\sum t^2$$

$$\sum tY_t = \hat{a}\sum t + \hat{b}\sum t^2 + \hat{c}\sum t^3$$

$$\sum t^2 Y_t = \hat{a}\sum t^2 + \hat{b}\sum t^3 + \hat{c}\sum t^4$$

3) **Fitting K^{th} degree Parabola** $Y_t = a_0 + a_1 t + a_2 t^2 + \ldots\ldots\ldots\ldots a_k t^k$

We can proceed as in the case of 2^{nd} degree parabola 1^{st} degree parabola above to get (k+1) normal equations after minimizing the sum of squares of errors and obtain the estimates of (k+1) parameters of the fit.

4) **Exponential Curve:** $Y_t = ab^t$

Taking logarithms of both sides, we have

$$\log Y_t = \log a + t \log b$$

or, $U_t = A + Bt$

and now proceed as in (1) to obtain the estimates of A and B which in turn, give us the estimates of ‘a’ & ‘b’.

5) **Second Degree Curve Fitted to the Logarithms** : $Y_t = ab^t c^{t^2}$

Taking logarithms of both sides, we have

$$\log Y_t = \log a + t \log b + t^2 \log c$$

or $U_t = A + Bt + Ct^2$

and now we can proceed as in case 2) to obtain the estimates of A, B, C and hence those of a,b and c.

We can use the principle of least squares only when the Number of Parameters is equal to the Number of Variables. In case of Growth Curves, the number of parameters to be estimated is not equal to the number of variables. So, the method of fitting by least squares fails.

Types of Growth Curves:

1. **Modified Exponential Curve** : $Y = a + bc^t$
2. **Gompertz Curve** : $Y_t = ab^{c^t}$
3. **Logistic Curve :**

1. Fitting a Modified Exponential Curve : $Y = a + bc^t$

a) Method of Partial Sums:

To determine the constant of the curve, the whole range of E covered by the data is divided into 3 equal parts, each including, say, m points of time. Equating the totals of these parts. i.e.

$$S_1 = \sum_{t=1}^{m} Y_t$$

$$\Rightarrow S_1 = am + bc\left\{\frac{1-c^m}{1-c}\right\}............(1)$$

$$S_2 = \sum_{t=m+1}^{2m} Y_t$$

$$S_2 = am + bc^{m+1}\left\{\frac{1-c^m}{1-c}\right\}............(2)$$

$$S_3 = \sum_{t=2m+1}^{3m} Y_t$$

$$S_3 = am + bc^{2m+1}\left\{\frac{1-c^m}{1-c}\right\}............(3)$$

$$\hat{c} = \left(\frac{S_2 - S_3}{S_1 - S_2}\right)^{1/m} ....(6)$$

$$\hat{b} = \frac{(S_1 - S_2)(1-\hat{c})}{\hat{c}\left(1-\hat{c}^m\right)^2}................(7)$$

$$\hat{a} = \frac{1}{m}\left[S_1 - \hat{b}\hat{c}\left\{\frac{1-\hat{c}^m}{1-\hat{c}}\right\}\right]$$

b) <u>Method of three Selected Points</u>

We take three ordinates Y_1, Y_2, Y_3 (say) corresponding to three equidistant values of t (say) t_1, t_2, t_3 respectively such that

$$t_2 - t_1 = t_3 - t_2$$

Substituting the values of t = t_1, t_2, t_3 in $Y_t = a + bc^t$, we have

$$Y_1 = a + bc^{t_1}$$

$$Y_2 = a + bc^{t_2}$$

$$Y_3 = a + bc^{t_3}$$

$$\hat{c} = \left[\frac{Y_2 - Y_3}{Y_1 - Y_2} \right]^{1/(t_2 - t_1)}$$

$$\hat{b} = \frac{Y_1 - Y_2}{\hat{c}^{t_1} \left[1 - \hat{c}^{(t_2 - t_1)} \right]}$$

$$\hat{a} = Y_1 - \hat{b}\hat{c}^{t_1}$$

2. **Fitting a Gompertz Curve**

$$Y_t = ab^{c^t}$$

Taking the logarithms of both sides, we have

$$\Rightarrow \log Y_t = \log a + c^t \log b$$

$$U_t = A + Bc^t$$

which is just the form of modified exponential curve. So, we can proceed as above.

3. Fitting a Logistic Curve

1st Form : $\frac{1}{Y_t} = a + bc^t$

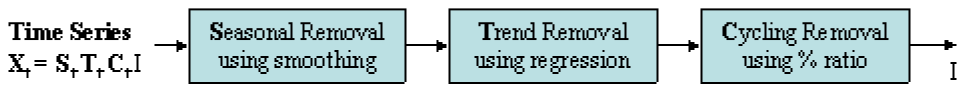
2nd Form : $Y_t = \frac{k}{1+e^{a+bt}}$

Time Series Models

Two models can be regarded as good approximations to the true relationship that exists amongst the four components.

- **Multiplicative Model**

$Y_t = T_t S_t C_t I_t$



The Three Signals Decomposition and Its Reversal Processes For Forecasting

- **Additive Model**

$Y_t = T_t + S_t + C_t + I_t$

<u>How to Choose Between Additive and Multiplicative Decompositions</u>

- The additive model is useful when the seasonal variation is relatively constant over time.
- The multiplicative model is useful when the seasonal variation increases over time.

Measurement of Seasonal Fluctuations

- Method of Simple Averages
- Ratio of Trend Method
- Ratio of Moving Average Method
- Link Relative Method

Method of Simple (Arithmetic) Averages

This is a simple method of isolating seasonal variations. It is based on the assumption that the series contains neither a trend nor cyclical fluctuations, but seasonal & irregular fluctuations.

This method consists of following steps:

- Arrange the data by years and months (or quarters if quarterly data are available)
- Compute the average $\bar{x}_i$ (i = 1,2,3…..12) for the ith month for all the years. This eliminates irregular variations.

- Compute the average $\bar{x}$ of the monthly (quarterly) averages $\bar{x} = \frac{1}{12}\sum_{i=1}^{12}\bar{x}_i$ $\left(\bar{x} = \frac{1}{4}\sum_{i=1}^{4}\bar{x}_i\right)$

- Seasonal indices for different months are obtained by expressing monthly averages as (% age) of $\bar{x}$. Thus, the seasonal index for ith month = $\frac{\bar{x}_i}{\bar{x}} \times 100$
- Total of seasonal indices is $12 \times 100 = 1200$ for monthly data & $4 \times 100 = 400$ for quarterly data.

Interpretation of Seasonal Indices

The index value for each month shows how that month's average value relates to the average annual value. Thus, the index for Jan of 142.26 indicates that on the average Jan value will be 42.26% higher than annual average value.

Similarly, the Feb. seasonal index of 79 indicates that on average the Feb value will be 21% less than annual average value.

Clearly, having such a seasonal index is helpful to the manager for purpose of control, since it tells him what fluctuations to expect simply because of seasonal causes. A study of the seasonal patterns is extremely useful to businessperson, producers, sales managers etc. in planning future operations & in formulation of policy decisions regarding purchase, production inventory control, personal requirements, selling & advertisement programs.

In the absence of any knowledge of seasonal variations, a seasonal upswing may be mistaken as indicator of better business conditions whereas a seasonal slump may be interpreted as deteriorating business conditions. Thus, to understand the behavior of time series properly it has to be adjusted for seasonal variations. This is done by isolating them from trend and other components by dividing the time series values by the seasonal variations when multiplicative model ($Y_t = T_t S_t C_t I_t$) is used and subtracting in case of additive model ($Y_t = T_t + S_t + C_t + I_t$).

Method of Moving Averages

Moving average consists of a series of arithmetic means calculated from overlapping groups of successive elements of a time series. Each moving average is based on values covering a fixed time interval, called 'period of moving average' and is shown against the center of the first. The composition of items is adjusted successively by replacing the first observation of the previously averaged group by the next observation below that group. Thus, the moving average for a period k is a series of successive averages of observations at a time starting with first, 2^{nd}, 3^{rd}, to k terms. Thus, the first average is the mean of the first to k terms, the second is the mean of the k terms from second to (k+1)th terms, the third is the mean of the third to (k+2)th term and so on.

Thus, if the time series values are Y_1, Y_2, Y_3 … for different periods, the moving average of period 'k' are given by

1^{st} value moving average = $(Y_1 + Y_2 + Y_3 + \ldots + Y_k) / k$

2^{nd} value moving average = $(Y_2 + Y_3 + Y_4 + \ldots + Y_{k+1}) / k$

3^{rd} value moving average = $(Y_3 + Y_4 + Y_5 + \ldots\ldots + Y_{k+2}) / k$

and so on. The sums in the numerators are called moving totals of order k.

Case 1. *When period is odd.* If the period 'k' of the moving average is odd, the successive values of the moving averages are placed against the middle value of concerned group of items. For example, if k=5, the first moving average value is placed against the middle period, i.e. third value and the second moving average value is placed against the time period four and so on.

Case 2. *When period is even.* If the period 'm' of M.A. is even then there are two middle periods and the M.A. value is placed in between the two middle terms of the time intervals it covers. Obviously, in this case the M.A. value will not coincide with a period

of the given time series, therefore an attempt is made to synchronize them with the original data by taking a two period averages of the moving averages and placing them in between the corresponding periods. This technique is called centering and the corresponding moving average values are called centered moving averages. In particular if the period k=4, the 1st moving average is placed against the middle of 2nd and 3rd items, the 2nd moving average is placed against the middle of 3rd and 4th items and so on.

Smoothing Techniques:

A time series is a sequence of observations, which are ordered in time. Inherent in the collection of data taken over time is some form of random variation. There exist methods for reducing of canceling the effect due to random variation. A widely used technique is "smoothing". This technique, when properly applied, reveals more clearly the underlying trend, seasonal and cyclic components.

Smoothing techniques are used to reduce irregularities (random fluctuations) in time series data. They provide a clearer view of the true underlying behavior of the series. Moving averages rank among the most popular techniques for the preprocessing of time series. They are used to filter random "white noise" from the data, to make the time series smoother or even to emphasize certain informational components contained in the time series.

Exponential smoothing is a very popular scheme to produce a smoothed time series. Whereas in moving averages the past observations are weighted equally, Exponential Smoothing assigns exponentially decreasing weights as the observation get older. In other words, recent observations are given relatively more weight in forecasting than the older observations. ***Double exponential smoothing is better at handling trends. Triple Exponential Smoothing is better at handling parabola trends.***

ADVANTAGE OF EXPONENTIAL SMOOTHING

Exponential smoothing is a widely method used of forecasting based on the time series itself. Unlike regression models, exponential smoothing does not imposed any deterministic model to fit the series other than what is inherent in the time series itself.

Exponential Smoothing

If the focus of interest is forecasting the future rather than reviewing the historical record, the relevant quantities to be estimated are the most recent trend and seasonal terms. These can then be projected forward to derive predictions of future values of the time series. This estimation problem and its solution is the basis of exponential smoothing, an approach to short-term forecasting that is widely used in industry**.**

There is not a unique forecasting algorithm known as exponential smoothing. Rather exponential smoothing is a general approach to the derivation of forecasting algorithms that has led to the development of several alternative procedures, based to some different assumptions about the characteristics of the time series of interest. The algorithms in popular use are typically justified on grounds of intuitive plausibility and successful practical experience in their application. ***Exponential smoothing is therefore a somewhat ad-hoc approach to the problem of forecasting a time series based on its own past.***

Exponential smoothing algorithm is particularly attractive when forecasts of a ***very large number of time series, are needed on a regular basis.*** Specifically, these procedures were developed for and are currently widely ***used in***, ***routine sales forecasting for inventory control purposes***. Typically, short-term forecasts are required, on a monthly basis, for demand for great many mature product lines. In these circumstances, it may not feasible or, given the costs involved, desirable to devote a great deal of time and effort to the tailoring of specific forecasting procedures to the observed properties of each individual sales series. The extra forecast precision and consequent inventory cost savings may fail or compensate for the additional costs incurred. What may be required instead is an expensive algorithm whose application yields adequate short-term forecasts for at least the great majority of series that need to be predicted. In such circumstances, both case of application and a successful track record render exponential smoothing algorithms particularly attractive.

Simple Exponential Smoothing: It calculates the smoothed series as a damping coefficient times the actual series plus 1 minus the damping coefficient times the lagged value of the smoothed series. The extrapolated smoothed series is a constant, equal to the last value of the smoothed series during the period when actual data on the underlying series are available. While the simple Moving Average method is a special case of the ES, the ES is more parsimonious in its data usage.

$$F_{t+1} = \omega D_t + (1 - \omega) F_t$$

where:

- D_t is the actual value at time t
- F_t is the forecasted value at time t
- ω is the weighting factor, which ranges from 0 to 1
- t is the current time period.

Notice that the smoothed value becomes the forecast for period t + 1.

A small a provides a detectable and visible smoothing. While a large a provides a fast response to the recent changes in the time series but provides a smaller amount of smoothing. Notice that the exponential smoothing and simple moving average techniques will generate forecasts having the same average age of information if moving average of order n is the integer part of (2-a)/a.

An exponential smoothing over an already smoothed time series is called **double-exponential smoothing**. In some cases, it might be necessary to extend it even to a **triple-exponential smoothing**. ***While simple exponential smoothing requires stationary condition, the double-exponential smoothing can capture linear trends, and triple-exponential smoothing can handle almost all other business time series***.

Double Exponential Smoothing: It applies the process described above three to account for linear trend. The extrapolated series has a constant growth rate, equal to the growth of the smoothed series at the end of the data period.

Triple Double Exponential Smoothing: It applies the process described above three to account for nonlinear trend.

Exponentially Weighted Moving Average: Suppose each day's forecast value is based on the previous day's value so that the weight of each observation drops exponentially the further back (k) in time it is. The weight of any individual is

$$a(1 - a)^k, \quad \text{where a is the smoothing constant.}$$

An exponentially weighted moving average with a smoothing constant a, corresponds roughly to a simple moving average of length n, where a and n are related by

$$a = 2/(n+1) \quad \text{OR} \quad n = (2 - a)/a.$$

Thus, for example, an exponentially weighted moving average with a smoothing constant equal to 0.1 would correspond roughly to a 19-day moving average. And a 40-day simple moving average would correspond roughly to an exponentially weighted moving average with a smoothing constant equal to 0.04878.

This approximation is helpful, however, it is harder to update, and may not correspond to an optimal forecast.

Smoothing techniques, such as the Moving Average, Weighted Moving Average, and Exponential Smoothing, are well suited for one-period-ahead forecasting

Holt's Linear Exponential Smoothing Technique: Suppose that the series { y_t } is ***non-seasonal but does display trend***. Now we need to estimate both the current level and the current trend. Here we define the trend T_t at time t as the difference between the current and previous level.

The updating equations express ideas similar to those for exponential smoothing. The equations are:

$$L_t = a\, y_t + (1 - a)\, F_t$$

for the level and

$$T_t = b\, (L_t - L_{t-1}) + (1 - b)\, T_{t-1}$$

for the trend. We have two smoothing parameters a and b; both must be positive and less than one. Then the forecasting for k periods into the future is:

$$F_{n+k} = L_n + k.\ T_n$$

Given that the level and trend remain unchanged, the initial (starting) values are

$$T_2 = y_2 - y_1, \qquad L_2 = y_2, \quad \text{and} \quad F_3 = L_2 + T_2$$

The Holt-Winters' Forecasting Technique*: Now in addition to Holt parameters, suppose that the series exhibits multiplicative seasonality* and let St be the multiplicative seasonal factor at time t. Suppose also that there are s periods in a year, so s=4 for quarterly data and s=12 for monthly data. St-s is the seasonal factor in the same period last year.

In some time series, seasonal variation is so strong it obscures any trends or cycles, which are very important for the understanding of the process being observed. ***Winters' smoothing method can remove seasonality and makes long term fluctuations in the series stand out more clearly***. A simple way of detecting trend in seasonal data is to take averages over a certain period. If these averages change with time we can say that there is evidence of a trend in the series. The updating equations are:

$$L_t = a\ (L_{t-1} + T_{t-1}) + (1 - a)\ y_t / S_{t-s}$$

for the level,

$$T_t = b\ (\ L_t - L_{t-1}\ ) + (1 - b)\ T_{t-1}$$

for the trend, and

$$S_t = g\ S_{t-s} + (1- g)\ y_t / L_t$$

for the seasonal factor.

We now have three smoothing parameters a , b, and g all must be positive and less than one.

To obtain starting values, one may use the first a few year data. For example for quarterly data, to estimate the level, one may use a centered 4-point moving average:

$$L_{10} = (y_8 + 2y_9 + 2y_{10} + 2y_{11} + y_{12}) / 8$$

as the level estimate in period 10. This will extract the seasonal component from a series with 4 measurements over each year.

$$T_{10} = L_{10} - L_9$$

as the trend estimate for period 10.

$$S_7 = (y_7 / L_7 + y_3 / L_3) / 2$$

as the seasonal factor in period 7. Similarly,

$$S_8 = (y_8 / L_8 + y_4 / L_4) / 2,$$

$$S_9 = (y_9 / L_9 + y_5 / L_5) / 2,$$

$$S_{10} = (y_{10} / L_{10} + y_6 / L_6) / 2$$

For Monthly Data, the correspondingly we use a centered 12-point moving average:

$$L_{30} = (y_{24} + 2y_{25} + 2y_{26} +.....+ 2y_{35} + y_{36}) / 24$$

as the level estimate in period 30.

$$T_{30} = L_{30} - L_{29}$$

as the trend estimate for period 30.

$$S_{19} = (y_{19} / L_{19} + y_7 / L_7) / 2$$

as the estimate of the seasonal factor in period 19, and so on, up to 30:

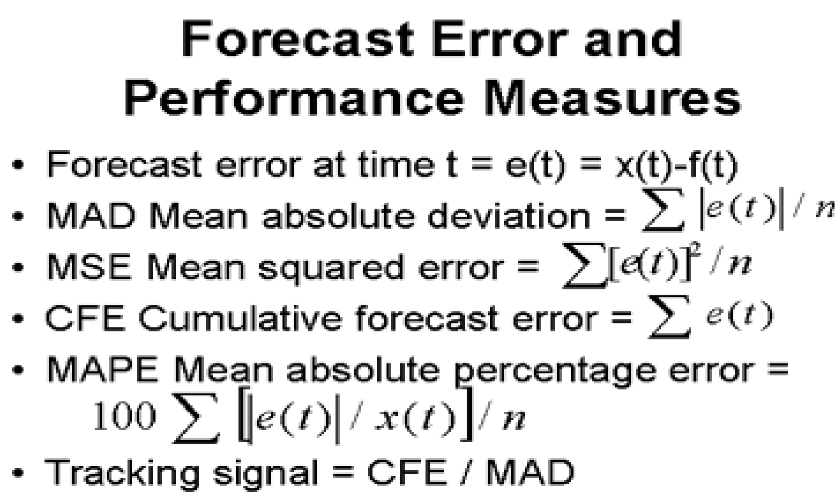
$$S_{30} = (y_{30} / L_{30} + y_{18} / L_{18}) / 2$$

Then the forecasting k periods into the future is:

$$F_{n+k} = (L_n + k.\ T_n)\ S_{t+k-s}, \quad \text{for } k = 1, 2, ...,s$$

Forecasting Errors

Performance Measures and Control Chart for Examine Forecasting Errors: Beside the Standard Error there are other performance measures. The following are some of the widely used performance measures:



Mean error: The mean error (ME) value is simply computed as the average error value (average of observed minus one-step-ahead forecast). Obviously, a drawback of this measure is that positive and negative error values can cancel each other out, so this measure is not a very good indicator of overall fit.

Mean absolute error: The mean absolute error (MAE) value is computed as the average *absolute* error value. If this value is 0 (zero), the fit (forecast) is perfect. As compared to the mean *squared* error value, this measure of fit will "de-emphasize" outliers, that is, unique or rare large error values will affect the MAE less than the MSE value.

Sum of squared error (SSE), Mean squared error. These values are computed as the sum (or average) of the squared error values. This is the most commonly used lack-of-fit indicator in statistical fitting procedures.

Percentage error (PE). All the above measures rely on the actual error value. It may seem reasonable to rather express the lack of fit in terms of the *relative* deviation of the one-step-ahead forecasts from the observed values, that is, relative to the magnitude of the observed values. For example, when trying to predict monthly sales that may fluctuate widely (e.g., seasonally) from month to month, we may be satisfied if our prediction "hits the target" with about ±10% accuracy. In other words, the absolute errors may be not so much of interest as are the relative errors in the forecasts. To assess the relative error, various indices have been proposed. The first one, the percentage error value, is computed as:

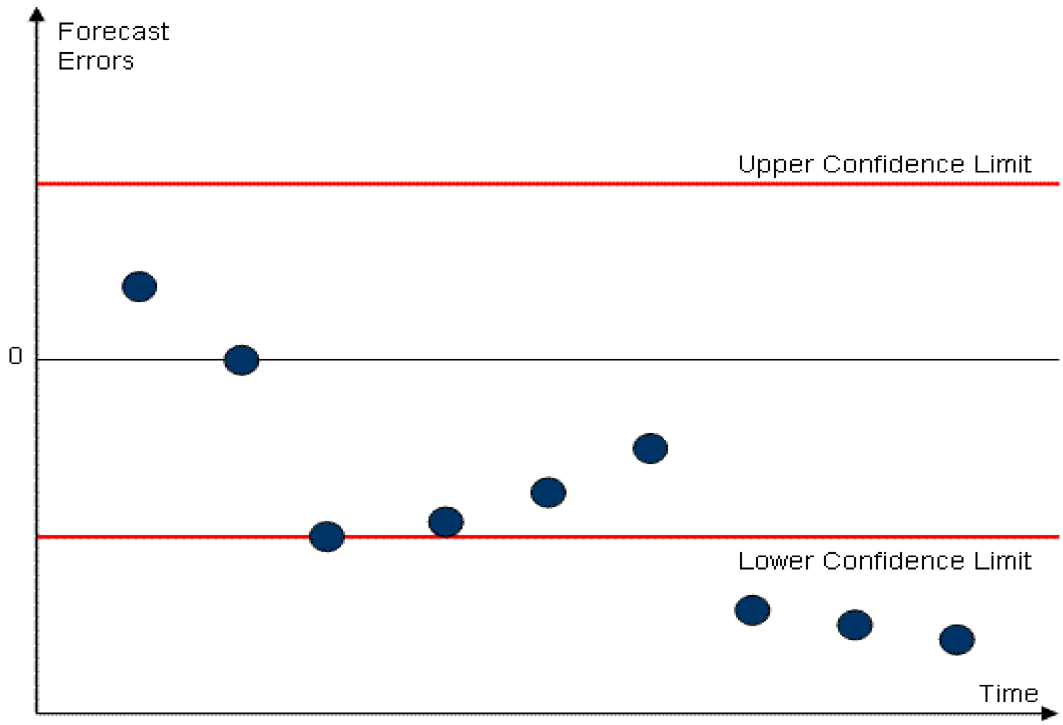
$$PE_t = 100*(X_t - F_t)/X_t$$

Where X_t is the observed value at time t, and F_t is the forecasts (smoothed values).

Mean percentage error (MPE). This value is computed as the average of the PE values.

Mean absolute percentage error (MAPE). As is the case with the mean error value (ME, see above), a mean percentage error near 0 (zero) can be produced by large positive and negative percentage errors that cancel each other out. Thus, a better measure of relative overall fit is the mean *absolute* percentage error. In addition, this measure is usually more meaningful than the mean squared error. For example, knowing that the average forecast is "off" by ±5% is a useful result in and of itself, whereas a mean squared error of 30.8 is not immediately interpretable.

Modeling for Forecasting with Accuracy: Control limits could be one-standard-error, or two-standard-error, and any point beyond these limits (i.e., outside of the error control limit) is an indication the need to revise the forecasting process, as shown below:



A Control Chart for Examining Periodic Forecasting Errors

Time-Critical Decision Modeling and Analysis

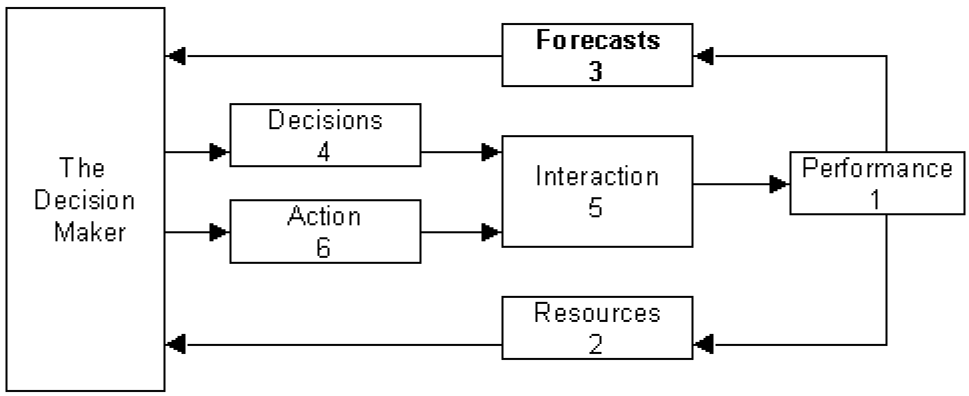
The ability to model and perform decision modeling and analysis is an essential feature of many real-world applications ranging from emergency medical treatment in intensive care units to military command and control systems. Existing formalisms and methods of inference have not

been effective in real-time applications where tradeoffs between decision quality and computational tractability are essential. In practice, an effective approach to time-critical dynamic decision modeling should provide explicit support for the modeling of temporal processes and for dealing with time-critical situations.

One of the most essential elements of being a high-performing manager is the ability to lead effectively one's own life, then to model those leadership skills for employees in the organization.

Almost all managerial decisions are based on forecasts. Every decision becomes operational at some point in the future, so it should be based on forecasts of future conditions.

Forecasts are needed throughout an organization -- and an isolated group of forecasters should certainly not produce them. Neither is forecasting ever "finished". Forecasts are needed continually, and as time moves on, the impact of the forecasts on actual performance is measured; original forecasts are updated; and decisions are modified, and so on. This process is shown in the following figure:



Forecasting Within an Organization:
Forecasting and Managerial Decision Making

The decision-maker uses forecasting models to assist him or her in decision-making process. The decision-making often uses the modeling process to investigate the impact of different courses of action **retrospectively**; that is, "as if" the decision has already been made under a course of action. That is why the sequence of steps in the modeling process, in the above figure must be considered in reverse order.

PROCUREMENT

Acquiring goods and/or services from an outside source

Why Procurement Is Needed?

Manufacturers often rely on different types of long term contracts with established suppliers to procure goods often involving delivery lead times. Commodity markets as well as online markets provide additional procurement flexibility; manufacturers can procure through their conventional channels or interact directly with the market either through spot or forward transactions.

In this project we explore the value of incorporating information about spot and futures

market prices in procurement decision making. We also model transaction costs associated with procurement from spot and forward markets. Due to shorter response times, transaction costs associated with spot market procurement (including freight) are typically higher. We develop optimal and approximate procurement policies for this problem, and our results suggest that it is possible to significantly reduce inventory related costs by incorporating spot and futures price information in the procurement decision making process. Our results also imply that, apart from risk reduction, the potential savings in transaction costs associated with forward procurement entice manufacturers to procure a relatively higher fraction of goods from forward markets, using spot procurement only to fine tune stocking levels and recover from emergencies.

(Dual procurement, marginal convenience yield, forward contracts, commodity markets, stochastic inventory)

Procurement Model.

Procurement and inventory management models in the operations management and supply chain management literature usually assume constant or known procurement prices while modeling in detail transaction costs, storage costs and costs associated with fulfilling a stochastic demand. In this research, we explore how exogenously determined random shocks in procurement costs affect operating decisions of a firm. In particular, we explore in detail the procurement process of commodities whose prices are subject to random shocks due to demand and supply fluctuations. Commodity prices exhibit volatility and substantial cyclical behavior that exacerbates the complexity of procurement for the commodity users. In this paper, we develop optimal and approximate procurement policies of a commodity under stochastic prices and random demand.

Inventory control is the activity, which organizes the availability. It coordinates the purchasing, manufacturing and distribution functions to meet marketing needs. This role includes the supply of current sales items, new products, consumables, spare parts and all other supplies.

Procurement/Production Model

Procurement/production planning is the process of identifying and consolidating requirements and determining the timeframes for their procurement with the aim of having them as and when they are required.

A good procurement/production plan will describe the process in the identification and selection of suppliers/contractors/consultants. Procurement and inventory management models in the operations management and supply chain management literature ***usually assume constant or known procurement prices*** while modeling in detail transaction costs, storage costs and costs associated with fulfilling a stochastic demand. Here, we explore how exogenously determined random shocks in procurement costs affect operating decisions of a firm. In particular, ***we explore in detail the procurement process of commodities whose prices are subject to random shocks due to demand and supply fluctuations.***

In this study, we are suggesting the procurement/production policy for management of raw material inventory for the manufacturing of shoes and sandals using Wagner-Whitin Model

(Dynamic Lot Size Model).

The basic assumptions of our model are:

1. Demand is **different** in each period.
2. Procurement/Production is **done at the beginning of period**.
3. Demand is met **uniformly throughout the period**.
4. Shortages are **not** allowed.

NOTATION:

Cn: Total cost up to and including the nth period

r_i : Requirement of the i^{th} period

A: Ordering Cost

IC: Inventory Carrying Cost

C: Cost per unit

OBJECTIVE: To determine procurement plan of raw material that satisfies all demand at minimal total cost.

The total cost up to and including n th period when last procurement/production is done at the beginning of j th period is given by -

C n (j) = C j-1 + A + C (r j + r j-1 +……..+ r n) + (I*C) (r j /2 + r j+1 +……+ r n) + (I*C) (r j+1 /2 + r j+2

+……..+ r n) +……….+ (I*C) (r n /2)

Thus we have,

Min C n (j) = Min { C j-1 + A + C (r j +……..+ r n) + (I*C /2) [r j +3 r j+1 +…… ..+ {2(n-j) +1}r n]

<u>Let Us Consider it as a first period problem</u>

C1(1) = C0+A+c(r1)+Ic((r1)/2)

Where C0=0

<u>Let Us Consider it as a Second period problem</u>

C2(1) = C0+A+c(r1+r2)+Ic/2((r1)+3r2)

C2(2) = C1+A+c(r2)+Ic/2(r2)

C2 = min{ C2(1), C2(2) }

<u>Let Us Consider it as a Third period problem</u>

C3(1) = C0+A+c(r1+r2+r3)+Ic/2((r1+3*r2+5r3*)

$$C3(2) = C1+A+c(r2+r3)+Ic/2(r2+3*r3)$$

$$C3(3) = C2+A+c(r3)+Ic((r3)/2)$$

$$C3=\min\{ C3(1),C3(2),C3(3) \}$$

Let Us Consider it as a Fourth period problem

$$C4(1) = C0+A+c(r1+r2+r3+r4)+Ic/2(r1+3*r2+5*r3*+7*r4)$$

$$C4(2) = C1+A+c(r2+r3+r4)+Ic/2(r2+3*r3+5*r4)$$

$$C4(3) = C2+A+c(r3+r4)+Ic/2(r3+3*r4)$$

$$C4(4) = C3+A+c(r4)+Ic/2(r4)$$

$$C4=\min\{ C4(1),C4(2),C4(3),C4(4) \}$$

Let Us Consider it as a Fifth period problem

$$C5(1) = C0+A+c(r1+r2+r3+r4+r5)+Ic/2(r1+3*r2+5*r3+7*r4+9*r5)$$

$$C5(2) = C1+A+c(r2+r3+r4+r5)+Ic/2(r2+3*r3+5*r4+7*r5)$$

C5(3) = C2+A+c(r3+r4+r5)+Ic/2(r3+3*r4+5*r5)

C5(4) = C3+A+c(r4+r5)+Ic/2(r4+3*r5)

C5(5) = C4+A+c(r5)+Ic/2(r5)

C5=min{ C5(1),C5(2),C5(3),C5(4),C5(5) }

Let Us Consider it as a Six period problem

C6(1) = C0+A+c(r1+r2+r3+r4+r5+r6)+Ic/2((r1+3*r2+5r*3+7*r4+9*r5+11*r6)

C6(2) = C1+A+c(r2+r3+r4+r5+r6)+Ic/2(r2+3*r3+5*r4+7*r5+9*r6)

C6(3) = C2+A+c(r3+r4+r5+r6)+Ic/2(r3+3*r4+5*r5+7*r6)

C6(4) = C3+A+c(r4+r5+r6)+Ic/2(r4+3*r5+5*r6)

C6(5) = C4+A+c(r5+r6)+Ic/2(r5+3*r6)

C6(6) = C5+A+c(r6)+Ic/2(r6)

C6=min{ C6(1),C6(2),C6(3),C6(4),C6(5),C6(6) }

Let Us Consider it as a Seventh period problem

C7(1)=C0+A+c(r1+r2+r3+r4+r5+r6+r7)+Ic/2(r1+3*r2+5*r3+7*r4+9*r5+11*r6+13* r7)

C7(2)   =   C1+A+c(r2+r3+r4+r5+r6+r7)+Ic/2(r2+3*r3+5*r4+7*r5+9*r6+11*r7)

C7(3) =   C2+A+c(r3+r4+r5+r6+r7)+Ic((r3+3*r4+5*r5+7*r6+9*r7)

C7(4) =   C3+A+c(r4+r5+r6+r7)+Ic(r4+3*r5+5*r6+7*r7)

C7(5) =   C4+A+c(r5+r6+r7)+Ic/2(r5+3*r6+5*r7)

C7(6) =   C5+A+c(r6+r7)+Ic/2(r6+3*r7)

C7(7) =   C6+A+c(r7)+Ic/2(r7)

C7= min{ C7(1),C7(2),C7(3),C7(4),C7(5),C7(6),C7(7) }

Let Us Consider it as a Eighth period problem

C8(1)=C0+A+c(r1+r2+r3+r4+r5+r6+r7+r8)+Ic/2(r1+3*r2+5*r3+7*r4+9*r5+11*r6 +13*r7+15*r8)

C8(2)=C1+A+c(r2+r3+r4+r5+r6+r7+r8)+Ic/2(r2+3*r3+5*r4+7*r5+9*r6+11*r7+13*r8)

C8(3) =   C2+A+c(r3+r4+r5+r6+r7+r8)+Ic/2(r3+3*r4+5*r5+7*r6+9*r7+11*r8)

C8(4) = C3+A+c(r4+r5+r6+r7+r8)+Ic/2(r4+3*r5+5*r6+7*r7+9*r8)

C8(5) = C4+A+c(r5+r6+r7+r8)+Ic/2(r5+3*r6+5*r7+7*r8)

C8(6) = C5+A+c(r6+r7+r8)+Ic/2(r6+3*r7+5*r8)

C8(7) = C6+A+c(r7+r8)+Ic/2(r7+3*r8)

C8(8) = C7+A+c(r8)+Ic/2(r8)

C8= min{ C8(1),C8(2),C8(3),C8(4),C8(5),C8(6),C8(7),C8(8) }

Let Us Consider it as a Ninth period problem

C9(1)=C0+A+c(r1+r2+r3+r4+r5+r6+r7+r8+r9)+Ic/2(r1+3*r2+5*r3+7*r4+9*r5+11*r6+13*r7+15*r8 +17*r9)

C9(2)=C1+A+c(r2+r3+r4+r5+r6+r7+r8+r9)+Ic/2(r2+3*r3+5*r4+7*r5+9*r6+11*r7+13*r8+15*r9)

C9(3)=C2+A+c(r3+r4+r5+r6+r7+r8+r9)+Ic/2(r3+3*r4+5*r5+7*r6+9*r7+11*r8+13*r9)

C9(4) = C3+A+c(r4+r5+r6+r7+r8+r9)+Ic/2(r4+3*r5+5*r6+7*r7+9*r8+11*r9)

C9(5) = C4+A+c(r5+r6+r7+r8+r9)+Ic/2(r5+3*r6+5*r7+7*r8+9*r9)

C9(6) = C5+A+c(r6+r7+r8+r9)+Ic/2(r6+3*r7+5*r8+7*r9)

C9(7) = C6+A+c(r7+r8+r9)+Ic/2(r7+3*r8+5*r9)

C9(8) = C7+A+c(r8+r9)+Ic/2(r8+3*r9)

C9(9) = C8+A+c(r9)+Ic(r9/2)

C9= min{ C9(1),C9(2),C9(3),C9(4),C9(5),C9(6),C9(7),C9(8),C9(9) }

Let Us Consider it as a Tenth period problem

C10(1)=C0+A+Ic/2(r1+3*r2+5*r3+7*r4+9*r5+11*r6+13*r7+15*r8+17*r9+19*r10)+c(r1+r2+r3+r4+r5+r6+r7+r8+r9+r10)

C10(2)=C1+A+c(r2+r3+r4+r5+r6+r7+r8+r9+r10)+Ic((r2+3*r3+5*r4+7*r5+9*r6+11*r7+13*r8+15*r9+17*r10)

C10(3)=C2+A+c(r3+r4+r5+r6+r7+r8+r9+r10)+Ic/2((r3+3*r4+5*r5+7*r6+9*r7+11*r8+13*r9+15*r10)

C10(4)=C3+A+c(r4+r5+r6+r7+r8+r9+r10)+Ic/2(r4+3*r5+5*r6+7*r7+9*r8+11*r9+13*r10)

C10(5)=C4+A+c(r5+r6+r7+r8+r9+r10)+Ic/2(r5+3*r6+5*r7+7*r8+9*r9+11*r10)

C10(6) = C5+A+c(r6+r7+r8+r9+r10)+Ic/2(r6+3*r7+5*r8+7*r9+9*r10)

C10(7) = C6+A+c(r7+r8+r9+r10)+Ic/2(r7+3*r8+5*r9+7*r10)

$C10(8) = C7+A+c(r8+r9+r10)+Ic/2(r8+3*r9+5*r10)$

$C10(9) = C8+A+c(r9+r10)+Ic/2(r9+3*r10)$

$C10(10) = C9+A+c(r10)+Ic(r10/2)$

$C10= \min\{ C10(1),C10(2),C10(3),C10(4),C10(5),C10(6),C10(7),C10(8),C10(9),C10(10) \}$

Let Us Consider it as a Eleventh period problem

$C11(1)=C0+A+c(r1+r2+r3+r4+r5+r6+r7+r8+r9+r10+r11)+Ic/2(r1+3*r2+5*r3+7*r4+9*r5+11*r6+13*r7+15*r8+17*r9+19*r10+21*r11)$

$C11(2)=C1+A+c(r2+r3+r4+r5+r6+r7+r8+r9+r10+r11)+Ic/2(r2+3*r3+5*r4+7*r5+9*r6+11*r7+13*r8+15*r9+17*r10+19*r11)$

$C11(3)=C2+A+c(r3+r4+r5+r6+r7+r8+r9+r10+r11)+Ic/2(r3+3*r4+5*r5+7*r6+9*r7+11*r8+13*r9+15*r10+17*r11)$

$C11(4)=C3+A+c(r4+r5+r6+r7+r8+r9+r10+r11)+Ic/2(r4+3*r5+5*r6+7*r7+9*r8+11*r9+13*r10+15*r11)$

$C11(5)=C4+A+c(r5+r6+r7+r8+r9+r10+r11)+Ic/2(r5+3*r6+5*r7+7*r8+9*r9+11*r10+13*r11)$

$C11(6)=C5+A+c(r6+r7+r8+r9+r10+r11)+Ic/2(r6+3*r7+5*r8+7*r9+9*r10+11*r11)$

$C11(7) = C6+A+c(r7+r8+r9+r10+r11)+Ic/2(r7+3*r8+5*r9+7*r10+9*r11)$

C11(8) = C7+A+c(r8+r9+r10+r11)+Ic/2(r8+3*r9+5*r10+7*r11)

C11(9) = C8+A+c(r9+r10+r11)+Ic/2(r9+3*r10+5*r11)

C11(10) = C9+A+c(r10+r11)+Ic(r10+3*r11)

C11(11) = C10+A+c(r11)+Ic(r11/2)

C11= min{C11(1),C11(2),C11(3),C11(4),C11(5),C11(6),C11(7),C11(8),C11(9),C11(10),c11(11)}

Let Us Consider it as a Twelth period problem

C12(1)=C0+A+c(r1+r2+r3+r4+r5+r6+r7+r8+r9+r10+r11+r12)+Ic/2(r1+3*r2+5*r3+7*r4+9*r5+11*r6+13*r7+15*r8+17*r9+19*r10+21*r11+23*r12)

C12(2)=C1+A+c(r2+r3+r4+r5+r6+r7+r8+r9+r10+r11+r12)+Ic/2(r2+3*r3+5*r4+7*r5+9*r6+11*r7+13*r8+15*r9+17*r10+19*r11+21*r12)

C12(3)=C2+A+c(r3+r4+r5+r6+r7+r8+r9+r10+r11+r12)+Ic/2(r3+3*r4+5*r5+7*r6+9*r7+11*r8+13*r9+15*r10+17*r11+19*r12)

C12(4)=C3+A+c(r4+r5+r6+r7+r8+r9+r10+r11+r12)+Ic/2(r4+3*r5+5*r6+7*r7+9*r8+11*r9+13*r10+15*r11+17*r12)

C12(5)=C4+A+c(r5+r6+r7+r8+r9+r10+r11+r12)+Ic/2(r5+3*r6+5*r7+7*r8+9*r9+11*r10+13*r11+15*r12)

C12(6)=C5+A+c(r6+r7+r8+r9+r10+r11+r12)+Ic/2(r6+3*r7+5*r8+7*r9+9*r10+11*r11+13*r12)

C12(7)=C6+A+c(r7+r8+r9+r10+r11+r12)+Ic/2(r7+3*r8+5*r9+7*r10+9*r11+11*r12)

C12(8) = C7+A+c(r8+r9+r10+r11+r12)+Ic/2(r8+3*r9+5*r10+7*r11+9*r12)

C12(9) = C8+A+c(r9+r10+r11+r12)+Ic/2(r9+3*r10+5*r11+7*r12)

C12(10) = C9+A+c(r10+r11+r12)+Ic/2(r10+3*r11+5*r12)

C12(11) = C10+A+c(r11+r12)+Ic/2(r11+3*r12)

C12(12) = C11+A+c(r12)+Ic(r12/2)

C12=min{
C12(1),C12(2),C12(3),C12(4),C12(5),C12(6),C12(7),C12(8),C12(9),C12(10),C12(11)
,C12(12) }

Methodology

AIM & OBJECTIVE:

To forecast the demand and to determine optimal procurement plan for the raw material for the company

PROCEDURE

Step 1: To Perform ABC analysis of raw material for producing firm. Items last 12 months and classify them, In A(Always), B (Better) and C (Control) categories based on their annual usage value.

↓

Step 2: To carry out forecasting by taking their last three years monthly consumption as base, for some items belonging to categories of ABC analysis

↓

Step 3: Apply the optimal procurement policy for forecasted demands.

↓

Step 4: Results and recommendations.

STEP-BY-STEP PROCECURE USED FOR SOLVING THE PROBLEM

1. Perform ABC analysis and for the A and B category items:-

2. First of all we collect data (minimum 3 years in present case since its monthly data)

3. Plot the data to study the behavior.

4. Study the plots if it is seasonal or non-seasonal.

5. Apply the appropriate forecasting method for various months of the next year.

6. If the methods we are using do not give good forecasts, we calculate the error and apply a different method until the good forecast is obtained.

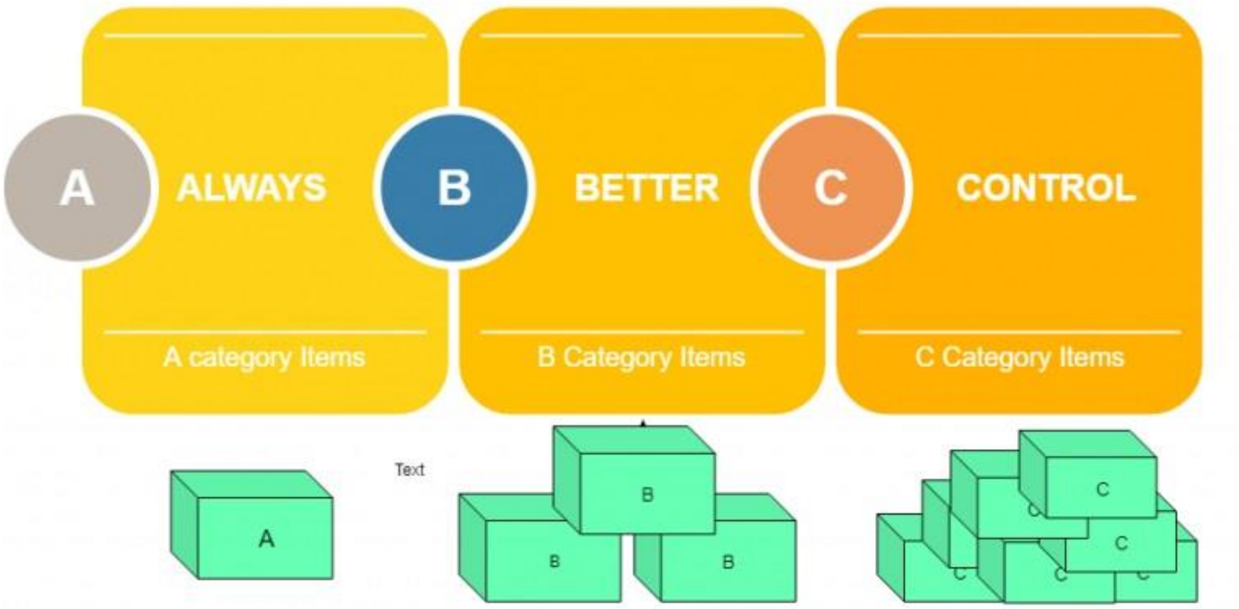
7. Here we have used Proportionate Method to forecast the demand.

8. Collect data for inventory carrying cost per annum (collect its components if possible) and ordering cost per order (if possible components also).

9. Fit the appropriate Procurement Plan.

10. looking into the result carefully conclude and recommend plan for the procurement of items

ABC ANALYSIS



Step for ABC – Analysis

The following are the steps of classification of items into A, B and C categories.

Step 1: Determine the no. of unit sold or used in the past one year.

Step 2: Determine the unit cost of each item.

Step 3: Compute the annual usage value (in Rs.) of each item constituted by multiplying the annual consumption (of units) by its unit piece.

Annual usage value = annual requirement x cost of one unit

Step 4: Arrange the items in descending order according to their respective usage value computed in Step 3.

Step 5: Prepare a table showing unit cost, annual consumption and annual usage value for each item.

Step 6: Calculate the cumulative sum of the no. of items and the usage value for each item obtained in Step 3.

Step 7: Find the percentage of the value obtained in step 6 with respect to grand total of the corresponding columns.

Step 8: Draw a graph by taking cumulative % age of items on x-axis and cumulative % age of annual consumption on y-axis. After plotting various points on the graph, we draw smooth curve.

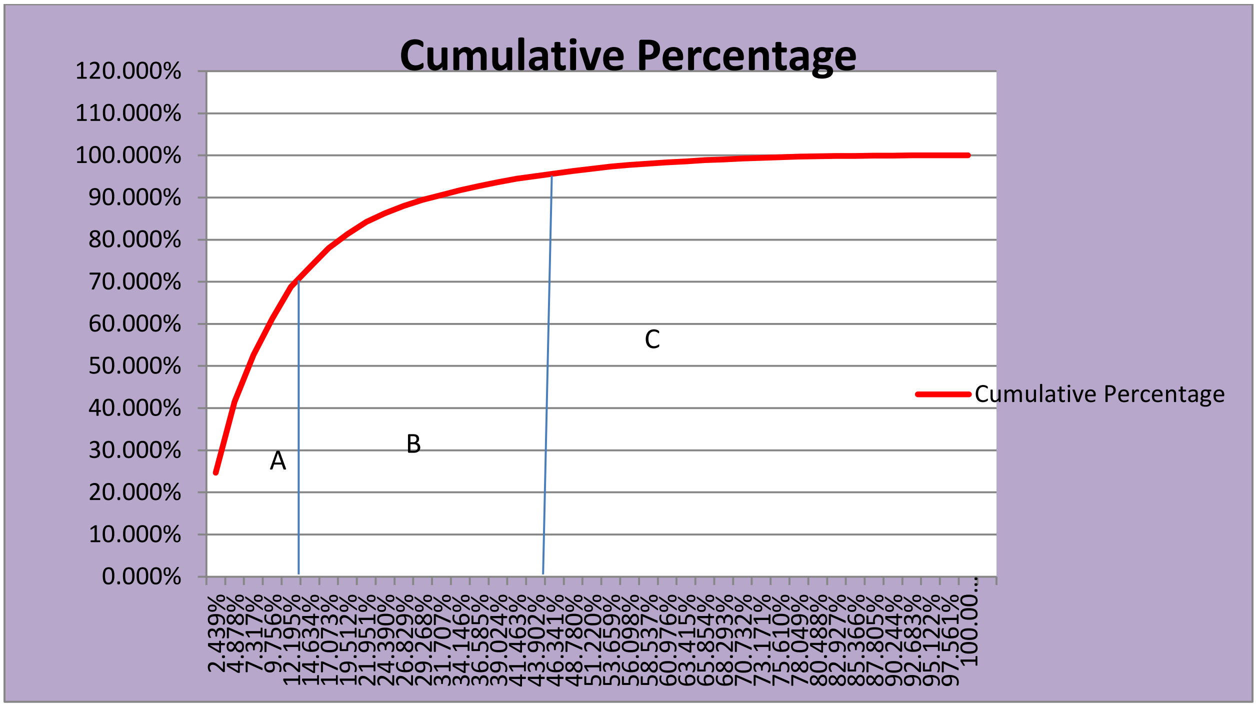
Step 9: Mark the points x and y where the slop of the curve changes sharply. Such points are called points of inflexion.

Step 10: finally, the usage value and the % of items corresponding to these points determine the classification of items as A, B or C.

Item name	**Quantity (in Kgs)**	**Effective Rate(in Rs/kg)**	**Value(in Rs)**	**Rank**	**Percentage**	**Cumulative Percentage**	**Item Usage**	**Class**
FLAT CR SHEET	268366.56	55.713	12713865.780	1	24.669%	24.669%	2.439%	A
316L HOT ROLLED SHEET	203825.44	50.232	8706258.080	2	16.893%	41.562%	4.878%	A
B Q PLATES	129662.4	51.7125	5701672.500	3	11.063%	52.626%	7.317%	A
TMT BAR	92025.8	48.68	4461414.391	4	8.657%	61.282%	9.756%	A
7209CR SHEETS	81982.992	55.713	3883944.246	5	7.536%	68.818%	12.195%	A
Service			2377533.647	6	4.613%	73.432%	14.634%	B
Aluminium Section	12322.912	225.141	2359177.492	7	4.578%	78.009%	17.073%	B
76ALUMINIUM ALLOYS	8490.2048	236.313	1706076.332	8	3.310%	81.320%	19.512%	B
72 COIL	33185.6	52.395	1478537.000	9	2.869%	84.188%	21.951%	B
Angle	27629.28	45.8115	1076308.470	10	2.088%	86.277%	24.390%	B
6082 ALUMMINIUM PLATE	19964	51.9015	881089.750	11	1.710%	87.986%	26.829%	B
72 H R Sheet	17250.24	52.017	763015.080	12	1.481%	89.467%	29.268%	B
Flat	16299.136	43.0815	597101.384	13	1.159%	90.626%	31.707%	B
79 Zinc Ingots	2727.0208	242.9175	563300.234	14	1.093%	91.719%	34.146%	B
72 M S Flat	12251.68	48.09	501006.200	15	0.972%	92.691%	36.585%	B

M S Plate	10633.448	52.731	476796.213	16	0.925%	93.616%	39.024%	B
Alloy Steel Bar	3887.03	113.0535	439442.944	17	0.853%	94.468%	41.463%	B
Cons Store			319742.934	18	0.620%	95.089%	43.902%	C
Purchase Labour Charges			318015.402	19	0.617%	95.706%	46.341%	C
M S Bar	6712.1705	45.2865	303970.714	20	0.590%	96.296%	48.780%	C
7312 ROPE	560	618.45	294500.000	21	0.571%	96.867%	51.220%	C
C R COIL	5745.6	55.944	273326.400	22	0.530%	97.397%	53.659%	C
AL EXTRUSION	967.904	235.116	193511.664	23	0.375%	97.773%	56.098%	C
S S Sheet	911.12	199.4055	154491.785	24	0.300%	98.073%	58.537%	C
72MSBAR	3584	49.875	152000.000	25	0.295%	98.368%	60.976%	C
LACING RING DRG NO 5015	5641.44	26.25	125925.000	26	0.244%	98.612%	63.415%	C
CLAMP 60MM	1510.88	97.65	125457.000	27	0.243%	98.855%	65.854%	C
CR COIL - 7209(TG01C0003)	2133.6	57.225	103822.500	28	0.201%	99.057%	68.293%	C
Poly Bag	722.064	161.7105	99290.247	29	0.193%	99.250%	70.732%	C
Crc Strips	1813.28	58.737	90566.860	30	0.176%	99.425%	73.171%	C
87 Forging	15266.72	6.3	81786.000	31	0.159%	99.584%	75.610%	C
72 HRCTLF	1528.8	52.5	68250.000	32	0.132%	99.716%	78.049%	C
CLAMP 54.5 MM	533.12	97.65	44268.000	33	0.086%	99.802%	80.488%	C
FOUNDRY			30458.400	34	0.059%	99.861%	82.927%	C
Oil			23472.960	35	0.046%	99.907%	85.366%	C
27 Hard Coke	1248.8	18.69	19847.000	36	0.039%	99.945%	87.805%	C
7228 TOOL & DIE STEEL	137.76	106.47	12472.200	37	0.024%	99.970%	90.244%	C
CUTTING CHARGES			7231.812	38	0.014%	99.984%	92.683%	C
Castings	92.624	69.3	5458.200	39	0.011%	99.994%	95.122	C

							%	
82 Hss	2240	1.1025	2100.000	40	0.004%	99.998%	97.561 %	C
72 Steel Flat	18.312	54.6	850.200	41	0.002%	100.000 %	100.00 0%	C



These are the items whose demand will be forecasted and hence an optimal procurement policy for each shall be suggested :

s.no	Item	Category
1	**FLAT CR SHEET**	**A**
2	**316L HOT ROLLED SHEET**	**A**
3	**B Q PLATES**	**A**
4	**TMT BAR**	**A**
5	**7209CR SHEET**	**A**
6	**72 ALUMINIUM ALLOY**	**B**
7	**6082 ALUMMINIUM PLATE**	**B**
8	**ALLOY STEEL BAR**	**B**

FORECASTING

FORECASTING

Forecasting of the 8(A(5) and B(3) class items is done using the IBM-SPSS 20 software and then compared with the forecasting done through time series decomposition method in excel.)

Method 1: Through SPSS

The steps involving in this procedure are as follows:

Step1: To define a time series in the Data Editor, click the Variable View tab And enter a variable name in any blank row.

Step2: Transformation of data in time series is done using define date procedure. The Define Dates procedure (on the Data menu) generates date variables used to establish periodicity and to distinguish between historical, validation, and forecasting periods.

Step3: From the menus choose: Analyze >Forecasting >Create Models...

Step4: On the Variables tab, select one or more dependent variables to be modelled.

Step5: From the Method drop-down box, select a modelling method. For automatic modelling, leave the default method of Expert Modeller. This will invoke the Expert Modeller to determine the best-fitting model for each of the dependent variables.

Step6: To produce forecasts: Click the Options tab. Specify the forecast period. This will produce a chart that includes forecasts and observed values.

NOTE: Expert Modeller: The Expert Modeller automatically finds the best-fitting model for each dependent series. If independent (predictor) variables are specified, the Expert

Modeller selects, for inclusion in ARIMA models, those that have a statistically significant relationship with the dependent series. By default, the Expert Modeller considers both exponential smoothing and ARIMA models. You can, however, limit the Expert Modeller to only search for ARIMA models or to only search for exponential smoothing models. You can also specify automatic detection of outliers.

Time Series Components

A useful abstraction for selecting forecasting methods is to break a time series down into systematic and unsystematic components.

- **Systematic**: Components of the time series that have consistency or recurrence and can be described and modeled.
- **Non-Systematic**: Components of the time series that cannot be directly modeled.

A given time series is thought to consist of three systematic components including level, trend, seasonality, and one non-systematic component called noise.

These components are defined as follows:

- **Level**: The average value in the series.
- **Trend**: The increasing or decreasing value in the series.
- **Seasonality**: The repeating short-term cycle in the series.
- **Noise**: The random variation in the series.

Combining Time Series Components

A series is thought to be an aggregate or combination of these four components. ***All series have a level and noise. The trend and seasonality components are optional.*** It is helpful to think of the components as combining either additively or multiplicatively.

Additive Model

An additive model is linear where changes over time are consistently made by the same amount.

```
y(t) = Level + Trend + Seasonality + Noise
```

A linear trend is a straight line. A linear seasonality has the same frequency (width of cycles) and amplitude (height of cycles).

Multiplicative Model

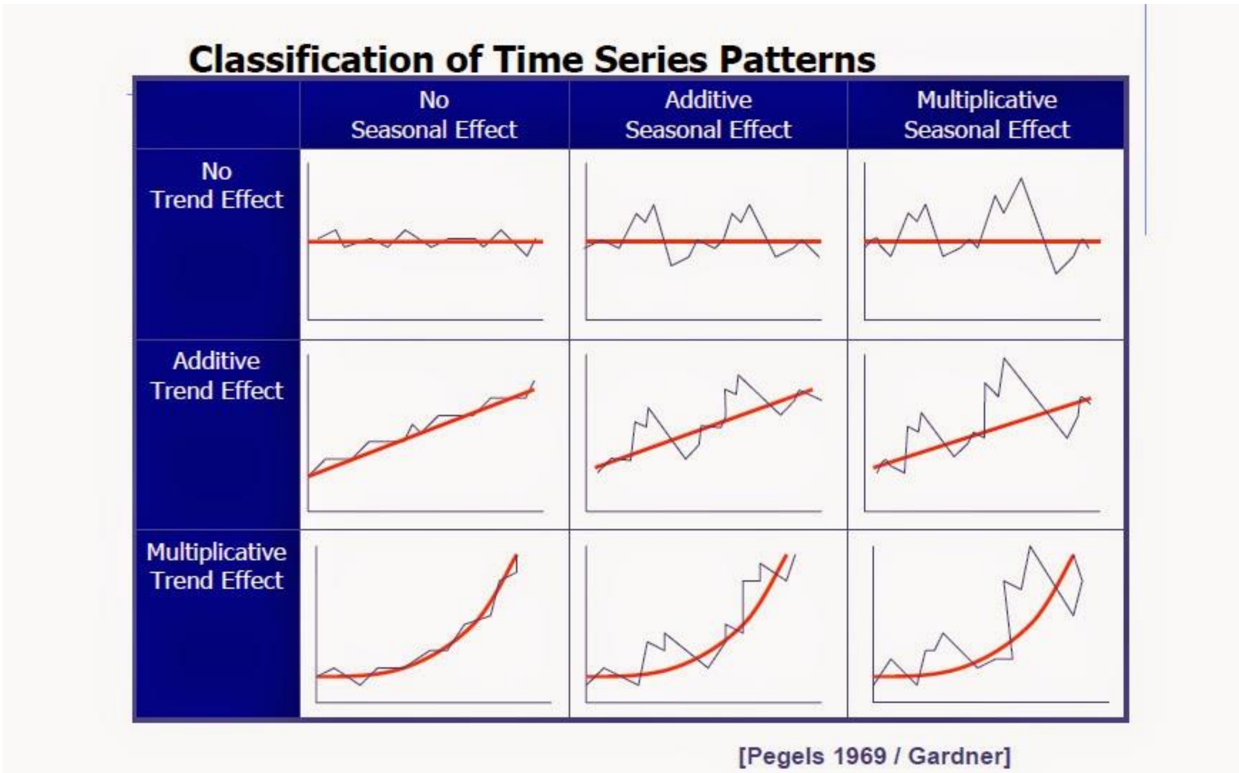
```
y(t) = Level * Trend * Seasonality * Noise
```

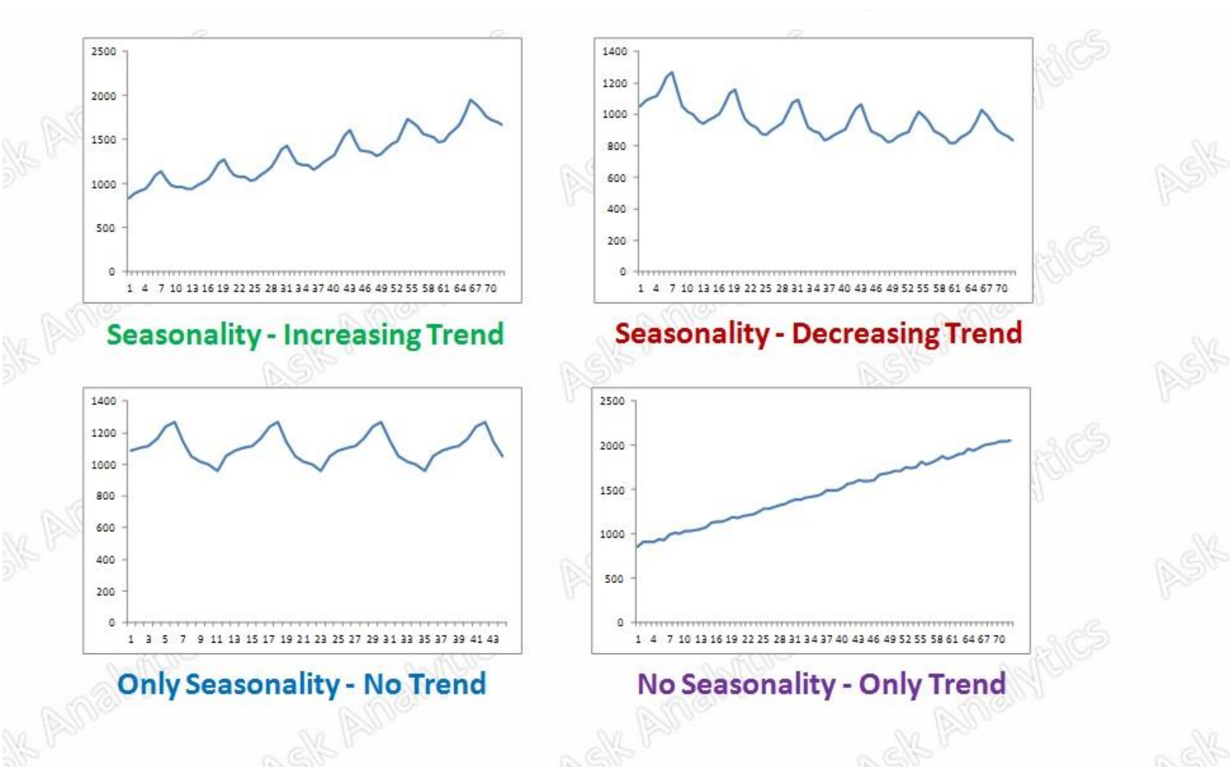
A multiplicative model is nonlinear, such as quadratic or exponential. Changes increase or decrease over time. A nonlinear trend is a curved line. A non-linear seasonality has an increasing or decreasing frequency and/or amplitude over time.

CONCEPTS BEHIND MODELS USED BY SPSS

s.no	name	level	trend	seasonality	Special points
1	**Simple**	**present**	**absent**	**Absent**	Level is the only smoothing parameter
2	**Holt's Linear**	**present**	Linear trend	**Absent**	Level and trend not constrained by each other
3	**Brown's Linear**	**present**	Linear trend	**Absent**	Smoothing parameter level and trend assumed to be equal
4	**damped**	**present**	Linear trend	**Absent**	Linear trend that is dying out
5	**Simple seasonal**	**present**	**absent**	**present**	Seasonal effect constant over time
6	**Winter's Additive**	**present**	Linear trend	**present**	Season effect doesn't depend on level
7	**Winter's Multiplicative**	**present**	Linear trend	**present**	Seasonal effect dependent on level

SPSS mostly categorizes the predicted models as mentioned above in the table.





THE FORECAST FOR 8 ITEMS ARE AS FOLLOWS:

FORECAST FOR A CATEGORY ITEMS

FLAT CR SHEET

Model Description

			Model Type
Model ID	demand	Model_1	Simple Seasonal

Model Summary

Model Fit

Fit Statistic	Mean	SE	Minimum	Maximum	Percentile 5	10	25	50	75	90	95
Stationary R-squared	.814	.	.814	.814	.814	.814	.814	.814	.814	.814	.814
R-squared	.756	.	.756	.756	.756	.756	.756	.756	.756	.756	.756
RMSE	**2990.354**	.	2990.354	2990.354	2990.354	2990.354	2990.354	2990.354	2990.354	2990.354	2990.354
MAPE	6.784	.	6.784	6.784	6.784	6.784	6.784	6.784	6.784	6.784	6.784
MaxAPE	35.235	.	35.235	35.235	35.235	35.235	35.235	35.235	35.235	35.235	35.235
MAE	1965.330	.	1965.330	1965.330	1965.330	1965.330	1965.330	1965.330	1965.330	1965.330	1965.330
MaxAE	10575.205	.	10575.205	10575.205	10575.205	10575.205	10575.205	10575.205	10575.205	10575.205	10575.205
Normalized BIC	16.205	.	16.205	16.205	16.205	16.205	16.205	16.205	16.205	16.205	16.205

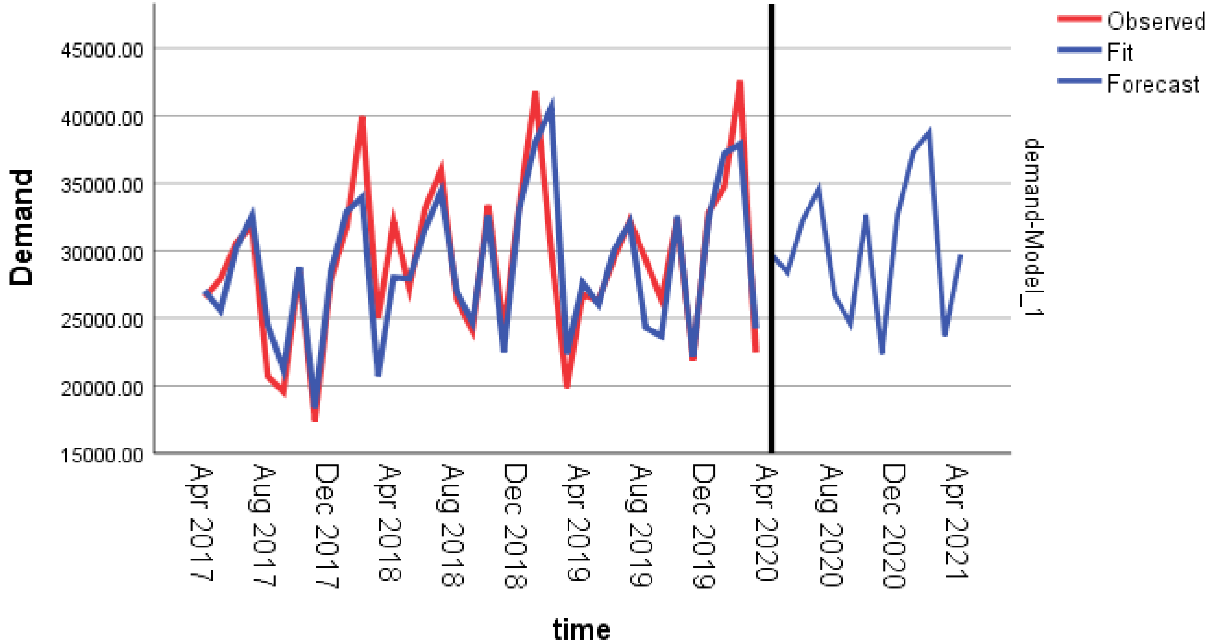
Model Statistics

Model	Number of Predictors	Model Fit statistics: Stationary R-squared	R-squared	RMSE	Ljung-Box Q(18): Statistics	DF	Sig.	Number of Outliers
demand-Model_1	0	.814	.756	**2990.354**	28.451	16	.028	0

time	**observed values**	**forecasted values**
1-Apr-17	26546.00	27046.16
1-May-17	27923.00	25570.78
1-Jun-17	30593.00	30205.47
1-Jul-17	31802.00	32569.41

1-Aug-17	20689.00	24504.19
1-Sep-17	19555.00	21206.62
1-Oct-17	28493.00	28800.14
1-Nov-17	17382.00	18378.36
1-Dec-17	27794.00	28390.50
1-Jan-18	31732.00	32878.61
1-Feb-18	39956.00	33978.72
1-Mar-18	25019.00	20709.76
1-Apr-18	32113.00	28019.73
1-May-18	27212.00	27922.67
1-Jun-18	33190.00	31638.29
1-Jul-18	35939.00	34351.39
1-Aug-18	26443.00	26992.42
1-Sep-18	24071.00	24674.80
1-Oct-18	33383.00	32582.80
1-Nov-18	23995.00	22493.17
1-Dec-18	33576.00	33254.82
1-Jan-19	41769.00	38018.20
1-Feb-19	30013.00	40588.21
1-Mar-19	19883.00	22353.21
1-Apr-19	26756.00	27629.27
1-May-19	26304.00	26041.78
1-Jun-19	29443.00	30049.48
1-Jul-19	32228.00	32115.10
1-Aug-19	29332.00	24313.52
1-Sep-19	26379.00	23666.31
1-Oct-19	32396.00	32569.41
1-Nov-19	21906.00	22187.75
1-Dec-19	32846.00	32414.20
1-Jan-20	34716.00	37211.07
1-Feb-20	42580.00	37905.98
1-Mar-20	22460.00	24246.61
1-Apr-20		29727.90
1-May-20		28402.50
1-Jun-20		32331.45
1-Jul-20		34579.09
1-Aug-20		26744.08
1-Sep-20		24591.07
1-Oct-20		32680.09
1-Nov-20		22350.45
1-Dec-20		32661.49

1-Jan-21		37328.55
1-Feb-21		38772.65
1-Mar-21		23710.45



Method 2: TIME SERIES DECOMPOSITION METHOD

STEP 1: Check for seasonality in data.

STEP 2: Deseasonalise the Data using Ratio to moving Average Method

STEP 3: Curve Fitting on Deseasonalised data using Spss and fit a suitable curve whose R^2 is highest or β's significant and find the trend values.

Forecast values = Trend* (Adjusted SI/100)

In this case linear has high R^2 value; we consider it as best curve to be fitted.

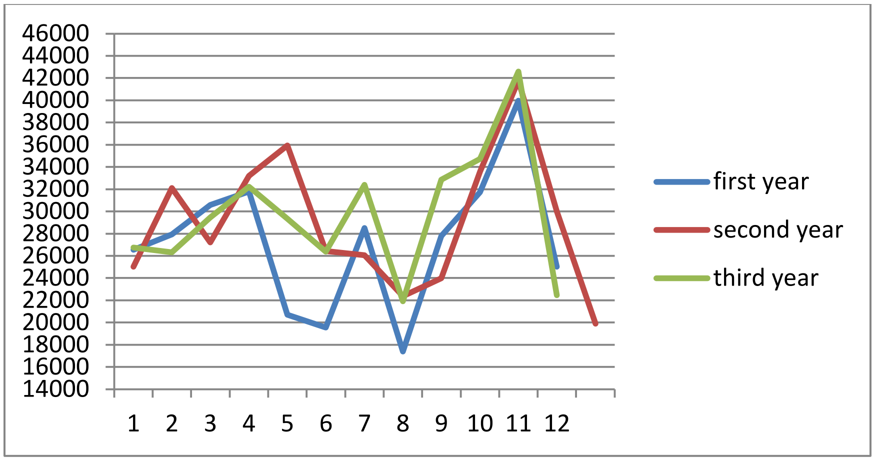
STEP 4: Find RMSE using Formula

RMSE= Sqrt(Avg((original data- forecasted data)^2))

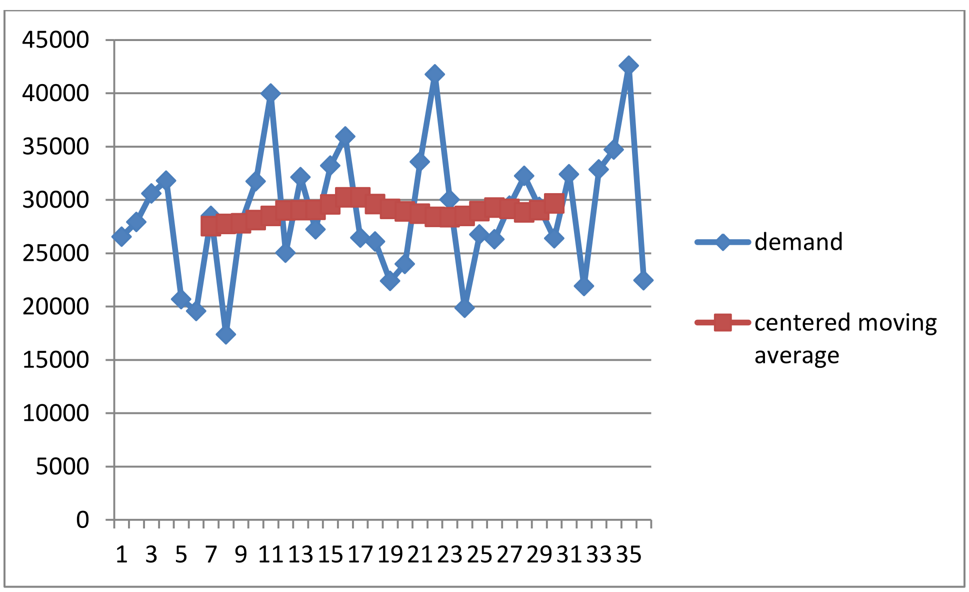
STEP 5: Compare the RMSE obtained from the results of Spss and excel. Forecast values of less RMSE are being considered as less RMSE gives better results.

FORECAST FOR FLAT CR SHEET USING EXCEL

The following graph shows seasonality in the data:

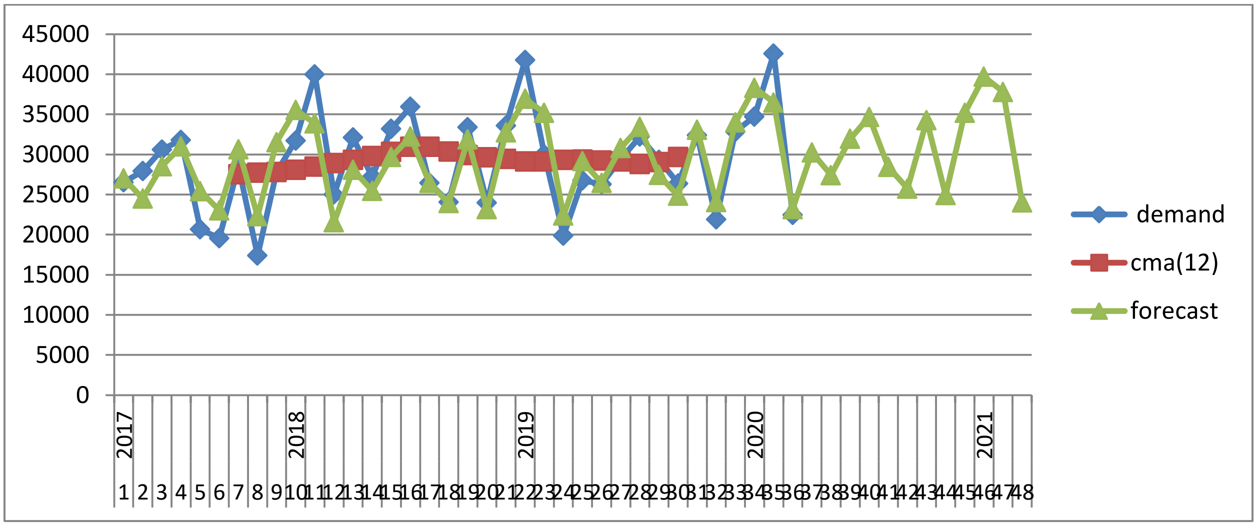


This graph shows 12 months centered moving average and demand for 36 months. A moving average technique gives an overall idea of trend in the data set. Moving averages is extremely crutial for forecasting long term trends. A regular 12-month average reduces a year of monthly figures into a single average number; hence we will use a 12 period moving average to estimate the trend. The shorter the time span used to create the moving average the more sensitive it is to changes. This statistical tool can help you gauge the overall direction of a series of monthly data, because it smooths out the effects of month-to-month changes.



Linear equation obtained after curve fitting →27312.81+91.36544 *t. Putting values of t in the equation we obtain the trend values.

Plotting demand, centered moving average (12 period) and the line depicting the forecasts we obtain the following graph.



The excel sheet for obtaining the above shown graphs has been shown on the next page. Furthermore two error measures were calculated and compared to that obtained in SPSS. The one with smaller value of both error measures shall be the preferred software for further analysis of remaining items.

				y_t			y_t/cma			$y_t/S_{t[c]}$			
t	year	month	date	demand	12 period m.a	cma(12)	S_t,I_t	S_t	corrected st	deseasonalized	T_t	forecast	(OR-FOR)^2
1	2017	4	1-Apr-17	26546				1.003	0.986	26929.24	27404.17248	27015	219192
2		5	1-May-17	27923				0.906	0.891	31351.12	27495.53793	24489	11792536
3		6	1-Jun-17	30593				1.053	1.035	29568.00	27586.90338	28543	4201593
4		7	1-Jul-17	31802				1.140	1.120	28396.93	27678.26883	30997	647766
5		8	1-Aug-17	20689				0.932	0.916	22589.99	27769.63427	25433	22503156
6		9	1-Sep-17	19555	27290			0.841	0.827	23654.87	27860.99972	23032	12089762
7		10	1-Oct-17	28493	27754	27522	1.035	1.116	1.097	25974.71	27952.36517	30663	4706310
8		11	1-Nov-17	17382	27695	27725	0.627	0.809	0.795	21853.07	28043.73062	22306	24246452
9		12	1-Dec-17	27794	27911	27803	1.000	1.140	1.120	24808.58	28135.09607	31521	13888982
10	2018	1	1-Jan-18	31732	28256	28084	1.130	1.282	1.260	25193.30	28226.46152	35552	14595045
11		2	1-Feb-18	39956	28736	28496	1.402	1.217	1.196	33416.98	28317.82697	33859	37173728
12		3	1-Mar-18	25019	29112	28924	0.865	0.772	0.758	32996.73	28409.19242	21541	12099607
13		4	1-Apr-18	32113	29520	29316	1.095	1.003	0.986	32575.93	28500.55787	28095	16139880
14		5	1-May-18	27212	30071	29795	0.913	0.906	0.891	30552.02	28591.92332	25466	3047760
15		6	1-Jun-18	33190	30552	30312	1.095	1.053	1.035	32078.23	28683.28877	29678	12338606
16		7	1-Jul-18	35939	31389	30971	1.160	1.140	1.120	32090.74	28774.65422	32225	13791798
17		8	1-Aug-18	26443	30560	30975	0.854	0.932	0.916	28872.65	28866.01967	26437	37
18		9	1-Sep-18	24071	30132	30346	0.793	0.841	0.827	29118.99	28957.38512	23938	17846
19		10	1-Oct-18	33383	29686	29909	1.116	1.116	1.097	30432.43	29048.75057	31865	2303809
20		11	1-Nov-18	23995	29610	29648	0.809	0.809	0.795	30166.83	29140.11602	23178	666918
21		12	1-Dec-18	33576	29298	29454	1.140	1.140	1.120	29969.49	29231.48147	32749	683614
22	2019	1	1-Jan-19	41769	28989	29143	1.433	1.282	1.260	33162.80	29322.84691	36933	23392030
23		2	1-Feb-19	30013	29229	29109	1.031	1.217	1.196	25100.86	29414.21236	35170	26599207
24		3	1-Mar-19	19883	29422	29326	0.678	0.772	0.758	26222.49	29505.57781	22372	6196918
25		4	1-Apr-19	26756	29339	29381	0.911	1.003	0.986	27141.53	29596.94326	29176	5858870
26		5	1-May-19	26304	29165	29252	0.899	0.906	0.891	29533.07	29688.30871	26442	19117
27		6	1-Jun-19	29443	29105	29135	1.011	1.053	1.035	28456.57	29779.67416	30812	1874085
28		7	1-Jul-19	32228	28517	28811	1.119	1.140	1.120	28777.14	29871.03961	33453	1500814
29		8	1-Aug-19	29332	29564	29040	1.010	0.932	0.916	32027.56	29962.40506	27441	3577249
30		9	1-Sep-19	26379	29779	29671	0.889	0.841	0.827	31909.95	30053.77051	24844	2354462
31		10	1-Oct-19	32396				1.116	1.097	29532.38	30145.13596	33068	451804
32		11	1-Nov-19	21906				0.809	0.795	27541.02	30236.50141	24050	4596709
33		12	1-Dec-19	32846				1.140	1.120	29318.48	30327.86686	33977	1278817
34	2020	1	1-Jan-20	34716				1.282	1.260	27563.01	30419.23231	38314	12941892
35		2	1-Feb-20	42580				1.217	1.196	35610.82	30510.59776	36481	37189238
36		3	1-Mar-20	22460				0.772	0.758	29621.91	30601.96321	23204	552220
37		4							0.986		30693.32866	30257	
38		5							0.891		30784.69411	27419	
39		6							1.035		30876.05955	31946	
40		7							1.120		30967.425	34681	
41		8							0.916		31058.79045	28445	
42		9							0.827		31150.1559	25751	
43		10							1.097		31241.52135	34271	
44		11							0.795		31332.8868	24922	
45		12							1.120		31424.25225	35206	
46	2021	1							1.260		31515.6177	39695	
47		2							1.196		31606.98315	37792	
48		3							0.758		31698.3486	24035	

RMSE using Excel= 3446.73 **MAE using Excel=2803**

RMSE using SPSS=2990.35 **MAE using SPSS=1965.3**

<u>After comparing the two error measures for the same data on SPSS and Excel. We observe that lower value of error measures is obtained by using SPSS software. Hence we shall use Spss for further forecasts</u>

316L HOT ROLLED SHEET

Model Description

			Model Type
Model ID	demand	Model_1	Simple Seasonal

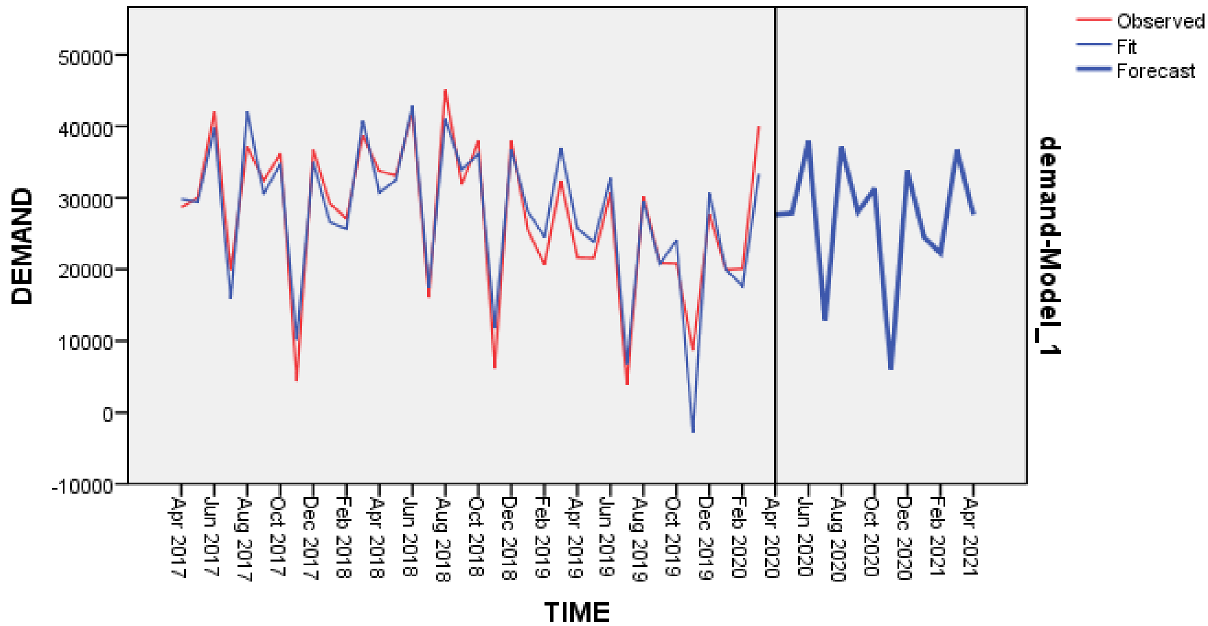
Model Summary

Model Fit

Fit Statistic	Mean	SE	Minimum	Maximum	Percentile						
					5	10	25	50	75	90	95
Stationary R-squared	.671	.	.671	.671	.671	.671	.671	.671	.671	.671	.671
R-squared	.888	.	.888	.888	.888	.888	.888	.888	.888	.888	.888
RMSE	3664.511	.	3664.511	3664.511	3664.511	3664.511	3664.511	3664.511	3664.511	3664.511	3664.511
MAPE	19.445	.	19.445	19.445	19.445	19.445	19.445	19.445	19.445	19.445	19.445
MaxAPE	135.839	.	135.839	135.839	135.839	135.839	135.839	135.839	135.839	135.839	135.839
MAE	2806.570	.	2806.570	2806.570	2806.570	2806.570	2806.570	2806.570	2806.570	2806.570	2806.570
MaxAE	11530.838	.	11530.838	11530.838	11530.838	11530.838	11530.838	11530.838	11530.838	11530.838	11530.838
Normalized BIC	16.612	.	16.612	16.612	16.612	16.612	16.612	16.612	16.612	16.612	16.612

Model Statistics

Model	Number of Predictors	Model Fit statistics				Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	R-squared	RMSE	MAPE	Statistics	DF	Sig.	
demand-Model_1	0	.671	.888	3664.511	19.445	19.780	16	.230	0

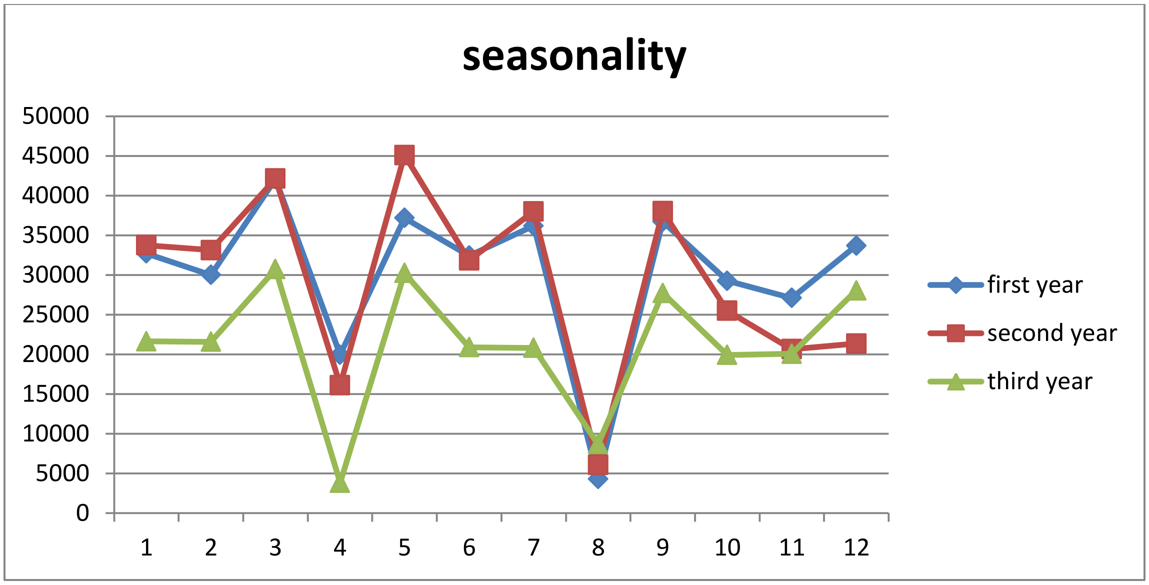


time	observed value	predicted value
1-Apr-17	28708	29791
1-May-17	30003	29450
1-Jun-17	42078	39810
1-Jul-17	19941	15926
1-Aug-17	37171	42141
1-Sep-17	32432	30542
1-Oct-17	36201	34769
1-Nov-17	4315	10176
1-Dec-17	36714	35037
1-Jan-18	29262	26615
1-Feb-18	27094	25648
1-Mar-18	38702	40803
1-Apr-18	33751	30747
1-May-18	33121	32449
1-Jun-18	42132	42869
1-Jul-18	16127	17483
1-Aug-18	45104	41012
1-Sep-18	31844	33944
1-Oct-18	37998	36176
1-Nov-18	6093	11778
1-Dec-18	38019	36727
1-Jan-19	25486	28112

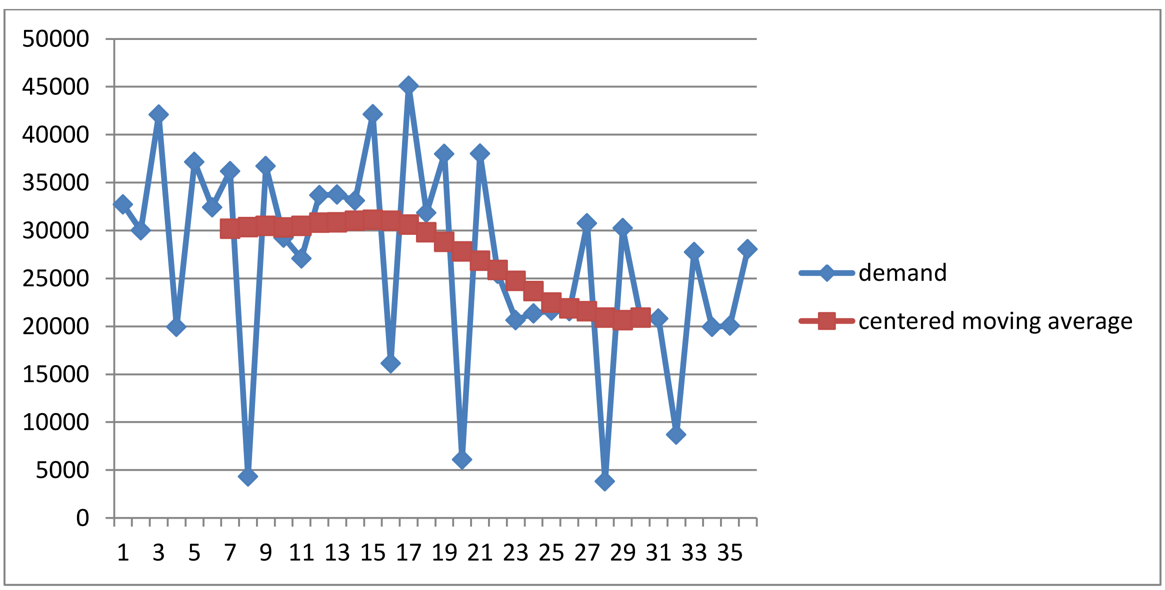
1-Feb-19	20650	24509
1-Mar-19	32357	37012
1-Apr-19	21636	25679
1-May-19	21572	23858
1-Jun-19	30737	32799
1-Jul-19	3826	6750
1-Aug-19	30240	29495
1-Sep-19	20898	20754
1-Oct-19	20820	24108
1-Nov-19	8686	-2845
1-Dec-19	27735	30712
1-Jan-20	19937	19962
1-Feb-20	20071	17660
1-Mar-20	40054	33298
1-Apr-20		27670
1-May-20		27870
1-Jun-20		37954
1-Jul-20		12936
1-Aug-20		37143
1-Sep-20		28030
1-Oct-20		31311
1-Nov-20		6003
1-Dec-20		33794
1-Jan-21		24533
1-Feb-21		22243
1-Mar-21		36676

316L HOT ROLLED SHEET FORECAST USING EXCEL

The following graph shows seasonality in the data:

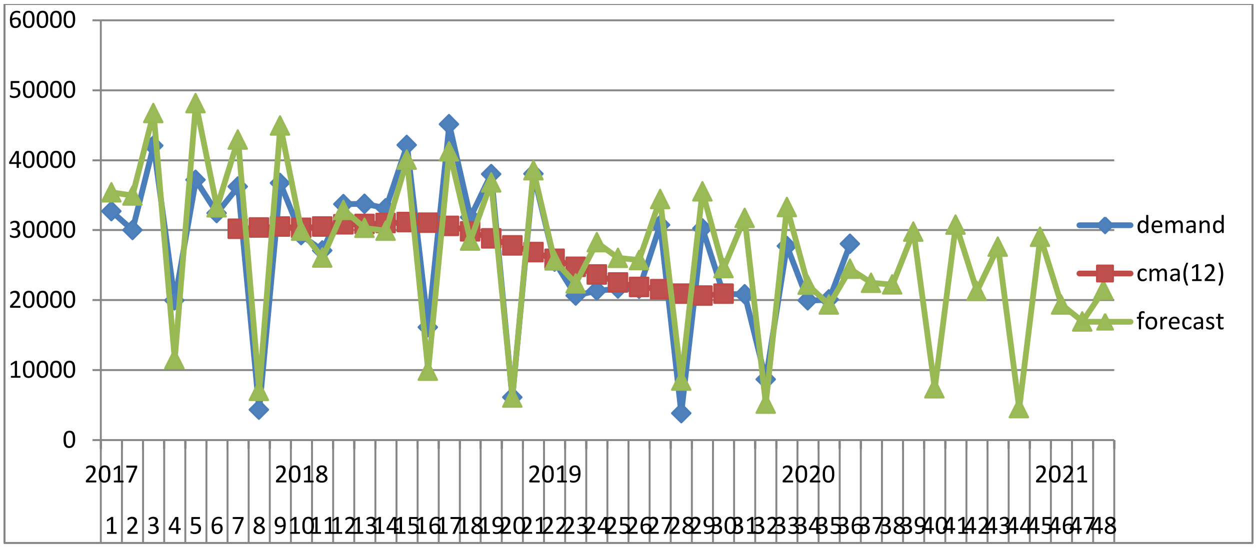


This graph shows 12 months centered moving average and demand for 36 months. A moving average technique gives an overall idea of trend in the data set. Moving averages is extremely crutial for forecasting long term trends. A regular 12-month average reduces a year of monthly figures into a single average number; hence we will use a 12 period moving average to estimate the trend. The shorter the time span used to create the moving average the more sensitive it is to changes. This statistical tool can help you gauge the overall direction of a series of monthly data, because it smoothes out the effects of month-to-month changes:



QUADRATIC TREND WAS OBSERVED

EQUATION USED FOR FINDING OUT TREND= **$35474.42 - 457.475T + 2.766T^2$.**



The excel sheet for obtaining the above shown graphs has been shown below. Furthermore two error measures were calculated and compared to that obtained in SPSS. The one with smaller value of both error measures shall be the preferred software for further analysis of remaining items

			yt			yt/cma			yt/st[c]		
t	year	month	demand	12 period m.a	cma(12)	St,It	St	corrected st	deseasonalized	Tt	Forecast
1	2017	4	32708				1.018	1.011	32364.2	35019.71	35391.42
2		5	30003				1.018	1.011	29688.54	34570.53	34936.44
3		6	42078				1.379	1.370	30724.96	34126.88	46737.23
4		7	19941				0.345	0.342	58264.88	33688.77	11530.04
5		8	37171				1.458	1.447	25683	33256.19	48131.99
6		9	32432	30135			1.020	1.013	32025.47	32829.14	33245.5
7		10	36201	30222	30179	1.199549	1.335	1.325	27318.29	32407.62	42944.84
8		11	4315	30482	30352	0.14218	0.222	0.220	19605.14	31991.64	7041.951
9		12	36714	30486	30484	1.204371	1.433	1.423	25801.91	31581.19	44937.71
10	2018	1	29262	30169	30327	0.964879	0.966	0.959	30511.47	31176.27	29899.89
11		2	27094	30830	30499	0.888366	0.853	0.847	31989.32	30776.88	26067.4
12		3	33702	30781	30805	1.094024	1.090	1.083	31130.28	30383.02	32892.52
13		4	33751	30930	30855	1.093852	1.018	1.011	33396.84	29994.69	30313.07
14		5	33121	31079	31004	1.068258	1.018	1.011	32773.85	29611.9	29925.33

15		6	42132	31187	31133	1.353285	1.379	1.370	30763.95	29234.64	40037.23
16		7	16127	30873	31030	0.519725	0.345	0.342	47120.22	28862.91	9878.383
17		8	45104	30335	30604	1.473787	1.458	1.447	31163.89	28496.71	41243.55
18		9	31844	29307	29821	1.067839	1.020	1.013	31445.38	28136.05	28492.89
19		10	37998	28297	28802	1.319283	1.335	1.325	28674.55	27780.92	36813.77
20		11	6093	27335	27816	0.219054	0.222	0.220	27681.42	27431.32	6038.139
21		12	38019	26385	26860	1.415432	1.433	1.423	26718.54	27087.25	38543.16
22	2019	1	25486	25360	25873	0.985056	0.966	0.959	26573.99	26748.71	25653.6
23		2	20650	24121	24741	0.834649	0.853	0.847	24380.61	26415.7	22373.57
24		3	21357	23209	23665	0.90247	1.090	1.083	19727.89	26088.23	28243
25		4	21636	21778	22494	0.961865	1.018	1.011	21408.57	25766.29	26039.79
26		5	21572	21994	21886	0.985663	1.018	1.011	21346.2	25449.88	25719.26
27		6	30737	21137	21565	1.42529	1.379	1.370	22443.8	25139	34428.2
28		7	3826	20675	20906	0.182991	0.345	0.342	11177.66	24833.66	8499.365
29		8	30240	20626	20650	1.464374	1.458	1.447	20893.96	24533.85	35508.06
30		9	20898	21184	20905	0.999668	1.020	1.013	20636.7	24239.57	24546.99
31		10	20820				1.335	1.325	15711.75	23950.82	31738.33
32		11	8686				0.222	0.220	39462.23	23667.6	5209.676
33		12	27735				1.433	1.423	19491.63	23389.91	33282.13
34	2020	1	19937				0.966	0.959	20788.23	23117.76	22171.31
35		2	20071				0.853	0.847	23696.74	22851.14	19354.46
36		3	28054				1.090	1.083	25913.68	22590.05	24455.88
37		4						1.006		22334.49	22478.31
38		5						1.006		22084.47	22226.02
39		6						1.364		21839.98	29786.57
40		7						0.341		21601.02	7362.443
41		8						1.441		21367.59	30797.74
42		9						1.008		21139.69	21319.35
43		10						1.320		20917.32	27604
44		11						0.219		20700.49	4537.736

45		12						1.417		20489.19	29034.16
46	2021	1						0.955		20283.42	19372.64
47		2						0.843		20083.18	16939.78
48		3						1.078		19888.48	21442.22

RMSE using Excel =4094 MAE using Excel=3824

RMSE using SPSS=3364 MAE using SPSS=2806.5

After comparing the two error measures for the same data on SPSS and Excel. We observe that lower value of error measures is obtained by using SPSS software. Hence we shall use Spss for further forecasts

B Q PLATES

Model Description

			Model Type
Model ID	demand	Model_1	Winters' Additive

Model Summary

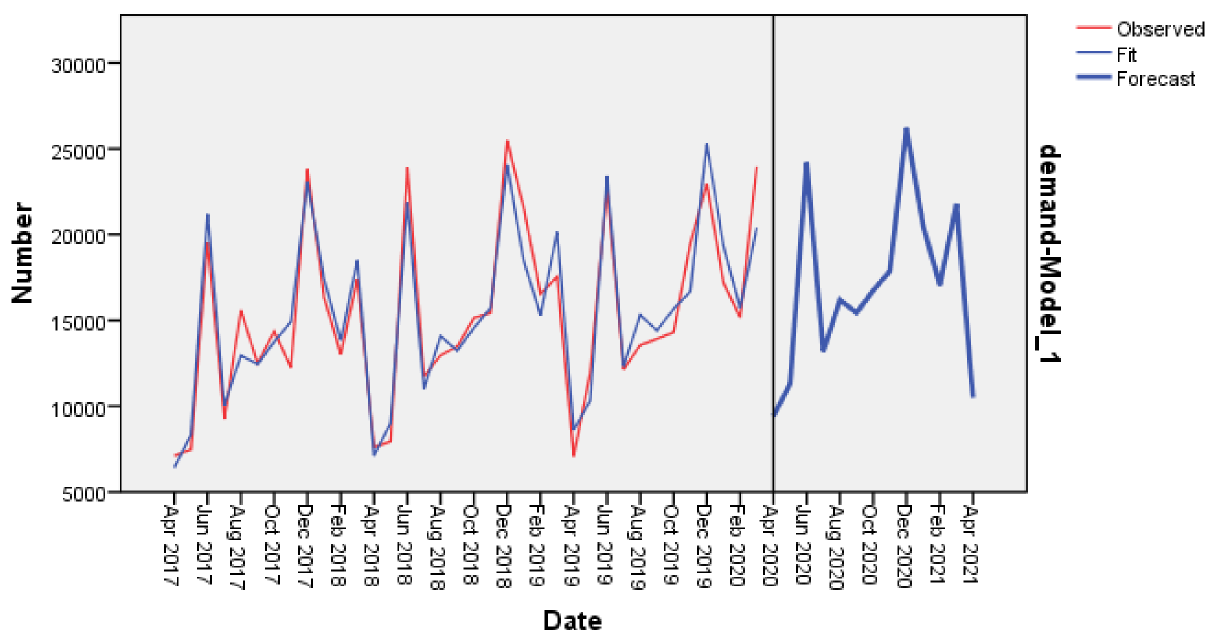
Model Fit

Fit Statistic	Mean	SE	Minimum	Maximum	Percentile						
					5	10	25	50	75	90	95
Stationary R-squared	.753	.	.753	.753	.753	.753	.753	.753	.753	.753	.753
R-squared	.895	.	.895	.895	.895	.895	.895	.895	.895	.895	.895
RMSE	1712.251	.	1712.251	1712.251	1712.251	1712.251	1712.251	1712.251	1712.251	1712.251	1712.251
MAPE	9.201	.	9.201	9.201	9.201	9.201	9.201	9.201	9.201	9.201	9.201
MaxAPE	27.869	.	27.869	27.869	27.869	27.869	27.869	27.869	27.869	27.869	27.869
MAE	1356.250	.	1356.250	1356.250	1356.250	1356.250	1356.250	1356.250	1356.250	1356.250	1356.250

MaxAE	3613.533	.	3613.533	3613.533	3613.533	3613.533	3613.533	3613.533	3613.533	3613.533	3613.533
Normalized BIC	15.190	.	15.190	15.190	15.190	15.190	15.190	15.190	15.190	15.190	15.190

Model Statistics

Model	Number of Predictors	Model Fit statistics							Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	R-squared	RMSE	MAPE	MAE	MaxAPE	MaxAE	Statistics	DF	Sig.	
demand-Model_1	0	.753	.895	1712.251	9.201	1356.250	27.869	3613.533	28.080	15	.021	0



Time	observed value	predicted values
1-Apr-17	8710	7086
1-May-17	7480	8546
1-Jun-17	19549	21382
1-Jul-17	9262	10216

1-Aug-17	15602	13127
1-Sep-17	12502	12592
1-Oct-17	14351	13891
1-Nov-17	12254	15048
1-Dec-17	23803	23164
1-Jan-18	16321	17505
1-Feb-18	13031	13947
1-Mar-18	17414	18601
1-Apr-18	7631	7675
1-May-18	7941	8990
1-Jun-18	23917	21828
1-Jul-18	11742	11003
1-Aug-18	12974	14061
1-Sep-18	13471	13216
1-Oct-18	15143	14545
1-Nov-18	15447	15714
1-Dec-18	25474	24049
1-Jan-19	21570	18459
1-Feb-19	16538	15274
1-Mar-19	17545	20117
1-Apr-19	7094	9071
1-May-19	11970	10218
1-Jun-19	22713	23299
1-Jul-19	12154	12241
1-Aug-19	13564	15228
1-Sep-19	13917	14333
1-Oct-19	14315	15604
1-Nov-19	19460	16609
1-Dec-19	22959	25215
1-Jan-20	17203	19305
1-Feb-20	15160	15667
1-Mar-20	23970	20356
1-Apr-20		9848
1-May-20		11166
1-Jun-20		24096
1-Jul-20		13089
1-Aug-20		16083
1-Sep-20		15333
1-Oct-20		16639
1-Nov-20		17756
1-Dec-20		26115

1-Jan-21		20401
1-Feb-21		16945
1-Mar-21		21679
1-Apr-21		10856

7209CR SHEETS

Time Series Modeler

Model Description

			Model Type
Model ID	demand	Model_1	Simple Seasonal

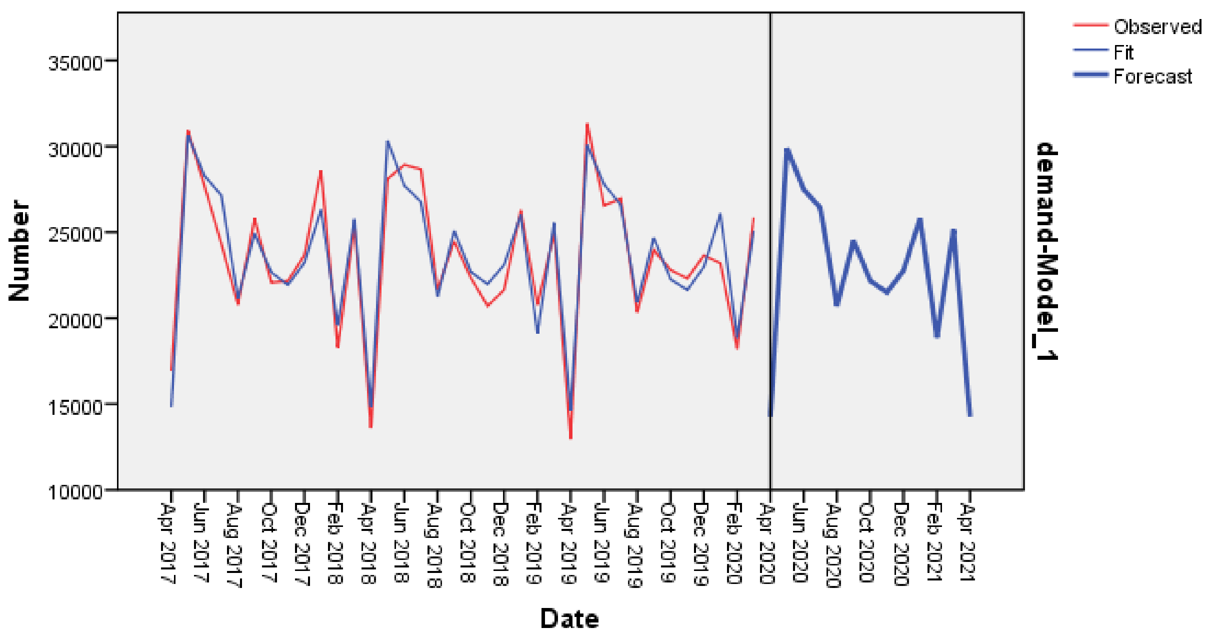
Model Summary

Model Fit

Fit Statistic	Mean	SE	Minimum	Maximum	Percentile						
					5	10	25	50	75	90	95
Stationary R-squared	.792	.	.792	.792	.792	.792	.792	.792	.792	.792	.792
R-squared	.909	.	.909	.909	.909	.909	.909	.909	.909	.909	.909
RMSE	1309.628	.	1309.628	1309.628	1309.628	1309.628	1309.628	1309.628	1309.628	1309.628	1309.628
MAPE	4.701	.	4.701	4.701	4.701	4.701	4.701	4.701	4.701	4.701	4.701
MaxAPE	12.732	.	12.732	12.732	12.732	12.732	12.732	12.732	12.732	12.732	12.732
MAE	1047.372	.	1047.372	1047.372	1047.372	1047.372	1047.372	1047.372	1047.372	1047.372	1047.372
MaxAE	2877.836	.	2877.836	2877.836	2877.836	2877.836	2877.836	2877.836	2877.836	2877.836	2877.836
Normalized BIC	14.554	.	14.554	14.554	14.554	14.554	14.554	14.554	14.554	14.554	14.554

Model Statistics

Model	Number of Predictors	Model Fit statistics						Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	R-squared	RMSE	MAPE	MAE	MaxAPE	Statistics	DF	Sig.	
demand-Model_1	0	.792	.909	1309.628	4.701	1047.372	12.732	27.372	16	.038	0



Time	Observed values	Predicted values
1-Apr-17	16945	14828
1-May-17	30924	30650
1-Jun-17	27663	28268
1-Jul-17	24334	27150
1-Aug-17	20778	21152
1-Sep-17	25818	24923

1-Oct-17	22067	22669
1-Nov-17	22170	21937
1-Dec-17	23683	23225
1-Jan-18	28614	26312
1-Feb-18	18287	19598
1-Mar-18	25379	25758
1-Apr-18	13616	14847
1-May-18	28102	30335
1-Jun-18	28925	27703
1-Jul-18	28660	26767
1-Aug-18	21678	21239
1-Sep-18	24460	25091
1-Oct-18	22334	22684
1-Nov-18	20708	21978
1-Dec-18	21649	23116
1-Jan-19	26290	26011
1-Feb-19	20784	19096
1-Mar-19	24918	25555
1-Apr-19	12967	14618
1-May-19	31334	30064
1-Jun-19	26545	27782
1-Jul-19	26965	26600
1-Aug-19	20351	20919
1-Sep-19	23955	24671
1-Oct-19	22801	22256
1-Nov-19	22310	21639
1-Dec-19	23650	22971
1-Jan-20	23202	26080
1-Feb-20	18205	18850
1-Mar-20	25851	25076
1-Apr-20		14280
1-May-20		29891
1-Jun-20		27482
1-Jul-20		26424
1-Aug-20		20706
1-Sep-20		24515
1-Oct-20		22171
1-Nov-20		21500
1-Dec-20		22765
1-Jan-21		25806
1-Feb-21		18863

1-Mar-21		25153
1-Apr-21		14280

TMT BAR

Model Description

			Model Type
Model ID	demand	Model_1	Simple Seasonal

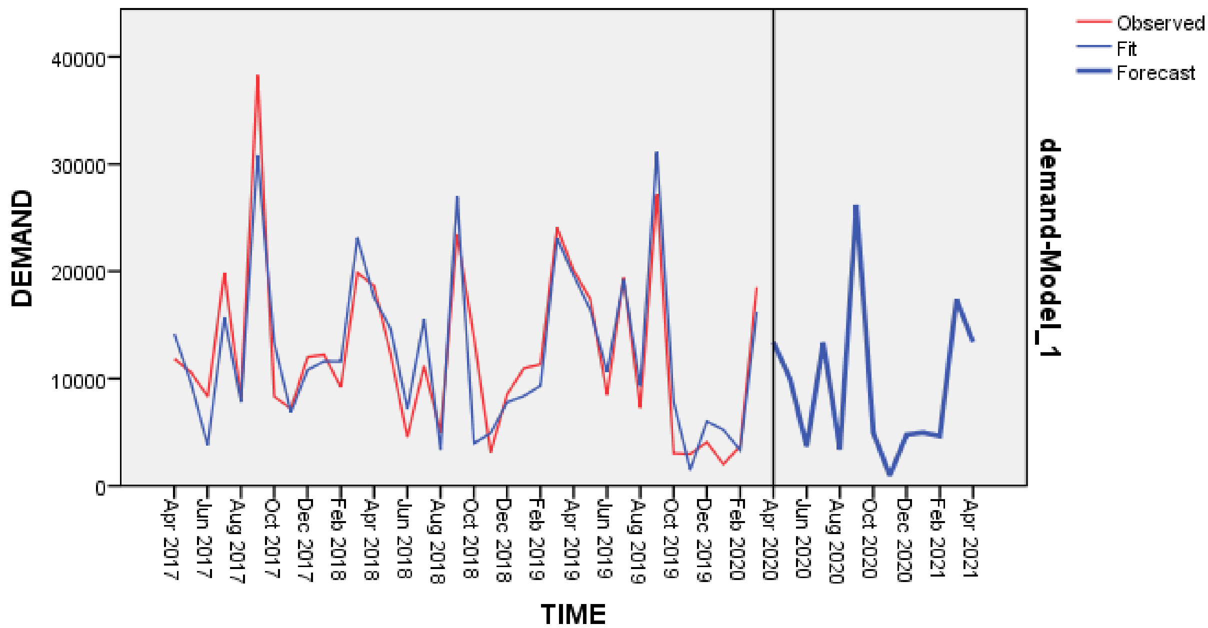
Model Summary

Model Fit

Fit Statistic	Mean	SE	Minimum	Maximum	Percentile						
					5	10	25	50	75	90	95
Stationary R-squared	.810	.	.810	.810	.810	.810	.810	.810	.810	.810	.810
R-squared	.834	.	.834	.834	.834	.834	.834	.834	.834	.834	.834
RMSE	3318.343	.	3318.343	3318.343	3318.343	3318.343	3318.343	3318.343	3318.343	3318.343	3318.343
MAPE	31.168	.	31.168	31.168	31.168	31.168	31.168	31.168	31.168	31.168	31.168
MaxAPE	160.778	.	160.778	160.778	160.778	160.778	160.778	160.778	160.778	160.778	160.778
MAE	2507.228	.	2507.228	2507.228	2507.228	2507.228	2507.228	2507.228	2507.228	2507.228	2507.228
MaxAE	9832.220	.	9832.220	9832.220	9832.220	9832.220	9832.220	9832.220	9832.220	9832.220	9832.220
Normalized BIC	16.414	.	16.414	16.414	16.414	16.414	16.414	16.414	16.414	16.414	16.414

Model Statistics

Model	Number of Predictors	Model Fit statistics			Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	R-squared	RMSE	Statistics	DF	Sig.	
demand-Model_1	0	.810	.834	3318.343	32.868	16	.008	0



Time	Observed values	predicted values
1-Apr-17	11842	14181
1-May-17	10582	9574
1-Jun-17	8335	3792
1-Jul-17	19853	15736
1-Aug-17	8219	7819
1-Sep-17	38289	30834
1-Oct-17	8315	13302
1-Nov-17	7175	6839
1-Dec-17	12013	10803
1-Jan-18	12221	11601

1-Feb-18	9223	11597
1-Mar-18	19852	23138
1-Apr-18	18647	17533
1-May-18	12242	14652
1-Jun-18	4566	7161
1-Jul-18	11147	15536
1-Aug-18	4972	3365
1-Sep-18	23465	26983
1-Oct-18	13797	3965
1-Nov-18	3092	4912
1-Dec-18	8540	7798
1-Jan-19	10953	8362
1-Feb-19	11339	9344
1-Mar-19	24064	23069
1-Apr-19	20059	19605
1-May-19	17411	16394
1-Jun-19	8476	10617
1-Jul-19	19395	19219
1-Aug-19	7276	9331
1-Sep-19	27157	31118
1-Oct-19	3021	7878
1-Nov-19	2959	1480
1-Dec-19	4060	6015
1-Jan-20	2019	5231
1-Feb-20	3689	3311
1-Mar-20	18518	16228
1-Apr-20		13411
1-May-20		9973
1-Jun-20		3687
1-Jul-20		13360
1-Aug-20		3384
1-Sep-20		26199
1-Oct-20		4939
1-Nov-20		970
1-Dec-20		4766
1-Jan-21		4959
1-Feb-21		4645
1-Mar-21		17373

FORECAST OF B CATEGORY ITEMS

76 ALUMINIUM ALLOY

Model Description

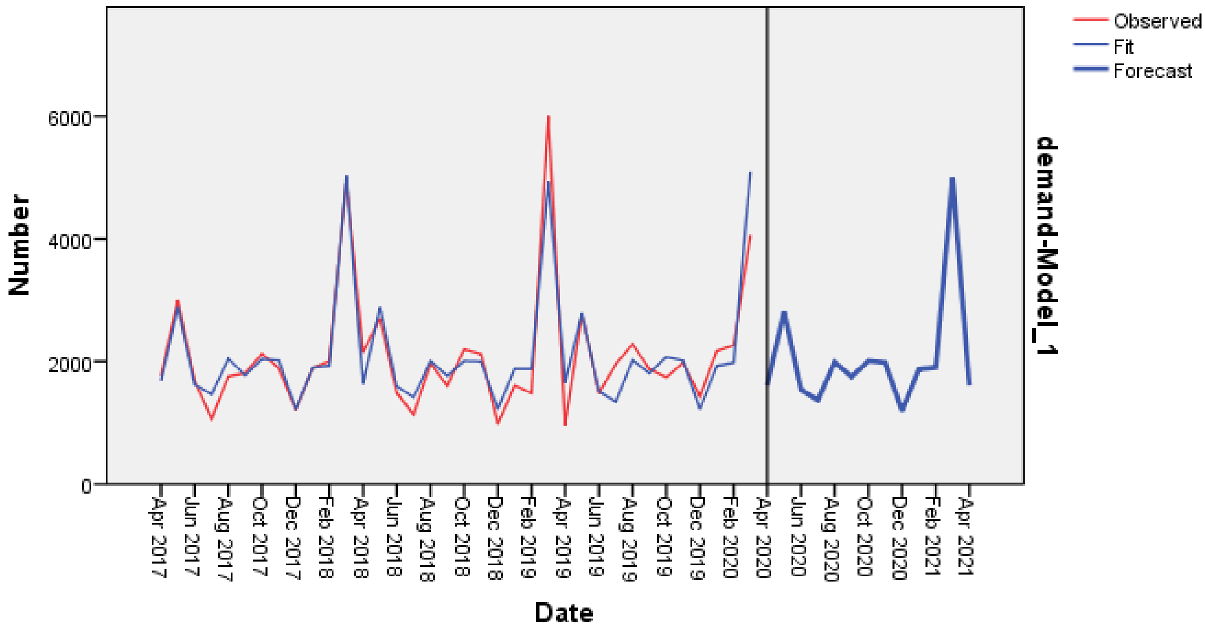
			Model Type
Model ID	demand	Model_1	Simple Seasonal

Model Fit

Fit Statistic	Mean	SE	Minimum	Maximum	Percentile 5	10	25	50	75	90	95
Stationary R-squared	.795	.	.795	.795	.795	.795	.795	.795	.795	.795	.795
R-squared	.879	.	.879	.879	.879	.879	.879	.879	.879	.879	.879
RMSE	364.393	.	364.393	364.393	364.393	364.393	364.393	364.393	364.393	364.393	364.393
MAPE	12.991	.	12.991	12.991	12.991	12.991	12.991	12.991	12.991	12.991	12.991
MaxAPE	72.243	.	72.243	72.243	72.243	72.243	72.243	72.243	72.243	72.243	72.243
MAE	243.663	.	243.663	243.663	243.663	243.663	243.663	243.663	243.663	243.663	243.663
MaxAE	1068.157	.	1068.157	1068.157	1068.157	1068.157	1068.157	1068.157	1068.157	1068.157	1068.157
Normalized BIC	11.996	.	11.996	11.996	11.996	11.996	11.996	11.996	11.996	11.996	11.996

Model Statistics

Model	Number of Predictors	Model Fit statistics: Stationary R-squared	R-squared	RMSE	MAPE	MAE	MaxAPE	MaxAE	Ljung-Box Q(18): Statistics	DF	Sig.	Number of Outliers
demand-Model_1	0	.795	.879	364.393	12.991	243.663	72.243	1068.157	30.313	16	.016	0



Time	observed value	forecasted value
1-Apr-17	1767	1680
1-May-17	2997	2888
1-Jun-17	1686	1625
1-Jul-17	1066	1464
1-Aug-17	1756	2042
1-Sep-17	1813	1775
1-Oct-17	2125	2037
1-Nov-17	1887	2019
1-Dec-17	1206	1218
1-Jan-18	1889	1898
1-Feb-18	2003	1925
1-Mar-18	4971	5029
1-Apr-18	2149	1637
1-May-18	2700	2887
1-Jun-18	1486	1594

1-Jul-18	1132	1417
1-Aug-18	1968	2006
1-Sep-18	1603	1764
1-Oct-18	2197	2006
1-Nov-18	2123	1998
1-Dec-18	982	1222
1-Jan-19	1607	1881
1-Feb-19	1482	1881
1-Mar-19	6005	4937
1-Apr-19	962	1657
1-May-19	2779	2787
1-Jun-19	1482	1512
1-Jul-19	1955	1342
1-Aug-19	2282	2021
1-Sep-19	1876	1809
1-Oct-19	1744	2074
1-Nov-19	1975	2014
1-Dec-19	1433	1222
1-Jan-20	2171	1925
1-Feb-20	2265	1977
1-Mar-20	4061	5102
1-Apr-20		1611
1-May-20		2811
1-Jun-20		1537
1-Jul-20		1370
1-Aug-20		1987
1-Sep-20		1749
1-Oct-20		2007
1-Nov-20		1980
1-Dec-20		1192
1-Jan-21		1874

1-Feb-21		1902
1-Mar-21		4998

6082 ALUMINIUM PLATE

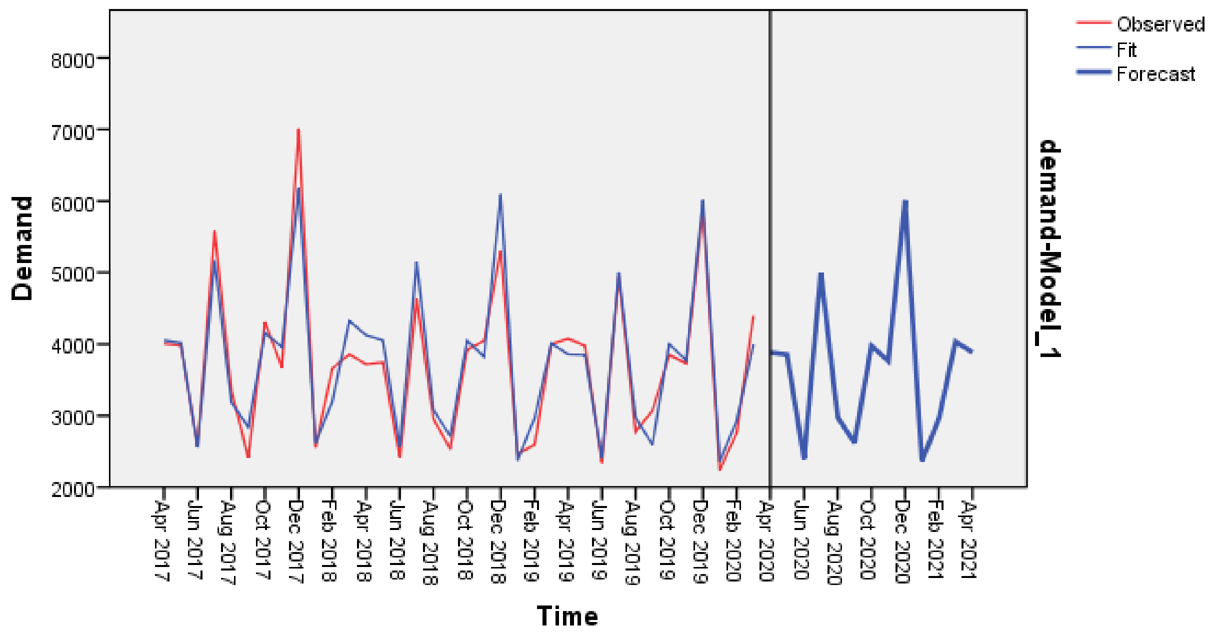
Model Description

			Model Type
Model ID	demand	Model_1	Simple Seasonal

Model Summary

Model Fit

Fit Statistic	Mean	SE	Minimum	Maximum	Percentile						
					5	10	25	50	75	90	95
Stationary R-squared	.871	.	.871	.871	.871	.871	.871	.871	.871	.871	.871
R-squared	.914	.	.914	.914	.914	.914	.914	.914	.914	.914	.914
RMSE	328.119	.	328.119	328.119	328.119	328.119	328.119	328.119	328.119	328.119	328.119
MAPE	6.596	.	6.596	6.596	6.596	6.596	6.596	6.596	6.596	6.596	6.596
MaxAPE	17.999	.	17.999	17.999	17.999	17.999	17.999	17.999	17.999	17.999	17.999
MAE	246.876	.	246.876	246.876	246.876	246.876	246.876	246.876	246.876	246.876	246.876
MaxAE	835.656	.	835.656	835.656	835.656	835.656	835.656	835.656	835.656	835.656	835.656
Normalized BIC	11.786	.	11.786	11.786	11.786	11.786	11.786	11.786	11.786	11.786	11.786



Time	observed values	Predicted values
1-Apr-17	4006	4018
1-May-17	3986	2557
1-Jun-17	2575	5163
1-Jul-17	5579	3185
1-Aug-17	3360	2841
1-Sep-17	2408	4156
1-Oct-17	4310	3958
1-Nov-17	3667	6176
1-Dec-17	7012	2618
1-Jan-18	2556	3197
1-Feb-18	3660	4325
1-Mar-18	3858	4125
1-Apr-18	3716	4054
1-May-18	3745	2566
1-Jun-18	2418	5156
1-Jul-18	4631	3083
1-Aug-18	2953	2709
1-Sep-18	2530	4049

1-Oct-18	3922	3824
1-Nov-18	4046	6093
1-Dec-18	5312	2373
1-Jan-19	2463	2967
1-Feb-19	2595	4011
1-Mar-19	4003	3858
1-Apr-19	4077	3850
1-May-19	3978	2405
1-Jun-19	2344	5003
1-Jul-19	4940	2977
1-Aug-19	2777	2596
1-Sep-19	3069	4001
1-Oct-19	3848	3773
1-Nov-19	3729	6016
1-Dec-19	5859	2358
1-Jan-20	2238	2932
1-Feb-20	2759	3996
1-Mar-20	4397	3883
1-Apr-20		3853
1-May-20		2395
1-Jun-20		5000
1-Jul-20		2980
1-Aug-20		2619
1-Sep-20		3976
1-Oct-20		3764
1-Nov-20		6011
1-Dec-20		2369
1-Jan-21		2954
1-Feb-21		4036
1-Mar-21		3883

ALLOY STEEL BAR

Model Description

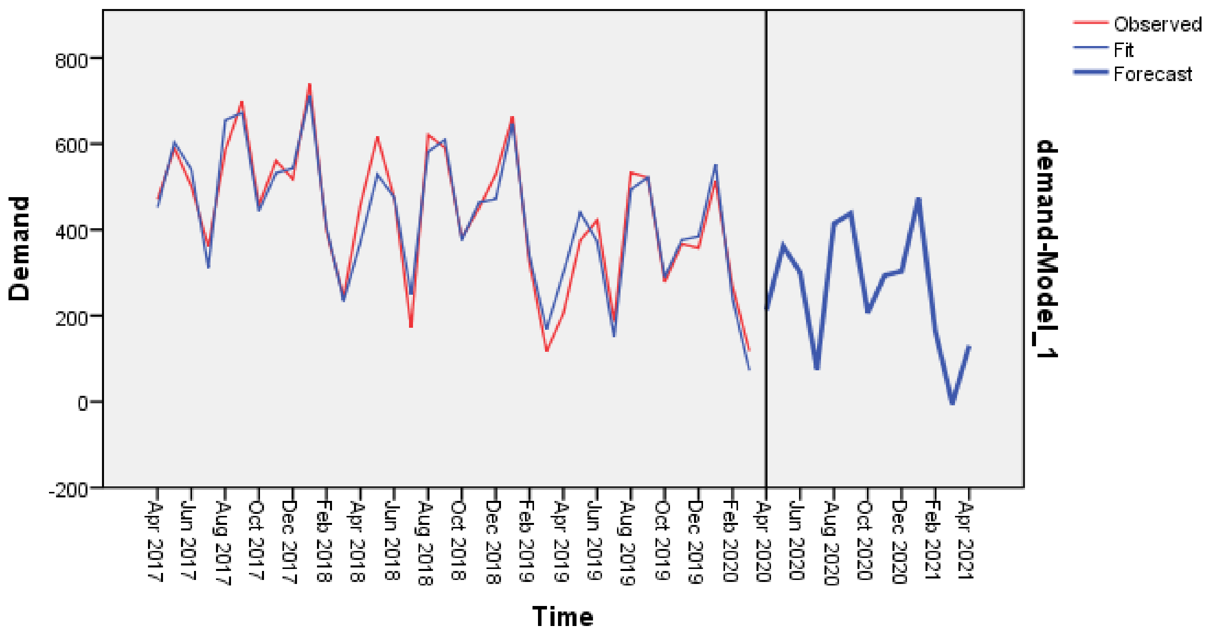
	Model Type
Model ID demand Model_1	Winters' Additive

Model Fit

Fit Statistic	Mean	SE	Minimum	Maximum	Percentile						
					5	10	25	50	75	90	95
Stationary R-squared	.790	.	.790	.790	.790	.790	.790	.790	.790	.790	.790
R-squared	.928	.	.928	.928	.928	.928	.928	.928	.928	.928	.928
RMSE	44.877	.	44.877	44.877	44.877	44.877	44.877	44.877	44.877	44.877	44.877
MAPE	10.930	.	10.930	10.930	10.930	10.930	10.930	10.930	10.930	10.930	10.930
MaxAPE	46.112	.	46.112	46.112	46.112	46.112	46.112	46.112	46.112	46.112	46.112
MAE	34.647	.	34.647	34.647	34.647	34.647	34.647	34.647	34.647	34.647	34.647
MaxAE	94.530	.	94.530	94.530	94.530	94.530	94.530	94.530	94.530	94.530	94.530
Normalized BIC	7.906	.	7.906	7.906	7.906	7.906	7.906	7.906	7.906	7.906	7.906

Model Statistics

Model	Number of Predictors	Model Fit statistics				Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	R-squared	RMSE	MAPE	Statistics	DF	Sig.	
demand-Model_1	0	.790	.928	44.877	10.930	30.647	15	.010	0



Time	observed value	predicted value
1-Apr-17	471	452
1-May-17	590	603
1-Jun-17	502	541
1-Jul-17	361	312
1-Aug-17	584	655
1-Sep-17	699	673
1-Oct-17	457	444
1-Nov-17	561	532
1-Dec-17	518	544
1-Jan-18	740	712
1-Feb-18	396	405
1-Mar-18	244	235
1-Apr-18	458	371
1-May-18	617	529
1-Jun-18	474	475
1-Jul-18	172	250
1-Aug-18	621	582
1-Sep-18	591	610
1-Oct-18	380	376
1-Nov-18	450	464
1-Dec-18	529	472
1-Jan-19	664	648
1-Feb-19	323	339
1-Mar-19	117	168

1-Apr-19	205	300
1-May-19	375	440
1-Jun-19	422	373
1-Jul-19	188	152
1-Aug-19	533	494
1-Sep-19	521	522
1-Oct-19	279	290
1-Nov-19	367	377
1-Dec-19	358	385
1-Jan-20	514	553
1-Feb-20	268	239
1-Mar-20	118	73
1-Apr-20		213
1-May-20		362
1-Jun-20		301
1-Jul-20		75
1-Aug-20		414
1-Sep-20		438
1-Oct-20		207
1-Nov-20		294
1-Dec-20		303
1-Jan-21		474
1-Feb-21		164
1-Mar-21		60

PROCUREMENT

The basic assumptions of our model are:

1. Demand is **different** in each period.
2. Procurement/Production is **done at the beginning of period**.
3. Demand is met **uniformly throughout the period**.
4. Shortages are **not** allowed.

NOTATION:

Cn: Total cost up to and including the nth period

r_i : Requirement of the i^{th} period

A: Ordering Cost

IC: Inventory Carrying Cost

C: Cost per unit

FLAT CR SHEET

Unit cost=Rs.55.71

Ordering cost=Rs.1350

(BREAK UP OF THE ORDERING COSTS

Paper work cost=Rs.150

Follow Up cost=Rs.450

Inspection Cost=Rs.500

Clerical and staff related cost=Rs.250)

Inventory carrying charge (I) =14 %(annual)

= 0.14 per year

= 0.14/12 per Month

= 0.01167 per Month

Inventory carrying cost(IC)=0.011667*55.71

=Rs.0.64995

<u>Breakup of the inventory carrying charge</u>

1. Capital cost = 8.25%

2. Insurance cost = 1%

3. Tax =1%

4. Warehouse = 0.75%

5. Shrinkage cost = 1%

6. Administrative cost = 2%

r_i	Month	Demand
1	Apr'20	29727.9
2	May'20	28402.5
3	June'20	32331.45
4	July'20	34579.09
5	Aug'20	26744.08
6	Sep'20	24591.07
7	Oct'20	32680.09
8	Nov'20	22350.45
9	Dec'20	32661.49
10	Jan'21	37328.55
11	Feb'21	38772.65
12	Mar'21	23710.45

Let us consider it as ONE period problem:

C 1 = C 0 + A + C * r 1 + (IC/2) * r 1 ; [C0=0]

= 1667150

Let Us consider it as a TWO period problem

C 2 (1) = C 0 + A + C * (r 1 + r 2) + (IC/2) *(r 1 + 3r 2)

= 3277137

C 2 (2) = C 1 + A + C * (r 2) + (IC/2) *(r 2)

= 3260031

C 2 = min {C 2 (1), C 2 (2)}

= 3260031

Let Us consider it as a THREE period problem

C 3 (1) = C 0 + A + C * (r 1 + r 2 + r 3) + (IC/2) *(r 1 + 3r 2 + 5r 3)

= 5130844

C 3 (2) = C 1 + A + C * (r 2 + r 3) + (IC/2) *(r 2 + 3r 3)

= 5092729

C 3 (3) = C 2 + A + C * (r 3) + (IC/2) *(r 3)

= 5073070

C 3 = min {C 3 (1),C 3 (2),C 3 (3) }

= 5073070

Let Us consider it as a FOUR period problem

C 4 (1) = C 0 + A + C * (r 1 + r 2 + r 3 + r 4) + (IC/2) *(r 1 + 3r 2 + 5r 3 + 7r 4)

= 7135889

C 4 (2) = C 1 + A + C * (r 2 + r 3 + r 4) + (IC/2) *(r 2 + 3r 3 + 5r 4)

= 7075304

C 4 (3) = C 2 + A + C * (r 3 + r 4) + (IC/2) *(r 3 + 3r 4)

= 7033176

C 4 (4) = C 3 + A + C * (r 4) + (IC/2) *(r 4)

= 7012056

$C_4 = \min \{C_4(1), C_4(2), C_4(3), C_4(4)\}$

$= 7012056$

Let Us consider it as a FIVE period problem

$C_5(1) = C_0 + A + C * (r_1 + r_2 + r_3 + r_4 + r_5) + (IC/2) *(r_1 + 3r_2 + 5r_3 + 7r_4 + 9r_5)$

$= 8704003$

$C_5(2) = C_1 + A + C * (r_2 + r_3 + r_4 + r_5) + (IC/2) *(r_2 + 3r_3 + 5r_4 + 7r_5)$

$= 8626041$

$C_5(3) = C_2 + A + C * (r_3 + r_4 + r_5) + (IC/2) *(r_3 + 3r_4 + 5r_5)$

$= 8566534$

$C_5(4) = C_3 + A + C * (r_4 + r_5) + (IC/2) *(r_4 + 3r_5)$

$= 8528036$

$C_5(5) = C_4 + A + C * (r_5) + (IC/2) *(r_5)$

$= 8512008$

$C_5 = \min \{C_5(1), C_5(2), C_5(3), C_5(4), C_5(5)\}$

$=8512008$

Let Us consider it as a SIX period problem

$C_6(1) = C_0 + A + C * (r_1 + r_2 + r_3 + r_4 + r_5 + r_6) + (IC/2) *(r_1 + 3r_2 + 5r_3 + 7r_4 + 9r_5 + 11r_6)$

$= 10161858$

$C_6(2) = C_1 + A + C * (r_2 + r_3 + r_4 + r_5 + r_6) + (IC/2) *(r_2 + 3r_3 + 5r_4 + 7r_5 + 9r_6)$

$= 10067916$

C 6 (3) = C 2 + A + C * (r 3 + r 4 + r 5 + r 6) + (IC/2) *(r 3 + 3r 4 + 5r 5 + 7r 6)

= 9992430

C 6 (4) = C 3 + A + C * (r 4 + r 5 + r 6) + (IC/2) *(r 4 + 3r 5 + 5r 6)

= 9937953

C 6 (5) = C 4 + A + C * (r 5 + r 6) + (IC/2) *(r 5 + 3r 6)

=9905946

C 6 (6) = C 5 + A + C * (r 6) + (IC/2) *(r 6)

= 9891316

C 6 = min {C 6 (1),C 6 (2),C 6 (3), C 6 (4), C 6 (5), C 6 (6) }

=9891316

Let Us consider it as a SEVEN period problem

C 7 (1) = C 0 + A + C * (r 1 + r 2 + r 3 + r 4 + r 5 + r 6 + r 7) + (IC/2) *(r 1 + 3r 2 + 5r 3 + 7r 4 + 9r 5 +11r 6 + 13r 7)

= 12120497

C 7 (2) = C 1 + A + C * (r 2 + r 3 + r 4 + r 5 + r 6 + r 7) + (IC/2) *(r 2 + 3r 3 + 5r 4 + 7r 5 + 9r 6 + 11r 7)

= 12005319

C 7 (3) = C 2 + A + C * (r 3 + r 4 + r 5 + r 6 + r 7) + (IC/2) *(r 3 + 3r 4 + 5r 5 + 7r 6 + 9r 7)

= 11908598

C 7 (4) = C 3 + A + C * (r 4 + r 5 + r 6 + r 7) + (IC/2) *(r 4 + 3r 5 + 5r 6 + 7r 7)

= 11832885

C 7 (5) = C 4 + A + C * (r 5 + r 6 + r 7) + (IC/2) *(r 5 + 3r 6 + 5r 7)

= 11779642

C 7 (6) = C 5 + A + C * (r 6 + r 7) + (IC/2) *(r 6 + 3r 7)

= 11743777

C 7 (7) = C 6 + A + C * (r 7) + (IC/2) *(r 7)

= 11723892

C 7 = min {C 7 (1),C 7 (2),C 7 (3), C 7 (4), C 7 (5), C 7 (6), C 7 (7) }

= 11723892

Let Us consider it as an EIGHT period problem

C 8 (1) = C 0 + A + C * (r 1 + r 2 + r 3 + r 4 + r 5 + r 6 + r 7 + r 8) + (IC/2) *(r 1 + 3r 2 + 5r 3 + 7r 4 + 9r 5 +11r 6 + 13r 7 + 15r 8)

= 13474565

C 8 (2) = C 1 + A + C * (r 2 + r 3 + r 4 + r 5 + r 6 + r 7 + r 8) + (IC/2) *(r 2 + 3r 3 + 5r 4 + 7r 5 + 9r 6 +11r 7 + 13r 8)

= 13344864

C 8 (3) = C 2 + A + C * (r 3 + r 4 + r 5 + r 6 + r 7 + r 8) + (IC/2) *(r 3 + 3r 4 + 5r 5 + 7r 6 + 9r 7 + 11r 8)

=13233619

C 8 (4) = C 3 + A + C * (r 4 + r 5 + r 6 + r 7 + r 8) + (IC/2) *(r 4 + 3r 5 + 5r 6 + 7r 7 + 9r 8)

= 13143383

C 8 (5) = C 4 + A + C * (r 5 + r 6 + r 7 + r 8) + (IC/2) *(r 5 + 3r 6 + 5r 7 + 7r 8)

= 13075617

C 8 (6) = C 5 + A + C * (r 6 + r 7 + r 8) + (IC/2) *(r 6 + 3r 7 + 5r 8)

= 13025229

C 8 (7) = C 6 + A + C * (r 7 + r 8) + (IC/2) *(r 7 + 3r 8)

= 12990820

C 8 (8) = C 7 + A + C * (r 8) + (IC/2) *(r 8)

= 12977647

C 8 = min {C 8 (1),C 8 (2),C 8 (3), C 8 (4), C 8 (5), C 8 (6), C 8 (7), C 8 (8) }

= 12977647

Let Us consider it as a NINE period problem

C 9 (1) = C 0 + A + C * (r 1 + r 2 + r 3 + r 4 + r 5 + r 6 + r 7 + r 8 + r 9) + (IC/2) *(r 1 + 3r 2 + 5r 3 + 7r 4 +9r 5 + 11r 6 + 13r 7 + 15r 8 + 17r 9)

= 15474536

C 9 (2) = C 1 + A + C * (r 2 + r 3 + r 4 + r 5 + r 6 + r 7 + r 8 + r 9) + (IC/2) *(r 2 + 3r 3 + 5r 4 + 7r 5 + 9r 6 +11r 7 + 13r 8 + 15r 9)

= 15323611

C 9 (3) = C 2 + A + C * (r 3 + r 4 + r 5 + r 6 + r 7 + r 8 + r 9) + (IC/2) *(r 3 + 3r 4 + 5r 5 + 7r 6 + 9r 7 +11r 8 + 13r 9)

= 15191143

C 9 (4) = C 3 + A + C * (r 4 + r 5 + r 6 + r 7 + r 8 + r 9) + (IC/2) *(r 4 + 3r 5 + 5r 6 + 7r 7 + 9r 8 + 11r 9)

= 15079684

C 9 (5) = C 4 + A + C * (r 5 + r 6 + r 7 + r 8 + r 9) + (IC/2) *(r 5 + 3r 6 + 5r 7 + 7r 8 + 9r 9)

= 14990694

C 9 (6) = C 5 + A + C * (r 6 + r 7 + r 8 + r 9) + (IC/2) *(r 6 + 3r 7 + 5r 8 + 7r 9)

= 14919082

C 9 (7) = C 6 + A + C * (r 7 + r 8 + r 9) + (IC/2) *(r 7 + 3r 8 + 5r 9)

= 14863450

C 9 (8) = C 7 + A + C * (r 8 + r 9) + (IC/2) *(r 8 + 3r 9)

= 14829053

C 9 (9) = C 8 + A + C * (r 9) + (IC/2) *(r 9)

= 14809180

C 9 = min {C 9 (1),C 9 (2),C 9 (3), C 9 (4), C 9 (5), C 9 (6), C 9 (7), C 9 (8), C 9 (9) }

= 14809180

Let Us consider it as a TEN period problem

C 10 (1) = C 0 + A + C * (r 1 + r 2 + r 3 + r 4 + r 5 + r 6 + r 7 + r 8 + r 9 + r 10) + (IC/2) *(r 1 + 3r 2 + 5r 3 +7r 4 + 9r 5 + 11r 6 + 13r 7 + 15r 8 + 17r 9 + 19r 10)

= 17784542

C 10 (2) = C 1 + A + C * (r 2 + r 3 + r 4 + r 5 + r 6 + r 7 + r 8 + r 9 + r 10) + (IC/2) *(r 2 + 3r 3 + 5r 4 + 7r 5 +9r 6 + 11r 7 + 13r 8 + 15r 9 + 17r 10)

= 17609362

C 10 (3) = C 2 + A + C * (r 3 + r 4 + r 5 + r 6 + r 7 + r 8 + r 9 + r 10) + (IC/2) *(r 3 + 3r 4 + 5r 5 + 7r 6 + 9r 7+ 11r 8 + 13r 9 + 15r 10)

= 17452637

C 10 (4) = C 3 + A + C * (r 4 + r 5 + r 6 + r 7 + r 8 + r 9 + r 10) + (IC/2) *(r 4 + 3r 5 + 5r 6 + 7r 7 + 9r 8 +11r 9 + 13r 10)

= 17316922

C 10 (5) = C 4 + A + C * (r 5 + r 6 + r 7 + r 8 + r 9 + r 10) + (IC/2) *(r 5 + 3r 6 + 5r 7 + 7r 8 + 9r 9 + 11r 10)

= 17203676

C 10 (6) = C 5 + A + C * (r 6 + r 7 + r 8 + r 9 + r 10) + (IC/2) *(r 6 + 3r 7 + 5r 8 + 7r 9 + 9r 10)

= 17107808

C 10 (7) = C 6 + A + C * (r 7 + r 8 + r 9 + r 10) + (IC/2) *(r 7 + 3r 8 + 5r 9 + 7r 10)

=17027920

C 10 (8) = C 7 + A + C * (r 8 + r 9 + r 10) + (IC/2) *(r 8 + 3r 9 + 5r 10)

= 16969267

C 10 (9) = C 8 + A + C * (r 9 + r 10) + (IC/2) *(r 9 + 3r 10)

= 16925138

C 10 (10) = C 9 + A + C * (r 10) + (IC/2) *(r 10)

= 16902231

C 10 = min {C 10 (1),C 10 (2),C 10 (3), C 10 (4), C 10 (5), C 10 (6), C 10 (7), C 10 (8), C 10 (9), C 10 (10)}

= 16902231

Let Us consider it as a ELEVEN period problem

C 11 (1) = C 0 + A + C * (r 1 + r 2 + r 3 + r 4 + r 5 + r 6 + r 7 + r 8 + r 9 + r 10 + r 11) + (IC/2) *(r 1 + 3r 2 +5r 3 + 7r 4 + 9r 5 + 11r 6 + 13r 7 + 15r 8 + 17r 9 + 19r 10 + 21r 11)

= 20209108

C 11 (2) = C 1 + A + C * (r 2 + r 3 + r 4 + r 5 + r 6 + r 7 + r 8 + r 9 + r 10 + r 11) + (IC/2) *(r 2 + 3r 3 + 5r 4 +7r 5 + 9r 6 + 11r 7 + 13r 8 + 15r 9 + 17r 10 + 19r 11)

=20008733

C 11 (3) = C 2 + A + C * (r 3 + r 4 + r 5 + r 6 + r 7 + r 8 + r 9 + r 10 + r 11) + (IC/2) *(r 3 + 3r 4 + 5r 5 + 7r 6+ 9r 7 + 11r 8 + 13r 9 + 15r 10 + 17r 11)

= 19826815

C 11 (4) = C 3 + A + C * (r 4 + r 5 + r 6 + r 7 + r 8 + r 9 + r 10 + r 11) + (IC/2) *(r 4 + 3r 5 + 5r 6 + 7r 7 + 9r 8+ 11r 9 + 13r 10 + 15r 11)

= 19665905

C 11 (5) = C 4 + A + C * (r 5 + r 6 + r 7 + r 8 + r 9 + r 10 + r 11) + (IC/2) *(r 5 + 3r 6 + 5r 7 + 7r 8 + 9r 9 +11r 10 + 13r 11)

= 19527464

C 11 (6) = C 5 + A + C * (r 6 + r 7 + r 8 + r 9 + r 10 + r 11) + (IC/2) *(r 6 + 3r 7 + 5r 8 + 7r 9 + 9r 10 +11r 11)

= 19406402

C 11 (7) = C 6 + A + C * (r 7 + r 8 + r 9 + r 10 + r 11) + (IC/2) *(r 7 + 3r 8 + 5r 9 + 7r 10 + 9r 11)

= 19301319

C 11 (8) = C 7 + A + C * (r 8 + r 9 + r 10 + r 11) + (IC/2) *(r 8 + 3r 9 + 5r 10 + 7r 11)

=19217472

C 11 (9) = C 8 + A + C * (r 8 + r 10 + r 11) + (IC/2) *(r 9 + 3r 10 + 5r 11)

= 19148148

C 11 (10) = C 9 + A + C * (r 10 + r 11) + (IC/2) *(r 10 + 3r 11)

= 19100047

C 11 (11) = C 10 + A + C * (r 11) + (IC/2) *(r 11)

= 19076203

C 11 = min {C 11 (1),C 11 (2),C 11 (3), C 11 (4), C 11 (5), C 11 (6), C 11 (7), C 11 (8), C 11 (9), C 11 (10),C 11 (11) }

= 19076203

Let Us consider it as a TWELVE period problem

C 12 (1) = C 0 + A + C * (r 1 + r 2 + r 3 + r 4 + r 5 + r 6 + r 7 + r 8 + r 9 + r 10 + r 11 + r 12) + (IC/2) *(r 1 +3r 2 + 5r 3 + 7r 4 + 9r 5 + 11r 6 + 13r 7 + 15r 8 + 17r 9 + 19r 10 + 21r 11 + 23r 12)

= 21707199

C 12 (2) = C 0 + A + C * (r 2 + r 3 + r 4 + r 5 + r 6 + r 7 + r 8 + r 9 + r 10 + r 11 + r 12) + (IC/2) *(r 2 + 3r 3 +5r 4 + 7r 5 + 9r 6 + 11r 7 + 13r 8 + 15r 9 + 17r 10 + 19r 11 + 21r 12)

= 21491417

C 12 (3) = C 1 + A + C * (r 3 + r 4 + r 5 + r 6 + r 7 + r 8 + r 9 + r 10 + r 11 + r 12) + (IC/2) *(r 3 + 3r 4 + 5r 5+ 7r 6 + 9r 7 + 11r 8 + 13r 9 + 15r 10 + 17r 11 + 19r 12)

= 21294091

$C_{12}(4) = C_2 + A + C * (r_4 + r_5 + r_6 + r_7 + r_8 + r_9 + r_{10} + r_{11} + r_{12}) + (IC/2) *(r_4 + 3r_5 + 5r_6 + 7r_7 + 9r_8 + 11r_9 + 13r_{10} + 15r_{11} + 17r_{12})$

= 21117774

$C_{12}(5) = C_3 + A + C * (r_5 + r_6 + r_7 + r_8 + r_9 + r_{10} + r_{11} + r_{12}) + (IC/2) *(r_5 + 3r_6 + 5r_7 + 7r_8 + 9r_9 + 11r_{10} + 13r_{11} + 15r_{12})$

= 20963927

$C_{12}(6) = C_4 + A + C * (r_6 + r_7 + r_8 + r_9 + r_{10} + r_{11} + r_{12}) + (IC/2) *(r_6 + 3r_7 + 5r_8 + 7r_9 + 9r_{10} + 11r_{11} + 13r_{12})$

= 20827457

$C_{12}(7) = C_5 + A + C * (r_7 + r_8 + r_9 + r_{10} + r_{11} + r_{12}) + (IC/2) *(r_7 + 3r_8 + 5r_9 + 7r_{10} + 9r_{11} + 11r_{12})$

= 20706967

$C_{12}(8) = C_6 + A + C * (r_8 + r_9 + r_{10} + r_{11} + r_{12}) + (IC/2) *(r_8 + 3r_9 + 5r_{10} + 7r_{11} + 9r_{12})$

= 20607713

$C_{12}(9) = C_7 + A + C * (r_9 + r_{10} + r_{11} + r_{12}) + (IC/2) *(r_9 + 3r_{10} + 5r_{11} + 7r_{12})$

= 20522982

$C_{12}(10) = C_8 + A + C * (r_{10} + r_{11} + r_{12}) + (IC/2) *(r_{10} + 3r_{11} + 5r_{12})$

= 20459474

$C_{12}(11) = C_9 + A + C * (r_{11} + r_{12}) + (IC/2) *(r_{11} + 3r_{12})$

= 20420223

$C_{12}(12) = C_{10} + A + C * (r_{12}) + (IC/2) *(r_{12})$

= 20406166

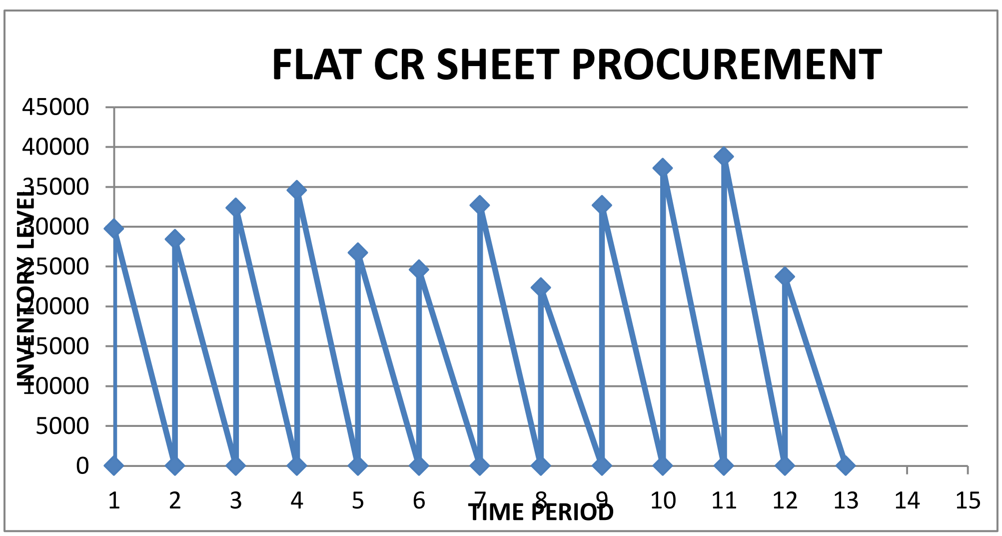
$C_{12} = \min\{C_{12}(1), C_{12}(2), C_{12}(3), C_{12}(4), C_{12}(5), C_{12}(6), C_{12}(7), C_{12}(8), C_{12}(9), C_{12}(10), C_{12}(11), C_{12}(12)\} = 20406166$

last period with ordering	Planning Horizon											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1667150	3277137	5130844	7135889	8704003	10161858	12120497	13474565	15474536	17784542	20209108	21707199
2		3260031	5092729	7075304	8626041	10067916	12005319	13344864	15323611	17609362	20008733	21491417
3			5073070	7033176	8566534	9992430	11908598	13233619	15191143	17452637	19826815	21294091
4				7012056	8528036	9937953	11832885	13143383	15079684	17316922	19665905	21117774
5					8512008	9905946	11779642	13075617	14990694	17203676	19527464	20963927
6						9891316	11743777	13025229	14919082	17107808	19406402	20827457
7							11723892	12990820	14863450	17027920	19301319	20706967
8								12977647	14829053	16969267	19217472	20607713
9									14809180	16925138	19148148	20522982
10										16902231	19100047	20459474
11											19076203	20420223
12												20406166
Ct(min cost)	1667150	3260031	5073070	7012056	8512008	9891316	11723892	12977647	14809180	16902231	19076203	20406166
jt(month of procurement)	1	2	3	4	5	6	7	8	9	10	11	12
Name of month (for procurement)	Apr'20	May'20	June'20	July'20	Aug'20	Sep'20	Oct'20	Nov'20	Dec'20	Jan'21	Feb'21	Mar'21
c (per unit cost)	*55.71*											
a (ordering cost)	1350											
ic/2 (inventory carrying cost/2)	0.3249											

The procurement cost by using this model=Rs.20406166

Procurement policy:

The table shows the cost of procurement provided by the model for each month. The Highlighted cells show the minimum cost of procurement. Application of Wagner Whiten procurement model suggests that the optimum procurement policy for the **FLAT CR SHEET** should ***be the procurement of each month's requirement should be done in beginning of each month, i.e. For April 2020 requirement must be procured at the beginning of April 2020, and so on***



MONTH	QUANTITY TO BE ORDERED
apr'20	29728
May'20	28402
June'20	32331
July'20	34579
Aug'20	26744
Sep'20	24591
Oct'20	32680
Nov'20	22350
Dec'20	32661
Jan'21	37329
Feb'21	38773
Mar'21	23710

316 L HOT ROLLED SHEETS

Unit cost=Rs.50.23

Ordering cost=Rs.1350

Inventory carrying charge (I) =16 %(annual)

= 0.16 per year

= 0.16/12 per Month

= 0.0133 per Month

Inventory carrying cost(IC)=0.01334*50.23

=Rs.0.6692

Breakup of the inventory carrying charge

1. Capital cost =11%

2. Insurance cost = 1%

3. Tax =1%

4. Warehouse = 2%

5. Shrinkage cost = 1%

6. Administrative cost = 2%

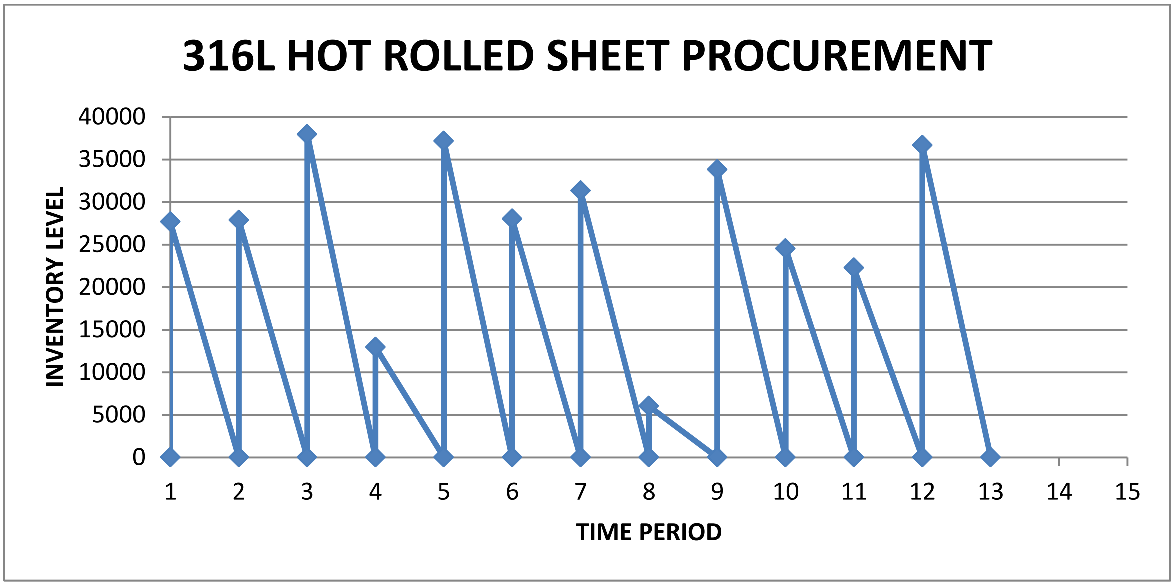
r_i	Month	Demand
1	Apr’20	27670
2	May’20	27870
3	June’20	37954
4	July’20	12936
5	Aug’20	37143
6	Sep’20	28030
7	Oct’20	31311
8	Nov’20	6003
9	Dec’20	33794
10	Jan’21	24533
11	Feb’21	22243
12	Mar’21	36676

last period with ordering	Planning Horizon											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1400478	2828381	4798345	5478437	7456049	8967225	10676255	11007932	12897747	14286099	15559751	17684406
2		2811069	4755619	5427050	7379791	8872198	10560261	10887920	12755106	14127030	15385788	17485885
3			4731555	5394324	7322194	8795832	10462930	10786568	12631126	13986623	15230487	17306026
4				5387012	7290011	8744880	10391012	10710631	12532560	13871630	15100600	17151581
5					7266490	8702590	10327756	10643356	12442656	13765299	14979375	17005798
6						8685171	10289372	10600951	12377624	13683839	14883021	16884886
7							10269756	10577316	12331360	13621148	14805436	16782742
8								10574646	12306062	13579422	14748817	16701565
9									12284783	13541717	14696217	16624407
10										13526639	14666246	16569877
11											14652702	16531775
12												16508567
Ct	1400478	2811069	4731555	5387012	7266490	8685171	10269756	10574646	12284783	13526639	14652702	16508567
jt	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Name of month (for procurement	Apr'20	May'20	June'20	July'20	Aug'20	Sep'20	Oct'20	Nov'20	Dec'20	Jan'21	Feb'21	Mar'21
c (per unit cost)	*50.23*											
a (ordering cost)	1350											
ic/2 (inventory carrying charge/2)	0.3348											

The procurement cost by using this model=Rs.16508567

Procurement policy:

The table shows the cost of procurement provided by the model for each month. The Highlighted cells show the minimum cost of procurement. Application of Wagner Whiten procurement model suggests that the optimum procurement policy for the **316L HOT ROLLED SHEET** should be ***the procurement of each month's requirement should be done in beginning of each month, i.e. For April 2020 requirement must be procured at the beginning of April 2020, and so on***



MONTH	QUANTITY TO BE ORDERED
apr'20	27670
May'20	27870
June'20	37954
July'20	12936
Aug'20	37143
Sep'20	28030
Oct'20	31311
Nov'20	6003
Dec'20	33794
Jan'21	24533
Feb'21	22243
Mar'21	36676

B Q PLATES

Unit cost=Rs.51.71

Ordering cost=Rs.1350

Inventory carrying charge (I) =15 %(annual)

= 0.15per year

= 0.15/12 per Month

= 0.0125 per Month

Inventory carrying cost(IC)=0.0125*51.71

=Rs.0.6463

Breakup of the inventory carrying charge

1. Capital cost =9.75%

2. Insurance cost = 1%

3. Tax =1%

4. Warehouse = 0.75%

5. Shrinkage cost = 1%

6. Administrative cost = 1.5%

r_i	Month	Demand
1	Apr'20	9848
2	May'20	11166
3	June'20	24096
4	July'20	13089
5	Aug'20	16083
6	Sep'20	15333
7	Oct'20	16639

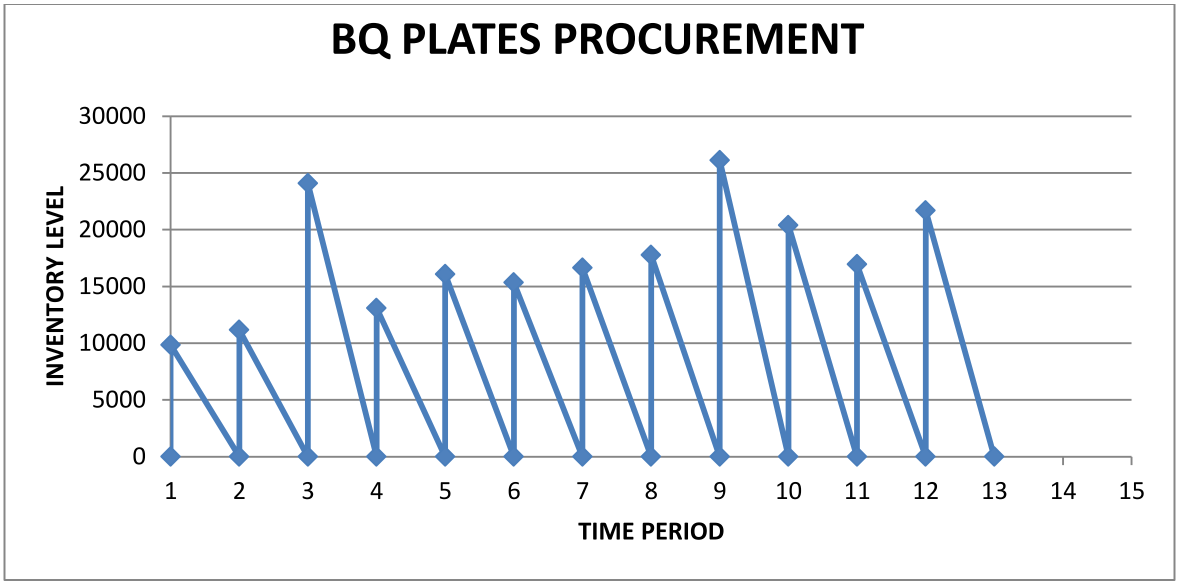
8	Nov’20	17756
9	Dec’20	26115
10	Jan’21	20401
11	Feb’21	16945
12	Mar’21	21679

last period with ordering	Planning Horizon											
	1	2	3	4	5	6	7	8	9	10	11	12
1	513773	1101993	2386937	3093381	3971816	4819197	5749510	6753754	8247647	9427861	10419096	11701270
2		1096126	2365493	3063477	3931515	4768985	5688543	6681310	8158322	9325349	10305630	11573791
3			2351268	3040791	3898433	4725992	5634794	6616083	8076214	9230054	10199383	11453530
4				3033680	3880926	4698574	5596621	6566432	8009683	9150335	10108711	11348845
5					3871880	4679616	5566908	6525242	7951612	9079077	10026499	11252620
6						4671055	5547591	6494448	7903937	9018215	9954684	11166791
7							5538186	6473565	7866173	8967264	9892780	11090874
8								6463437	7839165	8927069	9841631	11025712
9									7823634	8898351	9801960	10972027
10										8886513	9779169	10935224
11											9769566	10911607
12												10898944
Ct	513773	1096126	2351268	3033680	3871880	4671055	5538186	6463437	7823634	8886513	9769566	10898944
jt	1	2	3	4	5	6	7	8	9	10	11	12
Name of month (for procurement	Apr'20	May'20	June'20	July'20	Aug'20	Sep'20	Oct'20	Nov'20	Dec'20	Jan'21	Feb'21	Mar'21
c (per unit cost)	*51.71*											
a (ordering cost)	1350											
ic/2 (inventory carrying charge/2)	0.3232											

The procurement cost by using this model=Rs.10898944

Procurement policy:

The table shows the cost of procurement provided by the model for each month. The Highlighted cells show the minimum cost of procurement. Application of Wagner Whiten procurement model suggests that the optimum procurement policy for the **B Q PLATES** ***should be the procurement of each months requirement should be done in beginning of each month, i.e. For April 2020 requirement must be procured at the beginning of April 2020, and so on***



MONTH	QUANTITY TO BE ORDERED
apr'20	9848
May'20	11166
June'20	24096
July'20	13089
Aug'20	16083
Sep'20	15333
Oct'20	16639
Nov'20	17756
Dec'20	26115
Jan'21	20401
Feb'21	16945
Mar'21	21679

7209CR SHEETS

Unit cost=Rs.55.71

Ordering cost=Rs.1350

Inventory carrying charge (I) =18 %(annual)

= 0.18per year

= 0.18/12 per Month

= 0.015 per Month

Inventory carrying cost(IC) =0.015*55.71

=Rs.0.8356

<u>Breakup of the inventory carrying charge</u>

1. Capital cost =11.5%

2. Insurance cost = 1%

3. Tax =1%

4. Warehouse = 1.5%

5. Shrinkage cost = 1.5%

6. Administrative cost = 1.5%

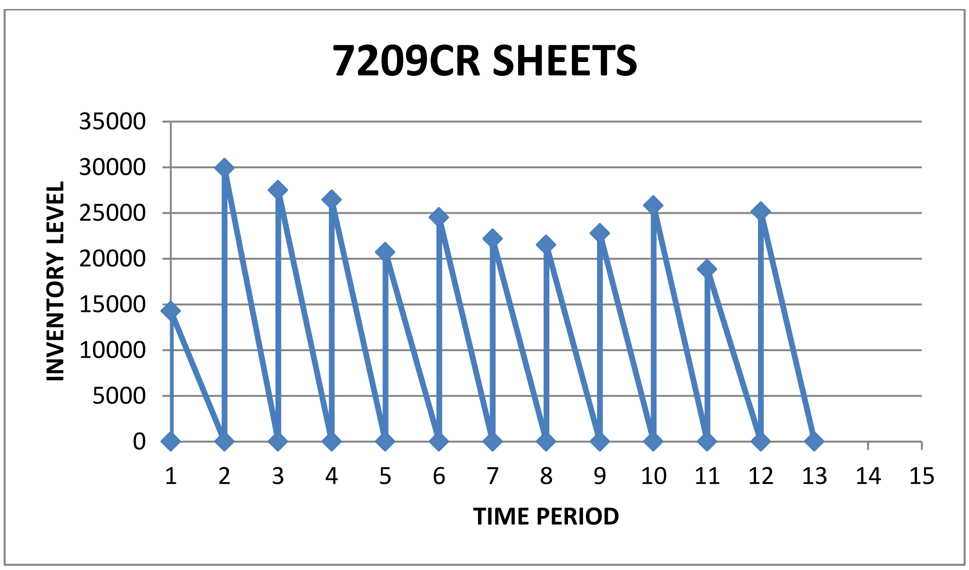
r_i	Month	Demand
1	Apr'20	14280
2	May'20	29891
3	June'20	27482
4	July'20	26424
5	Aug'20	20706
6	Sep'20	24515
7	Oct'20	22171
8	Nov'20	21500
9	Dec'20	22765
10	Jan'21	25806
11	Feb'21	18863
12	Mar'21	25153

last period with ordering	Planning Horizon											
	1	2	3	4	5	6	7	8	9	10	11	12
1	802884	2505636	4094123	5643537	6874968	8353414	9709024	11041573	12471547	14114104	15330500	16973529
2		2482009	4047533	5574866	6788996	8246957	9584041	10898624	12309576	13930569	15131203	16753214
3			4025919	5531172	6728000	8165476	9484034	10780652	12172581	13772011	14956883	16557877
4				5510442	6689968	8106959	9406992	10685644	12058551	13636417	14805527	16385503
5					6674016	8070523	9352029	10612716	11966600	13522903	14676251	16235209
6						8051388	9314368	10557089	11891952	13426691	14564277	16102217
7							9297192	10521948	11837788	13350964	14472788	15989710
8								10505333	11802150	13293763	14399825	15895729
9									11784477	13254527	14344827	15819713
10										13234313	14308851	15762720
11											14294440	15727290
12												15707622
Ct	802884	2482009	4025919	5510442	6674016	8051388	9297192	10505333	11784477	13234313	14294440	15707622
jt	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Name of month (for procurement)	Apr'20	May'20	June'20	July'20	Aug'20	Sep'20	Oct'20	Nov'20	Dec'20	Jan'21	Feb'21	Mar'21
c (per unit cost)	*55.712*											
a (ordering cost)	1350											
ic/2 (inventory carrying charge/2)	0.4178											

The procurement cost by using this model=Rs.15707622

Procurement policy:

The table shows the cost of procurement provided by the model for each month. The Highlighted cells show the minimum cost of procurement. Application of Wagner Whiten procurement model suggests that the optimum procurement policy for the **7209CR SHEETS** ***should be the procurement of each months requirement should be done in beginning of each month, i.e. For April 2020 requirement must be procured at the beginning of April 2020 and so on***



n

MONTH	QUANTITY TO BE ORDERED
apr'20	14280
May'20	29891
June'20	27482
July'20	26424
Aug'20	20706
Sep'20	24515
Oct'20	22171
Nov'20	21500
Dec'20	22765
Jan'21	25806
Feb'21	18863
Mar'21	25153

TMT BAR

Unit cost=Rs.48.68

Ordering cost=Rs.1350

Inventory carrying charge (I) =17 %(annual)

= 0.17 per year

= 0.17/12 per Month

= 0.01416 per Month

Inventory carrying cost(IC) =0.01416*48.68

=Rs.0.6896

Breakup of the inventory carrying charge

1. Capital cost =11.5%

2. Insurance cost = 1%

3. Tax =1%

4. Warehouse = 0.75%

5. Shrinkage cost = 1.25%

6. Administrative cost = 1.5%

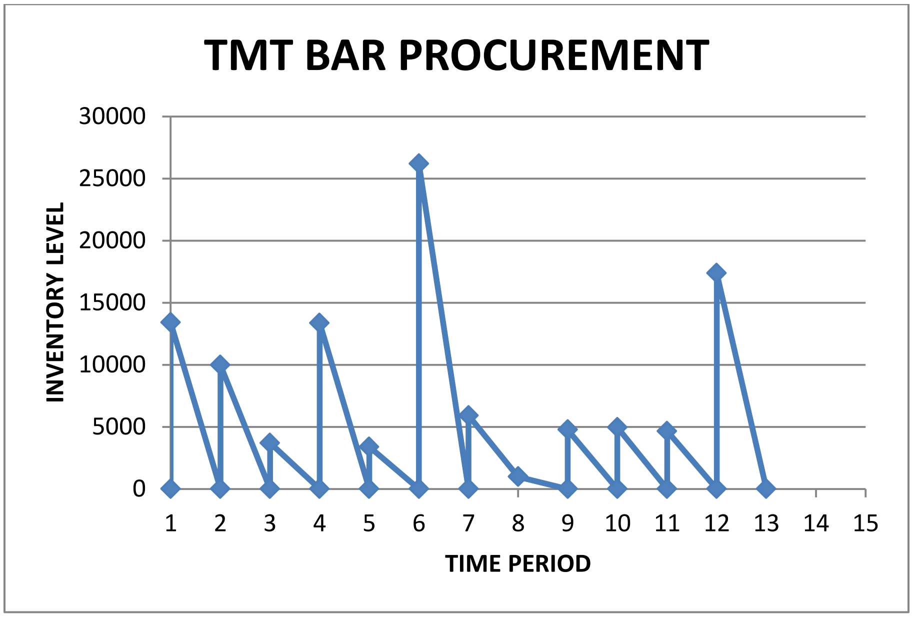
r_i	Month	Demand
1	Apr'20	13411
2	May'20	9973
3	June'20	3687
4	July'20	13360
5	Aug'20	3384
6	Sep'20	26199
7	Oct'20	4939
8	Nov'20	970
9	Dec'20	4766
10	Jan'21	4959
11	Feb'21	4645
12	Mar'21	17373

last period with ordering	Planning Horizon											
	1	2	3	4	5	6	7	8	9	10	11	12
1	658821.6	1154623	1340463	2023073	2198308	3573043	3835612	3887848	4147793	4421685	4681437	5664929
2		1149096	1332393	2005790	2178691	3535359	3794522	3846090	4102748	4373220	4629769	5601281
3			1331200	1995385	2165952	3504553	3760310	3811209	4064581	4331633	4584979	5544510
4				1987522	2155755	3476290	3728641	3778871	4028956	4292588	4542731	5490282
5					2154772	3457239	3706185	3755745	4002544	4262757	4509696	5445267
6						3440522	3686062	3734954	3978466	4235259	4478995	5402585
7							3684006	3732229	3972454	4225827	4466360	5377970
8								3732910	3969849	4219802	4457132	5356761
9									3967231	4213765	4447891	5335540
10										4211695	4442618	5318287
11											4440765	5304453
12												5293823
Ct	658821.6	1149096	1331200	1987522	2154772	3440522	3684006	3732229	3967231	4211695	4440765	5293823
jt	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**7**	**9**	**10**	**11**	**12**
Name of month (for procurer	Apr'20	May'20	June'20	July'20	Aug'20	Sep'20	Oct'20	Oct'20	Dec'20	Jan'21	Feb'21	Mar'21
c (per unit cost)	*48.68*											
a (ordering cost)	1350											
ic/2 (inventory carrying charg	0.3448											

The procurement cost by using this model=Rs.5293823

Procurement policy

The table shows the cost of procurement provided by the model for each month. The Highlighted cells show the minimum cost of procurement. Application of Wagner Whiten procurement model suggests that the optimum procurement policy for the **TMT BAR** ***should be the procurement of each month's requirement should be done in beginning of each month, i.e. for April 2020 requirement must be procured at the beginning of April 2020, and so on. However, a combined procurement for the requirements of months October 2020, and November 2020, should be carried out in the beginning of October, 2020***



MONTH	QUANTITY TO BE ORDERED
apr'20	13411
May'20	9973
June'20	3687
July'20	13360
Aug'20	3384
Sep'20	26199
Oct'20	5909
Nov'20	0
Dec'20	4766
Jan'21	4959
Feb'21	4645
Mar'21	17373

76 ALUMINIUM ALLOY

Unit cost=Rs.236.313

Ordering cost=Rs.1350

Inventory carrying charge (I) =20 %(annual)

= 0.2 per year

= 0.2/12 per Month

= 0.0167 per Month

Inventory carrying cost(IC)=0.0167*236.313

=Rs.3.938

Breakup of the inventory carrying charge

1. **Capital cost =13.25%**
2. **Insurance cost = 1%**
3. **Tax =1%**
4. **Warehouse = 0.75%**
5. **Shrinkage cost = 1.5%**
6. **Administrative cost = 2.5%**

r_i	Month	Demand
1	Apr'20	1611
2	May'20	2811
3	June'20	1537
4	July'20	1370
5	Aug'20	1987
6	Sep'20	1749
7	Oct'20	2007
8	Nov'20	1980
9	Dec'20	1192

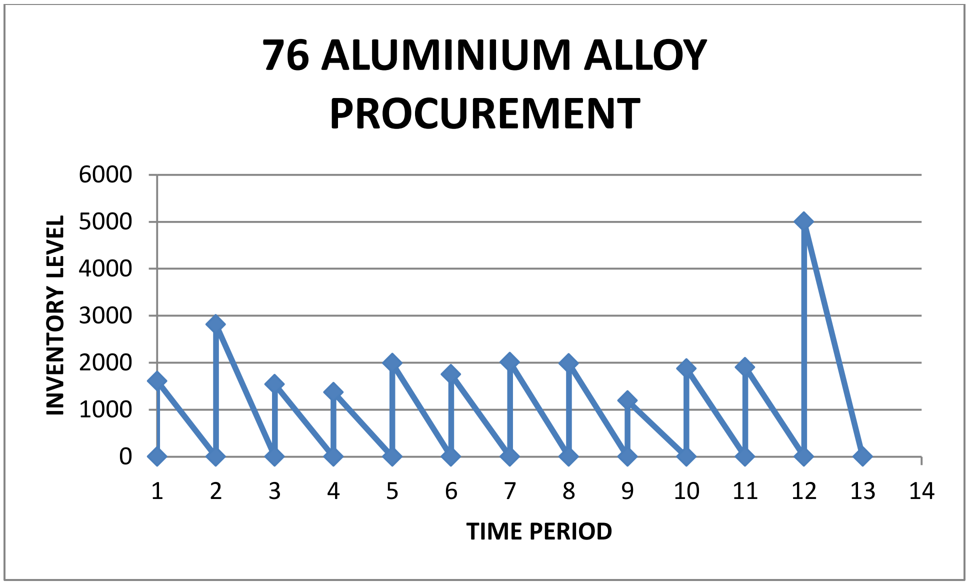
10	Jan’21	1874
11	Feb’21	1902
12	Mar’21	4998

last period with ordering	Planning Horizon											
	1	2	3	4	5	6	7	8	9	10	11	12
1	385222	1066103	1444448	1787079	2291845	2743038	3268691	3795070	4116655	4629614	5157727	6565164
2		1056383	1428675	1765912	2262852	2707158	3224908	3743489	4060380	4565959	5086582	6474337
3			1423972	1755814	2244930	2682348	3192194	3702978	4015175	4513374	5026507	6394580
4				1751769	2233060	2663590	3165533	3668520	3976023	4466842	4972485	6320876
5					2226585	2650228	3144267	3639457	3942266	4425705	4923858	6252566
6						2644690	3130826	3618219	3916333	4392393	4883056	6192082
7							3124272	3603868	3897288	4365968	4849141	6138485
8								3597421	3886147	4347447	4823130	6092792
9									3882803	4336723	4804916	6054895
10										4330693	4791396	6021693
11											4785256	5995871
12												5977539
Ct	385222	1056383	1423972	1751769	2226585	2644690	3124272	3597421	3882803	4330693	4785256	5977539
jt	1	2	3	4	5	6	7	8	9	10	11	12
Name of month (for procurement)	Apr'20	May'20	June'20	July'20	Aug'20	Sep'20	Oct'20	Nov'20	Dec'20	Jan'21	Feb'21	Mar'21
c (per unit cost)	*236.313*											
a (ordering cost)	1350											
ic/2 (inventory carrying charge/2)	1.969											

The procurement cost by using this model=Rs.5977539

Procurement policy:

The table shows the cost of procurement provided by the model for each month. The Highlighted cells show the minimum cost of procurement. Application of Wagner Whiten procurement model suggests that the optimum procurement policy for the **76 ALUMINIUM ALLOY** ***should be the procurement of each months requirement should be done in beginning of each month, i.e. For April 2020 requirement must be procured at the beginning of April 2020, and so on***



MONTH	QUANTITY TO BE ORDERED
apr'20	1611
May'20	2811
June'20	1537
July'20	1370
Aug'20	1987
Sep'20	1749
Oct'20	2007
Nov'20	1980
Dec'20	1192
Jan'21	1874
Feb'21	1902
Mar'21	4998

6082 ALUMMINIUM PLATE

Unit cost=Rs.51.90

Ordering cost=Rs.1350

Inventory carrying charge (I) =18 %(annual)

= 0.18 per year

= 0.18/12 per Month

= 0.015 per Month

Inventory carrying cost(IC) =0.015*51.90

=RS.0.7785

Breakup of the inventory carrying charge

1. Capital cost =11%

2. Insurance cost = 1%

3. Tax =1%

4. Warehouse = 1%

5. Shrinkage cost = 1.5%

6. Administrative cost = 2.5%

r_i	Month	Demand
1	Apr'20	3853
2	May'20	2395
3	June'20	5000
4	July'20	2980
5	Aug'20	2619
6	Sep'20	3976
7	Oct'20	3764

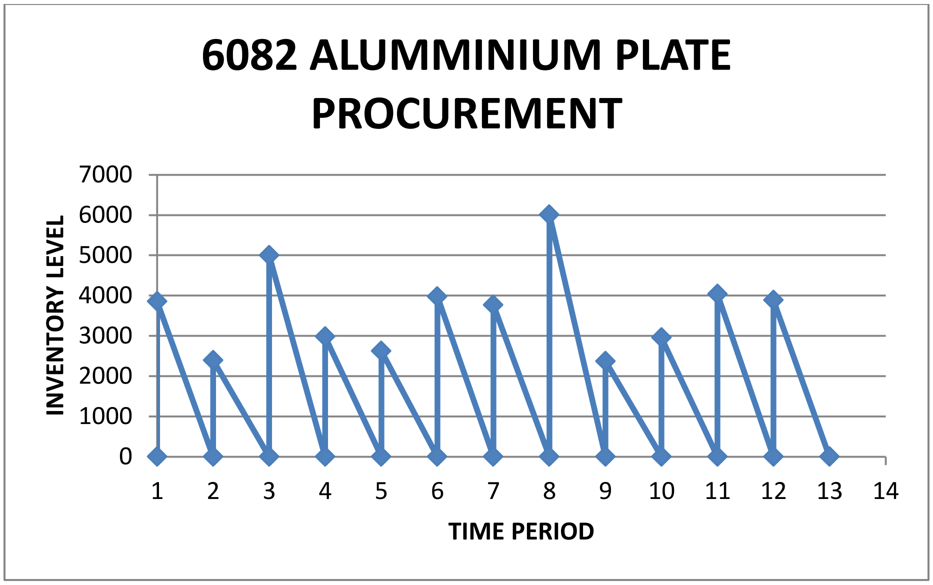
8	Nov’20	6011
9	Dec’20	2369
10	Jan’21	2954
11	Feb’21	4036
12	Mar’21	3883

last period with ordering	Planning Horizon											
	1	2	3	4	5	6	7	8	9	10	11	12
1	202824	329923	599158	761942	907045	1130425	1344825	1691894	1830522	2005681	2248141	2484432
2		329409	594752	755216	898280	1118566	1330035	1672426	1809209	1982070	2221388	2454656
3			592210	750355	891380	1108570	1317110	1654822	1789761	1960322	2196498	2426744
4				749385	888372	1102467	1308077	1641110	1774205	1942467	2175501	2402724
5					887683	1098684	1301364	1629717	1760969	1926931	2156824	2381024
6						1096939	1296689	1620363	1749771	1913434	2140185	2361363
7							1295109	1614105	1741668	1903031	2126641	2344797
8								1610776	1736495	1895559	2116027	2331160
9									1736001	1892766	2110092	2322203
10										1891816	2106001	2315089
11											2104210	2310275
12												2308602
Ct	202824	329409	592210	749385	887683	1096939	1295109	1610776	1736001	1891816	2104210	2308602
jt	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Name of month (for procurement)	Apr'20	May'20	June'20	July'20	Aug'20	Sep'20	Oct'20	Nov'20	Dec'20	Jan'21	Feb'21	Mar'21
c (per unit cost)	*51.901*											
a (ordering cost)	1350											
ic/2 (inventory carrying charge/2)	0.3892											

The procurement cost by using this model=Rs.2308602

Procurement policy:

The table shows the cost of procurement provided by the model for each month. The Highlighted cells show the minimum cost of procurement. Application of Wagner Whiten procurement model suggests that the optimum procurement policy for the **6082 ALUMINIUM PLATE** ***should be the procurement of each months requirement should be done in beginning of each month, i.e. For April 2020 requirement must be procured at the beginning of April 2020, and so on***



MONTH	QUANTITY TO BE ORDERED
apr'20	3853
May'20	2395
June'20	5000
July'20	2980
Aug'20	2619
Sep'20	3976
Oct'20	3764
Nov'20	6011
Dec'20	2369
Jan'21	2954
Feb'21	4036
Mar'21	3883

ALLOY STEEL

Unit cost=Rs.113.053

Ordering cost=Rs.1350

Inventory carrying charge (I) =18 %(annual)

= 0.18 per year

= 0.18/12 per Month

= 0.015 per Month

Inventory carrying cost(IC)=0.015*113.053

=Rs.1.695

<u>Breakup of the inventory carrying charge</u>

1. Capital cost =11.5%

2. Insurance cost = 1%

3. Tax =1%

4. Warehouse = 1%

5. Shrinkage cost = 1.5%

6. Administrative cost = 2%

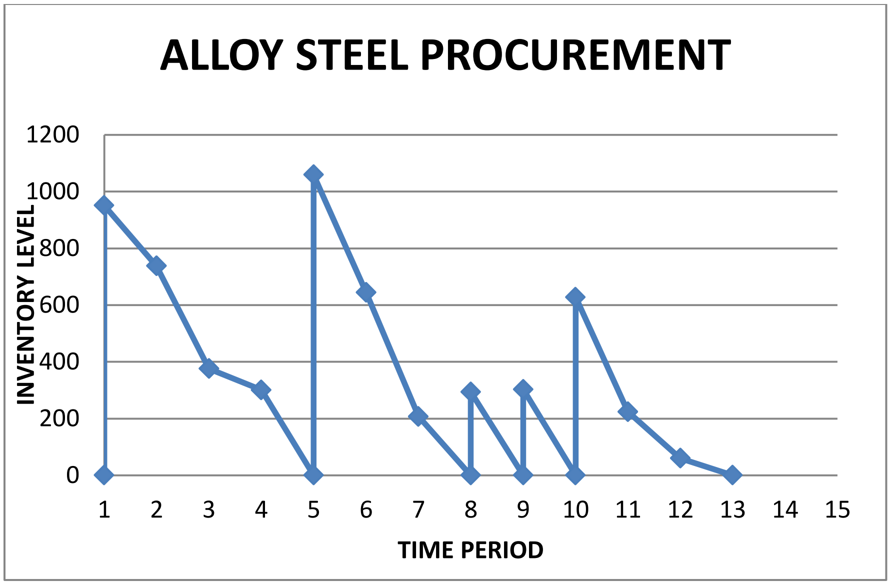
r_i	Month	Demand
1	Apr'20	213
2	May'20	362
3	June'20	301
4	July'20	75
5	Aug'20	414
6	Sep'20	438
7	Oct'20	207
8	Nov'20	294
9	Dec'20	303
10	Jan'21	474
11	Feb'21	164
12	Mar'21	60

last period with ordering	Planning Horizon											
	1	2	3	4	5	6	7	8	9	10	11	12
1	25610	67455	102759	111683	161644	215245	240928	277903	316525	377746	399206	407158
2		68191	102985	111782	161041	213899	239231	275708	313815	374233	395414	403266
3			103088	111758	160315	212431	237411	273390	310984	370597	391501	399251
4				112651	160507	211880	236509	271989	309069	367879	388505	396153
5					160187	210816	235095	270077	306643	364649	384997	392543
6						211424	235352	269835	305887	363089	383159	390603
7							235743	269728	305266	361665	381457	388799
8								269654	304956	360551	380065	387305
9									304872	360306	379542	386681
10										360210	379167	386204
11											380239	387174
12												387351
Ct	25610	67455	102759	111683	160187	210816	235095	269654	304872	360210	379167	386204
jt	1	1	1	1	5	5	5	8	9	10	10	10
Name of month (for procurement)	Apr'20	Apr'20	Apr'20	Apr'20	Aug'20	Aug'20	Aug'20	Nov'20	Dec'20	Jan'21	Jan'21	Jan'21
c (per unit cost)	*113.05*											
a (ordering cost)	1350											
ic/2 (inventory carrying cost/2)	0.8478											

The procurement cost by using this model=Rs.386204

Procurement policy:

The table shows the cost of procurement provided by the model for each month. The Highlighted cells show the minimum cost of procurement. Application of Wagner Whiten procurement model suggests that the optimum procurement policy should be that the requirement for product **ALLOY STEEL** ***for the months of April , may ,June and July ,2020 should be procured in the month of April,2020.Furthermore, requirement for the next three months i.e.(August, September and October 2020) should be procured in the beginning of August 2020.The requirement for the month of November should be done in the beginning of November 2020.Similarly as per the requirement of month of December, procurement must be done in the beginning of December 2021. The requirement for the last three months in the planning horizon (January, February and March, 2021) should be met by procuring in the beginning of January, 2021***.



MONTH	QUANTITY TO BE ORDERED
apr'20	951
May'20	0
June'20	0
July'20	0
Aug'20	1059
Sep'20	0
Oct'20	0
Nov'20	294
Dec'20	303
Jan'21	698
Feb'21	0
Mar'21	0

CONCLUSION

From the analysis carried out, the Wagner Whitin model suggests that the optimum policy for FLAT CR SHEET,316L HOT ROLLED SHEET, B Q PLATES, 7209CR SHEET, 76 ALUMINIUM ALLOY and 6082 ALUMINIUM PLATE would be to procure the requirements of the individual month in the beginning of that month itself. For Example: To meet the predicted requirement for the month of April 2020, in the products should be procured in the beginning of April 2020 and so on.

The analysis carried out further suggests that the optimum procurement policy for the product, TMT BAR should be the procurement of each month's requirement should be done in beginning of each month, i.e. for April 2020 requirement must be procured at the beginning of April 2020, and so on. However, a combined procurement for the requirements of months October 2020, and November 2020, should be carried out in the beginning of October, 2020

Lastly, we would like to suggest, the optimum procurement policy should be that the requirement for product ALLOY STEEL for the months of April , may ,June and July ,2020 should be procured in the month of April,2020.Furthermore, requirement for the next three months i.e.(August, September and October 2020) should be procured in the beginning of August 2020.The requirement for the month of November should be done in the beginning of November 2020.Similarly as per the requirement of month of December, procurement must be done in the beginning of December 2021. The requirement for the last three months in the planning horizon (January, February and March, 2021) should be met by procuring in the beginning of January, 2021. The company should produce items according to the forecasted demand to avoid the various problems such as overstocking.

REFERENCES

1. https://www.ibm.com/support/knowledgecenter/SSLVMB_23.0.0/spss/trends/idh_seas.html

2. https://machinelearningmastery.com/decompose-time-series-data-trend-seasonality/

3 .Operational research, Kanti Swoop

4. Analysis of Inventory System, Hadley G. and Witin T. M.

5. Fundamental of applied statistics, S.C. Gupta and V.K. Kapoor.

6. https://www.investopedia.com/terms/s/seasonality.asp

7. https://castlelab.princeton.edu/html/Presentations/ORF411_2013/ORF%20411%2014%20Deterministic%20inventory%20problems.pdf

8. https://www.accountingtools.com/articles/ordering-costs.html

9.https://www.inflowinventory.com/blog/pros-and-cons-of-holding-excess-inventory/