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Project Report

on

"Inventory Management and Procurement planning to improve the performance and efficiency of the production process of Dental Products "

For

S.K. DENT INDIA

Submitted by

ROHIT

In

Partial Fulfilment of the Requirement of the

Degree of Master of Operational Research

To

Department of Operational Research

Faculty of Mathematical Sciences

New Academic Block

University of Delhi

Delhi-110007

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Name of the Student	**:**	**ROHIT**
Date of Commencement of the Project	**:**	**15TH March, 2021**
Date of Submission of the Project	**:**	**30THApril, 2021**
Title of Project	**:**	**Inventory Management and Procurement Planning to improve the performance and efficiency of the production process of Dental products**
Name and Address of the Organization	**:**	**S.K. DENT INDIA**
Supervisors from the Teaching Faculty	**:**	Prof. (Dr.) Chandra K. Jaggi Prof. Prof. (Dr.) Prakash C. Jha Prof. (Dr.) Pankaj Gupta Prof. (Dr.) Preeti Wanti Srivastava Prof. (Dr.) K. K. Aggarwal Prof. (Dr.) Anu Gupta Aggarwal Prof. (Dr.) Ompal Singh Dr. Mukesh Kumar Mehlawat Dr. Aditi Khanna Dr. Vandana Khaitan Dr. Adarsh Anand Dr. Kaushal Kuma

DECLARATION

This is to certify that this project entitled "INVENTORY MANAGEMENT AND PROCUREMENT PLANNING TO IMPROVE THE PERFORMANCE AND EFFICIENCY OF THE PRODUCTION PROCESS OF DENTAL PRODUCTS" is my original work carried out in the year 2021, and has been submitted for partial fulfilment of the requirements of the course Master of 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.

ROHIT

Master of Operational Research

Department of Operational Research

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Professor Pankaj Gupta
Head
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ACKNOWLEDGEMENT

It is a great sense of satisfaction and a matter of privilege to me to have worked on a project entitled “**Inventory Management and Procurement planning to improve the performance and efficiency of the production process of Dental Products**”. It was a complete learning experience for me as far as application of operational research is concerned.

I would like to thank **(Head) Professor Pankaj Gupta, Department of Operational Research** for giving us student’s such a wonderful opportunity to prepare ourselves for what’s coming ahead. The Project is a complete learning experience in itself and it prepares us for our upcoming Corporate Journey.

The success and Final Outcome of this project required a lot of guidance and assistance and I was lucky enough to have been worked under the mentorship of **Prof.(Dr.) Chandra K. Jaggi** and **Prof. (Dr.) Preeti Wanti Srivastava** Even during these tough times, my mentors were available 24x7 to guide me through the technicalities of this project. It would not have been possible without the guidance of my mentors.

ROHIT

Master of Operational Research

Department of Operational Research

University of Delhi, Delhi-110007

15th March, 2021

To WHOM SO EVER IT MAY CONCERNS

This is to certify that **Mr. Rohit**, final year students of Masters of operational Research, university of Delhi (North campus) has been appointed as a project trainee at our company,

S.K. DENT INDIA.

The project will be based on **Inventory Management and Procurement Planning**, the duration of the project will be around 45 days, ending in the last week of April as you will need to submit your project by 30th April , 2021.

We extend our congratulations to you and we look forward to working with you.

S.K. DENT INDIA SKD Kirari, Delhi-86

15/3/21

(Sign. and Stamp)

Project Title

"INVENTORY MANAGEMENT AND PROCUREMENT PLANNING TO IMPROVE THE PERFORMANCE AND EFFICIENCY OF THE PRODUCTION PROCESS OF DENTAL PRODUCTS"

INTRODUCTION TO OPERATIONAL RESEARCH

➢ MEANING OF OPERATIONS RESEARCH

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, health-care, 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, 1950 O.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.

Operational Researchers apply their skills of incisive analysis and numeracy to real world problems. Now, more than ever before, the public and private sectors require the involvement of those who can approach highly complex problems in a systematic, creative and pragmatic manner.

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?
- What is the best breakdown of the marketing budget to maximize customer-response rates?
- Where warehouses should be located to minimize transportation costs?
- What is the impact of faster machinery on the factory-production process?

➢ HISTORY OF OR

The origin of OR takes us back to the time Of World War II, the military management in England called upon a team of scientists to study strategies and tactical problems associated with air and land defense of the country. Their objective was to decide upon the most effective utilization of limited military resources. The applications included, among others, studies of the way of use the newly invented radar and of the effectiveness of new types of bombers. The establishment of this scientific team marked the first formal operations research activity. The name " Operational Research " (sometimes abbreviated as OR) was apparently coined because the team was dealing with research on (military) operations, since its birth, this new decision-making field has been characterized by the use of **deciding upon the best utilization of limited resources.**

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, and even crime investigation studies, to mention only a few.

"...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 or controls. The purpose is to help management determine its policies and actions scientifically...."

➢ Basic Concept Of OR

- **FORMULATING THE PROBLEM**

Both the consumer's and the researcher's problem must be formulated. The person (or group) who controls the operations under study is referred to as the decision-maker. In formulating the consumer's problem, an analysis must be made of the system under his control, his objective, and alternative course of action. Others affected by the decision under study must be identified and their pertinent objectives and course of action must be uncovered. What we have called the overall viewpoint is closely connected with the attempt to define objectives. O.R. tries to take into account as broad a scope of objectives as possible. In most general terms, the research problem is to determine which alternative course of action is most effective relative to the set of pertinent objectives. Consequently, in formulating the research problem a measures of effectiveness must be specified and its suitability must be established.

- **CONSTRUCTING A MATHEMATICAL MODEL**

This model expresses the effectiveness of the system under study as a function of a set of variables at least one of which is subject to control. The general form of an O.R. model is

$$\mathbf{E = f(x_1,y_1)}$$

Where E represents the effectiveness of the system, x_j represents the variables of the system, which are subject to control and y_j those variables that are not subject to control. The restriction on values of the variables is expressed in a supplementary set of equations and/or inequations.

- **DERIVING A SOLUTION FROM THE MODEL**

There are essentially two types of procedures for deriving an optimum (or an approximation to an optimum) solution from a model: analytical and numerical. Analytical procedures consist of the use of mathematical deduction. This involves the application of various branches of mathematics such as calculus or modern algebra. Analytic solutions are obtained "in the abstract" i.e. the substitution of numbers for the symbol is generally made after the solution has been obtained.

- **TESTING THE MODEL AND SOLUTION**

A model is never more than a partial representation of reality. It is a good model if, despite its incompleteness, it can accurately predict the effect of changes in the system on the system's overall effectiveness. The adequacy of the model can be tested by determining how well it predicts the effect of these changes. The solution can be evaluated by comparing results obtained without applying the solution with results obtained when it is used. These evaluations may be performed retrospectively by the use of past data, or by a trial run or pretest. Testing requires careful analysis as to what are and what are not valid data.

- **ESTABLISHING CONTROLS OVER THE SOLUTION**

A solution derived from a model remains a solution only as long as the uncontrolled variables retain their values and the relationship between the variables in the model remains constant. The solution itself goes "out of control" when the value of one or more of the uncontrolled variables and/or one or more of the relationship between variables has changed significantly. The significance of the change depends of the amount by which the solution is made to deviate from the true optimum under the changed conditions and the cost of changing the solution in operation. To establish controls over the solutions, one must then develop tools for determining when significant changes occur and rules must be established for modifying the solutions to consider these changes.

- **IMPLEMENTATION**

The tested solution must be translated into a set of operating procedures capable of being understood and applied be the personnel who will be responsible of their use. Required changes in existing procedure and resources must be specified and carried out.

The steps enumerated are seldom, if ever, conducted in the order presented. Furthermore, the steps may take place simultaneously. In many projects, for example, the formulation of the problems is not completed until the project itself is virtually complete. There is usually a continuous interplay between these steps during the research.

➢ 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.

Besides, above areas O.R. Techniques ate successfully applied in Management, Finance and Accounting, Plant Engineering and Maintenance and Industrial Engineering.

COMPANY PROFILE

S.K DENT INDIA

As people's values diversify, so does the demand for products with a variety of specifications. Maintaining a consistently high level of quality while rapidly producing the necessary number of these nearly custom-made products requires shifting from mass production to a diverse, low-volume system of production.

S K DENT INDIA has been continually monitoring current dental equipment's industry and market needs as we design and introduce high quality, creative products that help increase work efficiency and productivity, while focusing on hygiene. Our aim is to combine cutting edge technology with traditional values for a dental treatment center that offers sophistication, performance, flexibility and above all durability.

The company offer various types of Dental and Medical equipment. All these products are manufactured as per the prescribed guidelines and regulations standardized for surgical products by various international authorities. These equipment are easy to operate and maintain as well as highly reliability.

S.K. DENT(INDIA) working since 1998 in the Indian market. Due to our extreme quality and best rates and company enjoying an excellent reputation in the market and working under highly professional skilled management.

The company is highly regarded in the industry because of its manufacturing integrity, system reliability, function versatility, incredible Affordability, outstanding job commitment and value for money.

TEAM

**REGAN MCCOOK : **Founder and CEO

ERIC TEAGAN : VICE PRESIDENT

TIMOTHY BARRETH: CEO

Vision & Mission

That is our goal. The strategy has prevailed in improving the efficiency of instruments, in expanding capabilities of electronic controls and in developing other systems. Our ambition is to offer our customers the best. This results in a constant search for technologically advanced and superbly engineered new generation of dental systems. Fundamental to the design of all our equipment is the desire to harmonize impersonal equipment with the people who use it. This matching of man & equipment minimizes doctors' fatigue & increases their productivity.

Focus:

- 100% Customer satisfaction
- Customer Support
- Expanding Product Lines
- Replacement Guarantee*
- Leading Technology
- Competitive Pricing
- Strong Brand Equity
- Our Mantra for Success

S K DENT INDIA passionately understand the needs of the customers and deliver products to the customers. Its commitment to our target customers will be to deliver new, Genuine and affordable products with excellent customer service.

Company Presence

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Inventory Management

INVENTORY MANAGEMENT

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, when to replenish the inventory and how much to order for replenishment.

➢ 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.

  In case of procurement, 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.

- **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.

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?

Inventories are held for the following reasons:

- 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.

A Factors-Guideline for Developing a "good" Inventory System

- A system to keep track of inventory by reviewing continuously or periodically.
- A reliable forecast of demand.
- Reasonable estimates of:
    - Holding costs
    - Ordering costs
    - Shortage costs
    - Lead Time

- 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.

How to Reduce the Inventory Costs?

- Cycle inventory.
- Streamline ordering/production process.
- Increase repeatability.
- Safety Stock inventory.
- Better timing of orders.
- Improve forecasts.
- Reduce supply uncertainties.
- Use capacity cushions instead.
- Anticipation inventory.
- Match production rate with demand rate.
- Use complementary products.
- Off-season promotions.
- Creative pricing.
- Pipeline inventory.
- Reduce lead-time.
- More responsive suppliers.
- Decrease lot size when it affects lead times.

➢ 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.

Techniques of selective control:

ABC analysis

A – Always

B – Better

C -- Control

Basis of classification : consumption value

Main uses : controlling raw material components & work in progress inventories

VED analysis

V – Vital

E – Essential

D – Desirable

Basis of classification: critically of items

Main uses : determining the inventory level of spare parts.

FNSD analysis

F – Fast moving items

N--Normal moving items

S--Slow moving items

D--Dead items

Basic of Classification: consumption rate of items

Main uses : controlling obsolescence

XYZ analysis

X – Items with high inventory value

Y – Items with moderate inventory value

Z -- Items with low inventory value

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 : more costly 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 70% 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 20% of items in an inventory account of 25% 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 70% of the inventory items account only for 5% 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, loose 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 n recording costs.

Significant points of ABC-Analysis

- Whenever the items can be substituted for each other they should be preferably considered as one item.
- More emphasis should be given to the value of consumption and not to the cost per items.
- While classifying as ABC all the items consumed by an organization should be considered together, instead of considering them like: spares, raw material, semi finished, and finished items and then classifying as A, B or C.
- If required, there may be more than three classes and period of consumption need necessarily be one year.

Procedure 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 × 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 percentage 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 percentage of items corresponding to these points determine the classification of items as A, B or C.

- **LIMITATION OF "ABC" ANALYSIS**

- ABC analysis does not permit precise consideration of al relevant problems inventory control. For example, never ending problem in inventory management is that of adequately handling thousands of low value "C" class items. Low value purchases frequently require more items, and consequently reduce the time allowance available and purchasing personnel for value analysis, vender investigation, and other "B" class items.

- If "ABC" analysis is not be updated and reviewed periodically the real purpose of control may be defeated for example, "C" class items like diesel oil in a firm will become most high value items during power crisis and therefore should require more attention.

- The periodic consumption value is the basis for "ABC" classification, hence ABC classification can lead to over looking the needs of spare parts whose criticality is high but consumption value is low.

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 a "*make to sell*" 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

➢ <u>Forecasting Techniques</u>

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.

Following are some of the important method of forecasting:

- **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:

a) Annual productions of steel in a particular factory over a no. of years from 1990-2004.
b) Daily closing price of shares in stock exchange.
c) The hourly temperature of a city recorded by weather bureau.
d) 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)

WHAT IS THE 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 change.

WHAT IS THE 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 behaviour**
  Christmas

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 seasonal series. There is an obvious large seasonal increase cember retail sales in New South Wales due to Christmas shopping. In this example, the magnitude of the seasonal component increases over time, as does the trend.

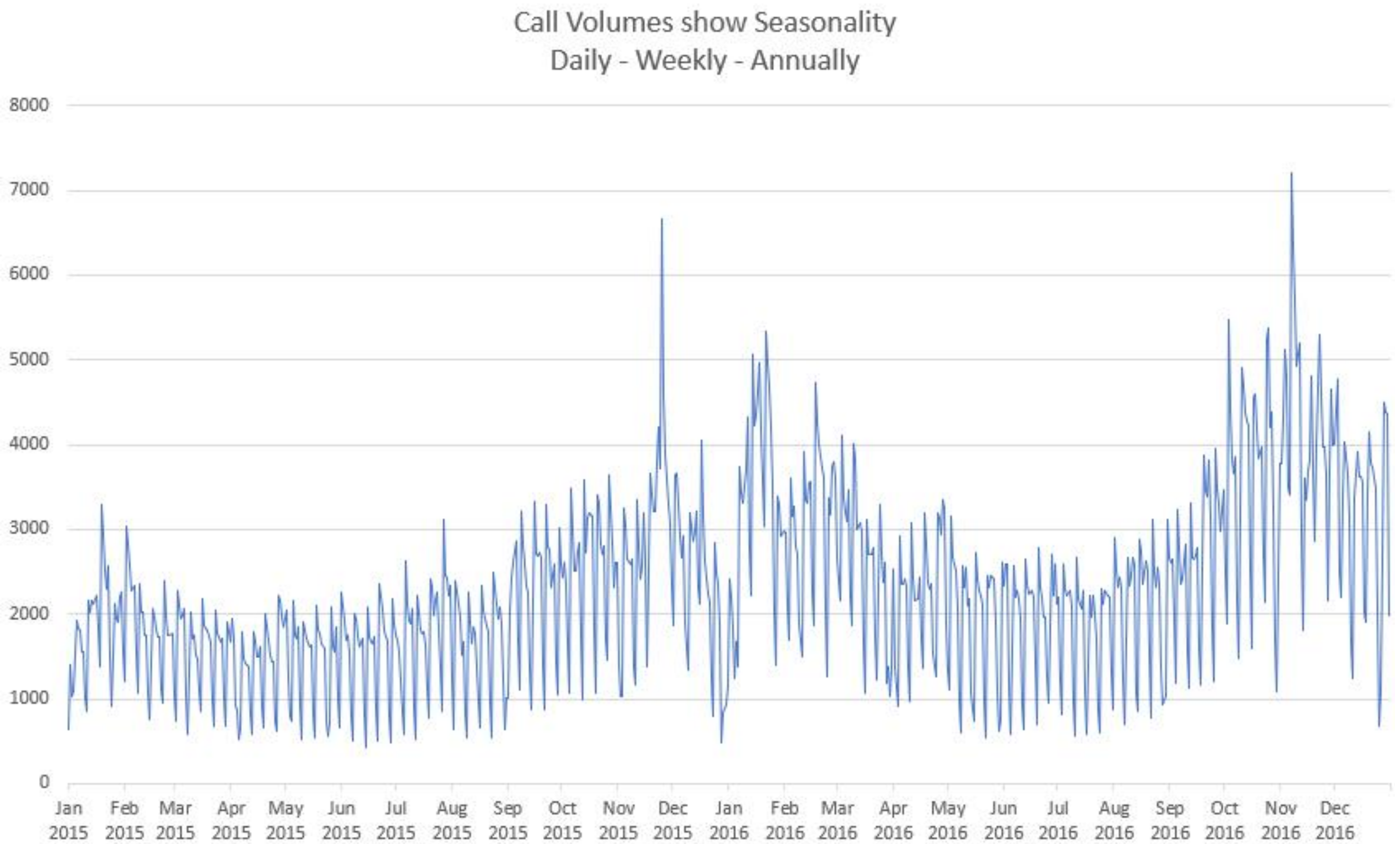


Figure Shows the sesonality

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:

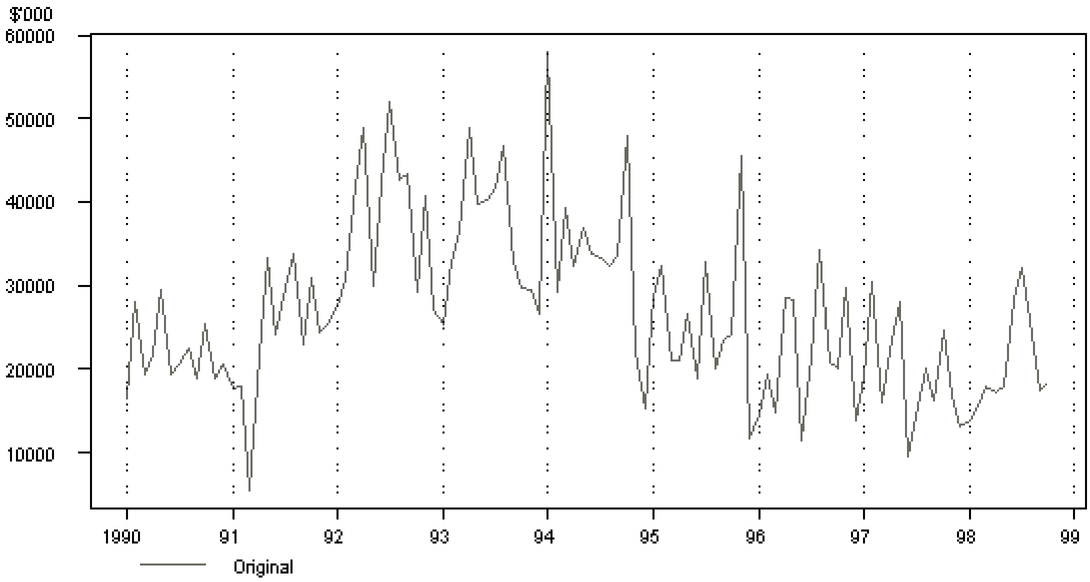


fig4.3: Shows the irregularity

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

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

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 $\hat{b}$

1. **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 $\hat{a}, \hat{b}, \hat{c}$

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

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

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

2. **Fitting Kth degree Parabola**

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

We can proceed as in the case of 2nd degree parabola 1st 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.

3. **Exponential Curve:**

   $$Y_t = ab^t$$

Taking logarithms of both sides, we have

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

or $\quad U_t = A + Bt$

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

4. **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 $\quad U_t = A + Bt + Ct^2$

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

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) **<u>Method of Partial Sums</u>:**

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**

  $$Y_t = T_t S_t C_t I_t$$

  - **Additive Model**

    $$Y_t = T_t + S_t + C_t + I_t$$

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 $\overline{x}_i$ (i = 1,2,3…..12) for the ith month for all the years. This eliminates irregular variations.
- Compute the average $\overline{x}$ of the monthly (quarterly) averages $\overline{x} = \frac{1}{12}\sum_{i=1}^{12}\overline{x}_i$ $\left(\overline{x} = \frac{1}{4}\sum_{i=1}^{4}\overline{x}_i\right)$

- Seasonal indices for different months are obtained by expressing monthly averages as (% age) of $\overline{x}$. Thus, the seasonal index for ith month = $\frac{\overline{x}_i}{\overline{x}} \times 100$
- 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, 2nd, 3rd, 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

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

2nd 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 1^{st} moving average is placed against the middle of 2^{nd} and 3^{rd} items, the 2^{nd} moving average is placed against the middle of 3^{rd} and 4^{th} 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.

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.

Exponential smoothing methods have been around since the 1950s , and are still the most popular forecasting methods used in business and industry. Initially, a big attraction was the limited requirements for computer storage. More importantly today, the equations in exponential smoothing methods for estimating the parameters and generating the forecasts are very intuitive and easy to understand. As a result, these methods have been widely implemented in business applications.

Historically, exponential smoothing describes a class of forecasting methods. In fact, some of the most successful forecasting methods are based on the concept of exponential smoothing. There are a variety of methods that fall into the exponential smoothing family, each having the property that forecasts are weighted combinations of past observations, with recent observations given relatively more weight than other observations. The name "Exponential smoothing" reflects the fact that the weights decrease exponentially as the observations get older. The idea seems to have originated with Robert G. Brown in about 1944 while he was working for the US Navy as an Operations Research Analyst. He used the idea in a mechanical computing device for tracking the velocity and angle used in firing at submarines. In the 1950s he extended this method from continuous to discrete time series, and included terms to handle trend and seasonality. One of his first applications was forecasting demand for spare parts in the US Navy inventory systems. This latter work was presented at a meeting of the Operations Research Society of America in 1956 and formed the basic of his first book on inventory control (Brown 1959). The ideas were further developed in Brown's second book (1963).

Classification of Exponential Smoothing method.

In exponential smoothing, we always start with the trend component, which is itself a combination of a level term(l) and a growth term(b). The level and growth can be combined in a number of ways, giving five future trend types.

In exponential smoothing, we always start with the trend component, which is itself a combination of a level term(l) and a growth term(b). the level and growth can be combined in a number of ways, giving five future trend types. Let T_h denote the forecast trend over the next h time periods, and let ∅ denote a damping parameter (0 < ∅ < 1). Then the five trend types or growth patterns are as follows:

None: $T_h = l$

Additive $T_h = l + bh$

Additive damped: $T_h = l + \left(\phi + \phi^2 + \ldots + \phi^h\right)b$

Multiplicative: $T_h = lb^h$

Multiplicative damped: $T_h = lb^{\left(\phi + \phi^2 + \ldots + \phi^h\right)}$.

A damped trend method is appropriate when there is a trend in the time series, but one believes that the growth rate at the end of the historical data is unlikely to continue more than a short time into the future. The equations for damped trend do what the name indicated: dampen the trend as the length of the forecast horizon increases, this often improves the forecast accuracy, particularly at long lead times. Having chosen a trend component, we may introduce a seasonal component, either additively or multiplicatively, Finally, we include an error, either additively or multiplicatively. Historically, the nature of the error component has often been ignored, because the distinction between addition and multiplicative error makes no difference to point forecasts.

If the error component is ignored, then we have the fifteen exponential smoothing methods given in the following table. This classification of methods originated with Pegels' (1969) taxonomy.

Trend component	Seasonal component		
	N (None)	A (Additive)	M (Multiplicative)
N (None)	N,N	N,A	N,M
A (Additive)	A,N	A,A	A,M
A_d (Additive damped)	A_d,N	A_d,A	A_d,M
M (Multiplicative)	M,N	M,A	M,M
M_d (Multiplicative damped)	M_d,N	M_d,A	M_d,M

- **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.

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

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

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:

$$L_t = a\, (L_{t-1} + T_{t-1}) + (1 - a)\, y_t / S_{t-s} \quad \text{for the level,}$$

$$T_t = b\, (L_t - L_{t-1}) + (1 - b)\, T_{t-1} \quad \text{for the trend, and}$$

$$S_t = g\, S_{t-s} + (1- g)\, y_t / L_t \quad \text{for the seasonal factor.}$$

Start the calculations at the first period(first quarter in case of quarterly data, and first month in case of monthly data) of the second year, with slope for the last period (last quarter in case of quarterly data, and last month in case of monthly data) of the first year set at zero.

- **DAMPED TREND METHOD**

Gardner and McKenzie (1985) proposed a modification of Holt's linear method to allow the "damping" of trends. The damped trend function will be appropriate if the analyst is uncomfortable in projecting far into the future continuing growth at a rate as steep as linear.

The equation for this method when non-seasonal data is available are:

$$\text{Level: } l_t = \alpha Y_t + (1-\alpha)(l_{t-1} + \phi\, b_{t-1})$$

$$\text{Growth: } b_t = \beta(l_t - l_{t-1}) + (1-\beta)\phi\, b_{t-1}$$

$$\text{Forecast: } \hat{Y}_t(h) = l_t + \left(\phi + \phi^2 + \ldots + \phi^h\right) b_t,\ h=1, 2, \ldots.$$

Thus, the growth for the one-step forecast of Y_{t+1} is ϕb_t and the growth is dampened by a factor of ϕ for each additional future time period. If $\phi = 1$, this method gives the same forecasts as Holt's linear method. We usually restrict $\phi > 0$ to avoid a negative coefficient being applied to b_{t-1} in growth equation, and $\phi \le 1$ to avoid b_t increasing exponentially.

In order to apply this algorithm to generate forecasts from a given data set, the values of three parameters (α, β. ϕ) must be chosen. The set of values for which the sum of squared one-step in sample forecast errors is minimum is selected. i.e. we choose those values for which'

$$S^2 = \sum_{t=4}^{n} e_t^2 \text{ , where } e_t = Y_t - \hat{Y}_{t-1}(1) = Y_t - l_{t-1} - \phi\, b_{t-1}$$

is smallest.

Then, h-step ahead forecasting equation is :

$$\hat{Y}_t(h) = l_t + \left(\phi + \phi^2 + \ldots + \phi^h\right) b_t,\ h=1, 2, \ldots.$$

THE DAMPED TREND FORECAST ALGORITHM FOR SEASONAL DATA USING MULTIPLICATIVE MODEL IS:

Intialize: Start the calculations at the first period (first quarter in case of quarterly data, and first month in case of monthly data) of the second year, with slope for the last period (last quarter in case of quarterly data, and last month in case of monthly data) of the first year set at zero.

Use:

$$\text{Level: } l_t = \alpha\left(Y_t - s_{t-m}\right) + (1-\alpha)\left(l_{t-1} + \phi\, b_{t-1}\right)$$

$$\text{Growth: } b_t = \beta\left(l_t - l_{t-1}\right) + (1-\beta)\,\phi\, b_{t-1}$$

$$\text{Seasonal: } s_t = \gamma\left(Y_t - l_t\right) + (1-\gamma)s_{t-m}\ ,$$

Where m is the length of seasonality (e. g number of months or quarters in a year), l_t represents the level of the series b_t denotes the growth, s_{t01} is the seasonal component.

Choose ((α, β, γ, ϕ) so that one-step ahead forecast error:

$$S^2 = \sum_{t=5}^{n} e_t^2\ \text{, where } e_t = Y_t - \hat{Y}_{t-1}(1) = Y_t - \left(l_{t-1} + \phi b_{t-1}\right)s_{t-m}\ \text{, for a quarterly data,}$$

$$S^2 = \sum_{t=13}^{n} e_t^2\ \text{, where } e_t = Y_t - \hat{Y}_{t-1}(1) = Y_t - \left(l_{t-1} + \phi b_{t-1}\right)s_{t-m}\ \text{, for a monthly data.}$$

is minimum.

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:

Forecast Error and Performance Measures

- Forecast error at time t = e(t) = x(t)-f(t)
- MAD Mean absolute deviation = $\sum |e(t)| / n$
- MSE Mean squared error = $\sum [e(t)]^2 / n$
- CFE Cumulative forecast error = $\sum e(t)$
- MAPE Mean absolute percentage error =
  $100 \sum \left[|e(t)| / x(t) \right] / n$
- Tracking signal = CFE / MAD

❖ **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 (see Makridakis, Wheelwright, and McGee, 1983). 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:

Time-Critical Decision Modeling and Analysis

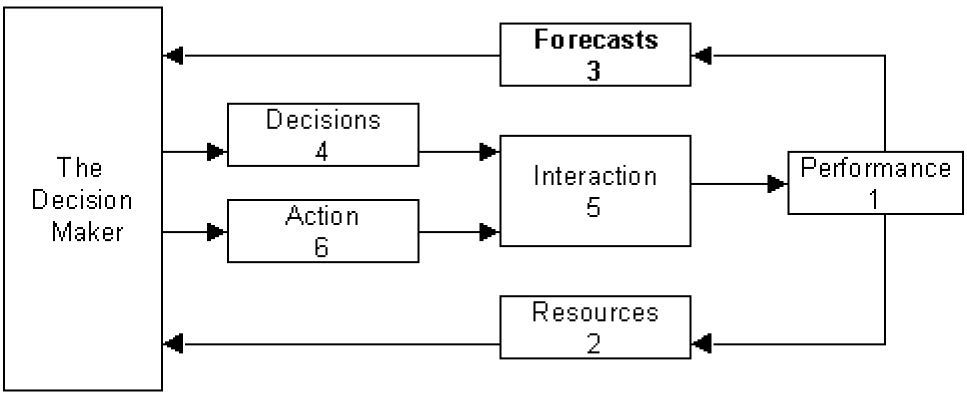
The ability to model and perform decision modeling and analysis is an essential feature of many real-world applications ranging from emergency medical treatment in intensive care units to military command and control systems. Existing formalisms and methods of inference have not

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.

- *Components Of Inventory Systems*

There are the various components of an inventory system:

1. Demand: By this term we mean that a customer requirement occurring at a time point.

2. Lead Time: When the demands sufficiently reduce the size of an inventory it becomes necessary to order replenishment stock so as to able to meet the future demands. The time that elapses from the moment a replenishment order is placed until that order is in stock and ready to satisfy demands is called lead time.

3. Costs : This includes different types of costs:

- ✓ Inventory Carrying costs
- ✓ Ordering costs
- ✓ Shortage costs or Penalty costs

Here we are suggesting the procurement policy for the items used by Food Corporation of India.
The model used here is described below:
Here the basic assumptions are

- ✓ Demand is different in each period.
- ✓ Procurement is done in the beginning of the period and demand is met through out the period.
- ✓ Shortages are not allowed.

Notations:

C_n = total cost up to and including the n^{th} period.
r_i = requirement of the i^{th} period
A = Ordering Cost
I= Inventory Carrying Cost
C= Cost per unit

The total cost for the n-periods is given by

$$C_n(j) = C_{j-1} + A + C(r_j + r_{j-1} + \ldots\ldots + r_n) + (I*C)(r_j/2 + r_{j+1}/2 + \ldots\ldots + r_n/2) + (I*C)(r_{j+1}/2 + r_{j+2}/2 + \ldots\ldots + r_n/2) + \ldots\ldots + (I*C)(r_n/2)$$

$$= C_{j-1} + A + C(r_j + \ldots\ldots + r_n) + (I*C)(r_j/2 + (r_{j+1})3/2 + \ldots\ldots + (r_n)(n-j+1)/2)$$

To minimize cost

$$\boxed{\mathbf{Min}\ C_n(j) = \mathbf{Min}\ \{C_{j-1} + A + C(r_j + \ldots\ldots + r_n) + (I*C)(r_j/2 + (r_{j+1})3/2 + \ldots\ldots + (r_n)(nj+1)/2)\}}$$

PROCEDURE FOR SOLVING THE PROBLEM

PROCEDURE

Step 1: To Perform ABC analysis of Dental equipment 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 there last four years monthly demand 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

- First of all we collect data (minimum 4 years in present case since its monthly data) related to sales of dental products
- Plot the data to study the behavior.
- Study the plots if it is seasonal or non-seasonal.
- Apply the appropriate forecasting method for various months of the next year.
- 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.
- Here we have used Proportionate Method to forecast the demand.
- Collect data for inventory carrying cost per annum (collect its components if possible) and ordering cost per order (if possible components also).
- Fit the appropriate Procurement Plan.
- Looking into the result carefully conclude and recommend plan for the procurement of the Suitcases and briefcases.

ABC ANALYSIS

Dataset Description: Data contains information about 113 inventory items that are used as a raw material in production process of TRACTORS. Each item in the dataset has following features:

Serial No.: Number assigned as an integer that helps in ordering and sorting the items in the dataset;

Order ID: It contains unique identification number assigned to each raw material in the list;

Annual Demand: This column contains the annual demand of a particular raw material for year 2019;

Market Value: The per unit price of the particular raw material.

With the given information, we calculated few other features that will be used in the ABC Analysis for the firm for year 2020. These features are:

- **Annual Usage Value**: The contains the total expenditure the firm did on all its inputs for year ending 2020. All the values in other columns are then sorted based on the annual usage value, i.e. the raw material with highest annual usage value is present at the top and others are placed in descending order;

- **Cumulative Sum:** This column contains the cumulative sum of annual usage value column which is already sorted in descending order. For example, for product with Serial No. 5, this column will add annual usage value of items ranked from 1-5. In the similar manner, we will calculate for all the items and the cumulative sum value of last item will show the total expenditure firm did on raw materials for year 2020;

- **Cumulative Percentage**: This column is extracted from the Cumulative Sum column by dividing every entry in the column with total annual amount spent for raw materials. This column will be our y-axis;

- **Cumulative Percentage Items:** It simply contains percentage value of items considered till certain point.

ABC Analysis is similar to pareto principle in that the ‘A’ items will typically account for large proportion of overall value, but a small percentage of the number of items. To perform ABC Analysis, we will first have to comply with the standard divisions for A, B and C items for our dataset as well. The guidelines are as follows:

- **‘A’ Items** – 10% of the item’s accounts for 70% of the annual consumption value of the items;
- **‘B’ Items** – 20% of the item’s accounts for 25% of the annual consumption value of the items;
- **‘C’ Items** – 70% of the item’s accounts for 5% of the annual consumption value of the items

DATASET

RANK	S.NO	PRODUCT	PRICE	Quantity	ANNUAL VALUE	ANNUAL VALUE IN %	COMM. VALUE	COMM. ANN. % VALUE	(100/n)% of items	Cumulative % of items	CATEGORY
1	24	DENTEQP024XXX	65000	910	59150000	16.58	59150000	16.58	1.02	1.02	A
2	23	DENTEQP023XXX	55000	975	53625000	15.03	112775000	31.61	1.02	2.04	A
3	22	DENTEQP022XXX	45000	950	42750000	11.98	155525000	43.59	1.02	3.06	A
4	18	DENTEQP018XXX	14500	1200	17400000	4.88	172925000	48.47	1.02	4.08	A
5	16	DENTEQP016XXX	28000	450	12600000	3.53	185525000	52.00	1.02	5.10	A
6	19	DENTEQP019XXX	3500	2500	8750000	2.45	194275000	54.45	1.02	6.12	B
7	7	DENTEQP007XXX	2500	3200	8000000	2.24	202275000	56.70	1.02	7.14	B
8	93	DENTEQP093XXX	95000	80	7600000	2.13	209875000	58.83	1.02	8.16	B
9	1	DENTEQP001XXX	12500	600	7500000	2.10	217375000	60.93	1.02	9.18	B
10	20	DENTEQP020XXX	2000	3700	7400000	2.07	224775000	63.00	1.02	10.20	B
11	94	DENTEQP094XXX	65000	110	7150000	2.00	231925000	65.01	1.02	11.22	B
12	21	DENTEQP021XXX	1800	3800	6840000	1.92	238765000	66.93	1.02	12.24	B
13	96	DENTEQP096XXX	45000	150	6750000	1.89	245515000	68.82	1.02	13.27	B
14	95	DENTEQP095XXX	62000	102	6324000	1.77	251839000	70.59	1.02	14.29	B
15	90	DENTEQP090XXX	82000	75	6150000	1.72	257989000	72.31	1.02	15.31	B
16	17	DENTEQP017XXX	12000	475	5700000	1.60	263689000	73.91	1.02	16.33	B
17	2	DENTEQP002XXX	11500	450	5175000	1.45	268864000	75.36	1.02	17.35	B
18	40	DENTEQP040XXX	1800	2800	5040000	1.41	273904000	76.77	1.02	18.37	B
19	8	DENTEQP008XXX	2800	1750	4900000	1.37	278804000	78.15	1.02	19.39	B
20	12	DENTEQP012XXX	12000	400	4800000	1.35	283604000	79.49	1.02	20.41	B
21	11	DENTEQP011XXX	2500	1560	3900000	1.09	287504000	80.59	1.02	21.43	B
22	6	DENTEQP006XXX	3500	1010	3535000	0.99	291039000	81.58	1.02	22.45	B
23	10	DENTEQP010XXX	2200	1530	3366000	0.94	294405000	82.52	1.02	23.47	B
24	47	DENTEQP047XXX	2500	1230	3075000	0.86	297480000	83.38	1.02	24.49	B
25	36	DENTEQP036XXX	55000	55	3025000	0.85	300505000	84.23	1.02	25.51	B
26	15	DENTEQP015XXX	6000	500	3000000	0.84	303505000	85.07	1.02	26.53	B
27	9	DENTEQP0093XXX	1800	1600	2880000	0.81	306385000	85.88	1.02	27.55	B
28	27	DENTEQP027XXX	135000	19	2565000	0.72	308950000	86.60	1.02	28.57	B
29	31	DENTEQP031XXX	850000	3	2550000	0.71	311500000	87.31	1.02	29.59	B
30	92	DENTEQP092XXX	22000	105	2310000	0.65	313810000	87.96	1.02	30.61	B
31	44	DENTEQP044XXX	1850	1200	2220000	0.62	316030000	88.58	1.02	31.63	B
32	39	DENTEQP039XXX	700	3100	2170000	0.61	318200000	89.19	1.02	32.65	B
33	26	DENTEQP026XXX	128000	16	2048000	0.57	320248000	89.76	1.02	33.67	B
34	52	DENTEQP052XXX	3500	560	1960000	0.55	322208000	90.31	1.02	34.69	B
35	25	DENTEQP025XXX	120000	15	1800000	0.50	324008000	90.82	1.02	35.71	B
36	14	DENTEQP014XXX	6500	250	1625000	0.46	325633000	91.27	1.02	36.73	B
37	70	DENTEQP070XXX	1200	1350	1620000	0.45	327253000	91.73	1.02	37.76	B
38	3	DENTEQP003XXX	3750	400	1500000	0.42	328753000	92.15	1.02	38.78	B
39	53	DENTEQP053XXX	6000	250	1500000	0.42	330253000	92.57	1.02	39.80	B
40	79	DENTEQP079XXX	5000	300	1500000	0.42	331753000	92.99	1.02	40.82	B
41	38	DENTEQP038XXX	300	4700	1410000	0.40	333163000	93.38	1.02	41.84	B
42	77	DENTEQP077XXX	6000	230	1380000	0.39	334543000	93.77	1.02	42.86	B
43	29	DENTEQP029XXX	2500	510	1275000	0.36	335818000	94.13	1.02	43.88	C
44	28	DENTEQP028XXX	12000	100	1200000	0.34	337018000	94.47	1.02	44.90	C
45	42	DENTEQP042XXX	250	4800	1200000	0.34	338218000	94.80	1.02	45.92	C
46	75	DENTEQP075XXX	800	1400	1120000	0.31	339338000	95.12	1.02	46.94	C
47	78	DENTEQP078XXX	4000	250	1000000	0.28	340338000	95.40	1.02	47.96	C
48	34	DENTEQP034XXX	35000	26	910000	0.26	341248000	95.65	1.02	48.98	C
49	48	DENTEQP048XXX	300	3000	900000	0.25	342148000	95.90	1.02	50.00	C
50	4	DENTEQP004XXX	3500	250	875000	0.25	343023000	96.15	1.02	51.02	C
51	91	DENTEQP091XXX	40000	20	800000	0.22	343823000	96.37	1.02	52.04	C
52	54	DENTEQP054XXX	5000	150	750000	0.21	344573000	96.58	1.02	53.06	C
53	41	DENTEQP041XXX	150	4650	697500	0.20	345270500	96.78	1.02	54.08	C
54	49	DENTEQP049XXX	150	4500	675000	0.19	345945500	96.97	1.02	55.10	C
55	35	DENTEQP035XXX	18000	33	594000	0.17	346539500	97.13	1.02	56.12	C
56	5	DENTEQP005XXX	800	700	560000	0.16	347099500	97.29	1.02	57.14	C
57	30	DENTEQP030XXX	800	685	548000	0.15	347647500	97.44	1.02	58.16	C
58	46	DENTEQP046XXX	250	2000	500000	0.14	348147500	97.59	1.02	59.18	C
59	33	DENTEQP033XXX	22000	22	484000	0.14	348631500	97.72	1.02	60.20	C
60	13	DENTEQP013XXX	1200	400	480000	0.13	349111500	97.86	1.02	61.22	C
61	86	DENTEQP086XXX	2950	150	442500	0.12	349554000	97.98	1.02	62.24	C
62	87	DENTEQP087XXX	3500	120	420000	0.12	349974000	98.10	1.02	63.27	C
63	45	DENTEQP045XXX	300	1390	417000	0.12	350391000	98.21	1.02	64.29	C
64	82	DENTEQP082XXX	1200	343	411600	0.12	350802600	98.33	1.02	65.31	C
65	55	DENTEQP055XXX	150	2700	405000	0.11	351207600	98.44	1.02	66.33	C
66	72	DENTEQP072XXX	800	470	376000	0.11	351583600	98.55	1.02	67.35	C
67	50	DENTEQP050XXX	100	3500	350000	0.10	351933600	98.65	1.02	68.37	C

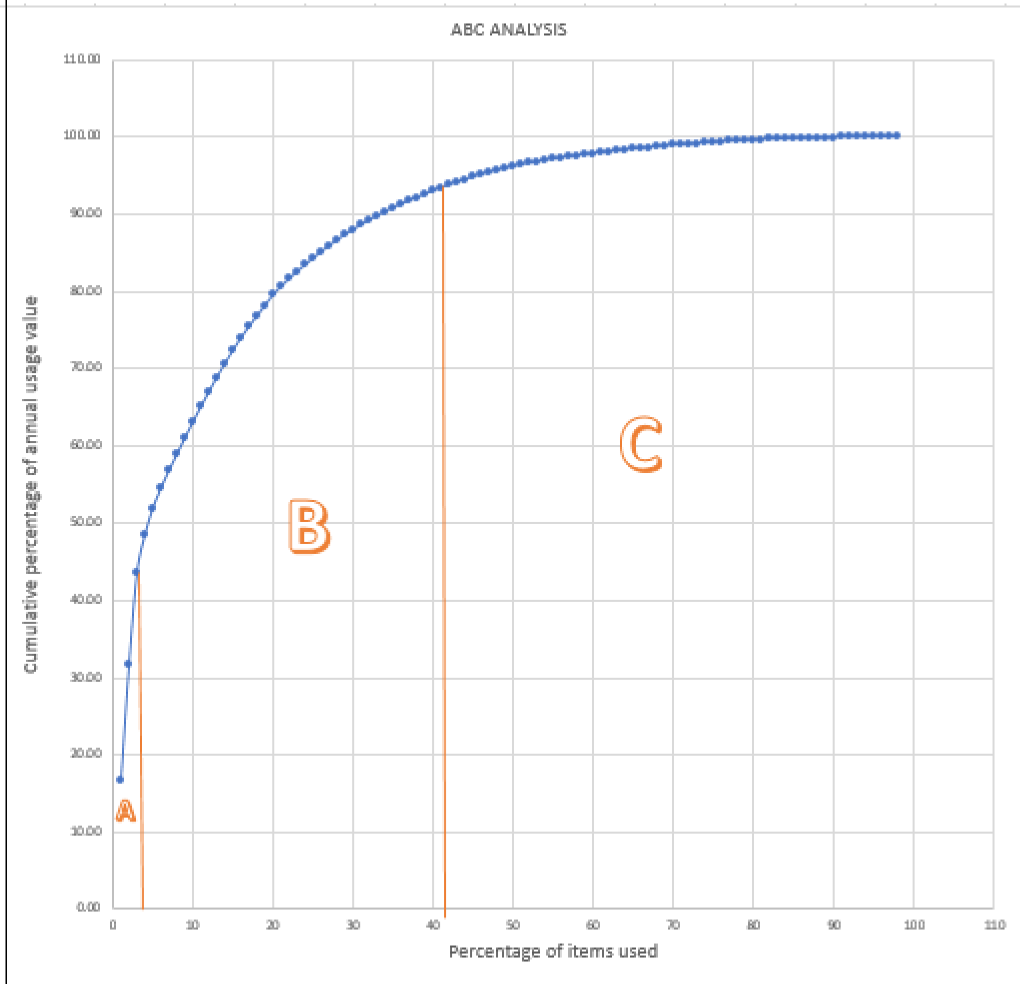
68	71	DENTEQP071XXX	800	430	344000	0.10	352277600	98.74	1.02	69.39	C
69	84	DENTEQP084XXX	1000	320	320000	0.09	352597600	98.83	1.02	70.41	C
70	76	DENTEQP076XXX	150	2100	315000	0.09	352912600	98.92	1.02	71.43	C
71	97	DENTEQP097XXX	2050	150	307500	0.09	353220100	99.01	1.02	72.45	C
72	83	DENTEQP083XXX	800	360	288000	0.08	353508100	99.09	1.02	73.47	C
73	43	DENTEQP043XXX	150	1900	285000	0.08	353793100	99.17	1.02	74.49	C
74	56	DENTEQP056XXX	150	1790	268500	0.08	354061600	99.24	1.02	75.51	C
75	37	DENTEQP037XXX	2500	100	250000	0.07	354311600	99.31	1.02	76.53	C
76	73	DENTEQP073XXX	550	420	231000	0.06	354542600	99.38	1.02	77.55	C
77	32	DENTEQP032XXX	25000	9	225000	0.06	354767600	99.44	1.02	78.57	C
78	51	DENTEQP051XXX	250	850	212500	0.06	354980100	99.50	1.02	79.59	C
79	58	DENTEQP058XXX	16000	13	208000	0.06	355188100	99.56	1.02	80.61	C
80	64	DENTEQP064XXX	2500	70	175000	0.05	355363100	99.61	1.02	81.63	C
81	74	DENTEQP074XXX	350	490	171500	0.05	355534600	99.66	1.02	82.65	C
82	85	DENTEQP085XXX	400	385	154000	0.04	355688600	99.70	1.02	83.67	C
83	61	DENTEQP061XXX	2500	55	137500	0.04	355826100	99.74	1.02	84.69	C
84	62	DENTEQP062XXX	800	170	136000	0.04	355962100	99.78	1.02	85.71	C
85	63	DENTEQP063XXX	700	180	126000	0.04	356088100	99.81	1.02	86.73	C
86	80	DENTEQP080XXX	800	150	120000	0.03	356208100	99.84	1.02	87.76	C
87	98	DENTEQP098XXX	28500	4	114000	0.03	356322100	99.88	1.02	88.78	C
88	57	DENTEQP057XXX	8000	12	96000	0.03	356418100	99.90	1.02	89.80	C
89	89	DENTEQP089XXX	150	540	81000	0.02	356499100	99.93	1.02	90.82	C
90	65	DENTEQP065XXX	1200	65	78000	0.02	356577100	99.95	1.02	91.84	C
91	88	DENTEQP088XXX	200	320	64000	0.02	356641100	99.97	1.02	92.86	C
92	68	DENTEQP068XXX	1500	19	28500	0.01	356669600	99.97	1.02	93.88	C
93	67	DENTEQP067XXX	800	29	23200	0.01	356692800	99.98	1.02	94.90	C
94	66	DENTEQP066XXX	400	53	21200	0.01	356714000	99.99	1.02	95.92	C
95	81	DENTEQP081XXX	400	49	19600	0.01	356733600	99.99	1.02	96.94	C
96	60	DENTEQP060XXX	750	18	13500	0.00	356747100	100.00	1.02	97.96	C
97	59	DENTEQP059XXX	750	17	12750	0.00	356759850	100.00	1.02	98.98	C
98	69	DENTEQP069XXX	200	17	3400	0.00	356763250	100.00	1.02	100.00	C

Rows marked in yellow are classified as A class, whereas Green and Blue are B and C classes respectively.

Category	Number of Items	Cumulative Annual Value
A' Items	3	43.59%
B' Items	39	50.18%
C' Items	56	6.23%

For Forecasting and procurement model, we'll take following number of items from each category:

- **'A' Category Items:** There are 3 items in the A category.
  1. **DENTEQP024XXX:** Name - Auto clave front loading(22 ltr), Price - 65000
  2. **DENTEQP023XXX:** Name - Auto clave front loading(18 ltr), Price - 55000
  3. **DENTEQP022XXX:** Name - Auto clave front loading(11 ltr), Price - 45000
- **'B' Category Items:** There are 3 items in the A category.
  1. **DENTEQP018XXX:** Name - Motorized Sunction, Price - 14500
  2. **DENTEQP016XXX:** Name - Scissor Arms wall mounted , Price – 28000



From the graph, we can clearly see that our dataset is meeting the required category slices. Approximately 3 % of the items account of **43.59%** for annual usage value and **42.86%** of the items account for **93.77%** of the annual usage value.

FORECASTING

Demand Forecasting for 'A' Item 'DENTEQP024XXX'

Using the data of past four years of demand for item 'DENTEQP024XXX' which is a category 'A' item, we'll prepare a time series forecasting model based on what kind of features the demand data is following.

Monthly Demand of last 4 years				
Material Code: DENTEQP024XXX				
Month/Ye	2017-2018	2018-2019	2019-2020	2020-2021
April	33	42	53	0
May	49	54	60	21
June	32	45	42	64
July	37	43	50	59
August	50	47	57	63
Septembe	63	73	75	84
October	97	108	103	123
novembe	77	87	101	110
Decembe	89	92	99	106
January	99	104	119	130
February	63	69	73	81
March	55	61	66	69
Total	744	825	898	910

Table containing information regarding monthly demand of DENTEQP024XXX every year

The data has four columns which are years and 12 indexes which are months. The cross-section is providing month-wise demand of DENTEQP024XXX every year.

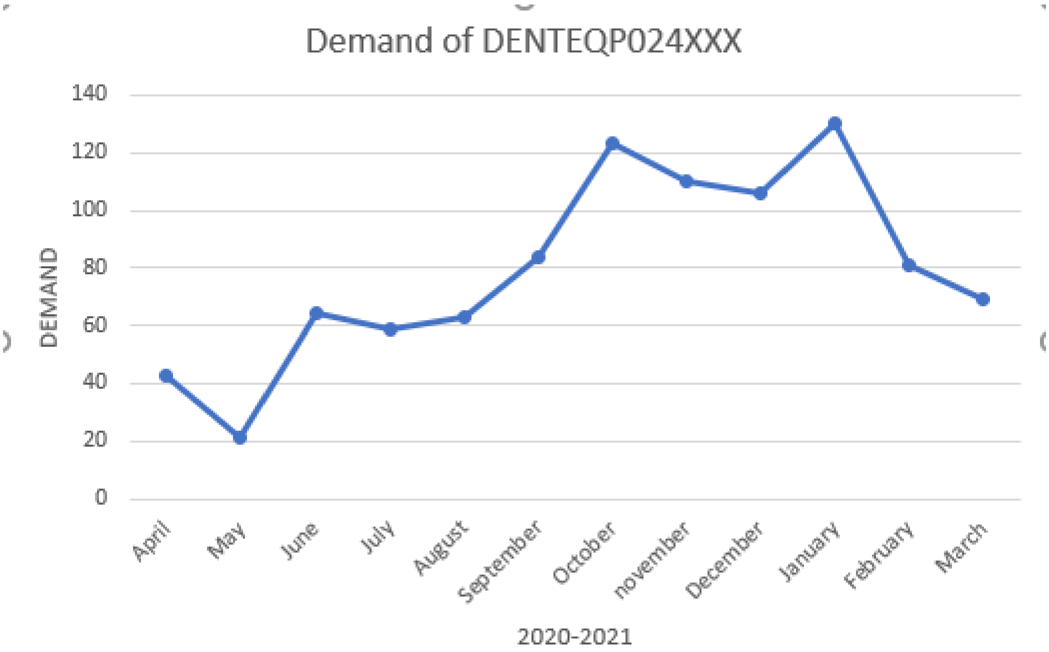
We'll have to follow a stepwise approach to solving this problem. The steps involved are as follows:

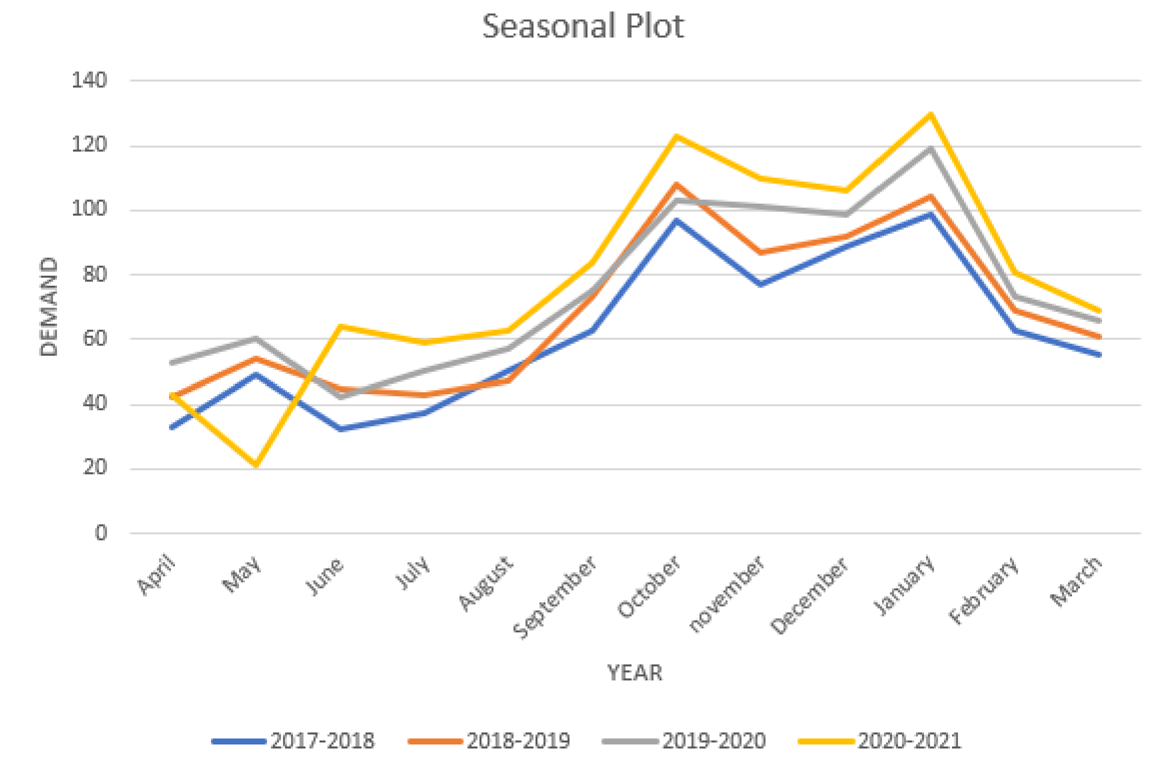
I. **Exploratory Data Analysis:** First of all, we'll plot our data into different information charts to extract useful insights and to visually feel what kind of pattern and behaviour of demand line is following. The main aim of this step is showing the trend, seasonality and irregular behaviour as well the whether the time series is stationary or not;
II. **Model Building:** Next up, we'll create the model that will provide the best results based on the information provided above. The main aim of this step is to deploy a pattern creating model that will be used in forecasting the demand for coming years. The last stage of this step is to create a plot showing actual V/s predicted values to see visually the kind of fit our model is providing;
III. **Comparison based on performance metric:** In our case, we'll be using 'RMSE' as a metric to compare the models and to find out which one is yielding the best possible result;
IV. **Forecasting:** After finalizing the model, the last step is to forecast the demand for next period. In our case, we'll forecast the demand data for next year that will serve as a benchmark for the firm to order the 'DENTEQP024XXX' next year.

In April, 2020, the demand of DENTEQP024XXX is 0. However, for handling this outlier, we have taken the Average of last three April month demand. Which significantly improve the accuracy of our model.

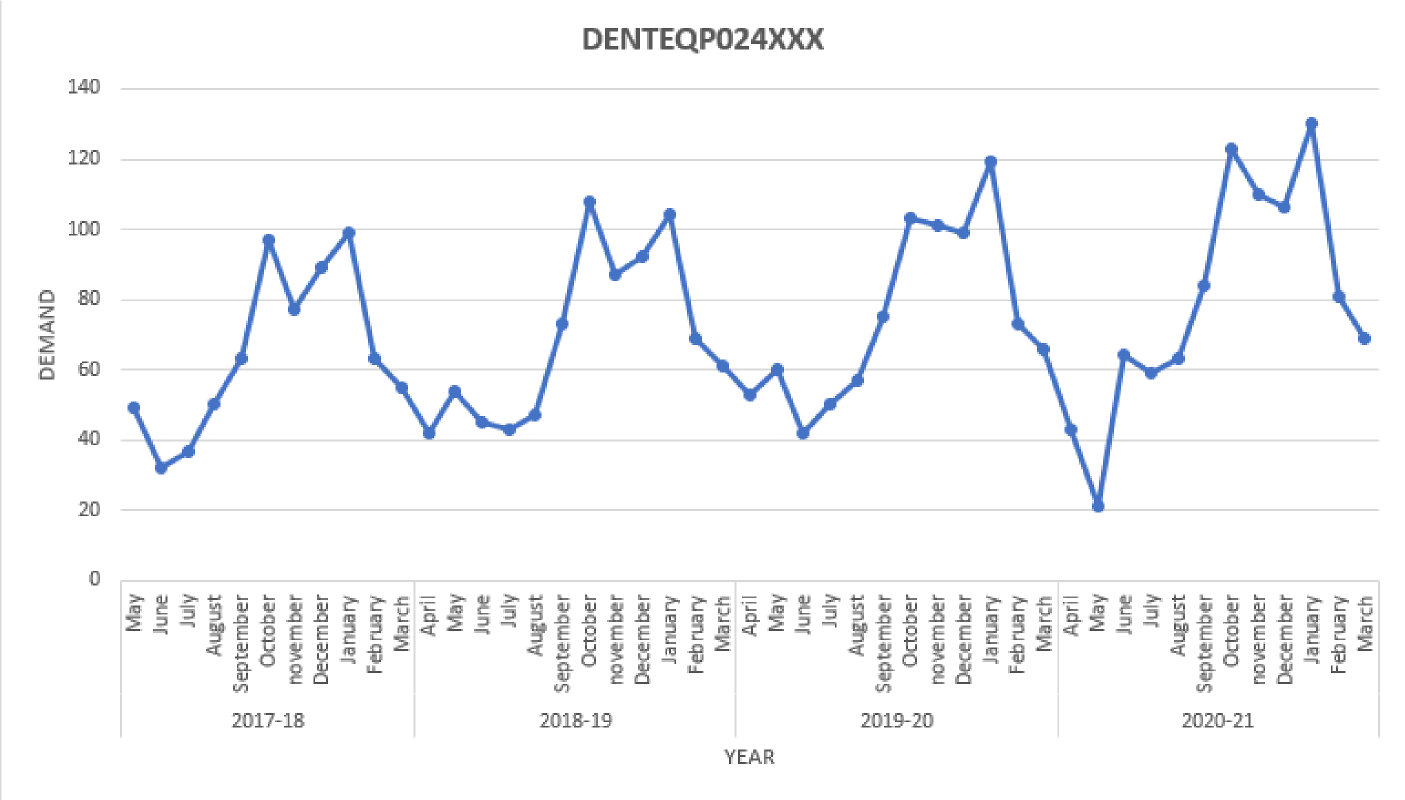
EXPLORATORY DATA ANALYSIS(EDA)

Plotting this data to understand better the variations in the inter and intra monthly demand, we can see th





From the Seasonal Plot, we can clearly see that our data is seasonal.There is seasonality in the month October and January.



MODEL BUILDING

Decomposition Method

Under Decomposition method, we'll use multiplicate model with the following equation:

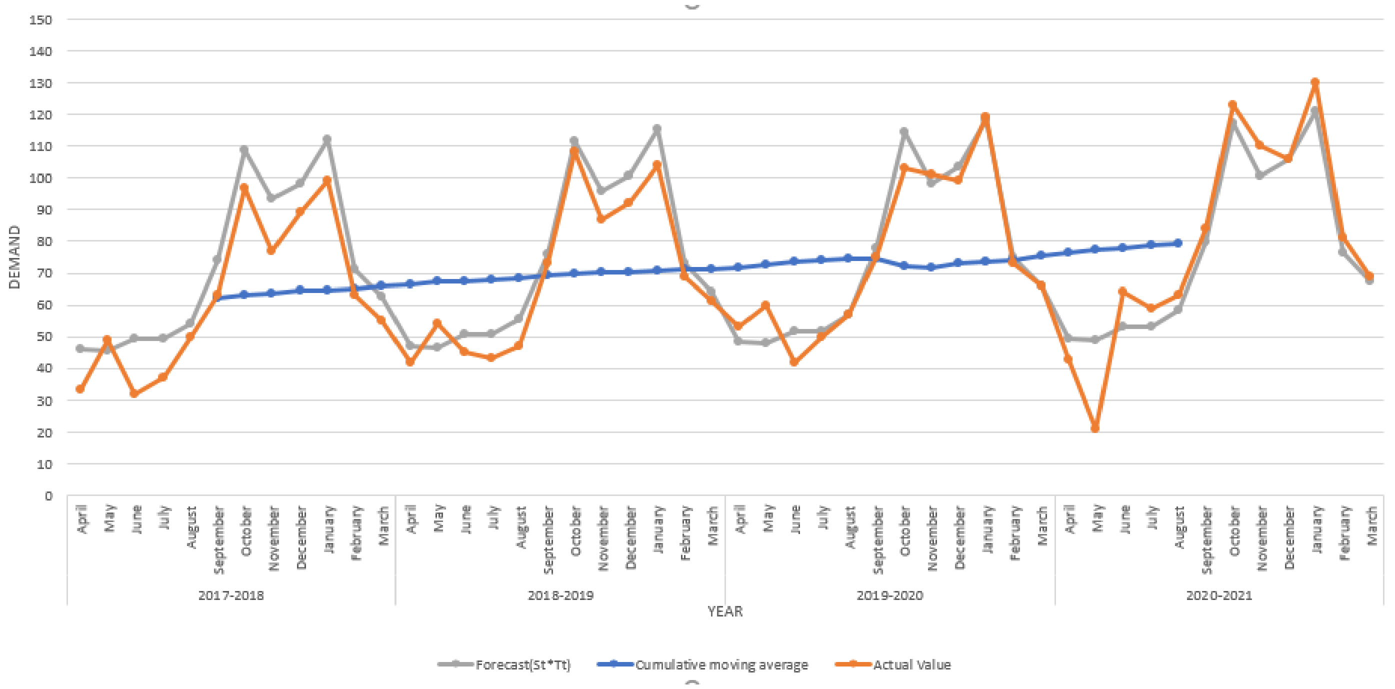
$$y_t = T_t \times C_t \times S_t \times I_t.$$

where,
T_t is the trend element;
S_t is the Seasonal component;
C_t is the Cyclical component;
I_t is the Irregular component;

DATASET

Year	Time	Demand	Time period	Moving average(12)	Cummulative moving avg(CMA - 12)	Seasonal and Irregular Components, (Y_t /CMA)	Seasonal index(S_t	Deseasonalize(Y_t/S_t)	Trend	Forecast(S_t*T_t)	Error
2017-2018	April	33	1				0.64	51.39	71.52	46	-12.93
	May	49	2				0.63	77.27	71.68	45	3.55
	June	32	3				0.69	46.64	71.84	49	-17.29
	July	37	4				0.68	54.03	71.99	49	-12.30
	August	50	5				0.75	66.82	72.15	54	-3.99
	September	63	6	62	62.38	1.01	1.02	61.51	72.30	74	-11.06
	October	97	7	63	62.96	1.54	1.50	64.54	72.46	109	-11.91
	November	77	8	63	63.71	1.21	1.29	59.84	72.62	93	-16.45
	December	89	9	64	64.50	1.38	1.35	65.96	72.77	98	-9.19
	January	99	10	65	64.63	1.53	1.54	64.34	72.93	112	-13.22
	February	63	11	65	64.92	0.97	0.97	64.71	73.09	71	-8.16
	March	55		65	65.79	0.84	0.86	64.28	73.24	63	-7.67
2018-2019	April	42	13	66	66.67	0.63	0.64	65.40	73.40	47	-5.14
	May	54	14	67	67.21	0.80	0.63	85.16	73.56	47	7.36
	June	45	15	67	67.54	0.67	0.69	65.59	73.71	51	-5.58
	July	43	16	68	68.00	0.63	0.68	62.79	73.87	51	-7.59
	August	47	17	68	68.50	0.69	0.75	62.81	74.03	55	-8.39
	September	73	18	69	69.21	1.05	1.02	71.27	74.18	76	-2.98
	October	108	19	70	69.92	1.54	1.50	71.85	74.34	112	-3.73
	November	87	20	70	70.04	1.24	1.29	67.61	74.50	96	-8.87
	December	92	21	70	70.21	1.31	1.35	68.19	74.65	101	-8.72
	January	104	22	71	70.92	1.47	1.54	67.59	74.81	115	-11.11
	February	69	23	71	71.42	0.97	0.97	70.87	74.97	73	-3.98
	March	61	24	72	71.29	0.86	0.86	71.29	75.12	64	-3.28
2019-2020	April	53	25	71	71.67	0.74	0.64	82.53	75.28	48	4.66
	May	60	26	72	72.54	0.83	0.63	94.62	75.44	48	12.16
	June	42	27	73	73.46	0.57	0.69	61.21	75.59	52	-9.87
	July	50	28	74	74.25	0.67	0.68	73.01	75.75	52	-1.87
	August	57	29	74	74.63	0.76	0.75	76.18	75.90	57	0.20
	September	75	30	75	74.40	1.01	1.02	73.22	76.06	78	-2.91
	October	103	31	74	72.35	1.42	1.50	68.53	76.22	115	-11.56
	November	101	32	71	71.64	1.41	1.29	78.49	76.37	98	2.72
	December	99	33	73	72.93	1.36	1.35	73.38	76.53	103	-4.26
	January	119	34	73	73.56	1.62	1.54	77.34	76.69	118	1.00
	February	73	35	74	74.18	0.98	0.97	74.98	76.84	75	-1.81
	March	66	36	75	75.39	0.88	0.86	77.13	77.00	66	0.11
2020-2021	April	43	37	76	76.60	0.56	0.64	66.44	77.16	50	-6.88
	May	21	38	77	77.26	0.27	0.63	33.12	77.31	49	-28.03
	June	64	39	78	78.01	0.82	0.69	93.28	77.47	53	10.85
	July	59	40	78	78.81	0.75	0.68	86.16	77.63	53	5.84
	August	63	41	79	79.26	0.79	0.75	84.20	77.78	58	4.80
	September	84	42	79			1.02	82.01	77.94	80	4.17
	October	123	43				1.50	81.83	78.10	117	5.62
	November	110	44				1.29	85.48	78.25	101	9.30
	December	106	45				1.35	78.56	78.41	106	0.21
	January	130	46				1.54	84.48	78.57	121	9.11
	February	81	47				0.97	83.20	78.72	77	4.36
	March	69	48				0.86	80.64	78.88	67	1.50

RMSE : 8.92



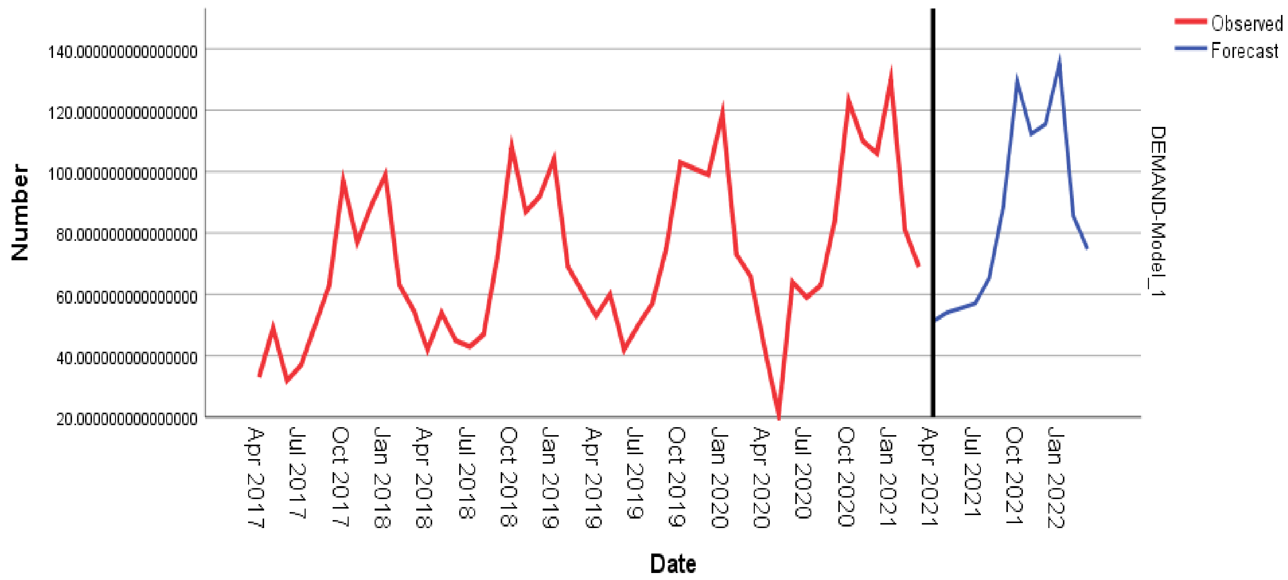
HOLT'S WINTER TRIPLE EXPONENTIAL SMOOTHING METHOD

We'll use SPSS to solve Holt's winter exponential smoothing method

Model Description			
			Model Type
Model ID	DEMAND	Model_1	Winters' Multiplicative

Model Statistics

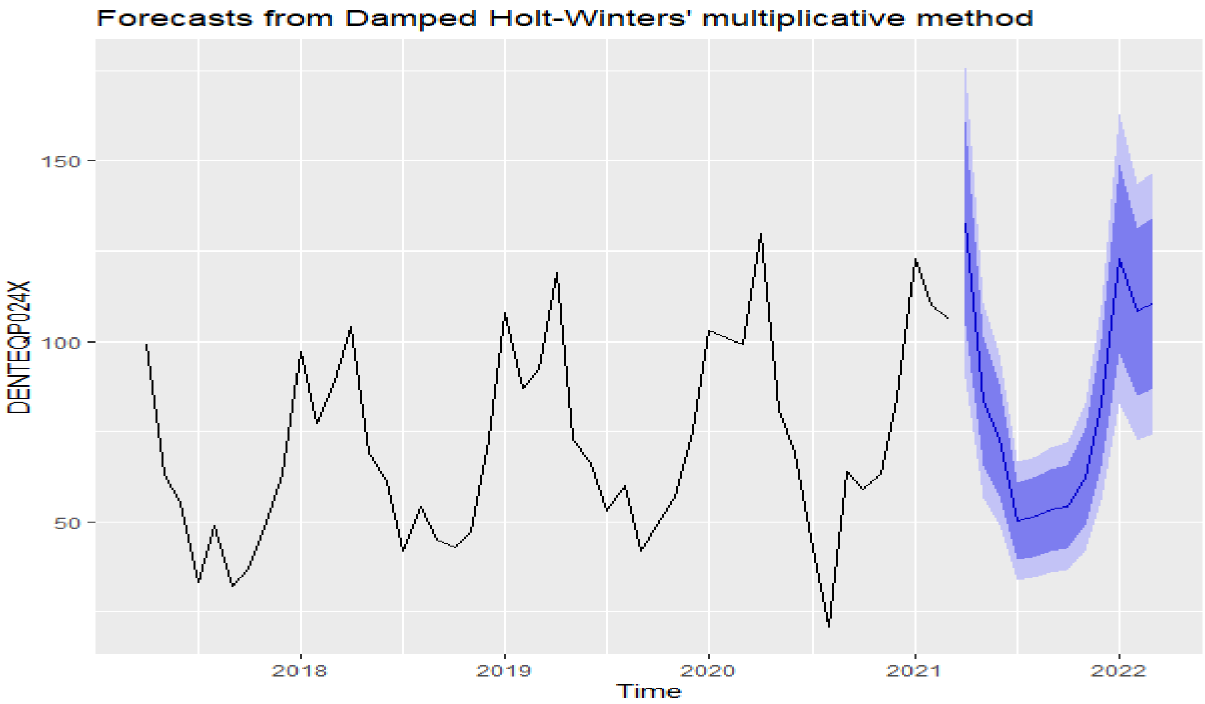
Model	Number of Predictors	Model Fit statistics: Stationary R-squared	Model Fit statistics: RMSE	Ljung-Box Q(18): Statistics	Ljung-Box Q(18): DF	Ljung-Box Q(18): Sig.	Number of Outliers
DEMAND-Model_1	0	.575	8.033	14.469	15	.490	0



HOLT'S WINTER (DAMPED) METHOD

```
  Smoothing parameters:
    alpha = 0.0061
    beta  = 0.006
    gamma = 1e-04
    phi   = 0.9778

  Initial states:
    l = 58.9574
    b = 0.6806
    s = 1.3234 1.2972 1.4802 1.001 0.7553 0.6591
           0.6506 0.6276 0.6176 0.8992 1.036 1.6529

  sigma:  0.1659

     AIC     AICc      BIC
431.2714 454.8576 464.9530

Error measures:
                    ME   RMSE      MAE       MPE     MAPE      MASE        ACF1
Training set 0.3678455 6.6502 4.430945 -1.965214 9.218151 0.4843543 -0.06861598
```

```
Forecasts:
         Point Forecast
Apr 2021      132.70657 1
May 2021       83.52567
Jun 2021       72.78481
Jul 2021       50.18932
Aug 2021       51.19823
Sep 2021       53.27084
Oct 2021       54.16333
Nov 2021       62.28604
Dec 2021       82.83869
Jan 2022      122.90691
Feb 2022      108.05953
Mar 2022      110.59336
```



CONCLUSION:

We have Used three method for forecasting		RMSE
1) Decomposition Method(Excel)		8.92
2) Exponential smoothing method(SPSS)		8.0333
3) Holt-winter(damped) method (R)		6.65

RMSE for Holt-winter(damped) method is less compare to other two method. Therefore, I have finally forecasted value via. this method.

Year	Month	Forecas
	April	133
	May	83
	June	73
	July	50
	August	51
2021-2022	September	53
	October	54
	November	62
	December	83
	January	122
	February	108
	March	110

FORECASTING

Demand Forecasting for 'A' Item **'DENTEQP023XXX'**

Using the data of past four years of demand for item 'DENTEQP023XXX' which is a category 'A' item, we'll prepare a time series forecasting model based on what kind of features the demand data is following.

Monthly Demand of last 4 years				
Material Code: DENTEQP023XXX				
Month/Ye	2017-2018	2018-2019	2019-2020	2020-2021
April	33	42	75	0
May	52	54	60	17
June	49	45	42	80
July	82	93	105	122
August	50	47	75	103
Septembe	64	72	81	97
October	97	108	77	93
novembe	77	87	61	79
Decembe	89	92	76	95
January	105	104	69	87
February	63	69	73	99
March	55	61	84	103
Total	816	874	878	975

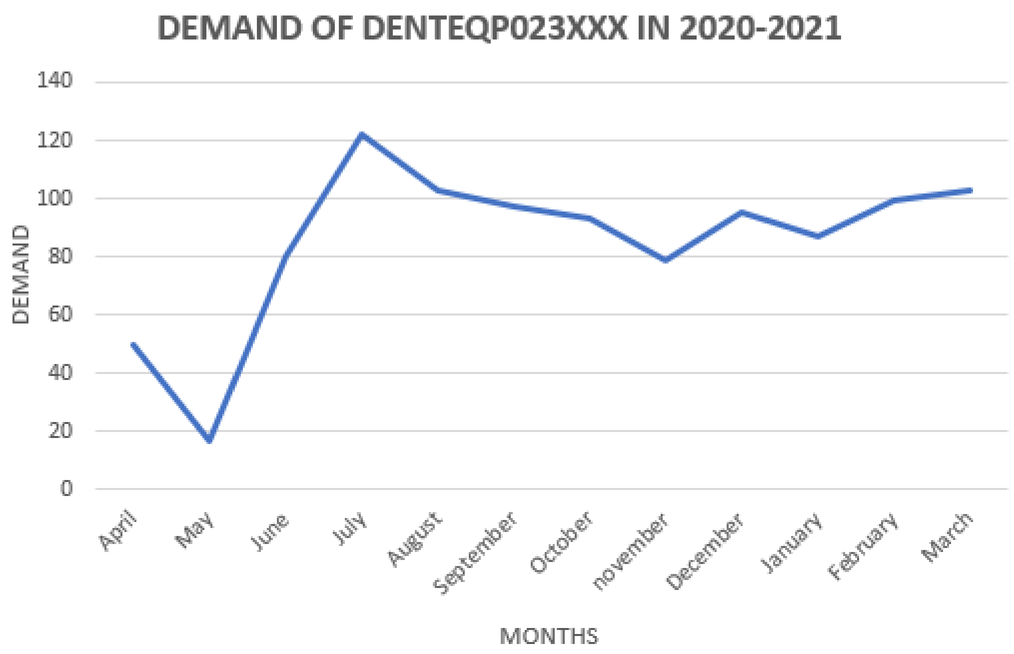
Table containing information regarding monthly demand of DENTEQP023XXX every year

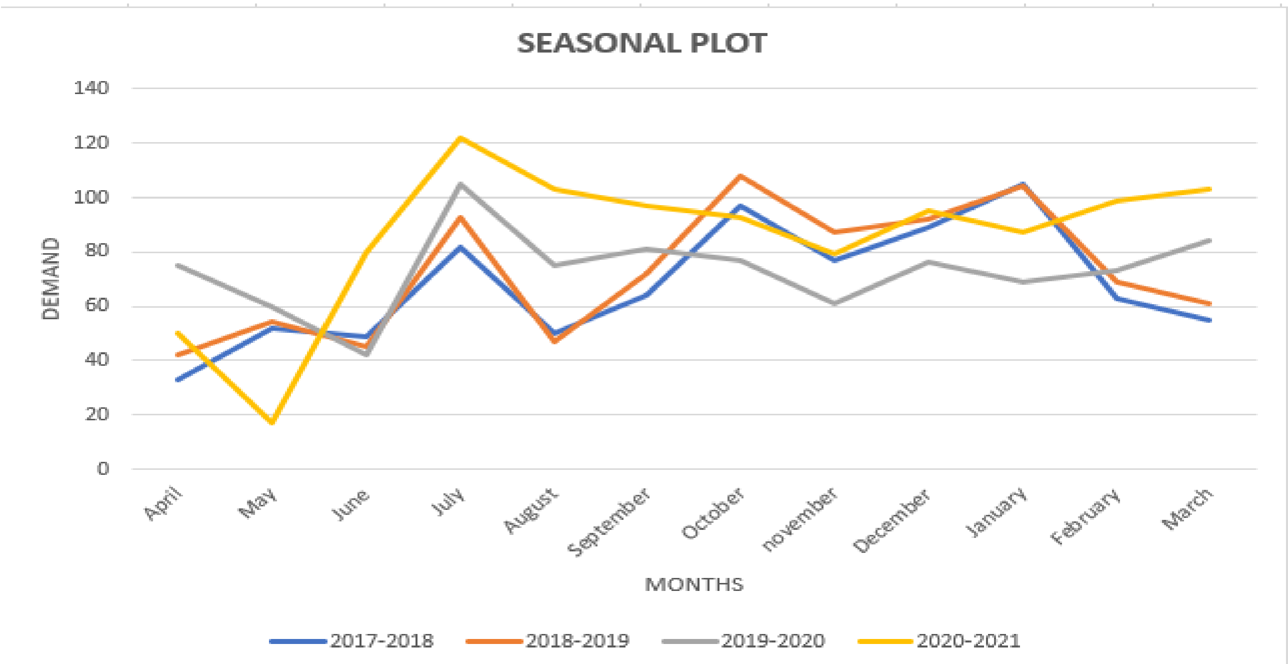
The data has four columns which are years and 12 indexes which are months. The cross-section is providing month-wise demand of DENTEQP023XXX every year.

We'll have to follow a stepwise approach to solving this problem. The steps involved are as follows:

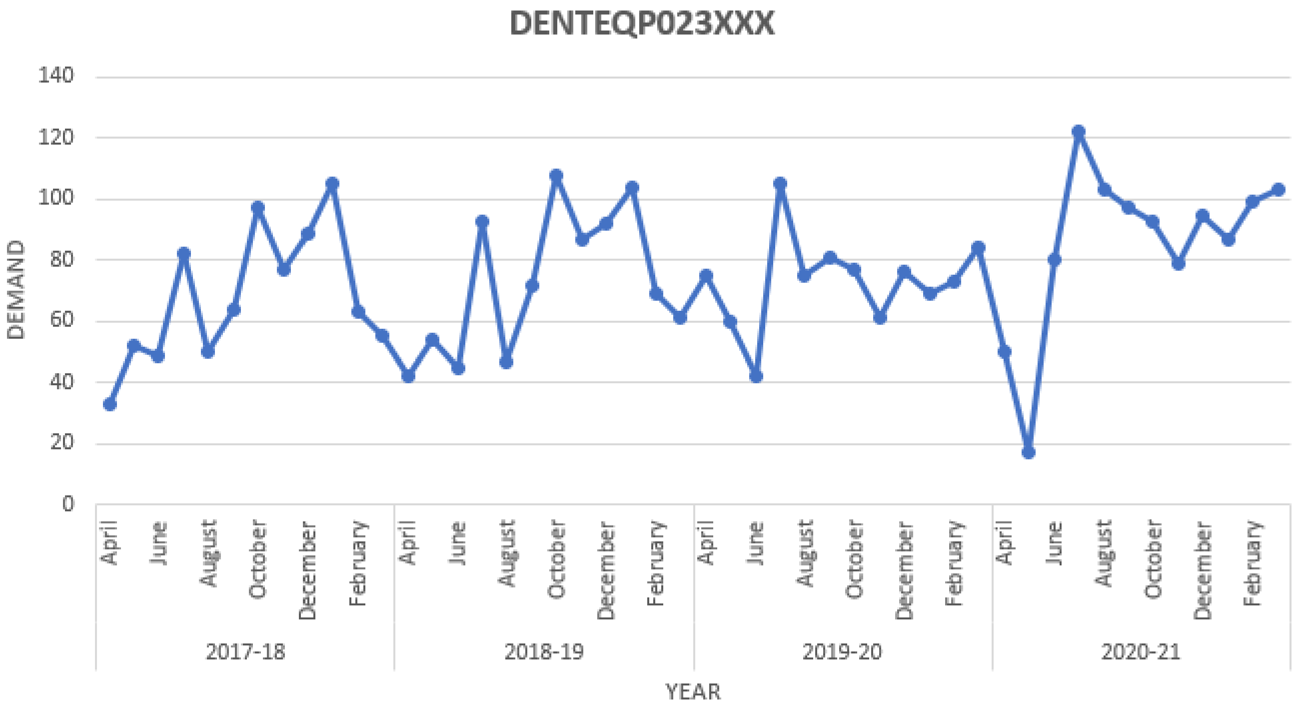
Exploratory Data Analysis: First of all, we'll plot our data into different information charts to extract useful insights and to visually feel what kind of pattern and behaviour of demand line is following. The main aim of this step is showing the trend, seasonality and irregular behaviour as well the whether the time series is stationary or not;
Model Building: Next up, we'll create the model that will provide the best results based on the information provided above. The main aim of this step is to deploy a pattern creating model that will be used in forecasting the demand for coming years. The last stage of this step is to create a plot showing actual V/s predicted values to see visually the kind of fit our model is providing;
Comparison based on performance metric: In our case, we'll be using 'RMSE' as a metric to compare the models and to find out which one is yielding the best possible result;
Forecasting: After finalizing the model, the last step is to forecast the demand for next period. In our case, we'll forecast the demand data for next year that will serve as a benchmark for the firm to order the 'DENTEQP023XXX' next year.
In April, 2020, the demand of DENTEQP023XXX is 0. However, for handling this outlier, we have taken the Average of last three April month demand. Which significantly improve the accuracy of our model

EXPLORATORY DATA ANALYSIS(EDA)





From the Seasonal Plot, we can clearly see that our data is seasonal.There is seasonality in the month July and October.



MODEL BUILDING

Decomposition Method

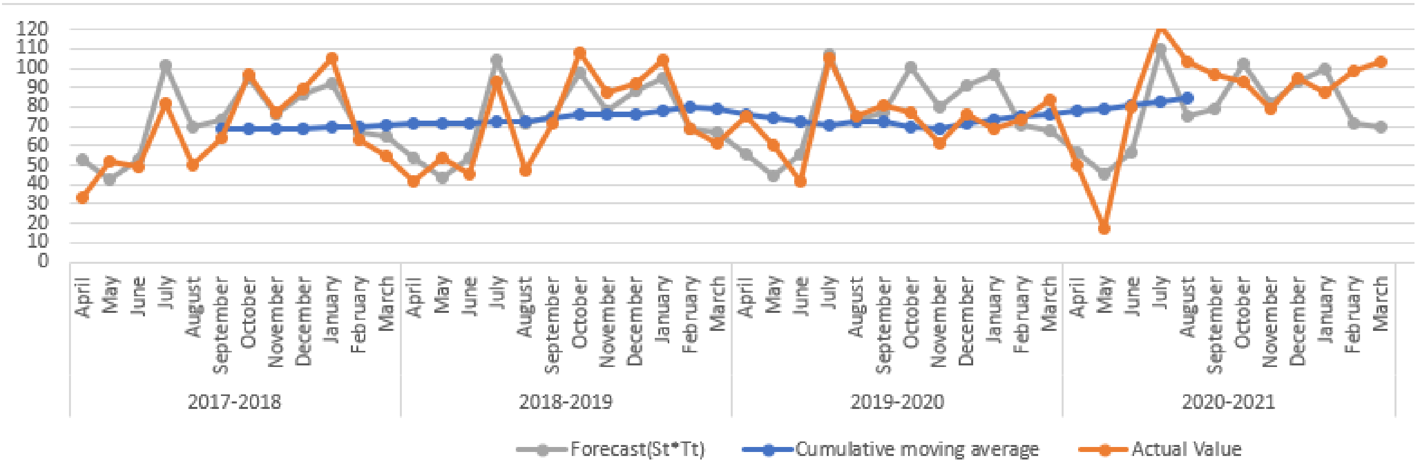
Under Decomposition method, we'll use multiplicate model with the following equation:

$$y_t = T_t \times C_t \times S_t \times I_t.$$

where,
T_t is the trend element;
S_t is the Seasonal component;
C_t is the Cyclical component;
I_t is the Irregular component;

DATESET

Year	Time	Demand	Time period	Moving average(12)	Cummulative moving avg(CMA - 12)	Seasonal and Irregular Components, (Y_t/CMA)	Seasonal index(S_t	Deseasonalize(Y_t/S_t)	Trend	Forecast(S_t*T_t)	Error
	April	33	1				0.74	44.69	71.52	53	-19.82
	May	52	2				0.59	88.05	71.68	42	9.67
	June	49	3				0.73	66.97	71.84	53	-3.56
	July	82	4				1.41	58.00	71.99	102	-19.79
	August	50	5				0.97	51.66	72.15	70	-19.82
2017-2018	September	64	6	68	68.38	0.94	1.01	63.38	72.30	73	-9.01
	October	97	7	69	68.83	1.41	1.31	73.77	72.46	95	1.72
	November	77	8	69	68.75	1.12	1.05	73.37	72.62	76	0.79
	December	89	9	69	69.04	1.29	1.19	75.02	72.77	86	2.66
	January	105	10	70	69.38	1.51	1.26	83.14	72.93	92	12.89
	February	63	11	69	69.58	0.91	0.92	68.85	73.09	67	-3.88
	March	55	12	70	70.38	0.78	0.89	62.11	73.24	65	-9.86
	April	42	13	71	71.25	0.59	0.74	56.87	73.40	54	-12.21
	May	54	14	72	71.79	0.75	0.59	91.44	73.56	43	10.56
	June	45	15	72	71.88	0.63	0.73	61.50	73.71	54	-8.94
	July	93	16	72	72.08	1.29	1.41	65.78	73.87	104	-11.44
	August	47	17	72	72.58	0.65	0.97	48.56	74.03	72	-24.64
2018-2019	September	72	18	73	74.21	0.97	1.01	71.30	74.18	75	-2.91
	October	108	19	76	75.83	1.42	1.31	82.14	74.34	98	10.25
	November	87	20	76	75.96	1.15	1.05	82.90	74.50	78	8.82
	December	92	21	76	76.33	1.21	1.19	77.55	74.65	89	3.43
	January	104	22	77	78.00	1.33	1.26	82.35	74.81	94	9.52
	February	69	23	79	79.54	0.87	0.92	75.41	74.97	69	0.40
	March	61	24	80	78.63	0.78	0.89	68.89	75.12	67	-5.52
	April	75	25	77	76.25	0.98	0.74	101.56	75.28	56	19.41
	May	60	26	75	74.50	0.81	0.59	101.60	75.44	45	15.45
	June	42	27	74	72.38	0.58	0.73	57.40	75.59	55	-13.31
	July	105	28	71	71.08	1.48	1.41	74.26	75.75	107	-2.10
	August	75	29	71	72.21	1.04	0.97	77.50	75.90	73	1.54
2019-2020	September	81	30	73	72.13	1.12	1.01	80.22	76.06	77	4.20
	October	77	31	71	69.29	1.11	1.31	58.56	76.22	100	-23.22
	November	61	32	68	69.08	0.88	1.05	58.13	76.37	80	-19.15
	December	76	33	71	71.38	1.06	1.19	64.06	76.53	91	-14.79
	January	69	34	72	73.25	0.94	1.26	54.63	76.69	97	-27.85
	February	73	35	74	75.08	0.97	0.92	79.78	76.84	70	2.68
	March	84	36	76	76.42	1.10	0.89	94.86	77.00	68	15.81
	April	50	37	77	77.83	0.64	0.74	67.71	77.16	57	-6.98
	May	17	38	79	79.38	0.21	0.59	28.79	77.31	46	-28.66
	June	80	39	80	80.92	0.99	0.73	109.34	77.47	57	23.32
	July	122	40	82	82.75	1.47	1.41	86.29	77.63	110	12.25
	August	103	41	84	84.63	1.22	0.97	106.43	77.78	75	27.72
2020-2021	September	97	42	85			1.01	96.06	77.94	79	18.30
	October	93	43				1.31	70.73	78.10	103	-9.69
	November	79	44				1.05	75.28	78.25	82	-3.12
	December	95	45				1.19	80.08	78.41	93	1.98
	January	87	46				1.26	68.89	78.57	99	-12.22
	February	99	47				0.92	108.19	78.72	72	26.97
	March	103	48				0.89	116.31	78.88	70	33.15



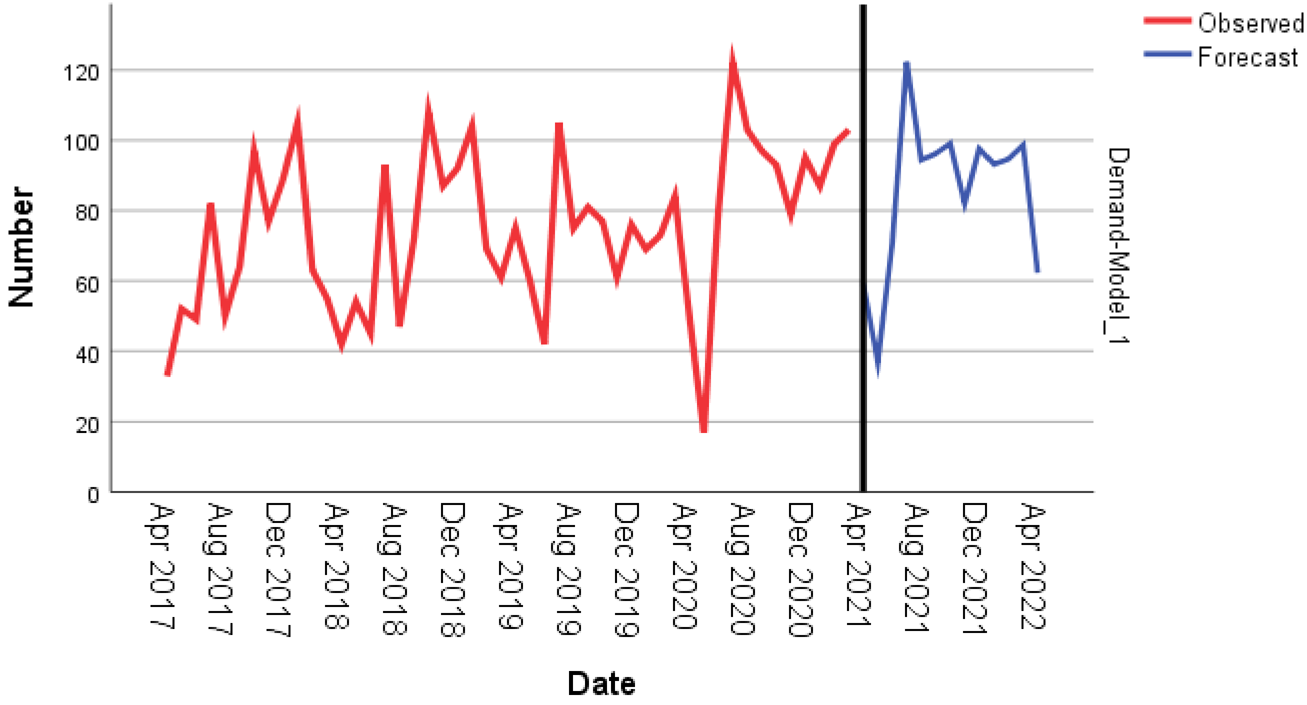
RMSE : 14.99

SPSS : EXPONENTIAL SMOOTHING

Model Description			
			Model Type
Model ID	DEMAND	Model_1	Winters' Multiplicative

Model Statistics

Model	Number of Predictors	Model Fit statistics		Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	RMSE	Statistics	DF	Sig.	
Demand-Model_1	0	.260	16.859	20.439	15	.156	0

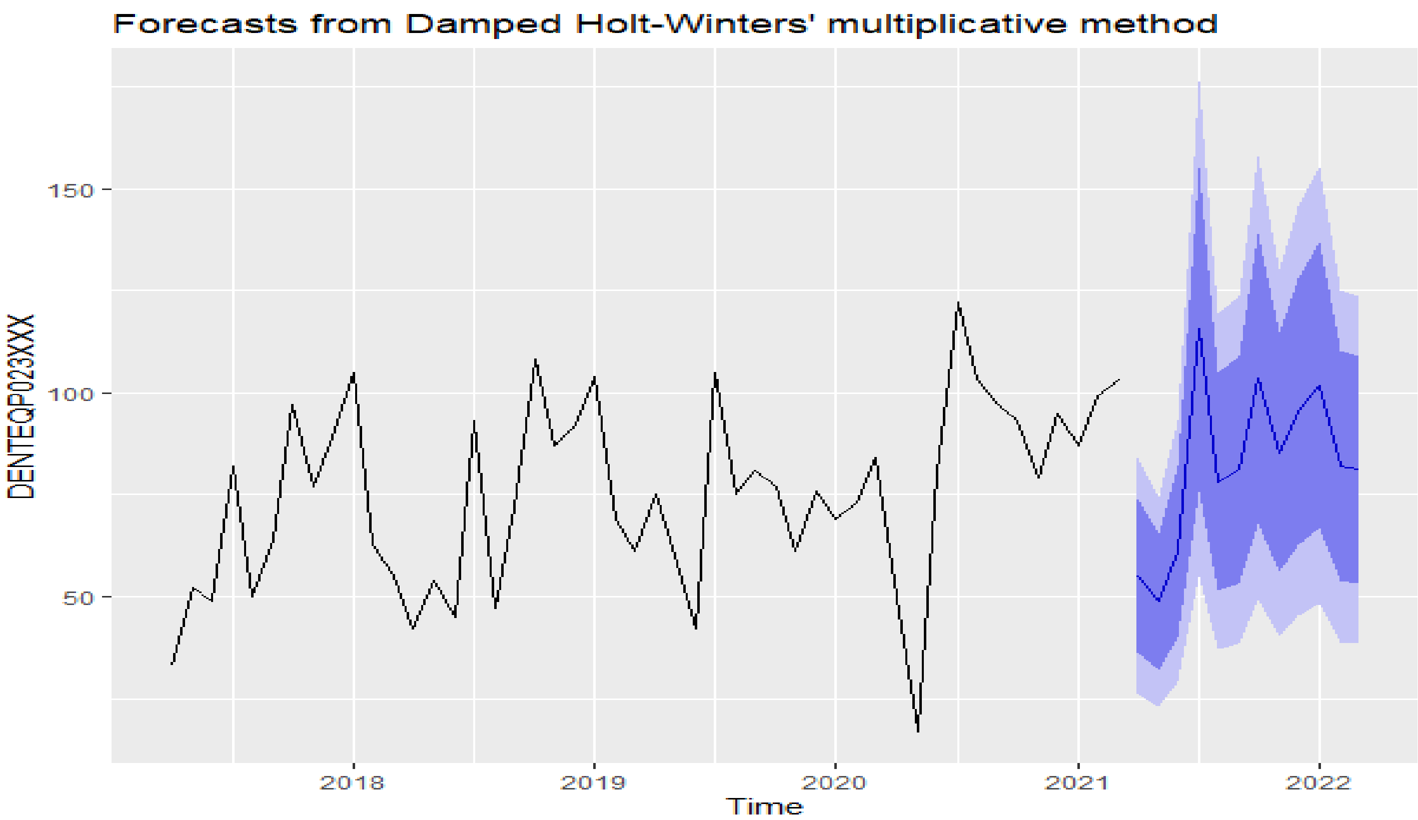


YEAR_	MONTH_	DATE_	Predicted_Demand_Model_1	LCL_Demand_Model_1	UCL_Demand_Model_1
2021	4	APR 2021	59	25	93
2021	5	MAY 2021	37	3	71
2021	6	JUN 2021	71	37	105
2021	7	JUL 2021	122	88	156
2021	8	AUG 2021	94	60	128
2021	9	SEP 2021	96	62	130
2021	10	OCT 2021	99	65	133
2021	11	NOV 2021	82	48	116
2021	12	DEC 2021	98	64	132
2022	1	JAN 2022	93	59	127
2022	2	FEB 2022	95	61	129
2022	3	MAR 2022	99	65	133
2022	4	APR 2022	62	23	102

HOLT'S WINTER (DAMPED) METHOD

```
  Smoothing parameters:
    alpha = 1e-04
    beta  = 1e-04
    gamma = 1e-04
    phi   = 0.9759

  Initial states:
    l = 63.5266
    b = 0.6305
    s = 0.974 0.9867 1.2277 1.1513 1.0322 1.2568
           0.986 0.9515 1.4111 0.7469 0.5981 0.6777

  sigma:  0.2681

     AIC     AICc      BIC
484.9185 508.5047 518.6001

Error measures:
                    ME     RMSE      MAE       MPE     MAPE      MASE      ACF1
Training set 0.5104123 14.07893 11.90277 -5.016758 19.50938 0.7349909 0.2298433
```

```
     Forecasts:
              Point Forecast    Lo 80     Hi 80    Lo 95     Hi 95
     Apr 2021       55.11517 36.17514  74.05520 26.14889  84.08145
     May 2021       48.76500 32.00717  65.52283 23.13611  74.39388
     Jun 2021       61.03541 40.06092  82.00990 28.95769  93.11312
     Jul 2021      115.56438 75.85130 155.27746 54.82846 176.30030
     Aug 2021       78.10000 51.26135 104.93865 37.05383 119.14618
     Sep 2021       81.10538 53.23394 108.97682 38.47969 123.73107
     Oct 2021      103.59309 67.99386 139.19232 49.14876 158.03741
     Nov 2021       85.25108 55.95498 114.54718 40.44655 130.05560
     Dec 2021       95.28205 62.53884 128.02526 45.20564 145.35847
     Jan 2022      101.79287 66.81223 136.77351 48.29460 155.29114
     Feb 2022       81.96935 53.80096 110.13774 38.88951 125.04919
     Mar 2022       81.05624 53.20162 108.91086 38.45627 123.65621
```



CONCLUSION:

We have used three method for forecasting		RMSE
1) Decomposition Method(Excel)		14.99
2) Exponential smoothing method(SPSS)		16.859
3) Holt-winter(damped) method (R)		14.07

RMSE for Holt-winter(damped) method is less compare to other two method. Therefore, We have finally forecasted value via. this method.

Year	Month	Forecas
	April	55
	May	49
	June	61
	July	115
	August	78
2021-2022	September	81
	October	104
	November	85
	December	95
	January	101
	February	82
	March	81

FORECASTING

Demand Forecasting for 'A' Item '**DENTEQP022XXX'**

Using the data of past four years of demand for item 'DENTEQP022XXX' which is a category 'A' item, we'll prepare a time series forecasting model based on what kind of features the demand data is following.

Monthly Demand of last 4 years				
Material Code: DENTEQP022XXX				
Month/Ye	2017-2018	2018-2019	2019-2020	2020-2021
April	53	69	77	0
May	70	83	89	27
June	78	85	90	66
July	47	60	57	48
August	60	50	68	57
Septembe	90	85	111	97
October	140	157	165	155
novembe	104	108	125	122
Decembe	92	101	114	120
January	72	79	80	89
February	70	76	86	99
March	60	67	72	70
Total	936	1020	1134	950

Table containing information regarding monthly demand of DENTEQP022XXX every year

The data has four columns which are years and 12 indexes which are months. The cross-section is providing month-wise demand of DENTEQP022XXX every year.

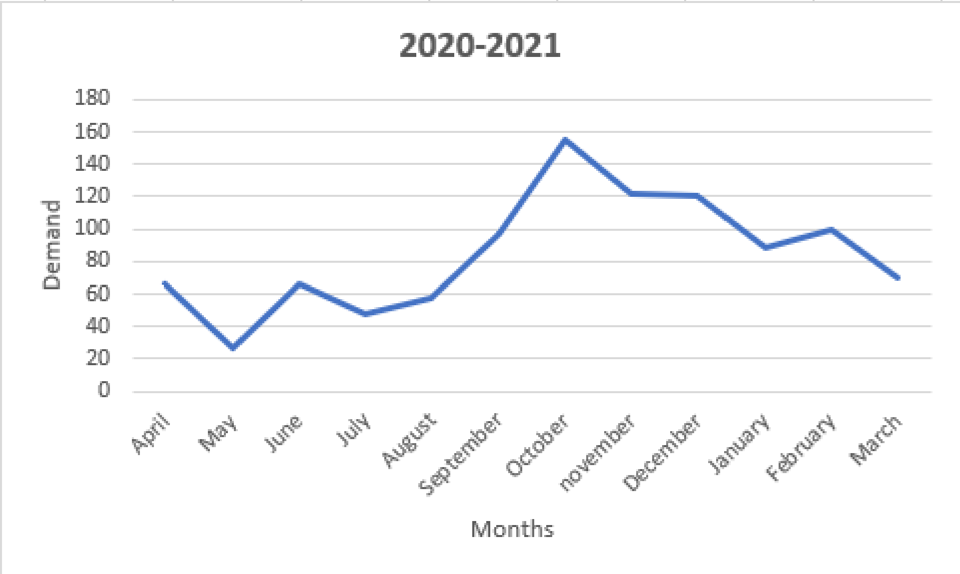
We'll have to follow a stepwise approach to solving this problem. The steps involved are as follows:

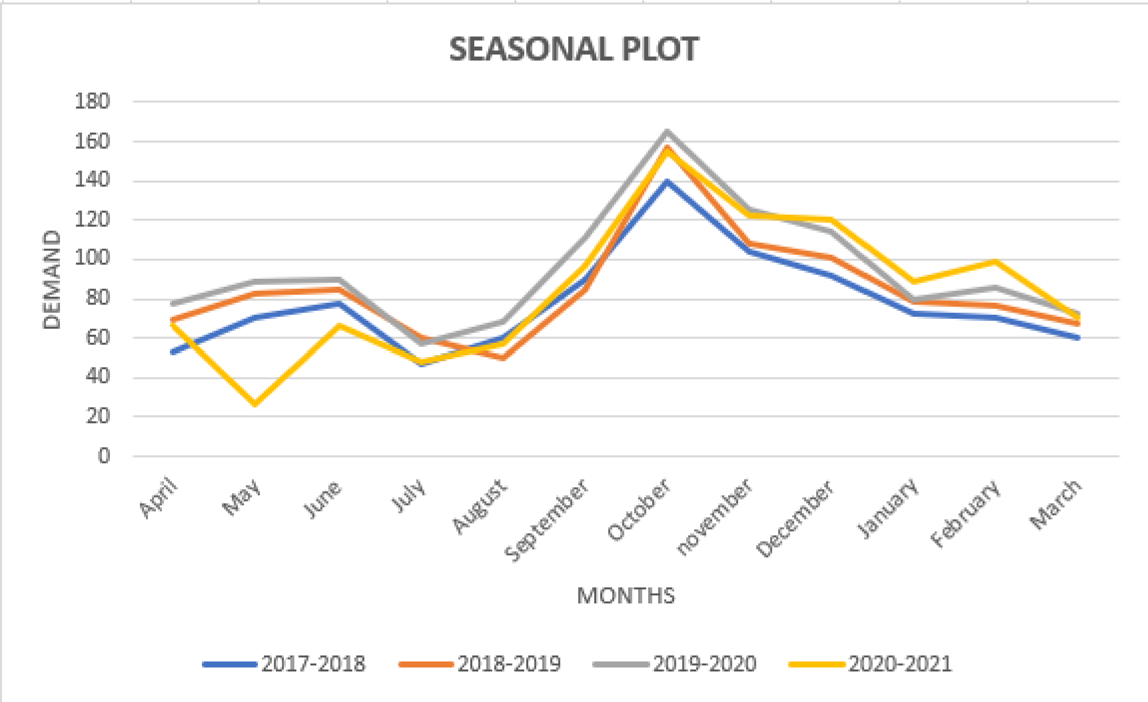
- **Exploratory Data Analysis:** First of all, we'll plot our data into different information charts to extract useful insights and to visually feel what kind of pattern and behaviour of demand line is following. The main aim of this step is showing the trend, seasonality and irregular behaviour as well the whether the time series is stationary or not;
- **Model Building:** Next up, we'll create the model that will provide the best results based on the information provided above. The main aim of this step is to deploy a pattern creating model that will be used in forecasting the demand for coming years. The last stage of this step is to create a plot showing actual V/s predicted values to see visually the kind of fit our model is providing;
- **Comparison based on performance metric:** In our case, we'll be using 'RMSE' as a metric to compare the models and to find out which one is yielding the best possible result;
- **Forecasting:** After finalizing the model, the last step is to forecast the demand for next period. In our case, we'll forecast the demand data for next year that will serve as a benchmark for the firm to order the 'DENTEQP022XXX' next year.

  In April, 2020, the demand of DENTEQP022XXX is 0. However, for handling this outlier, we have taken the Average of last three April month demand. Which significantly improve the accuracy of our model

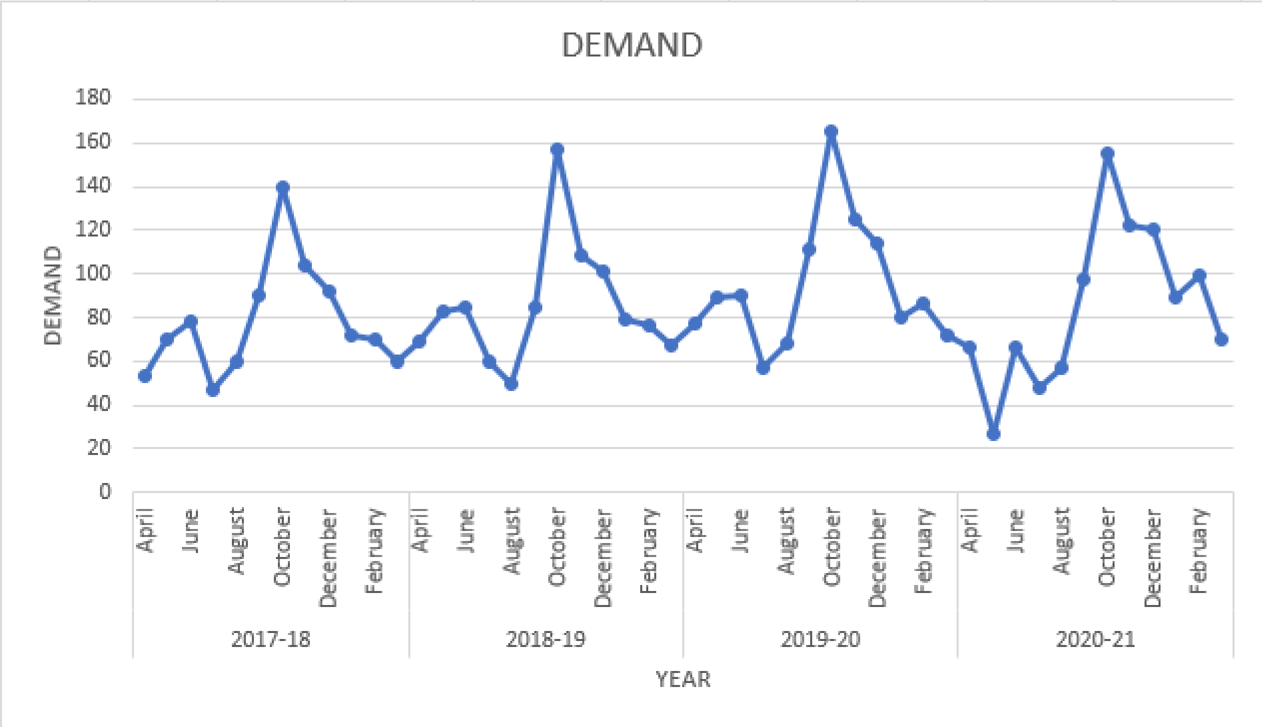
EXPLORATORY DATA ANALYSIS(EDA)

Plotting this data to understand better the variations in the inter and intra monthly demand, we can see that:





From the Seasonal Plot, we can clearly see that our data is seasonal.There is seasonality in the month October.



MODEL BUILDING

Decomposition Method

Under Decomposition method, we'll use multiplicate model with the following equation:

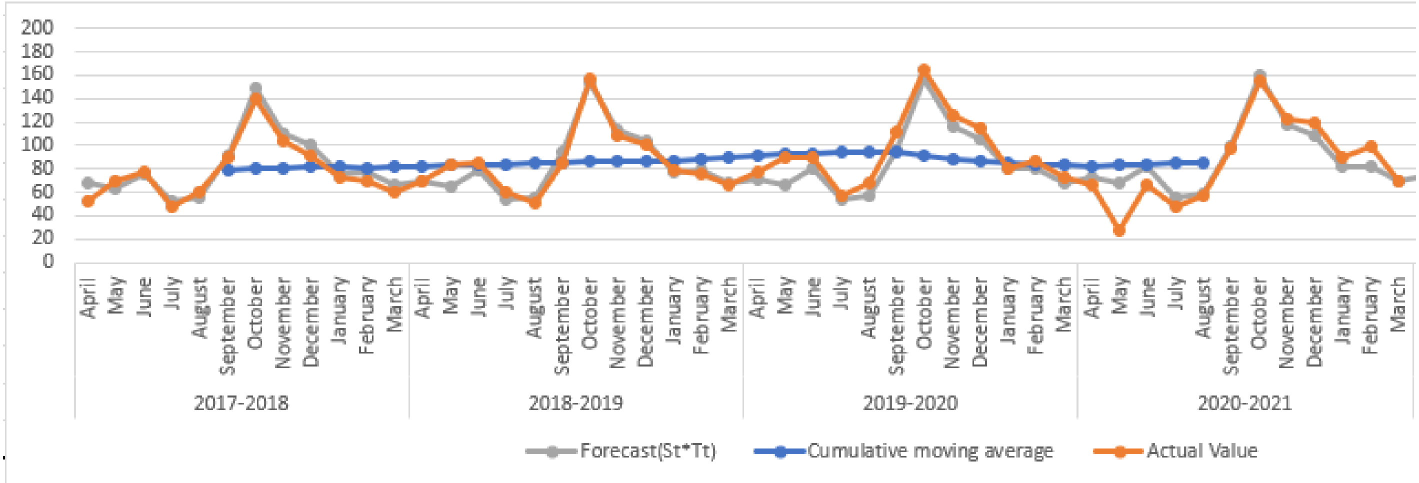
$$y_t = T_t \times C_t \times S_t \times I_t.$$

where,
T_t is the trend element;
S_t is the Seasonal component;
C_t is the Cyclical component;
I_t is the Irregular component;

DATESET

Year	Time	Demand	Time period	Moving average(12)	Cummulative moving avg(CMA - 12)	Seasonal and Irregular Components, (Y_t/CMA)	Seasonal index(S_t	Deseasonalize(Y_t/ S_t)	Trend	Forecast(S_t*T_t)	Error
2017-2018	April	53	1				0.83	64.15	82.23	68	-14.94
	May	70	2				0.76	91.80	82.39	63	7.17
	June	78	3				0.92	84.37	82.55	76	1.68
	July	47	4				0.63	74.57	82.71	52	-5.13
	August	60	5				0.66	90.73	82.88	55	5.19
	September	90	6	78	78.67	1.14	1.11	81.31	83.04	92	-1.91
	October	140	7	79	79.88	1.75	1.80	77.87	83.20	150	-9.58
	November	104	8	80	80.71	1.29	1.32	78.61	83.37	110	-6.29
	December	92	9	81	81.54	1.13	1.21	76.21	83.53	101	-8.83
	January	72	10	82	81.67	0.88	0.91	79.19	83.69	76	-4.10
	February	70	11	81	81.04	0.86	0.91	76.63	83.86	77	-6.60
	March	60	12	81	81.54	0.74	0.78	76.82	84.02	66	-5.63
2018-2019	April	69	13	82	82.42	0.84	0.83	83.51	84.18	70	-0.55
	May	83	14	83	82.96	1.00	0.76	108.85	84.35	64	18.68
	June	85	15	83	83.63	1.02	0.92	91.94	84.51	78	6.87
	July	60	16	84	84.17	0.71	0.63	95.19	84.67	53	6.63
	August	50	17	84	84.71	0.59	0.66	75.61	84.84	56	-6.10
	September	85	18	85	85.33	1.00	1.11	76.80	85.00	94	-9.08
	October	157	19	86	85.92	1.83	1.80	87.33	85.16	153	3.90
	November	108	20	86	86.38	1.25	1.32	81.64	85.32	113	-4.88
	December	101	21	87	86.46	1.17	1.21	83.67	85.49	103	-2.19
	January	79	22	86	87.08	0.91	0.91	86.89	85.65	78	1.12
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	March	67	24	90	90.33	0.74	0.78	85.78	85.98	67	-0.16
2019-2020	April	77	25	91	91.38	0.84	0.83	93.19	86.14	71	5.83
	May	89	26	92	92.63	0.96	0.76	116.71	86.30	66	23.19
	June	90	27	93	93.21	0.97	0.92	97.35	86.47	80	10.06
	July	57	28	93	93.67	0.61	0.63	90.43	86.63	55	2.40
	August	68	29	94	94.29	0.72	0.66	102.82	86.79	57	10.60
	September	111	30	95	94.04	1.18	1.11	100.29	86.96	96	14.75
	October	165	31	94	91.00	1.81	1.80	91.78	87.12	157	8.38
	November	125	32	88	87.42	1.43	1.32	94.48	87.28	115	9.53
	December	114	33	86	86.04	1.32	1.21	94.44	87.45	106	8.44
	January	80	34	86	85.21	0.94	0.91	87.99	87.61	80	0.34
	February	86	35	85	84.17	1.02	0.91	94.15	87.77	80	5.83
	March	72	36	84	83.17	0.87	0.78	92.18	87.93	69	3.32
2020-2021	April	66	37	83	82.63	0.80	0.83	79.88	88.10	73	-6.79
	May	27	38	83	82.75	0.33	0.76	35.41	88.26	67	-40.30
	June	66	39	83	83.38	0.79	0.92	71.39	88.42	82	-15.75
	July	48	40	84	84.29	0.57	0.63	76.16	88.59	56	-7.84
	August	57	41	85	84.75	0.67	0.66	86.19	88.75	59	-1.69
	September	97	42	85			1.11	87.64	88.91	98	-1.41
	October	155	43				1.80	86.22	89.08	160	-5.14
	November	122	44				1.32	92.22	89.24	118	3.94
	December	120	45				1.21	99.41	89.40	108	12.08
	January	89	46				0.91	97.89	89.57	81	7.56
	February	99	47				0.91	108.38	89.73	82	17.04
	March	70	48				0.78	89.62	89.89	70	-0.21

RMSE: 10.26



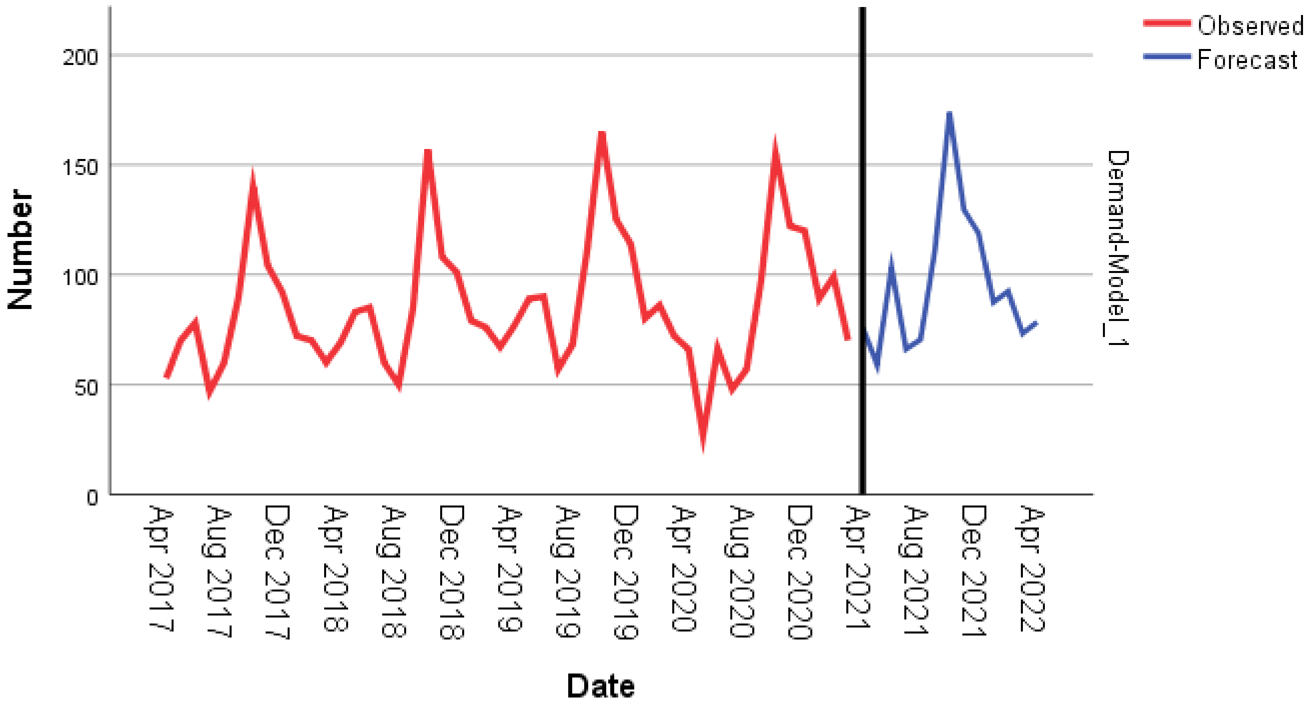
SPSS : EXPONENTIAL SMOOTHING

Model Description			
			Model Type
Model ID	DEMAND	Model_1	Winters' Multiplicative

Model Statistics

Model	Number of Predictors	Model Fit statistics: Stationary R-squared	Model Fit statistics: RMSE	Ljung-Box Q(18): Statistics	Ljung-Box Q(18): DF	Ljung-Box Q(18): Sig.	Number of Outliers
Demand-Model_1	0	.268	11.337	12.278	15	.658	0

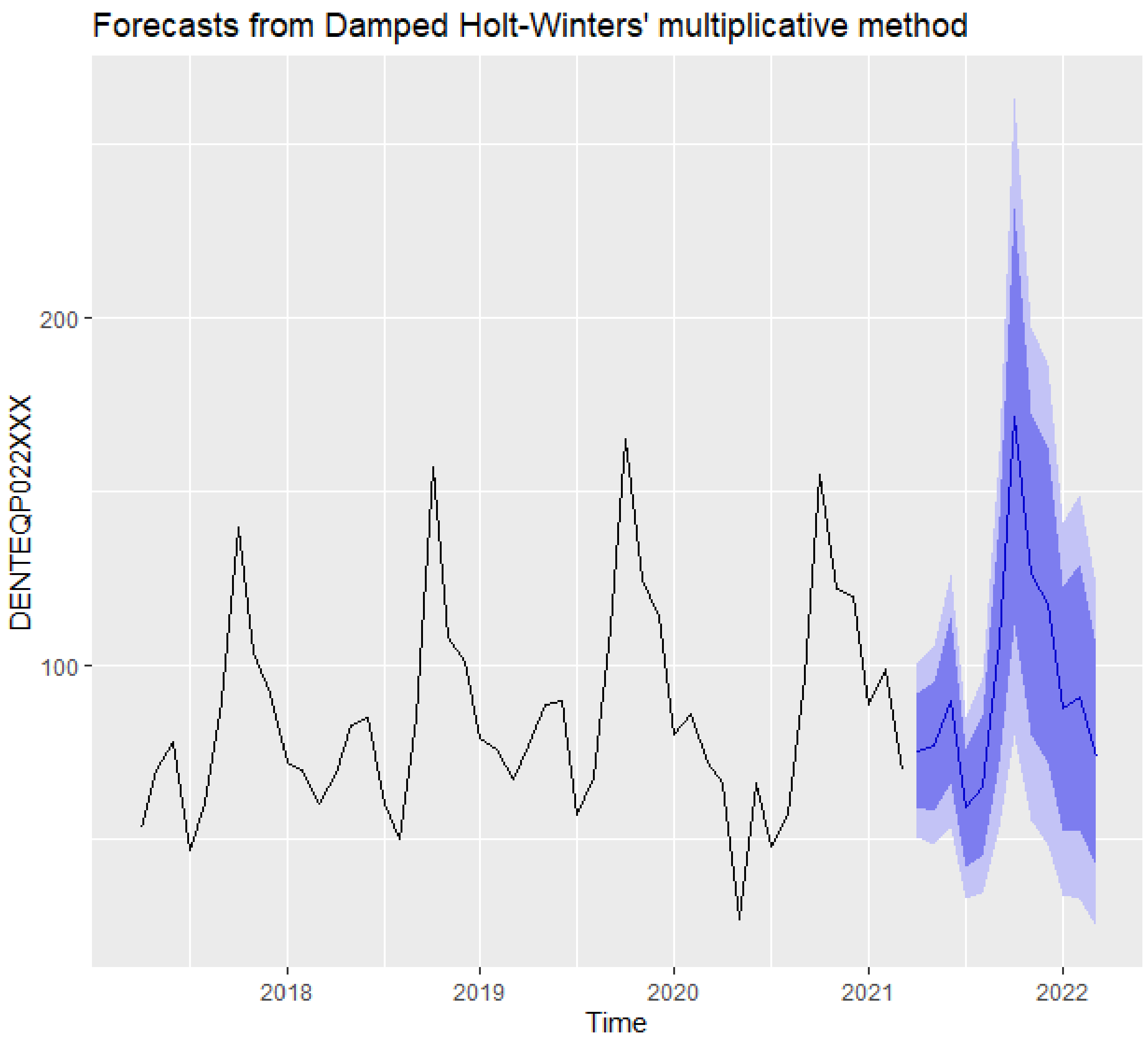
Demand	YEAR_	MONTH_	DATE_	Predicted_Demand_Model_1	LCL_Demand_Model_1	UCL_Demand_Model_1
.	2021	4	APR 2021	76	53	99
.	2021	5	MAY 2021	59	34	84
.	2021	6	JUN 2021	103	65	141
.	2021	7	JUL 2021	66	35	97
.	2021	8	AUG 2021	70	35	106
.	2021	9	SEP 2021	111	59	164
.	2021	10	OCT 2021	174	93	254
.	2021	11	NOV 2021	129	67	192
.	2021	12	DEC 2021	119	59	178
.	2022	1	JAN 2022	87	40	135
.	2022	2	FEB 2022	92	41	144
.	2022	3	MAR 2022	73	29	118
.	2022	4	APR 2022	78	27	130



HOLT'S WINTER (DAMPED) METHOD

```
  Smoothing parameters:
    alpha = 0.5113
    beta  = 1e-04
    gamma = 3e-04
    phi   = 0.9544

  Initial states:
    l = 78.1454
    b = 0.3849
    s = 0.7735 0.955 0.9179 1.2347 1.3271 1.8044
           1.1282 0.6862 0.621 0.9468 0.8093 0.7959

  sigma:  0.1677

     AIC     AICc      BIC
451.1925 474.7787 484.8741

Error measures:
                    ME     RMSE      MAE       MPE     MAPE      MASE       ACF1
Training set 0.3541631 9.743009 7.048465 -2.100468 11.08702 0.6219234 0.08255966
```

```
Forecasts:
         Point Forecast
Jan 2021       91.41138
Feb 2021       98.70366
Mar 2021       78.30392
Apr 2021       78.92716
May 2021       75.70027
Jun 2021       90.76398
Jul 2021       59.75680
Aug 2021       66.00182
Sep 2021      107.75049
Oct 2021      173.03704
Nov 2021      127.36455
Dec 2021      117.05875
```


Forecasts from Damped Holt-Winters' multiplicative method
DENTEQP022XXX
200
100
2018
2019
2020
2021
2022
Time

CONCLUSION:

We have Used three method for forecasting		RMSE
1) Decomposition Method(Excel)		10.26
2) Exponential smoothing method(SPSS)		11.337
3) Holt-winter(damped) method (R)		9.743

RMSE for Holt-winter(damped) method is less compare to other two method. Therefore, We have finally forecasted value via. this method.

Year	Month	Forecas
	April	76
	May	77
	June	90
	July	59
	August	65
2021-2022	September	107
	October	172
	November	126
	December	118
	January	87
	February	91
	March	74

FORECASTING

Demand Forecasting for 'A' Item '**DENTEQP018XXX'**

Using the data of past four years of demand for item 'DENTEQP018XXX' which is a category 'A' item, we'll prepare a time series forecasting model based on what kind of features the demand data is following.

Monthly Demand of last 4 years				
Material Code: DENTEQP018XXX				
Month/Ye	2017-2018	2018-2019	2019-2020	2020-2021
April	27	35	54	39
May	70	84	82	11
June	78	73	106	127
July	97	121	136	129
August	41	32	43	77
Septembe	93	77	114	117
October	31	38	51	87
novembe	40	42	36	76
Decembe	83	98	116	155
January	91	96	121	171
February	28	53	56	103
March	63	86	113	147
Total	742	835	1028	1239

Table containing information regarding monthly demand of DENTEQP018XXX every year

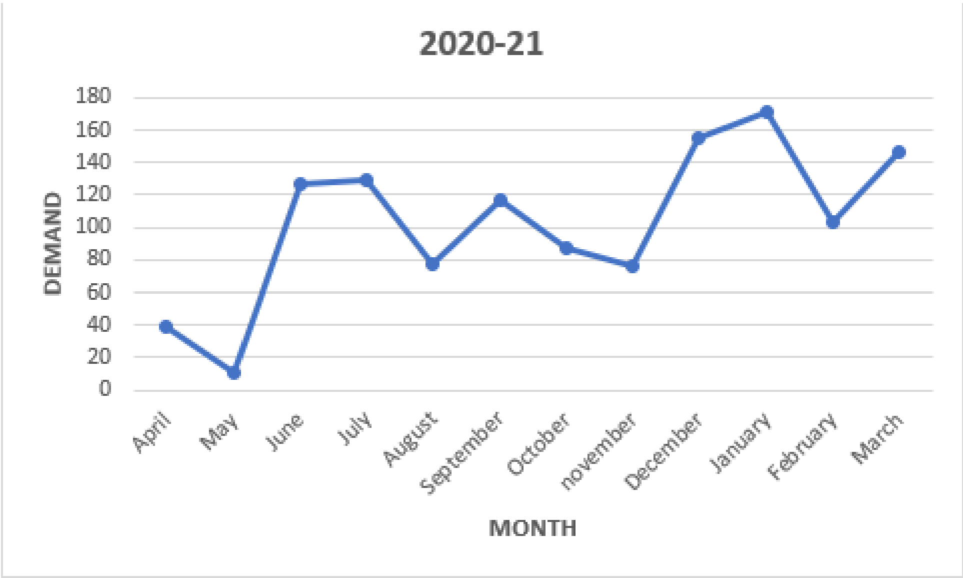
The data has four columns which are years and 12 indexes which are months. The cross-section is providing month-wise demand of DENTEQP018XXX every year.

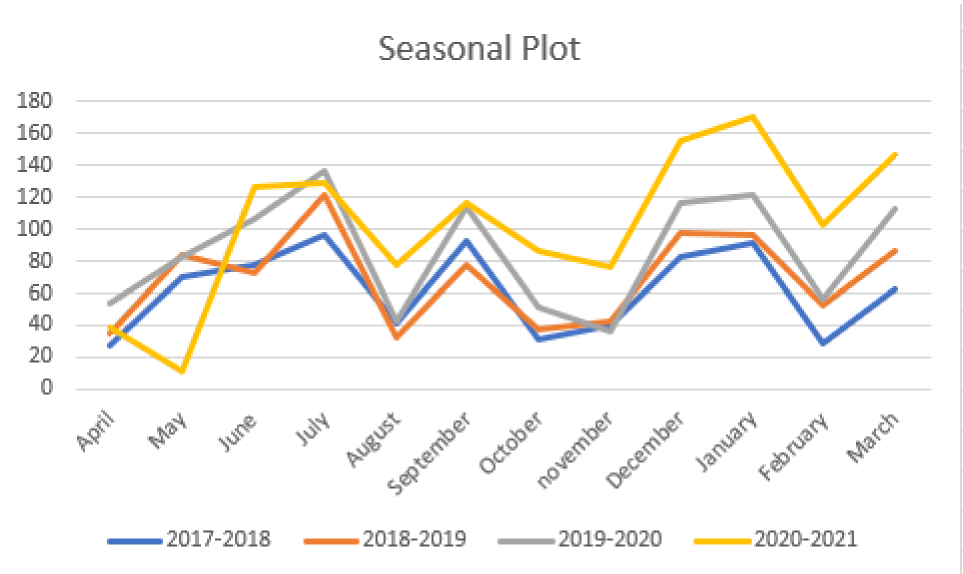
We'll have to follow a stepwise approach to solving this problem. The steps involved are as follows:

- **Exploratory Data Analysis:** First of all, we'll plot our data into different information charts to extract useful insights and to visually feel what kind of pattern and behaviour of demand line is following. The main aim of this step is showing the trend, seasonality and irregular behaviour as well the whether the time series is stationary or not;
- **Model Building:** Next up, we'll create the model that will provide the best results based on the information provided above. The main aim of this step is to deploy a pattern creating model that will be used in forecasting the demand for coming years. The last stage of this step is to create a plot showing actual V/s predicted values to see visually the kind of fit our model is providing;
- **Comparison based on performance metric:** In our case, we'll be using 'RMSE' as a metric to compare the models and to find out which one is yielding the best possible result;
- **Forecasting:** After finalizing the model, the last step is to forecast the demand for next period. In our case, we'll forecast the demand data for next year that will serve as a benchmark for the firm to order the 'DENTEQP018XXX' next year.
  In April, 2020, the demand of DENTEQP018XXX is 0. However, for handling this outlier, we have taken the Average of last three April month demand. Which significantly improve the accuracy of our model

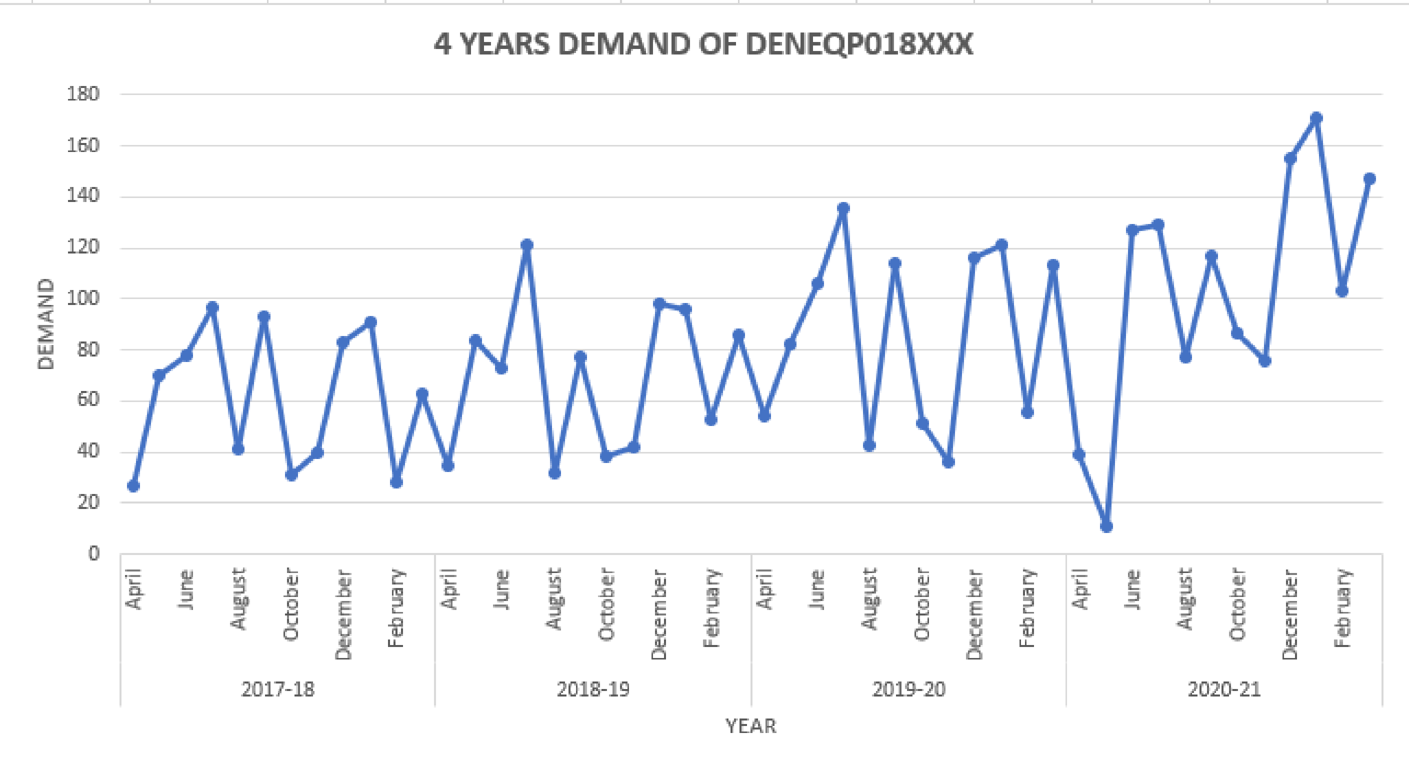
EXPLORATORY DATA ANALYSIS(EDA)

Plotting this data to understand better the variations in the inter and intra monthly demand, we can see that:





We can clearly see there is seasonality in our dataset



MODEL BUILDING

Decomposition Method

Under Decomposition method, we'll use multiplicate model with the following equation:

$$y_t = T_t \times C_t \times S_t \times I_t.$$

where,
T_t is the trend element;
S_t is the Seasonal component;
C_t is the Cyclical component;
I_t is the Irregular component;

DATESET

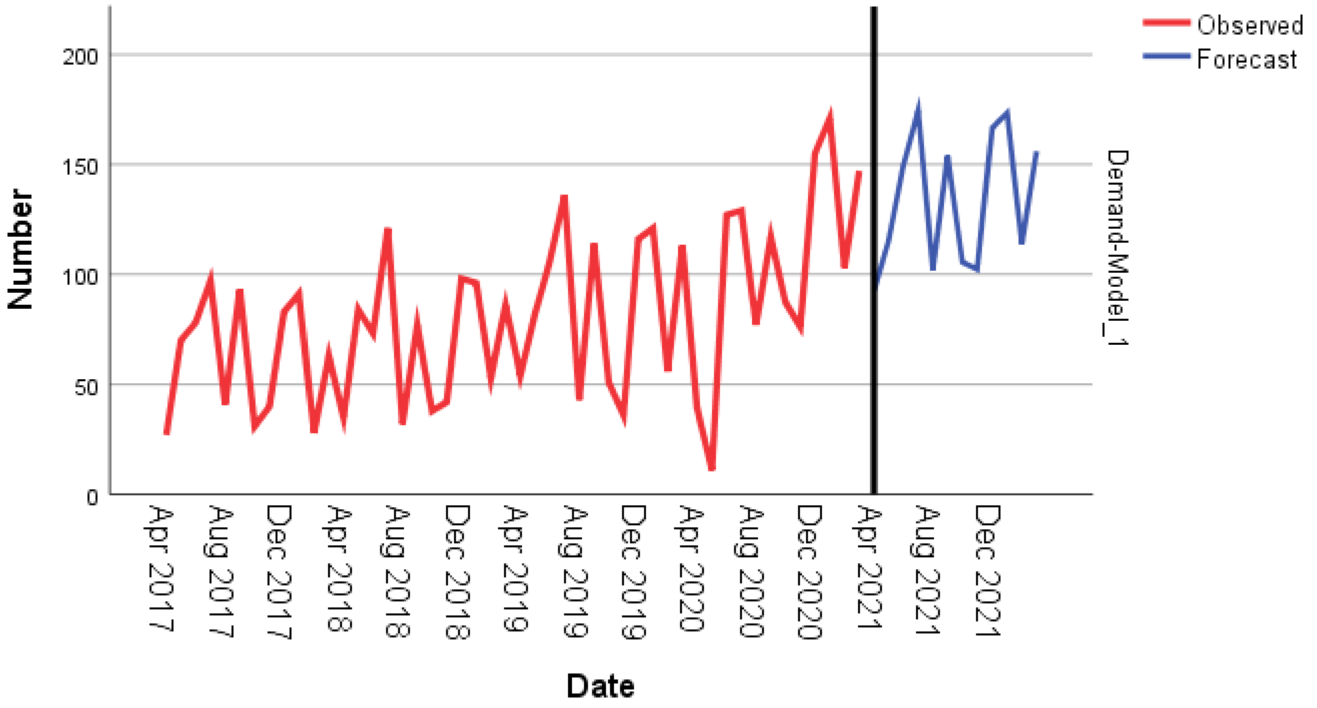
Year	Time	Demand	Time period	Moving average(12)	Cummulative moving avg(CMA - 12)	Seasonal and Irregular Components, (Y_t /CMA)	Seasonal index(S_t	Deseasonalize(Y_t/S_t)	Trend	Forecast(S_t*T_t)	Error
	April	27	1				0.56	48.48	51.53	29	-1.70
	May	70	2				0.81	85.94	52.88	43	26.93
	June	78	3				1.25	62.36	54.23	68	10.17
	July	97	4				1.59	61.15	55.58	88	8.83
	August	41	5				0.58	71.05	56.93	33	8.15
2017-2018	September	93	6	62	62.17	1.50	1.31	70.98	58.28	76	16.64
	October	31	7	63	63.08	0.49	0.55	56.29	59.63	33	-1.84
	November	40	8	64	63.46	0.63	0.55	72.11	60.98	34	6.17
	December	83	9	63	64.25	1.29	1.35	61.33	62.33	84	-1.36
	January	91	10	65	64.88	1.40	1.39	65.51	63.68	88	2.54
	February	28	11	65	63.83	0.44	0.60	46.65	65.04	39	-11.04
	March	63	12	63	63.46	0.99	1.14	55.34	66.39	76	-12.57
	April	35	13	64	63.83	0.55	0.56	62.84	67.74	38	-2.73
	May	84	14	64	64.54	1.30	0.81	103.13	69.09	56	27.73
	June	73	15	65	65.38	1.12	1.25	58.36	70.44	88	-15.11
	July	121	16	66	66.63	1.82	1.59	76.27	71.79	114	7.11
	August	32	17	68	68.63	0.47	0.58	55.46	73.14	42	-10.20
2018-2019	September	77	18	70	70.38	1.09	1.31	58.77	74.49	98	-20.60
	October	38	19	71	71.08	0.53	0.55	69.00	75.84	42	-3.77
	November	42	20	71	72.38	0.58	0.55	75.71	77.19	43	-0.82
	December	98	21	74	74.38	1.32	1.35	72.41	78.54	106	-8.30
	January	96	22	75	75.46	1.27	1.39	69.11	79.90	111	-14.98
	February	53	23	76	77.46	0.68	0.60	88.30	81.25	49	4.23
	March	86	24	79	79.54	1.08	1.14	75.54	82.60	94	-8.03
	April	54	25	80	79.83	0.68	0.56	96.96	83.95	47	7.24
	May	82	26	80	80.33	1.02	0.81	100.68	85.30	69	12.52
	June	106	27	81	82.13	1.29	1.25	84.74	86.65	108	-2.38
	July	136	28	83	83.29	1.63	1.59	85.73	88.00	140	-3.60
	August	43	29	83	84.54	0.51	0.58	74.52	89.35	52	-8.56
2019-2020	September	114	30	86	85.04	1.34	1.31	87.01	90.70	119	-4.84
	October	51	31	84	81.46	0.63	0.55	92.61	92.05	51	0.31
	November	36	32	79	79.38	0.45	0.55	64.90	93.40	52	-15.81
	December	116	33	80	79.96	1.45	1.35	85.71	94.76	128	-12.24
	January	121	34	80	81.08	1.49	1.39	87.11	96.11	133	-12.50
	February	56	35	83	82.63	0.68	0.60	93.30	97.46	58	-2.50
	March	113	36	83	84.25	1.34	1.14	99.26	98.81	112	0.52
	April	39	37	86	87.42	0.45	0.56	70.02	100.16	56	-16.78
	May	11	38	89	90.71	0.12	0.81	13.51	101.51	83	-71.68
	June	127	39	92	94.42	1.35	1.25	101.53	102.86	129	-1.66
	July	129	40	97	98.46	1.31	1.59	81.32	104.21	165	-36.32
	August	77	41	100	101.83	0.76	0.58	133.44	105.56	61	16.09
2020-2021	September	117	42	103			1.31	89.30	106.91	140	-23.08
	October	87	43				0.55	157.98	108.27	60	27.38
	November	76	44				0.55	137.00	109.62	61	15.19
	December	155	45				1.35	114.53	110.97	150	4.82
	January	171	46				1.39	123.10	112.32	156	14.98
	February	103	47				0.60	171.61	113.67	68	34.77
	March	147	48				1.14	129.13	115.02	131	16.06

RMSE: 17.48

USING SPSS : EXPONENTIAL SMOOTHING

Model Statistics

Model	Number of Predictors	Model Fit statistics		Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	RMSE	Statistics	DF	Sig.	
Demand-Model_1	0	.578	17.198	7.365	15	.947	0

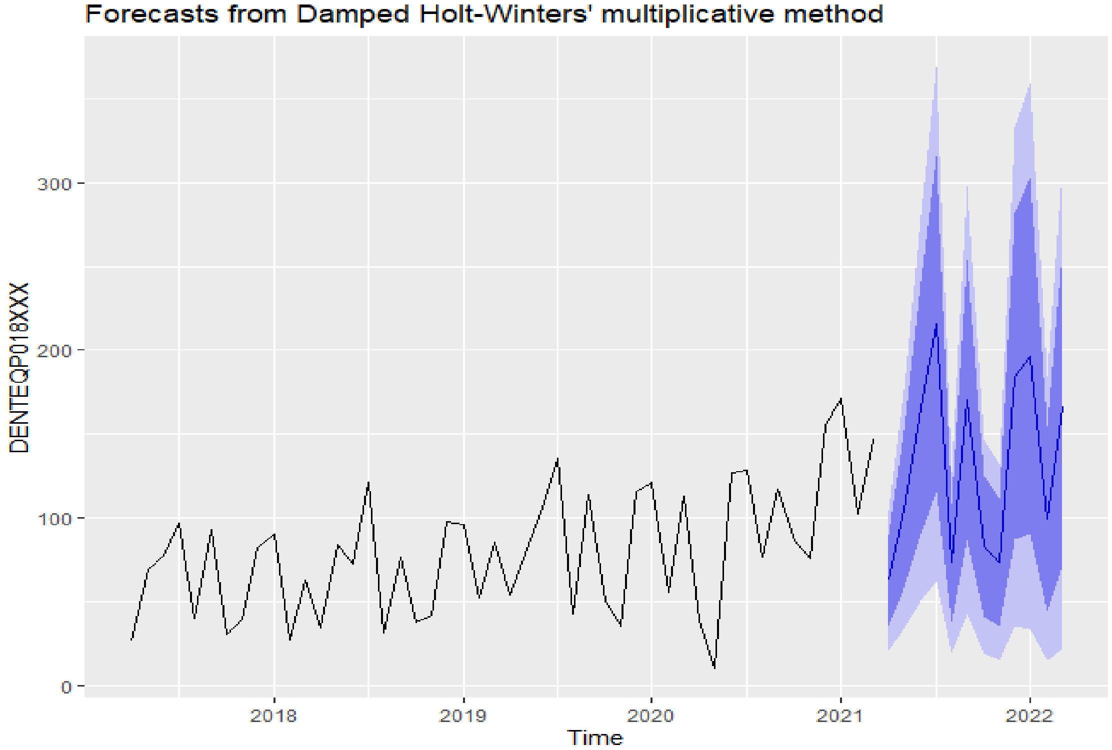


YEAR_	MONTH_	DATE_	Predicted_Demand_Model_1	LCL_Demand_Model_1	UCL_Demand_Model_1
2021	4	APR 2021	92	58	127
2021	5	MAY 2021	115	79	152
2021	6	JUN 2021	150	112	187
2021	7	JUL 2021	174	135	214
2021	8	AUG 2021	102	62	142
2021	9	SEP 2021	154	112	196
2021	10	OCT 2021	105	62	148
2021	11	NOV 2021	102	58	146
2021	12	DEC 2021	167	121	212
2022	1	JAN 2022	173	127	220
2022	2	FEB 2022	114	66	161
2022	3	MAR 2022	156	107	205

HOLT'S WINTER (DAMPED) METHOD

```
  Smoothing parameters:
    alpha = 0.2012
    beta  = 0.0096
    gamma = 2e-04
    phi   = 0.9746

  Initial states:
    l = 59.7988
    b = 0.6165
    s = 1.1853 0.7158 1.4264 1.3512 0.5468 0.6233
           1.2898 0.5612 1.6661 1.2963 0.8327 0.505

  sigma:  0.3372

     AIC     AICc      BIC
503.9451 527.5313 537.6267

Error measures:
                   ME     RMSE      MAE       MPE     MAPE      MASE       ACF1
Training set 2.596981 15.93571 11.18115 -9.337201 26.02666 0.5303312 -0.1049741
```

```
Forecasts:
         Point Forecast
Apr 2021       62.95497
May 2021      105.15357
Jun 2021      165.74835
Jul 2021      215.61721
Aug 2021       73.48640
Sep 2021      170.76504
Oct 2021       83.42028
Nov 2021       73.93816
Dec 2021      184.54792
Jan 2022      196.71368
Feb 2022       99.64073
Mar 2022      166.49549
```



CONCLUSION:

I Have Used three method for forecasting		RMSE
1) Decomposition Method(Excel)		17.48
2) Exponential smoothing method(SPSS)		17.198
3) Holt-winter(damped) method (R)		15.935

RMSE for Holt-winter(damped) method is less compare to other two method. Therefore, We have finally forecasted value via. this method.

Year	Month	Forecas
	April	63
	May	105
	June	166
	July	216
	August	73
2021-2022	September	171
	October	83
	November	74
	December	185
	January	197
	February	100
	March	166

FORECASTING

Demand Forecasting for ‘A’ Item ‘**DENTEQP016XXX’**

Using the data of past four years of demand for item ‘DENTEQP016XXX’ which is a category ‘A’ item, we’ll prepare a time series forecasting model based on what kind of features the demand data is following.

Material Code: DENTEQP016XXX				
Monthly Demand of last 4 years				
Month/Year	2017-2018	2018-2019	2019-2020	2020-2021
April	12	15	21	16
may	7	12	10	5
june	17	28	37	50
July	32	32	45	61
August	14	16	17	30
September	21	26	56	44
October	14	13	12	23
November	16	22	35	49
December	15	25	27	39
January	23	29	55	63
February	17	22	19	37
March	23	26	37	51
Total	211	266	371	468

Table containing information regarding monthly demand of DENTEQP016XXX every year

The data has four columns which are years and 12 indexes which are months. The cross-section is providing month-wise demand of DENTEQP016XXX every year.

We’ll have to follow a stepwise approach to solving this problem. The steps involved are as follows:

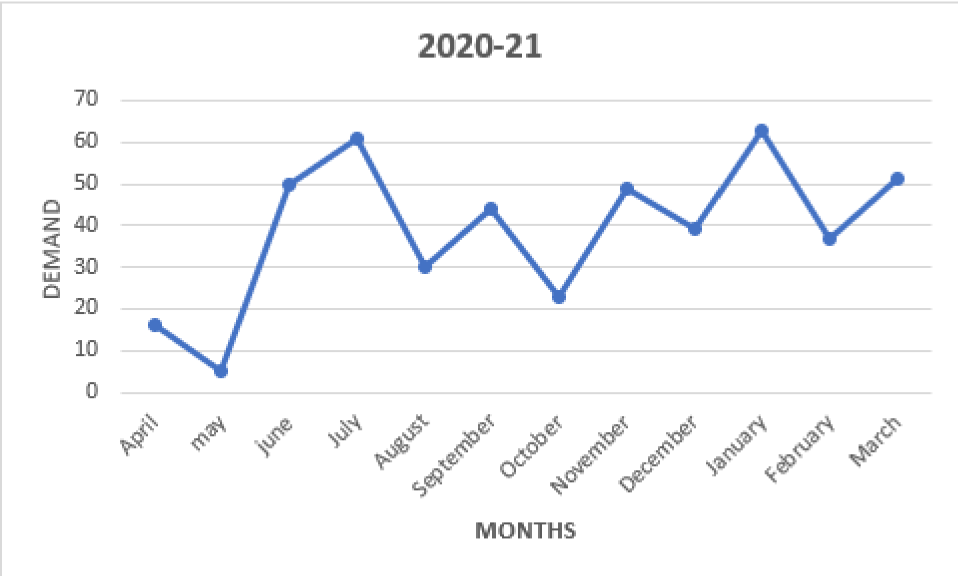
- **Exploratory Data Analysis:** First of all, we’ll plot our data into different information charts to extract useful insights and to visually feel what kind of pattern and behaviour of demand line is following. The main aim of this step is showing the trend, seasonality and irregular behaviour as well the whether the time series is stationary or not;
- **Model Building:** Next up, we’ll create the model that will provide the best results based on the information provided above. The main aim of this step is to deploy a pattern creating model that will be used in forecasting the demand for coming years. The last stage of this step is to create a plot showing actual V/s predicted values to see visually the kind of fit our model is providing;
- **Comparison based on performance metric:** In our case, we’ll be using ‘RMSE’ as a metric to compare the models and to find out which one is yielding the best possible result;

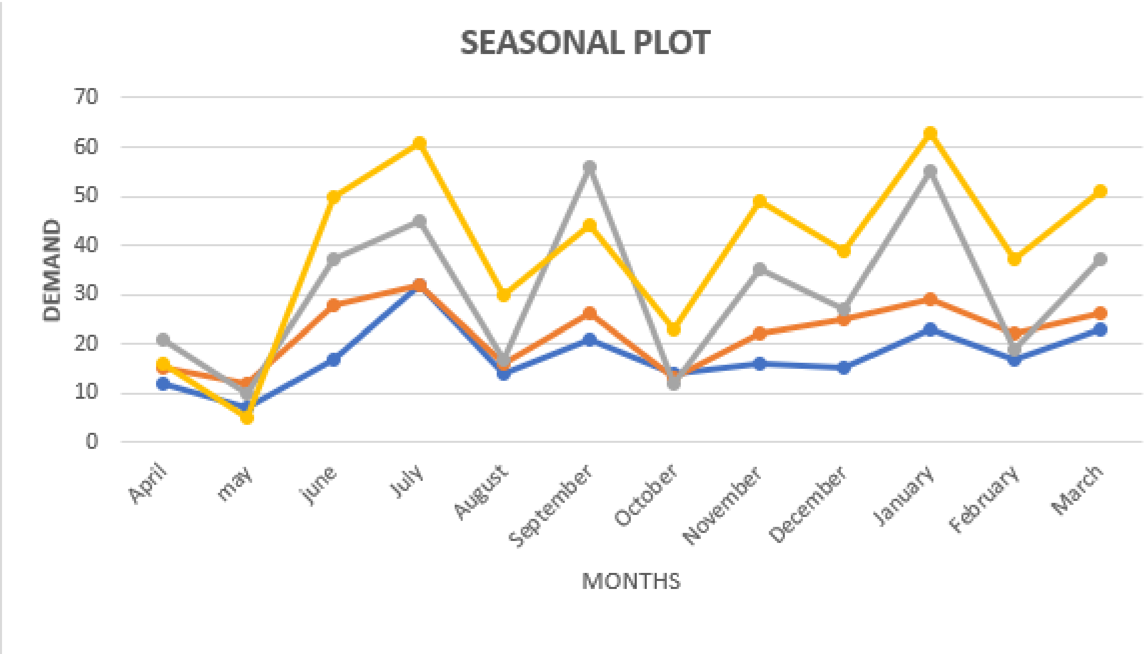
- **Forecasting:** After finalizing the model, the last step is to forecast the demand for next period. In our case, we'll forecast the demand data for next year that will serve as a benchmark for the firm to order the 'DENTEQP018XXX' next year

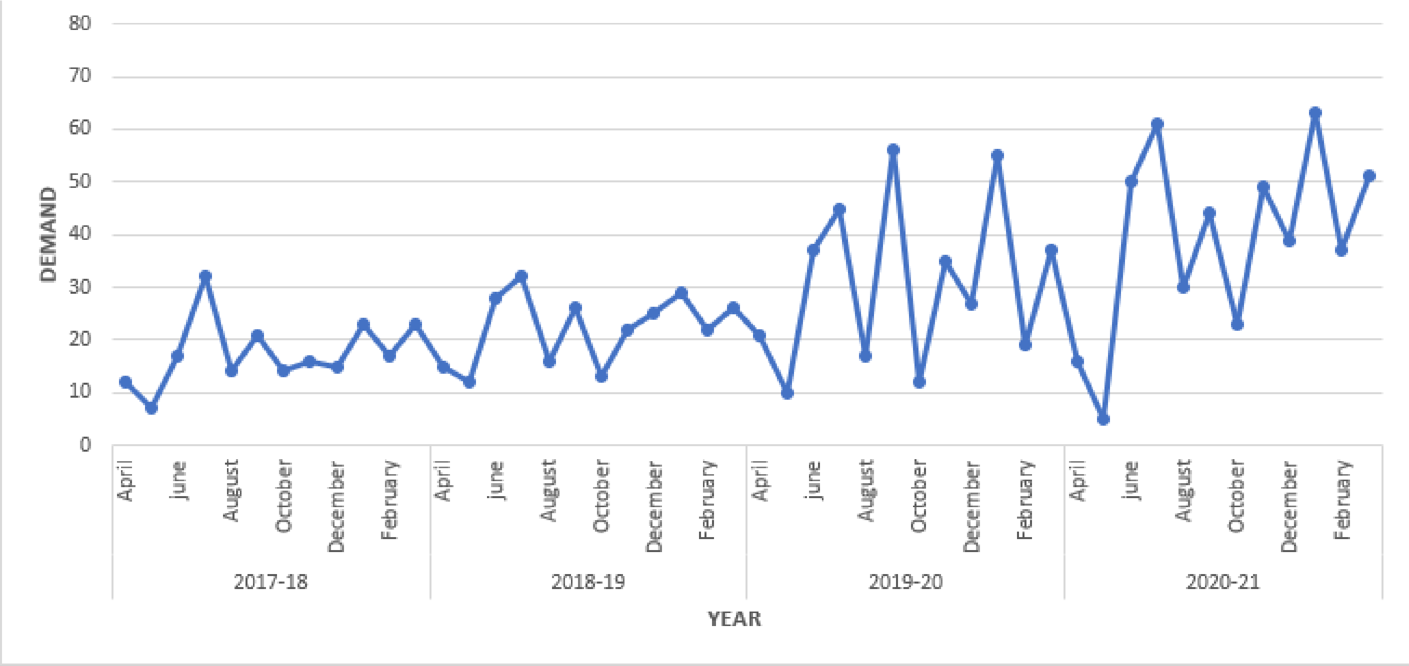
  In April, 2020, the demand of DENTEQP016XXX is 0. However, for handling this outlier, we have taken the Average of last three April month demand. Which significantly improve the accuracy of our model

EXPLORATORY DATA ANALYSIS(EDA)

Plotting this data to understand better the variations in the inter and intra monthly demand, we can see that:







MODEL BUILDING

Decomposition Method

Under Decomposition method, we'll use multiplicate model with the following equation:

$$y_t = T_t \times C_t \times S_t \times I_t.$$

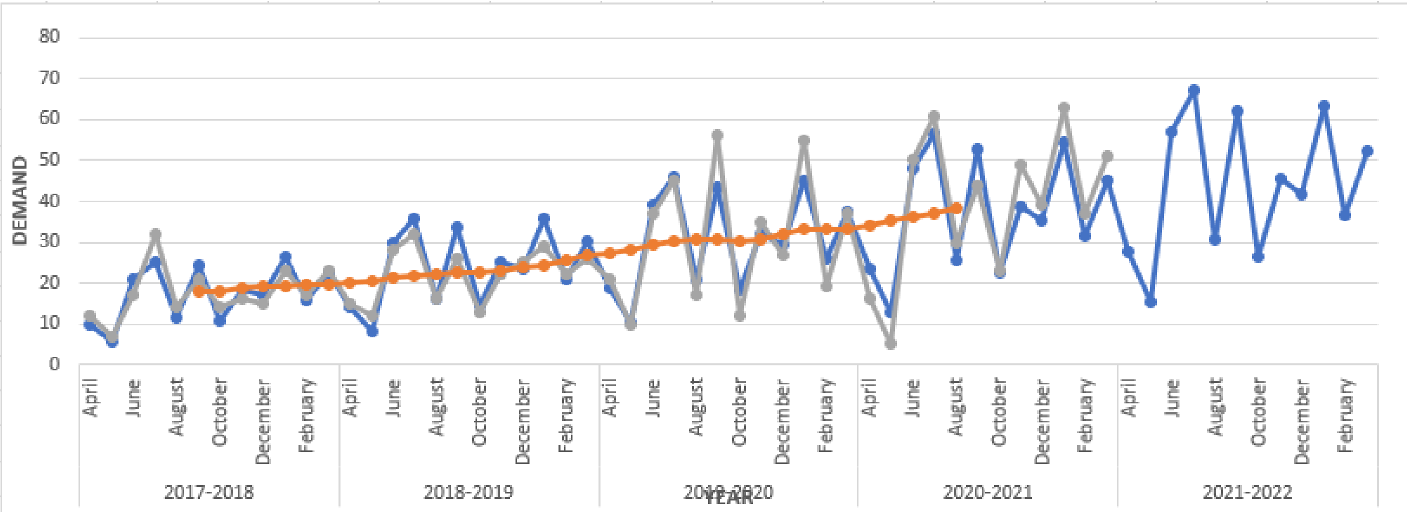
where,
T_t is the trend element;
S_t is the Seasonal component;
C_t is the Cyclical component;
I_t is the Irregular component;

DATASET

Year	Time	Demand	Time period	Moving average(12)	Cummulative moving avg(CMA - 12)	Seasonal and Irregular Components, (Y_t/CMA)	Seasonal index(S_t	Deseasonalize(Y_t/ S_t)	Trend	Forecast(S_t*T_t)	Error
2017-2018	April	12	1				0.66	18.09	14.58	10	2.33
	May	7	2				0.36	19.40	15.15	5	1.54
	June	17	3				1.33	12.83	15.72	21	-3.83
	July	32	4				1.54	20.81	16.29	25	6.96
	August	14	5				0.69	20.34	16.86	12	2.40
	September	21	6	18	17.71	1.19	1.39	15.11	17.43	24	-3.22
	October	14	7	18	18.04	0.78	0.58	24.03	18.00	10	3.51
	November	16	8	18	18.71	0.86	0.99	16.22	18.57	18	-2.32
	December	15	9	19	19.17	0.78	0.89	16.78	19.14	17	-2.11
	January	23	10	19	19.25	1.19	1.35	17.04	19.71	27	-3.60
	February	17	11	19	19.54	0.87	0.77	22.16	20.28	16	1.44
	March	23	12	20	19.71	1.17	1.08	21.20	20.85	23	0.38
2018-2019	April	15	13	20	19.92	0.75	0.66	22.62	21.42	14	0.79
	May	12	14	20	20.58	0.58	0.36	33.26	21.99	8	4.07
	June	28	15	21	21.25	1.32	1.33	21.13	22.56	30	-1.90
	July	32	16	22	21.71	1.47	1.54	20.81	23.14	36	-3.57
	August	16	17	22	22.04	0.73	0.69	23.25	23.71	16	-0.32
	September	26	18	22	22.42	1.16	1.39	18.71	24.28	34	-7.74
	October	13	19	23	22.58	0.58	0.58	22.31	24.85	14	-1.48
	November	22	20	23	22.88	0.96	0.99	22.30	25.42	25	-3.08
	December	25	21	23	23.79	1.05	0.89	27.97	25.99	23	1.77
	January	29	22	24	24.38	1.19	1.35	21.49	26.56	36	-6.85
	February	22	23	24	25.67	0.86	0.77	28.68	27.13	21	1.19
	March	26	24	27	26.88	0.97	1.08	23.97	27.70	30	-4.05
2019-2020	April	21	25	27	27.38	0.77	0.66	31.66	28.27	19	2.25
	May	10	26	28	28.00	0.36	0.36	27.72	28.84	10	-0.41
	June	37	27	28	29.17	1.27	1.33	27.92	29.41	39	-1.97
	July	45	28	30	30.13	1.49	1.54	29.27	29.98	46	-1.10
	August	17	29	30	30.46	0.56	0.69	24.70	30.55	21	-4.03
	September	56	30	31	30.71	1.82	1.39	40.29	31.12	43	12.74
	October	12	31	31	30.29	0.40	0.58	20.60	31.69	18	-6.47
	November	35	32	30	30.63	1.14	0.99	35.47	32.27	32	3.17
	December	27	33	31	31.83	0.85	0.89	30.21	32.84	29	-2.35
	January	55	34	33	33.04	1.66	1.35	40.75	33.41	45	9.91
	February	19	35	34	33.08	0.57	0.77	24.77	33.98	26	-7.07
	March	37	36	33	33.04	1.12	1.08	34.11	34.55	37	-0.48
2020-2021	April	16	37	34	34.08	0.47	0.66	24.12	35.12	23	-7.29
	May	5	38	35	35.17	0.14	0.36	13.86	35.69	13	-7.88
	June	50	39	36	36.00	1.39	1.33	37.73	36.26	48	1.95
	July	61	40	36	37.08	1.64	1.54	39.67	36.83	57	4.37
	August	30	41	38	38.42	0.78	0.69	43.58	37.40	26	4.26
	September	44	42	39			1.39	31.66	37.97	53	-8.77
	October	23	43				0.58	39.48	38.54	22	0.55
	November	49	44				0.99	49.66	39.11	39	10.41
	December	39	45				0.89	43.63	39.68	35	3.53
	January	63	46				1.35	46.68	40.25	54	8.67
	February	37	47				0.77	48.23	40.83	31	5.68
	March	51	48				1.08	47.02	41.40	45	6.10

2021-2022	April		49		0.66		41.97	28
	May		50		0.36		42.54	15
	June		51		1.33		43.11	57
	July		52		1.54		43.68	67
	August		53		0.69		44.25	30
	September		54		1.39		44.82	62
	October		55		0.58		45.39	26
	November		56		0.99		45.96	45
	December		57		0.89		46.53	42
	January		58		1.35		47.10	64
	February		59		0.77		47.67	37
	March		60		1.08		48.24	52

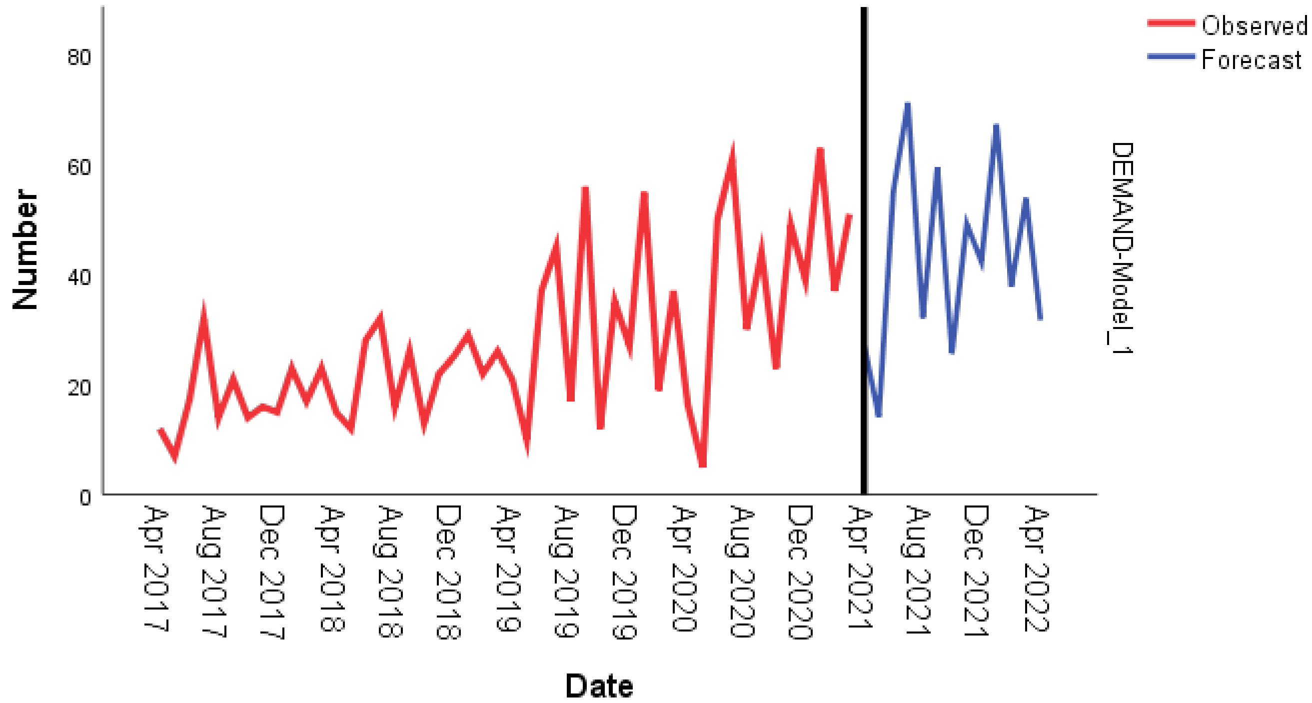
RMSE: 4.98



SPSS : EXPONENTIAL SMOOTH

Model Description			
			Model Type
Model ID	DEMAND	Model_1	Winters' Multiplicative

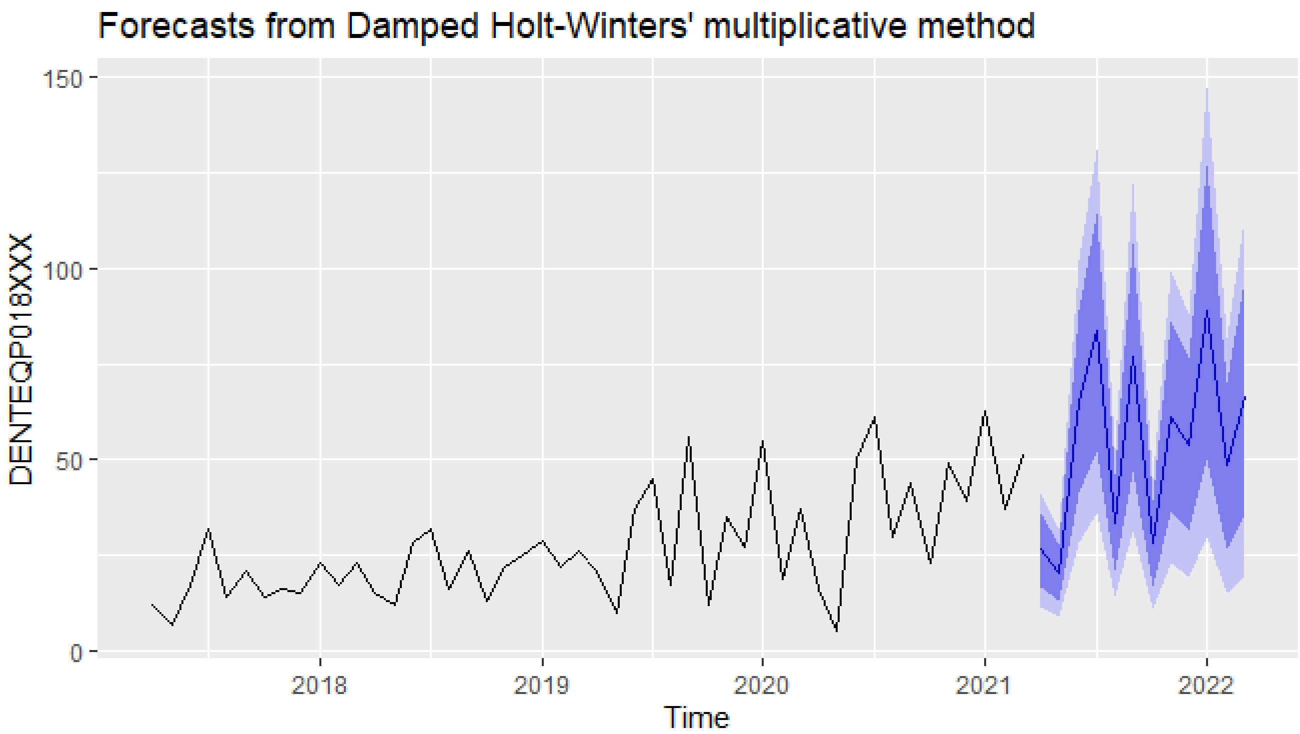
Model Statistics							
		Model Fit statistics		Ljung-Box Q(18)			
Model	Number of Predictors	Stationary R-squared	RMSE	Statistics	DF	Sig.	Number of Outliers
DEMAND-Model_1	0	.696	6.575	13.254	15	.583	0



HOLT'S WINTER (DAMPED) METHOD

```
Forecast method: Damped Holt-Winters' multiplicative method

Model Information:
Damped Holt-Winters' multiplicative method

Call:
 hw(y = DENTEQP018XXX, h = 12, seasonal = "multiplicative", damped = TRUE)

  Smoothing parameters:
    alpha = 0.0513
    beta  = 0.04
    gamma = 1e-04
    phi   = 0.9703
```

```
Error measures:
                     ME     RMSE     MAE       MPE    MAPE      MASE
Training set 0.9553387 5.576747 4.52371 -3.291138 20.9113 0.5169955
                    ACF1
Training set -0.00739516

Forecasts:
         Point Forecast    Lo 80     Hi 80     Lo 95     Hi 95
Apr 2021       26.48549 16.82345  36.14753 11.708678  41.26230
May 2021       20.43860 12.95172  27.92548  8.988412  31.88879
Jun 2021       65.16353 41.10993  89.21714 28.376719 101.95035
Jul 2021       83.51291 52.32434 114.70148 35.814109 131.21171
Aug 2021       33.35171 20.69742  46.00600 13.998639  52.70478
Sep 2021       77.06076 47.23374 106.88778 31.444271 122.67726
Oct 2021       28.06022 16.93798  39.18246 11.050223  45.07022
Nov 2021       61.33799 36.35419  86.32179 23.128566  99.54742
Dec 2021       53.69305 31.15159  76.23451 19.218862  88.16724
Jan 2022       88.81644 50.28713 127.34576 29.890939 147.74195
Feb 2022       48.41764 26.66920  70.16608 15.156266  81.67901
Mar 2022       66.47183 35.50565  97.43800 19.113152 113.83050
```



CONCLUSION:

We have used three method for forecasting		RMSE
1) Decomposition Method(Excel)		4.98
2) Exponential smoothing method(SPSS)		6.575
3) Holt-winter(damped) method (R)		5.57

RMSE for Decomposition method is less compare to other two method. Therefore, We have finally forecasted value via. this method.

Year	Month	Forecas
	April	28
	May	15
	June	57
	July	67
	August	30
2021-2022	September	62
	October	26
	November	45
	December	42
	January	64
	February	37
	March	52

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 modelling 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.

In this study, we are suggesting the procurement/production policy for management of raw material inventory for the production of dental equipment 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 : Totalcost up to and including the nth period

ri : 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 jth period is given by

$C_n(j) = C_{j-1} + A + C(r_j + r_{j-1} + \dots\dots + r_n) + (I*C)(r_j/2 + r_{j+1} + \dots\dots + r_n) + (I*C)(r_{j+1}/2 + r_{j+2} + \dots\dots + r_n) + \dots\dots + (I*C)(r_n/2)$

Thus we have,

$\text{Min } C_n(j) = \text{Min}\{C_{j-1} + A + C(r_j + \dots\dots + r_n) + (I*C/2)[r_j + 3r_{j+1} + \dots\dots + \{2(n-j)+1\}r_n]$

Let us consider it as ONE period problem:

$C_1 = C_0 + A + C * r_1 + (IC/2) * r_1$

Let Us consider it as a TWO period problem

$C_2(1) = C_0 + A + C * (r_1 + r_2) + (IC/2) *(r_1 + 3r_2)$
$C_2(2) = C_1 + A + C * (r_2) + (IC/2) *(r_2)$
$C2 = \min\{C_2(1), C_2(2)\}$

Let Us consider it as a THREE period problem

$C_3(1) = C_0 + A + C * (r_1 + r_2 + r_3) + (IC/2) *(r_1 + 3r_2 + 5r_3)$
$C_3(2) = C_1 + A + C * (r_2 + r_3) + (IC/2) *(r_2 + 3r_3)$
$C_3(3) = C_2 + A + C * (r_3) + (IC/2) *(r_3)$
$C_3 = \min\{C_3(1), C_3(2), C_3(3)\}$

Let Us consider it as a FOUR period problem
$C_4(1) = C_0 + A + C * (r_1 + r_2 + r_3 + r_4) + (IC/2) *(r_1 + 3r_2 + 5r_3 + 7r_4)$
$C_4(2) = C_1 + A + C * (r_2 + r_3 + r_4) + (IC/2) *(r_2 + 3r_3 + 5r_4)$
$C_4(3) = C_2 + A + C * (r_3 + r_4) + (IC/2) *(r_3 + 3r_4)$
$C_4(4) = C_3 + A + C * (r_4) + (IC/2) *(r_4)$

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

and so on.

We are doing procurement policy modelling for 12 periods so we'll go on until $C_{12}(12)$.

Components of inventory carrying cost in Percentage

Capital cost	7.25
Storage Cost	2.5
Taxes and Insurance	4.75
Administrative cost	1.25
Handling cost	3.5
Total	19.25

So, for the purpose of analysis, we're taking Inventory Carrying charge as 19.25% per year of Unit cost.

ORDERING COST

Ordering Costs depends on the supplier and type of item. From the introspection, we find out that ordering cost was based on the type of item since we have different suppliers catering to our needs. So, for the purpose of analysis, the ordering cost is Divided as under:

Procurement Policy for item ' DENTEQP024XXX'

- **INVENTORY CARRYING CHARGE**

IC COST PER UNIT PER MONTH	521.3542
Cost per unit of item	65000.00
SETUP COST/ORDER COST	75000
Inventory carrying charge	0.0160

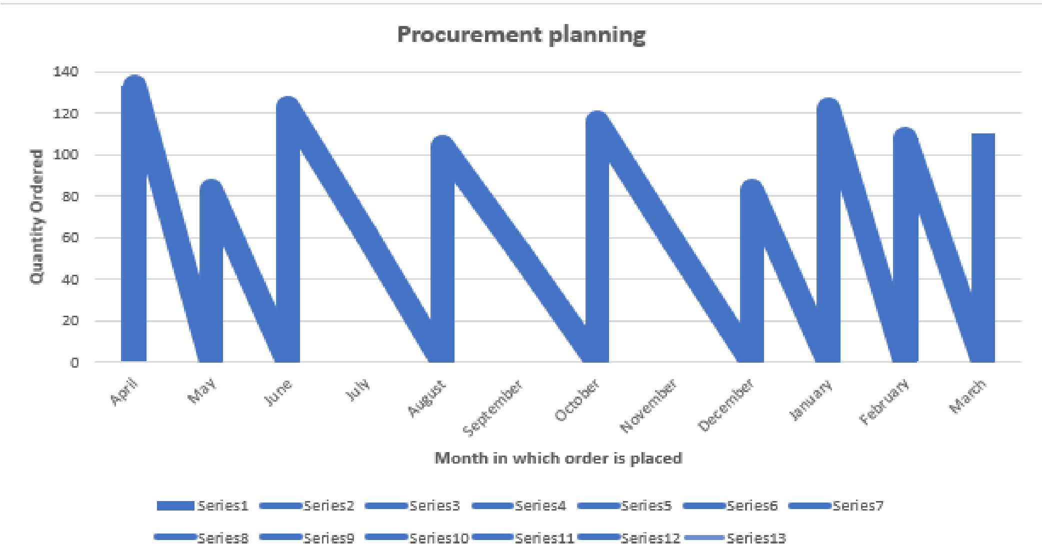
- **FORECASTED DEMAND**

Months	FORECASTED demand	
April	r1	133
May	r2	83
June	r3	73
July	r4	50
August	r5	51
September	r6	53
October	r7	54
November	r8	62
December	r9	83
January	r10	122
February	r11	108
March	r12	110

OPTIMAL POLICY TABLE				
Year	Month	Period in which the order is placed	Minimum Cost	Units order
2021-2022	April	1	8789340	133
	May	2	14302613	83
	June	3	19160671	73
	July	3	22488874	50
	August	5	25905464	51
	Septembe	5	29433359	53
	October	7	33046512	54
	Novembe	7	37173484	62
	Decembe	9	42686756	83
	January	10	50755361	122
	February	11	57906668	108
	March	12	65189017	110

OPTIMAL POLICY RESULTS INTERPRETATION FOR 'DENTEQP024XXX'

- There are 6 months in which we should procure demand of two months at the beginning. The demand for June and July should be procured at the beginning of the month July, and same decision should be taken in the case of August and September, and October, November.
- The Demand policy for April month shows that the required units should be procured in the beginning of that April month. And same decision should be taken in May.
- Similarly, the Demand for December month shall be procured in December only, Progressing in the same manner, the same policy is applicable till the month of march i.e. to procure the required units in the same month only.



Procurement Policy for item ‘ DENTEQP023XXX’

- **INVENTORY CARRYING CHARGE**

IC COST PER UNIT PER MONTH	441.1458
Cost per unit of item	55000.00
SETUP COST/ORDER COST	70000
Inventory carrying charge	0.0160

- **FORECASTED DEMAND**

Month	FORECASTED demand	
April	r1	55
May	r2	49
June	r3	61
July	r4	115
August	r5	78
September	r6	81
October	r7	104
November	r8	85
December	r9	95
January	r10	101
February	r11	82
March	r12	81

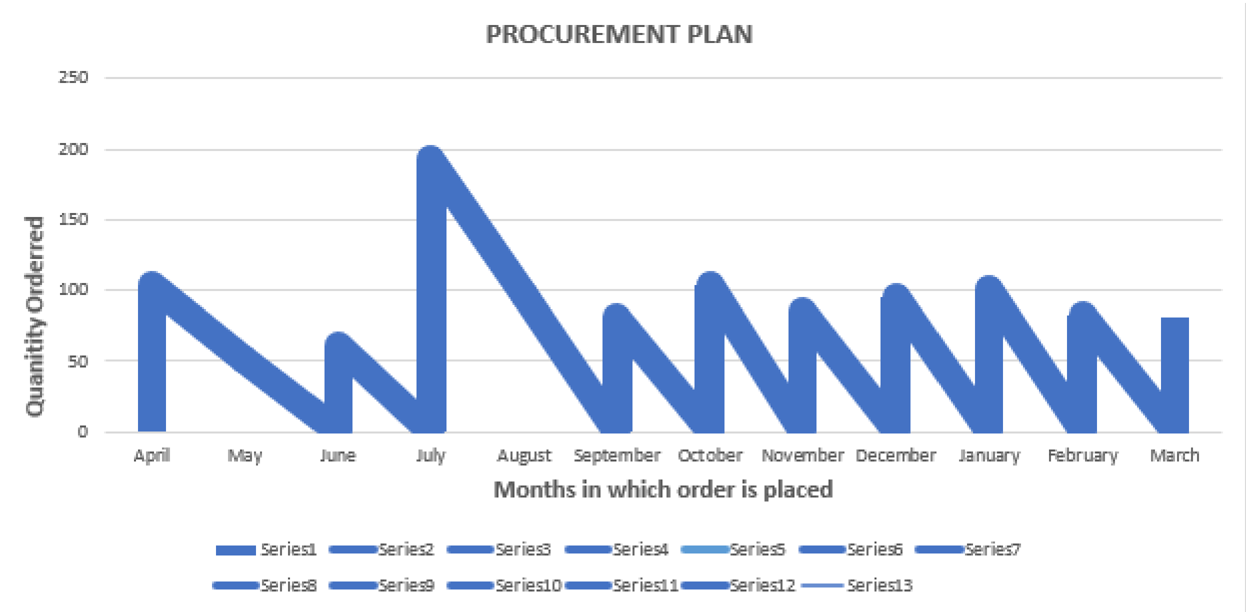
- **OPTIMAL ORDER POLICY:**

OPTIMAL POLICY TABLE				
Year	Month	Period in which the order is placed	Minimum Cost	Units order
2021-2022	April	1	3119263	55
	May	1	5879111	49
	June	3	9331021	61
	July	4	15776753	115
	August	4	20169981	78
	Septembe	6	24730714	81
	October	7	30566593	104
	Novembe	8	35349091	85
	December	9	40685999	95
	January	10	46355555	101
	February	11	50971729	82
	March	12	55532462	81

OPTIMAL POLICY RESULTS INTERPRETATION FOR 'DENTEQP023XXX'

Using the backtracking method to find out the recommended policy, we draw the following conclusion:

- **The demand require in the month of April and May shall be procured in April only, and the same decision should be taken in the Month of July for the July and August demand.**
- **The demand require for September shall be procured in September month only, and same procurement policy should be made for October, November, Decemeber, January, February, march and June months. i.e Demand of particular month shall be procured in that month only.**



Procurement Policy for item ‘ DENTEQP022XXX’

INVENTORY CARRYING CHARGES

IC COST PER UNIT PER MONTH	360.9375
Cost per unit of item	45000.00
SETUP COST/ORDER COST	50000
Inventory carrying charge	0.0160

FORECASTED DEMAND:

Months	FORECASTED demand	
April	r1	76
May	r2	77
June	r3	90
July	r4	59
August	r5	65
September	r6	107
October	r7	172
November	r8	126
December	r9	118
January	r10	87
February	r11	91
March	r12	74

OPTIMAL ORDER POLICY:

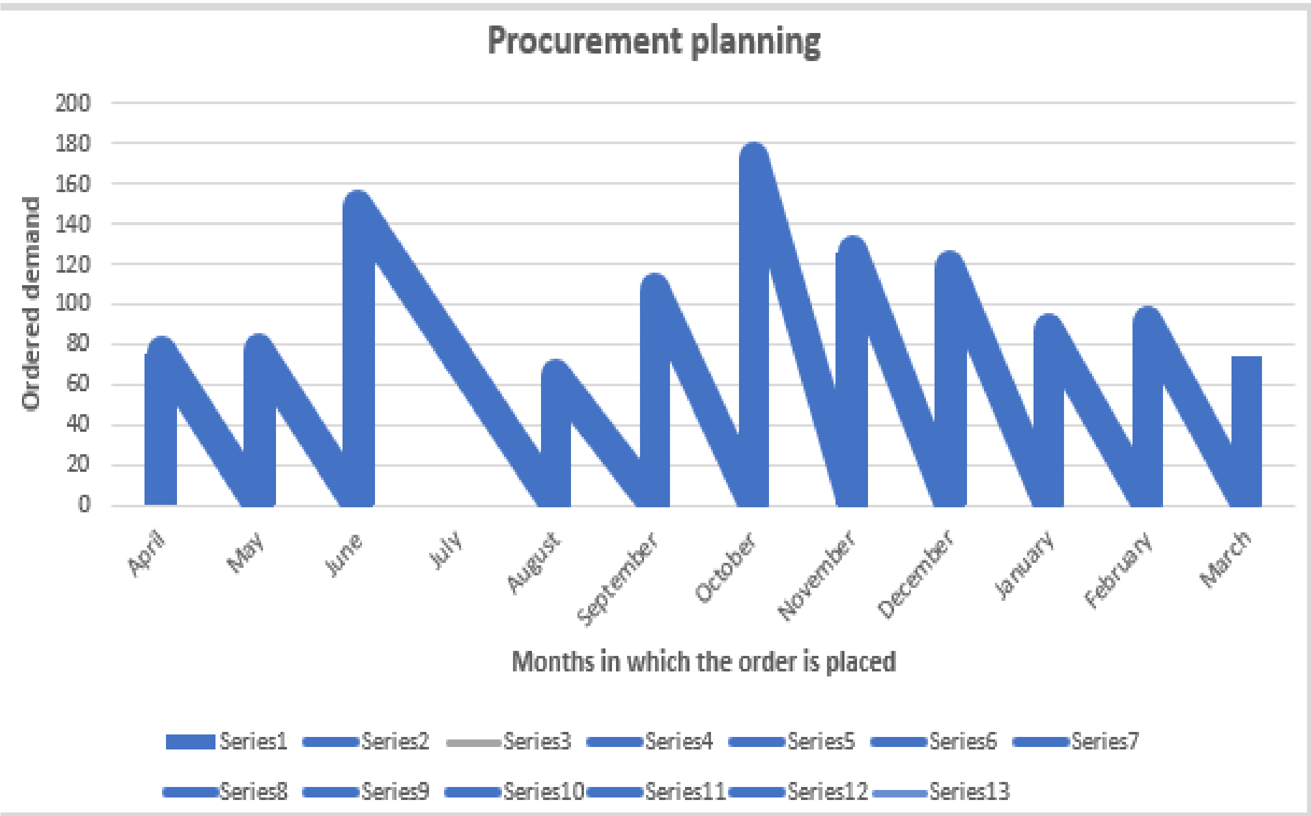
OPTIMAL POLICY TABLE

Year	Month	Period in which the order is placed	Minimum Cost	Units order
2021-2022	April	1	3497431	76
	May	2	7040223	77
	June	3	11172708	90
	July	3	13891594	59
	August	5	16890055	65
	Septembe	6	21793675	107
	October	7	29645756	172
	Novembe	8	35411234	126
	December	9	40813825	118
	January	10	44810227	87
	February	11	48988072	91
	March	12	52394781	74

OPTIMAL POLICY RESULTS INTERPRETATION FOR 'DENTEQP022XXX'

Using the backtracking method to find out the recommended policy,
we draw the following conclusion:

- The demand require for each month shall be procured in its respective month. i.e Demand for April shall be procured only in April. Except June and July, In this case demand of both month shall be procured in the month of June to minimize the cost.



Procurement Policy for item ‘ DENTEQP018XXX’

- **INVENTORY CARRYING CHARGES**

IC COST PER UNIT PER MONTH	116.3021
Cost per unit of item	14500.00
SETUP COST/ORDER COST	20000
Inventory carrying charge	0.0160

- **FORECASTED DEMAND**

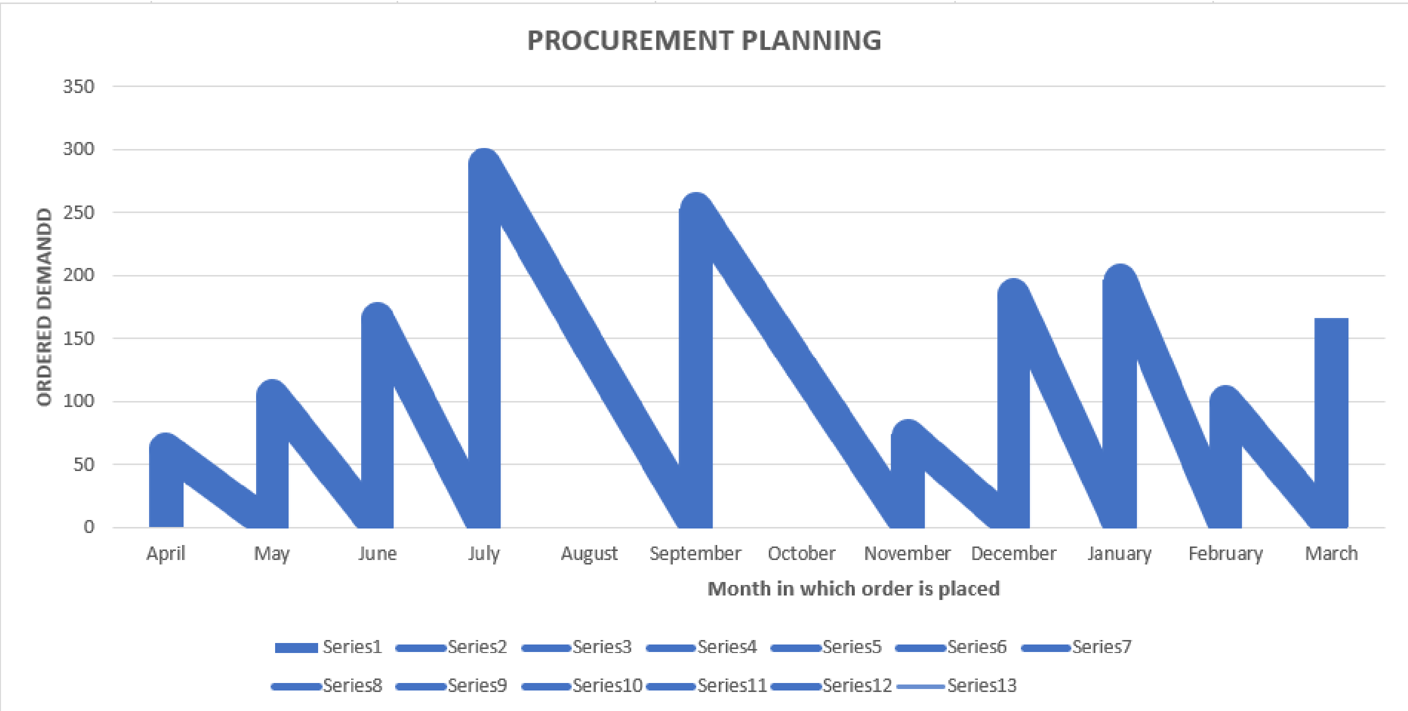
Months	FORECASTED demand	
April	r1	63
May	r2	105
June	r3	166
July	r4	216
August	r5	73
September	r6	171
October	r7	83
November	r8	74
December	r9	185
January	r10	197
February	r11	100
March	r12	166

- **OPTIMAL ORDER POLICY**

OPTIMAL POLICY TABLE				
Year	Month	Period in which the order is placed	Minimum Cost	Units order
2021-2022	April	1	940827.03	63
	May	2	2495538.8	105
	June	3	4941844.9	166
	July	4	8118966.1	216
	August	4	9202936.3	73
	Septembe	6	11722324	171
	October	6	12954783	83
	Novembe	7	14054296	74
	Decembe	9	16778312	185
	January	10	19677723	197
	February	11	21159354	100
	March	12	23605660	166

OPTIMAL POLICY RESULTS INTERPRETATION FOR 'DENTEQP018 XXX'

- Using the backtracking method to find out the recommended policy, we draw the following conclusion:
- The Demand for April month shall be procured in April only, and this will have to be continue till June. i.e the demand of each month shall be procurement in that month only to minimize the cost.
- The Demand require in the month of July and August shall be procured in July to minimize the cost. Similarly, demand of September and October shall be procured in September only.
- The Demand of every month from November to December shall be procured in their respective months.



Procurement Policy for item ' DENTEQP016XXX'

- **INVENTORY CARRYING CHARGES**

IC COST PER UNIT PER MONTH	224.5833
Cost per unit of item	28000.00
SETUP COST/ORDER COST	30000
Inventory carrying charge	0.0160

- **FORECASTED DEMAND**

Months	FORECASTED demand	
April	r1	28
May	r2	15
June	r3	57
July	r4	67
August	r5	30
September	r6	62
October	r7	26
November	r8	45
December	r9	42
January	r10	64
February	r11	37
March	r12	52

- **OPTIMAL ORDER POLICY**

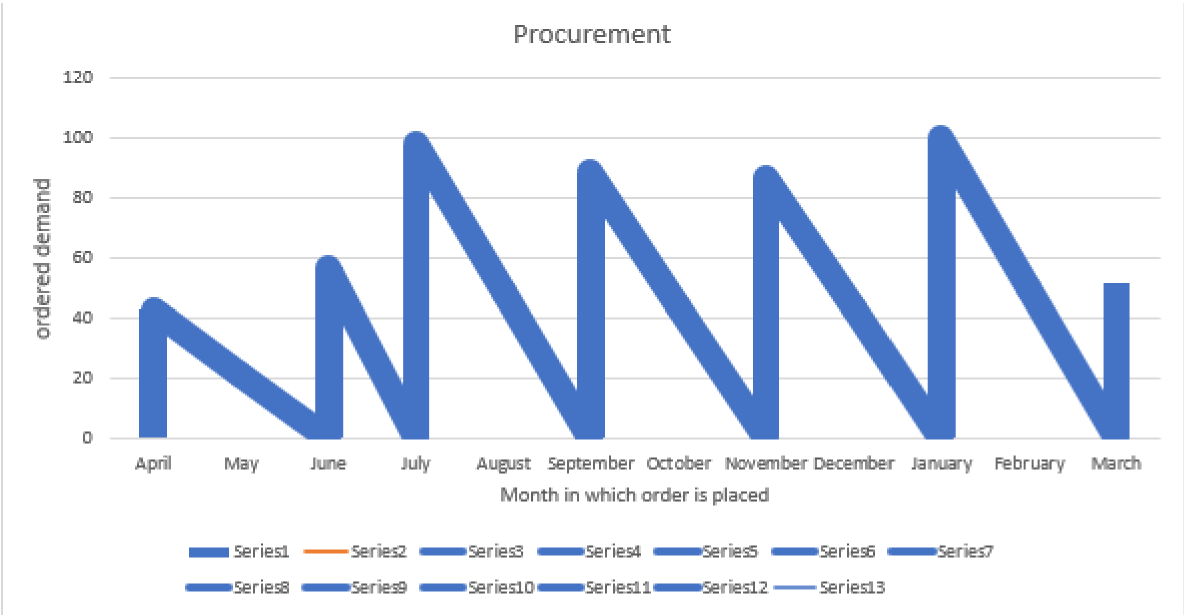
OPTIMAL POLICY TABLE

Year	Month	Period in which the order is placed	Minimum Cost	Units order
2021-2022	April	1	815592.6	28
	May	1	1255628	15
	June	3	2897802	57
	July	4	4823372	67
	August	4	5696701	30
	Septembe	6	7484804	62
	October	6	8243056	26
	Novembe	8	9552925	45
	Decembei	8	10745542	42
	January	10	12569903	64
	February	10	13618542	37
	March	12	15125606	52

OPTIMAL POLICY RESULTS INTERPRETATION FOR 'DENTEQP016XXX'

Using the backtracking method to find out the recommended policy, we draw the following conclusion:

- The Demand require in the month of April and May shall be procured in April to minimize the cost.
- The Demand for June month shall be procured in July only;
- The Demand require in the month of July and August shall be procured in July to minimize the cost. Similarly, the demand for September and October will be procured in September,
  And for November and December demand shall be procured in November month. In the same way, January and February demand shall be procured in January.
- Lastly, The Demand for march month shall be procured in March only;



RESULTS & CONCLUSION

Results:

ABC ANALYSIS: Approximately 3 % of the items account of **43.59%** for annual usage value and **42.86%** of the items account for **93.77%** of the annual usage value.

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FORECASTING:

- For item **'DENTEQP024XXX'**: The RMSE of decomposition method is **8.92** while RMSE for Holt winter's exponential smoothing method is **8.033** and RMSE for Holt winter's (DAMPED) method is **6.65** which shows the Holt winter's (DAMPED) method is better off in fitting the demand pattern for this item and therefore, we'll use Holt winter's (DAMPED) method to predict the demand for next year.

- For item **'DENTEQP023XXX'**:The RMSE of decomposition method is **14.99** while RMSE for Holt winter's exponential smoothing method is **16.859** and RMSE for Holt winter's (DAMPED) method is **14.07** which shows the Holt winter's (DAMPED) method is better off in fitting the demand pattern for this item and therefore, we'll use Holt winter's (DAMPED) method to predict the demand for next year

- For item **'DENTEQP022XXX'**: The RMSE of decomposition method is **10.26** while RMSE for Holt winter's exponential smoothing method is **11.337** and RMSE for Holt winter's (DAMPED) method is **9.743** which shows the Holt winter's (DAMPED) method is better off in fitting the demand pattern for this item and therefore, we'll use Holt winter's (DAMPED) method to predict the demand for next year

- For item **'DENTEQP018XXX'**: The RMSE of decomposition method is **17.48** while RMSE for Holt winter's exponential smoothing method is **17.198** and RMSE for Holt winter's (DAMPED) method is **15.935** which shows the Holt winter's (DAMPED) method is better off in fitting the demand pattern for this item and therefore, we'll use Holt winter's (DAMPED) method to predict the demand for next year

- For item **'DENTEQP016XXX'**: The RMSE of decomposition method is **4.98** while RMSE for Holt winter's exponential smoothing method is **6.575** and RMSE for Holt winter's (DAMPED) method is **5.57** which shows the decomposition method is better off in fitting the demand pattern for this item and therefore, we'll decomposition method to predict the demand for next year.

PROCUREMENT:

- For Item '**DENTEQP024XXX**':
  There are 6 months in which we should procure demand of two months at the beginning. The demand for June and July should be procured at the beginning of the month July, and same procurement plan should be taken in the case of (August &September), and (October& November). The Demand policy for April month shows that the required units should be procured in the beginning of that April month. And same decision should be taken in May. Similarly, the Demand for December month shall be procured in December only, Progressing in the same manner, the same policy is applicable till the month of march i.e. to procure the required units in the same month only.

- For item '**DENTEQP023XXX**': The demand require in the month of April and May shall be procured in April only, and the same decision should be taken in the Month of July for the July and August demand. The demand require for September shall be procured in September month only, and same procurement policy should be made for October, November, Decemeber, January, February, march and June months. i.e Demand of particular month shall be procured in that month only.

- For item '**DENTEQP022XXX**': The demand require for each month shall be procured in its respective month. i.e Demand for April shall be procured only in April. Except June and July, In this case demand of both month shall be procured in the month of June to minimize the cost.

- For item '**DENTEQP018XXX**' The Demand for April month shall be procured in April only, and this will have to be continue till June. i.e the demand of each month shall be procurement in that month only to minimize the cost. The Demand require in the month of July and August shall be procured in July to minimize the cost. Similarly, demand of September and October shall be procured in September only. The Demand of every month from November to December shall be procured in their respective months.

- for item '**DENTEQP016XXX**': The Demand require in the month of April and May shall be procured in April to minimize the cost. The Demand for June month shall be procured in July only. Furthermore, For the month of July and august demand shall be procured in July to minimize the cost. Similarly, the demand for September and October will be procured in September, And for November and December demand shall be procured in November month. In the same way, January and February demand shall be procured in January. Lastly, The Demand for march month shall be procured in March only.

SK DENT
GSTIN : 07ACCPV6789M1ZL

S.K. DENT INDIA
Mfg. of: Dental Chair Unit,
Dental Compressor & Dental Suction Etc.

Date : 12th May 2021

TO WHOM SO EVER IT MAY CONCERN

This is to certify that **Mr. Rohit,** final year student of Masters of Operational Research, University of Delhi has successfully completed his project title **"Inventory Management and Procurement Planning"** in a given time.

His conduct was found satisfactory during the term of the project, we wish him all the best.

S.K. DENT INDIA SKD Kirari, Delhi-86

(Sign. and Stamp)

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References

- Introduction to Operational research
    - Hiller and Liberman

- Analysis of Inventory System
    - Hadley G. and Witin T. M.

- Operational research
    - Kanti Swaroop.

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

- Statistics for management
    - Levin and Rubin

Software used for analysis:

- ❖ Microsoft Excel
- ❖ R studio
- ❖ SPSS

Link to data base for ABC analysis and Forecasting

https://drive.google.com/drive/folders/1dji2ILVYy2EitpX6fbrcRIkUBHqs4hsE?usp=sharing