Understanding Operation Management: Newsvendor Model Creating a Forecast and its Applications

Major Project Report

Semester – 1

Four Year Undergraduate Program-Design Your Degree

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BY

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CERTIFICATE

The report titled **Understanding Operation Management: Newsvendor Model Creating a Forecast and its Applications** has been completed by group Newton comprised of Adil Mahajan, Avichal Badyal, Gourav Sharma, Mohd. Sajid, Raghav Sharma and Tavishi Amla, as a major project for Semester I. It was conducted under the guidance of Prof. K.S. Charak, Dr. Jatinder Manhas, Dr. Sandeep Arya, Dr. Sunil Kumar for the partial fulfilment of the Design Your Degree, Four Year Undergraduate Programme at the University of Jammu, Jammu. This project report is original and has not been submitted anywhere else.

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ABSTRACT

This mathematical problem appears to date from 1888 and this work investigates the Working of Newsvendor model utilizing computational software, specifically Excel. The primary objective is to forecast demand. Conventional Supply-Demand techniques often prove inefficient and cumbersome, prompting the exploration of new methodologies. This study presents a case study and application of various tools to create a forecast. Investigating the properties of Newsvendor model and getting managerial insights. Furthermore, maximize expected profit and minimize expected loss. In conclusion, the utilization of C language and code for advancing our comprehension of Newsvendor model. Future endeavors may focus on refining accuracy and optimizing forecasts. This approach holds promise for revolutionizing inventory/operation management across diverse domains.

CHAPTER- 1
INTRODUCTION TO NEWSVENDOR MODEL

1.1 Introduction

The newsvendor model is a mathematical model that helps determine the optimal inventory level for a product that has uncertain demand and a limited shelf life. The model balances the costs of ordering too much or too little inventory and aims to maximize the expected profit. The model is also known as the newsboy problem, because it can be applied to the situation of a newspaper vendor who must decide how many copies of the day's paper to stock in advance, knowing that unsold copies will be worthless at the end of the day [2].

1.2 Origin

The newsvendor model is a classic inventory problem that dates back to 1888, when Francis Ysidro Edgeworth [13] used the central limit theorem to find the optimal cash reserves needed to satisfy random withdrawals from depositors. The term "newsvendor problem" was coined by Matt Sobel, and the modern formulation of the problem was developed by Kenneth Arrow, T. Harris, and Jacob Marshak [16] in 1951. The model can be applied to various situations that involve perishable or seasonal products with uncertain demand and fixed prices [3].

1.2.1 Applications

The newsvendor problem has many applications in various industries and domains, where the optimal order quantity of a perishable product under uncertain demand has to be determined. Some common applications include:

- **Personal Investments:** An investor must decide how much to invest in a risky asset with a random return and a risk-free asset with a fixed return. The investor's objective is to maximize the expected utility of the final wealth, which depends on the investment decision and the realized return of the risky asset. This problem can be formulated as a newsvendor problem, where the order quantity is the amount invested in the risky asset, the demand is the return of the risky asset, the selling price is the return of the risk-free asset, the wholesale cost is the initial wealth, and the salvage value is zero.

- **Emergency Resources:** A hospital must decide how many units of blood to keep in stock for emergency situations, where the demand is uncertain, and the blood has a limited shelf life. The hospital's objective is to minimize the expected total cost, which includes the procurement cost, the holding cost, the shortage cost, and the disposal cost of the blood. This problem can be formulated as a newsvendor problem, where the order quantity is the number of blood units ordered, the demand is the number of blood units needed, the selling price is the shortage cost, the wholesale cost is the procurement cost, the holding cost is the inventory cost, and the salvage value is the negative disposal cost.

- **Manufacturing:** A manufacturer must decide how many units of a product to produce for a single selling season, where the demand is uncertain, and the product becomes obsolete after the season. The manufacturer's objective is to maximize the expected profit, which includes the revenue from sales, the production cost, and the salvage value of the unsold units. This problem can be formulated as a newsvendor problem, where the order quantity is the number of units produced, the demand is the number of units sold, the selling price is the unit price, the wholesale cost is the unit production cost, and the salvage value is the unit salvage value.

- **Real Estate:** A real estate developer has to decide how many units of a residential project to build for a single selling period, where the demand is uncertain, and the project has a fixed completion date. The developer's objective is to maximize the expected profit, which includes the revenue from sales, the construction cost, and the opportunity cost of the unsold units. This problem can be formulated as a newsvendor problem, where the order quantity is the number of units built, the demand is the number of units sold, the selling price is the unit selling price, the wholesale cost is the unit construction cost, and the salvage value is the negative opportunity cost.

- **Fashion:** A fashion retailer must decide how many units of a seasonal product to order from a supplier, where the demand is uncertain, and the product has a short life cycle. The retailer's objective is to maximize the expected profit, which includes the revenue from sales, the ordering cost, and the salvage value of the unsold units. This problem can be formulated as a newsvendor problem, where the order quantity is the number of units ordered, the demand is the number of units sold, the selling price is the unit selling price, the wholesale cost is the unit ordering cost, and the salvage value is the unit salvage value [11].

1.2.2 Advantages and Disadvantages of Newsvendor model

The newsvendor model has some advantages and disadvantages as a decision-making tool for inventory management.

Some of the advantages are:

- It is a simple and intuitive model that can be easily applied to various scenarios and products.
- It provides a clear trade-off between the costs of overstocking and understocking and helps find the optimal order quantity that maximizes the expected profit or minimizes the expected cost.
- It can be extended and modified to incorporate multiple products, multiple periods, multiple sources, and multiple objectives.

Some of the disadvantages are:

- It assumes that the demand is random and follows a known probability distribution, which may not be realistic or accurate in some cases.
- It assumes that the order quantity is fixed and independent of the demand, which may not be feasible or optimal in some situations where the order quantity can be adjusted or updated based on the demand information.
- It ignores some factors that may affect the inventory decisions, such as customer satisfaction, service level, competition, and environmental impact [8].

1.2.3 Influence of News vendor model

The newsvendor model, also known as the single period inventory model, is one of the most widespread and influential models. It follows only the economic order quantity (EOQ).

That popularity is due to its versatility. Newsvendor, for instance, allows variable and stochastic demand while maintaining a single period for your cycle. That means, all inventories must be ordered beforehand.

Differently from EOQ, that tries to minimize the expected costs, the newsvendor is seeking to maximize the profit expected from that period.

It does that by ordering sufficient inventory, in a way that the probability that the demand is less or equal to this amount is equal to the critical ratio, which is the ratio of the shortage costs divided by the sum of the shortage and excess costs [13].

1.2.4 Working of Newsvendor model (Brief)

Imagine you are a person who sells newspapers. You buy them from a big company for ₹41.51 each and sell them to people for ₹207.57 each. You want to make as much money as possible, right? But you don’t know how many people will want to buy your newspapers every day. Sometimes you may have too many newspapers and you must throw them away at the end of the day. That means you lose ₹41.51 for each newspaper you don’t sell. Sometimes you may have too few newspapers and you have to say sorry to the people who want to buy them. That means you lose ₹166.06 for each newspaper you could have sold. You want to avoid both situations, right? So how do you decide how many newspapers to buy every day?

Well, there is a way to find the best number of newspapers to buy. It is based on some math and some guessing. The math part is called the Critical Fractile. It is a fancy way of saying how much you care about losing ₹166.06 versus losing ₹41.51. In your case, you care about losing ₹166.06 four times more than losing ₹41.51. So, the Critical Fractile is 0.8 or 80%. That means you want to buy enough newspapers so that you have an 80% chance of selling them all and a 20% chance of having some left over.

The guessing part is called the Demand Distribution. It is a way of saying how likely it is that a certain number of people will want to buy your newspapers. For example, maybe on average 100 people want to buy your newspapers every day, but sometimes it can be. The Demand Distribution is a shape that shows how the number of people can vary around the average. In your case, the shape is called a Normal Distribution. It looks like a bell. It has a middle point, which is the average, and two sides, which show how much the number can go up or down from the average. In your case, the middle point is 100 and the sides are 15. That means most of the time, the number of people who want to buy your newspapers is between 85 and 115.

Now, you can use the Critical Fractile and the Demand Distribution to find the best number of newspapers to buy. You must find the point on the bell shape that matches the 80% mark. That means you want to buy enough newspapers so that there is only a 20% chance that more people will want to buy them. You can use a calculator or a computer to find this point. It is called a z-score. In your case, the z-score is 0.84. That means you must add 0.84 times 15 to the average of 100. That gives you 112.6. But you can’t buy half a newspaper, so you must round up to 113. That is the best number of newspapers to buy!

$$C.F. = \frac{CU}{(CU + CO)} = \frac{166.06}{(166.06 + 41.51)} = 0.8 \; or \; 80\%$$

But wait, there is one more thing to remember. Sometimes, the big company only sells newspapers in packs of 10. That means you can't buy exactly 113 newspapers. You must buy either 110 or 120. In that case, you should always buy more, not less. That is called the Round Up Rule. It is better to have some extra newspapers than to miss some customers. So, if you must buy newspapers in packs of 10, you should buy 120, not 110 [10].

1.3 Forecast

A forecast is an estimate or prediction of the future demand for a product, based on historical data, market trends, or other factors. A forecast is important for the newsvendor model, because it helps determine the optimal order quantity that balances the costs of overstocking and understocking. The newsvendor model uses the forecast to calculate the critical fractile, which is the probability of meeting the demand without having excess inventory. The critical fractile depends on the ratio of the marginal profit and the marginal cost of ordering one more unit. The optimal order quantity is then the inverse of the critical fractile applied to the demand distribution [7].

1.3.1 Working of a Forecast

Forecasting is a technique that uses historical data as inputs to make informed estimates that are predictive in determining the direction of future trends.

Data Collection: Gather historical data that will serve as the basis for making predictions.

Choosing a Forecast Model: Select a model that best fits the collected data. This could be a qualitative or quantitative model. Qualitative models are based on expert opinion, while quantitative models use statistical data based on quantitative information.

Analysis: Analyze the data using the chosen model. This could involve looking at trends, patterns, and relationships in the data.

Estimation: Make informed estimates about future trends based on the analysis. These estimates are then used to make predictions about future events or trends.

Verification: Compare the forecasted results with the actual results once they are available. This helps in refining the model and making more accurate forecasts in the future.

It’s important to note that the accuracy of forecasts can vary, and they often need to be revised as new data becomes available. In finance, for example, companies use forecasting to estimate earnings or other data for subsequent periods. In weather prediction, meteorologists use forecasting to predict future weather conditions [12].

1.4 Description

The project aims to Understand Operation Management: Newsvendor Model and Creating a Forecast. The Forecast is used to determine our future inventory and maximize our expected profit. This project will involve exploring various excel tools, forecasts, and graphs to increase our expected profit and reduce our loss.

1.5 Problem Statement

How to determine the optimal order quantity of a perishable product with uncertain demand and fixed prices, such that the expected profit is maximized, or the expected cost is minimized, while considering the trade-off between the costs of overstocking and understocking?

1.6 Objectives

- To gain a comprehensive understanding of the Newsvendor model, focusing on the forecasting of it on excel.
- To check the working of Newsvendor model through c language code.
- To check the local markets for supply demand-issue.
- To maximize expected profit through Newsvendor Model.
- To check stock probability.

1.7 Expected Outcomes

- A running code which negates the middle steps and initiates a Demand forecast.
- Insights into the working of forecasting and creating a normal distribution forecast.

- Getting managerial insights into Newsvendor model.

Fig1.1 Newspaper vendor selling newspaper [5].

CHAPTER 2
LITERATURE REVIEW

2.1 History of Newsvendor Problem

The newsvendor problem is a classic model in operations research and inventory management that deals with the optimal order quantity of a perishable product under uncertain demand.

• The newsvendor problem has a long history, dating back to 1888, when Edgeworth used the central limit theorem to find the optimal cash reserves for a bank.

• The newsvendor problem has been extended and generalized to include various aspects, such as price effects, salvage value, stochastic costs, multiple products, multiple constraints, multiple periods, multiple echelons, learning and updating, robust optimization, and behavioural factors.

• The newsvendor problem has many applications in different domains, such as personal investments, emergency resources, manufacturing, real estate, and others.

• The newsvendor problem is still an active area of research, with many open questions and challenges, such as incorporating customer preferences, environmental concerns, social responsibility, and ethical issues.

2.1.1 Edgeworth introduces the problem of optimal cash reserves: 1888:

In 1888, Francis Ysidro Edgeworth made a significant contribution to the field of economics by introducing the problem of optimal cash reserves. At this time, banking systems were evolving rapidly, and there was a growing need to understand how banks could best manage their reserves to meet the demands of depositors while minimizing costs and risks.

Edgeworth's insight was to apply the central limit theorem, a fundamental concept in probability theory, to address this problem. By leveraging this theorem, Edgeworth aimed to determine the optimal amount of money that a bank should keep on hand to satisfy random withdrawals from depositors. This marked a crucial step in the development of inventory management theory, as it laid the groundwork for later formulations of the newsvendor problem.

One of the key considerations in Edgeworth's work was the trade-off between the cost of holding cash reserves and the risk of running out of cash. This trade-off remains central to the newsvendor problem and is a recurring theme in inventory management theory.

Edgeworth's pioneering efforts in addressing optimal resource allocation under uncertain demand scenarios paved the way for future research in this area. His work laid the foundation for the development of the newsvendor model and provided valuable insights into the principles of inventory management and operations research [9].

2.1.2 Morse and Kimball coin the terms "newsboy" and "newsvendor":1951:

In 1951, the newsvendor problem gained further prominence with the work of Morse and Kimball, who coined the terms "newsboy" and "newsvendor" to describe the problem of optimal inventory management under uncertainty. Their contribution was significant as it provided a clear and intuitive framework for understanding the challenges faced by vendors in determining how much inventory to stock.

The example presented by Morse and Kimball involved a newspaper vendor who must decide how many copies of the day's paper to stock, knowing that unsold copies would be worthless at the end of the day. This scenario captured the essence of the newsvendor problem, highlighting the need to balance the costs of overstocking with the risks of understocking.

One of the key insights from Morse and Kimball's work was the derivation of the optimal order quantity that maximizes the expected profit for the vendor. This optimal order quantity represents the delicate balance between the potential revenue from selling additional units and the costs incurred from holding excess inventory.

Morse and Kimball's formulation of the newsvendor problem provided a solid theoretical foundation for subsequent research in inventory management and operations research. Their work helped to popularize the newsvendor model and laid the groundwork for its application in various industries and contexts [14].

2.1.3 Whitin incorporates price effects and demand functions into the model: 1955:

Building upon the foundational work of Morse and Kimball, Whitin made significant advancements to the newsvendor model by incorporating price effects and demand functions. His extension of the model introduced the notion that selling price and stocking quantity could be set simultaneously, thereby allowing vendors to optimize their pricing strategies in addition to their inventory management decisions.

Whitin's work was motivated by the recognition that pricing decisions play a crucial role in determining the profitability of a business, especially in markets with uncertain demand. By incorporating price effects into the newsvendor model, Whitin provided a more comprehensive framework for analyzing the trade-offs involved in inventory management and pricing strategies.

One of the key contributions of Whitin's work was the development of methods for finding the optimal price and quantity that maximize the expected profit for the vendor. This involved modeling demand as a function of the selling price and deriving the conditions under which the vendor should adjust the price to maximize profitability.

Whitin's extension of the newsvendor model opened new avenues for research in inventory management and pricing strategy. His work laid the foundation for subsequent developments in the field and provided valuable insights into the complex interplay between inventory management decisions and pricing strategies [19].

2.1.4 Arrow, Harris, and Marshak publish a seminal paper on the newsvendor model: 1961:

In 1961, Arrow, Harris, and Marshak published a seminal paper that expanded the scope of the newsvendor model to include multiple products, periods, locations, and objectives. This represented a significant advancement in the field of inventory management, as it allowed for a more comprehensive analysis of the factors influencing inventory decisions in complex supply chain environments.

The work of Arrow, Harris, and Marshak was motivated by the recognition that real-world inventory management problems often involve multiple products, periods, and locations, each with its own unique demand patterns and cost structures. By generalizing the newsvendor model to accommodate these complexities, they provided a more robust framework for analyzing inventory management decisions in diverse contexts.

One of the key contributions of their work was the development of methods for optimizing inventory decisions across multiple dimensions, considering the interdependencies between different parts of the supply chain. This involved formulating mathematical models that capture the relationships between supply, demand, and inventory levels, and deriving optimal strategies for coordinating inventory decisions across the entire supply chain.

Arrow, Harris, and Marshak's paper laid the foundation for a new era of research in inventory management, as it provided a unified framework for analyzing inventory decisions in complex supply chain environments. Their work has had a lasting impact on the field, influencing the development of new methodologies and tools for optimizing inventory decisions in practice [16].

2.1.5 Porteus analyses the effects of lead time and demand variability on the newsvendor model: 1975:

In 1975, Porteus made significant contributions to the newsvendor model by analyzing the effects of lead time and demand variability on inventory decisions. His work addressed the challenges faced by vendors in managing inventory when faced with uncertain lead times and demand patterns, providing valuable insights into the factors influencing inventory decisions in practice.

Porteus's analysis was motivated by the recognition that real-world inventory management problems often involve uncertainties in both demand and lead time, each of which can have a significant impact on inventory decisions. By studying the effects of lead time and demand variability on the newsvendor model, Porteus aimed to develop strategies for mitigating the risks associated with these uncertainties and improving inventory management performance.

One of the key findings of Porteus's work was the identification of optimal inventory policies that take into account both demand variability and lead time uncertainty. This involved developing mathematical models that capture the relationships between lead time, demand variability, and inventory levels, and deriving optimal strategies for setting inventory levels in the face of these uncertainties.

Porteus's research has had a significant impact on the field of inventory management, as it has provided valuable insights into the factors influencing inventory decisions in practice. His work has helped to improve our understanding of the complexities involved in managing inventory in uncertain environments and has provided practical strategies for optimizing inventory decisions in practice [17].

2.1.6 Petruzzi and Dada extend the newsvendor model to include salvage value and stochastic costs: 1985:

In 1985, Petruzzi and Dada made significant advancements to the newsvendor model by extending it to include salvage value and stochastic costs. Their work addressed the challenges faced by vendors in managing inventory when faced with uncertainties in salvage values and costs, providing valuable insights into the factors influencing inventory decisions in practice.

Petruzzi and Dada's extension of the newsvendor model was motivated by the recognition that real-world inventory management problems often involve uncertainties in both salvage values and costs, each of which can have a significant impact on inventory decisions. By incorporating these uncertainties into the model, Petruzzi and Dada aimed to develop strategies for optimizing inventory decisions in the face of these uncertainties.

One of the key contributions of Petruzzi and Dada's work was the development of mathematical models that capture the relationships between salvage values, costs, and inventory levels. This involved extending the traditional newsvendor model to include stochastic costs and salvage values and deriving optimal strategies for setting inventory levels in the face of these uncertainties.

Petruzzi and Dada's research has had a significant impact on the field of inventory management, as it has provided valuable insights into the factors influencing inventory decisions in practice. Their work has helped to improve our understanding of the complexities involved in managing inventory in uncertain environments and has provided practical strategies for optimizing inventory decisions in practice [18].

2.1.7 Gallego and Moon propose a dynamic version of the newsvendor model with learning and updating: 1997:

In 1997, Gallego and Moon introduced a dynamic variant of the newsvendor model that incorporates learning and updating mechanisms. This innovative approach addressed the common real-world scenario where vendors lack precise knowledge of demand distributions but can gather insights from past observations and adjust their strategies accordingly.

The core assumption in Gallego and Moon's model is that the vendor's knowledge of demand is uncertain and evolves over time. To manage this uncertainty, they developed a Bayesian framework that allows the vendor to update their beliefs about demand based on historical data.

By leveraging Bayesian inference, the vendor can strike a balance between exploration (learning from new observations) and exploitation (leveraging existing knowledge to maximize profit).

One of the key contributions of Gallego and Moon's work was the development of different learning rules, including constant, decreasing, and adaptive strategies. These rules govern how the vendor updates their beliefs over time and determine the rate at which new information is incorporated into decision-making. By comparing the performance of these learning rules, Gallego and Moon provided valuable insights into the effectiveness of different learning strategies in the context of the newsvendor problem.

Overall, Gallego and Moon's dynamic newsvendor model with learning and updating represents a significant advancement in the field of inventory management. By addressing the challenges of demand uncertainty and evolving knowledge, their approach offers practical strategies for vendors to optimize inventory decisions in dynamic environments [15].

2.1.8 Khouja studies the newsvendor model with multiple products and multiple constraints: 2002:

In 2002, Khouja [20] extended the traditional newsvendor model to accommodate multiple products and multiple constraints, addressing the complexities often encountered in real-world inventory management scenarios. This extension was motivated by the recognition that many businesses sell a variety of products, each with its own demand patterns, costs, and constraints.

Khouja's model considers situations where vendors must allocate limited resources, such as budget, space, and service level, among multiple products while maximizing overall profitability. This involves determining the optimal order quantities for each product to achieve the desired balance between meeting demand and minimizing costs.

One of the key challenges addressed by Khouja's work is the management of demand correlation and substitution effects across multiple products. By analyzing how changes in demand for one product impact the demand for others, Khouja provided insights into the complex interactions between different parts of the product portfolio.

Khouja's research offers practical strategies for optimizing inventory decisions in multi-product environments, helping vendors allocate resources more effectively and improve overall profitability. By considering multiple constraints and demand patterns, Khouja's model provides a more comprehensive framework for addressing the challenges of inventory management in complex supply chain environments [20].

2.1.9 Chen, Simchi-Levi, and Sun develop a robust optimization approach to the newsvendor model with demand uncertainty: 2012:

In 2012, Chen, Simchi-Levi, and Sun [21] introduced a robust optimization approach to the newsvendor model to address the challenges of demand uncertainty. Unlike traditional approaches that rely on specific assumptions about demand distributions, their method considers a range of possible demand scenarios and seeks to minimize the worst-case expected cost.

The core idea behind robust optimization is to hedge against uncertainty by optimizing decisions under the assumption that the true demand lies within a certain range. This approach allows vendors to develop strategies that perform well across a variety of demand scenarios, rather than being overly sensitive to specific assumptions about demand distributions.

Chen, Simchi-Levi, and Sun's robust optimization approach offers several advantages over traditional methods. By focusing on worst-case scenarios, it provides a more conservative estimate of expected costs, helping vendors avoid potential losses due to unforeseen fluctuations in demand.

Additionally, their approach provides a more flexible framework for decision-making, allowing vendors to adapt to changing market conditions and uncertainties. By incorporating robust optimization techniques into the newsvendor model, Chen, Simchi-Levi, and Sun offer practical strategies for managing demand uncertainty and improving inventory management performance[17].

2.1.10 Chen, Cheng, Choi, and Wang provide a comprehensive survey of the newsvendor problem and its variants: 2016:

In 2016, Chen, Cheng, Choi, and Wang [18] conducted a comprehensive survey of the newsvendor problem and its various extensions and applications. Their work aimed to provide a comprehensive overview of the state-of-the-art in newsvendor research, highlighting key developments, trends, and areas for future exploration.

One of the key contributions of Chen et al.'s survey is the classification of the newsvendor problem into four categories: single-product, multi-product, multi-period, and multi-echelon. This classification helps to organize the vast body of literature on the newsvendor problem and provides a framework for understanding the different variants and their implications.

Chen et al. also discusses the extensions and applications of the newsvendor problem in various domains, including pricing, quality, competition, sustainability, and behavioral aspects. By examining how the newsvendor problem has been applied in different contexts, they highlight its versatility and relevance across a wide range of industries and disciplines.

Additionally, Chen et al. identify research gaps and future directions for the newsvendor problem, pointing out areas where further investigation is needed to advance the state-of-the-art. Their survey provides valuable insights for researchers and practitioners interested in the newsvendor problem, helping to guide future research efforts and applications.

In summary, Chen et al.'s survey offers a comprehensive overview of the newsvendor problem and its variants, highlighting key developments, trends, and areas for future exploration. By synthesizing the existing literature and identifying research gaps, their work provides valuable insights for advancing the field of inventory management [22].

2.2 Primary data

Primary data of local Jammu Street vendors on supply demand issue (newsvendor problem) and their experiences. We have conducted the study according to our convenience. It comprises perception of local street vendors in Jammu towards supply demand, operation management: Newsvendor model.

Methodology

2.2.1 Introduction

This chapter covers the research design, study area, sample size, sampling unit, data collection method, data collection and data presentation

2.2.2 Research Design

The cross-sectional survey design is adopted for the study. It is used because it examines a group of individuals at a specific point in time. This approach is useful for studying patterns and in-depth analysis of characteristics in a population.

2.2.3 Study Area

The study was conducted in old Jammu city.

2.2.4 Sample Size

A sample of 50 vegetable vendors was taken in account from the chosen study area.

2.2.5 Sampling Unit

The sampling unit for this study is defined as the street vendors who sells vegetables

2.2.6 Data Collection method

Primary data was collected using interview schedule method.

2.2.7 Data collection

Collected data, conducted interviews and performed other relevant activities necessary for the successful completion of the survey.

2.2.8 Data Presentations

The data collected from the schedule was sorted, tabulated and interpreted. It was also analysed and organised to draw conclusions.

People's opinion about balance between supply and demand in the market?

Table 2.1

Row Labels	Count of Do you feel there is a good balance between supply and demand in the vegetable market?	Percentage
Agree	18	36%
Disagree	13	26%
Neutral	16	32%
Strongly agree	2	4%
Strongly disagree	1	2%
Grand Total	**50**	100%

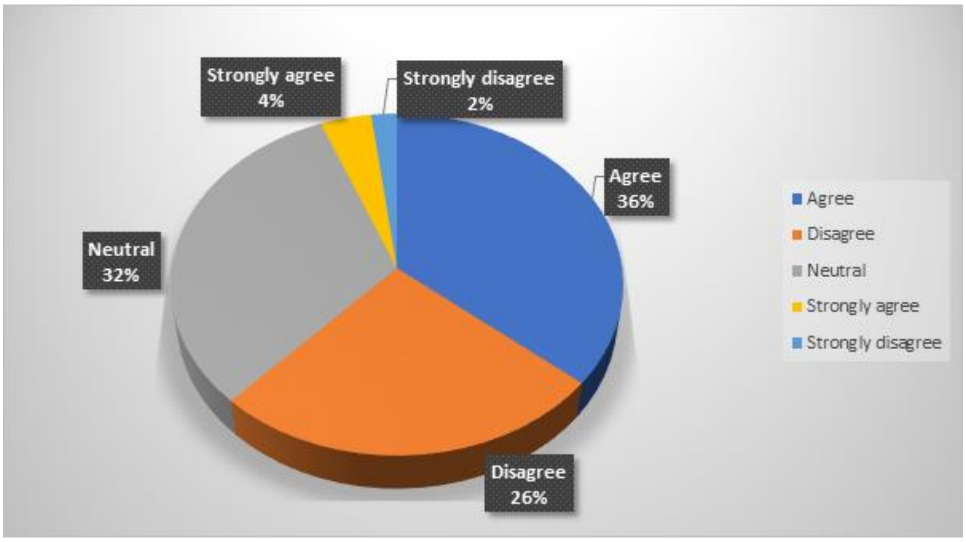

Fig 2.1 People opinion about balance between supply and demand

~According to statistics most people agree the Jammu market to be in equilibrium hence inducing a need for inventory management.

Do fluctuations in demand and supply affect profit margins?

Table 2.2

Row Labels	Count of How do fluctuations in demand and supply affect your profit margins?	Percentage
Moderately	23	46%
much	5	10
Significantly	22	44%
Grand Total	**50**	100%

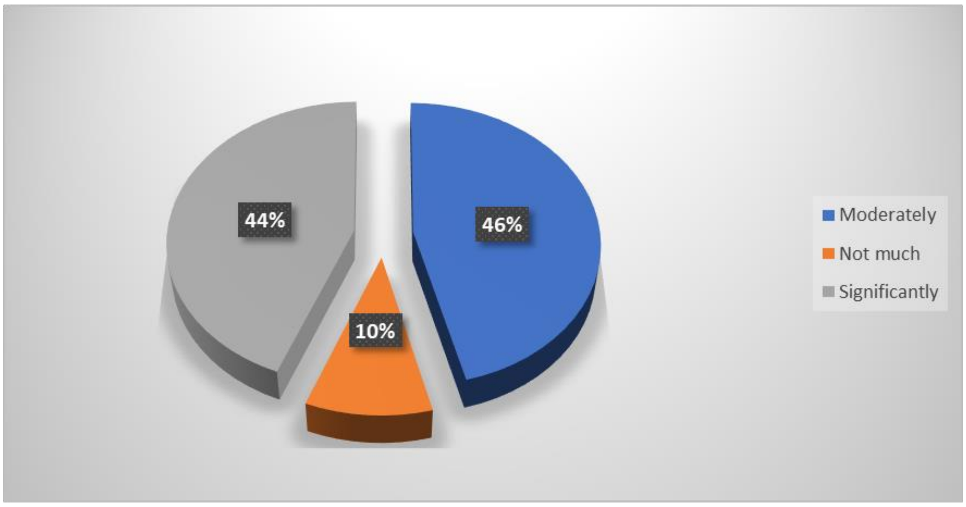

Fig 2.2 Demand and Supply fluctuations affecting profit margins

~According to statistics more than 90% of people have their money lost due to no proper supply demand solution.

Do you find it necessary to adjust your pricing based on demand and supply fluctuations?

Table 2.3

Row Labels	**Count of Do you find it necessary to adjust your pricing based on demand and supply fluctuations?**	**Percentage**
Always	21	42%
Rarely	8	16%
Sometimes	21	42%
Grand Total	**50**	100%

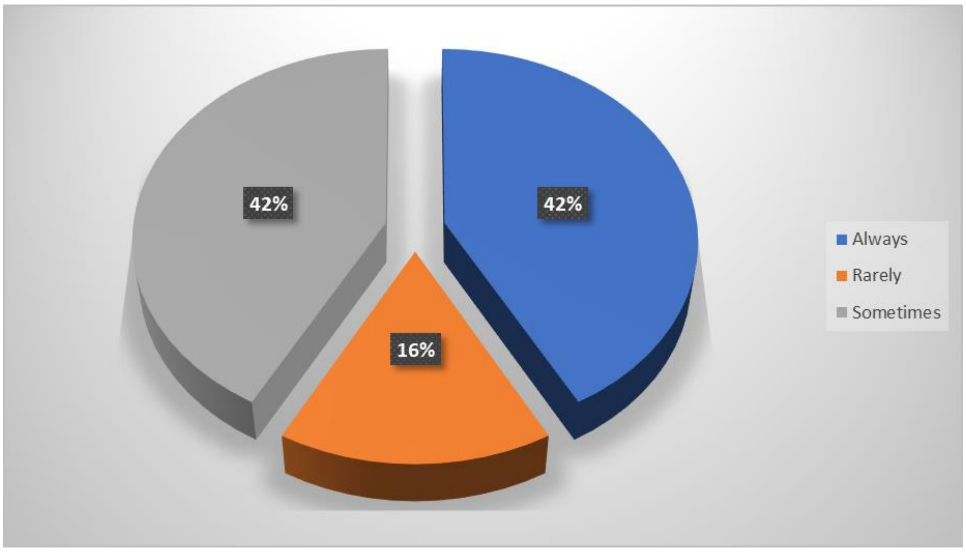

Fig 2.3 Adjustment of prices based on demand and supply

~According to statistics most of the people have to sell their products at salvage value because of no proper forecast of how much stuff to keep.

Do some of your items remain unsold?

Table 2.4

Row Labels	Count of Do some of your items remain unsold?	Percentage
No	1	2%
occasionally	7	14%
Yes	42	84%
Grand Total	**50**	100%

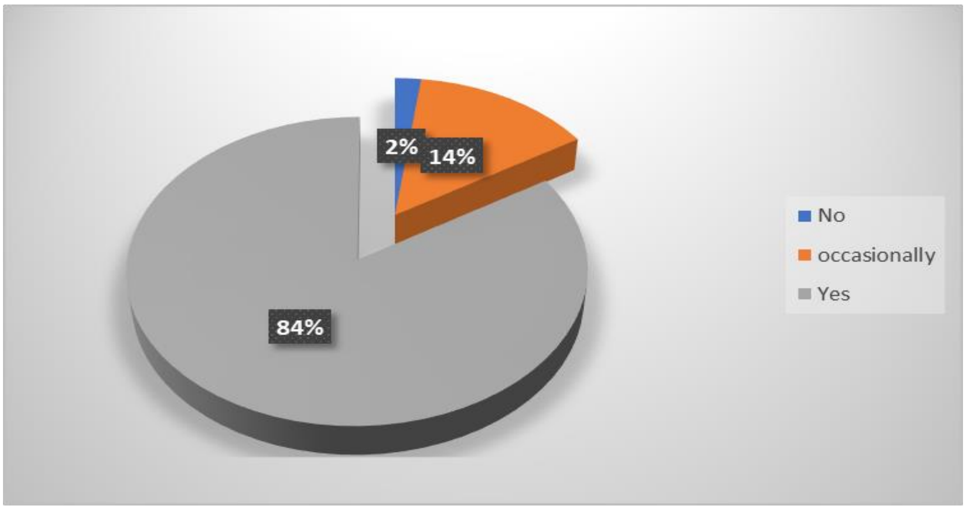

Fig 2.4 Goods unsold

~According to statistics more than 80% of people have their stock remain unsold due to NO managerial insights to their stock.

Count of Is quantity of your leftover items more than you sell?

Table 2.5

Row Labels	Count of Is quantity of your leftover vegetables more than you sell?	Percentage
No	41	82%
sometimes	7	14%
Yes	2	4%
Grand Total	**50**	100%

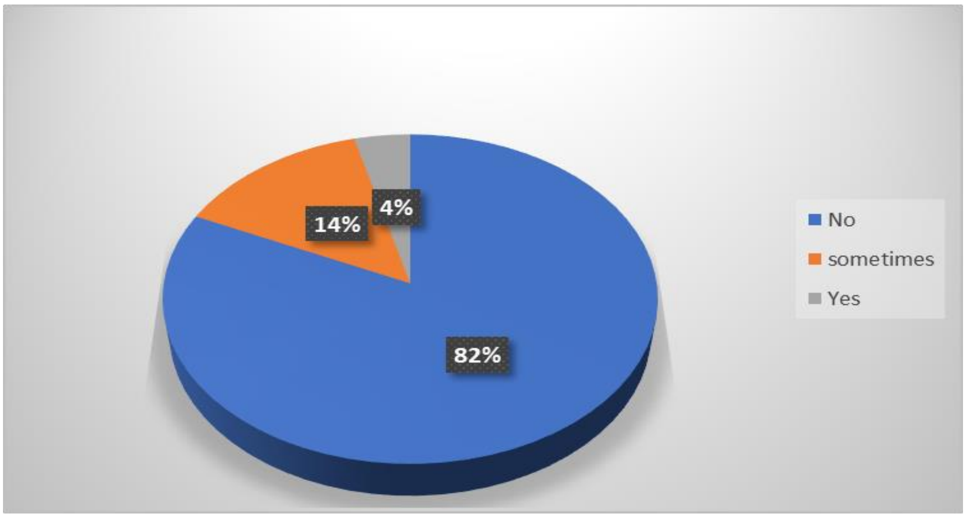

Fig 2.5 Quantity of leftovers with respect to selling proportions.

~According to statistics most people buy more items than they sell as they don't know much about supply and demand resulting in them inducing loss.

What do the vendors do with their leftover items?

Table 2.6

Row Labels	Count of What do you do with your leftover vegetables?	Percentage
Give it to domestic animals (cows etc)	3	6%
Keep for the next day	46	92%
Provide/distribute it to entities (like charities, local communities etc)	1	2%
Grand Total	**50**	100%

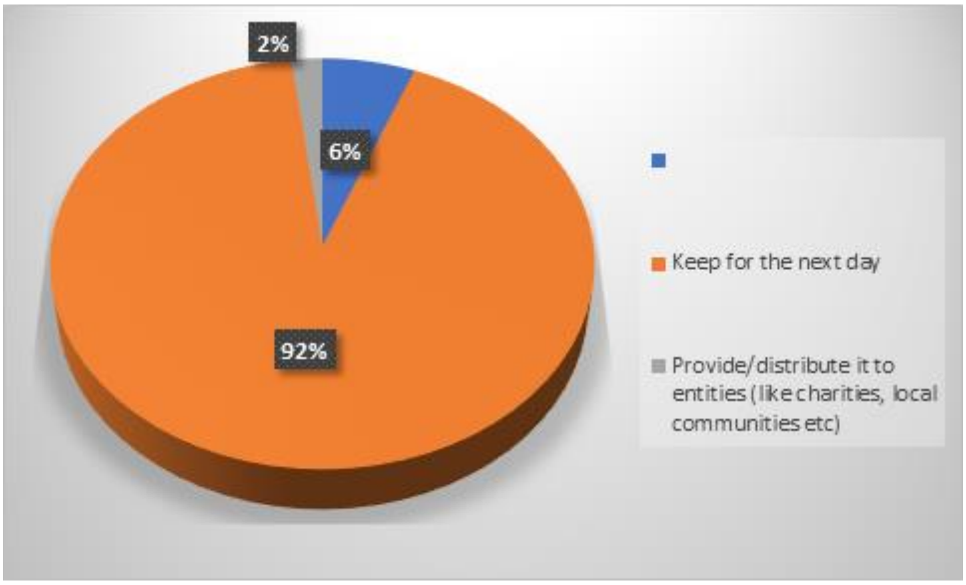

Fig 2.6 Selling leftover items

~According to statistics most people can't sell their stock in General expected time and must extend its sale duration and provide discounts and maybe sell at salvage value.

Average monetary impact done by not managing inventory?

Table 2.7

Row Labels	Count of Average impact (in rupees)	Percentage
200	3	15%
300	1	5%
400	1	5%
450	1	5%
500	10	50%
1000	1	5%
2000	1	5%
3000	1	5%
5000	1	5%
Grand Total	**20**	100%

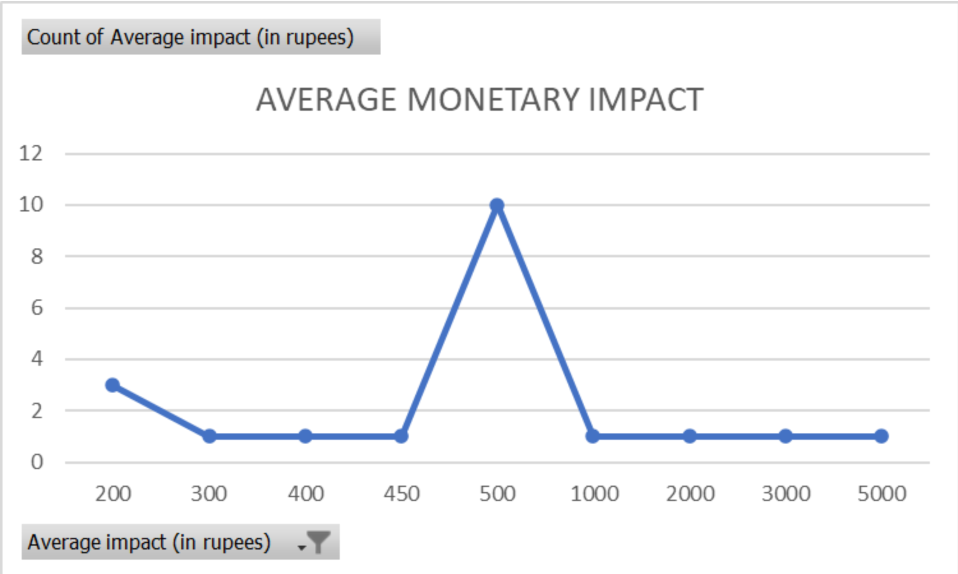

Fig 2.7 Monetary impact done by not managing inventory

~According to statistics on an average most people lose almost about 500 rupees every week to not managing inventory. They even lose as low as 200 rupees to as high as 5000 rupees per week to not managing inventory.

How vendors handle their supply and demand?

Table 2.8

Row Labels	Count of Handling supply and demand	Percentage
buy it from somewhere else	2	5%
No need	13	33%
nothing	10	26%
On spot	5	13%
other jobs	2	5%
Stock	7	18%
Grand Total	**39**	100%

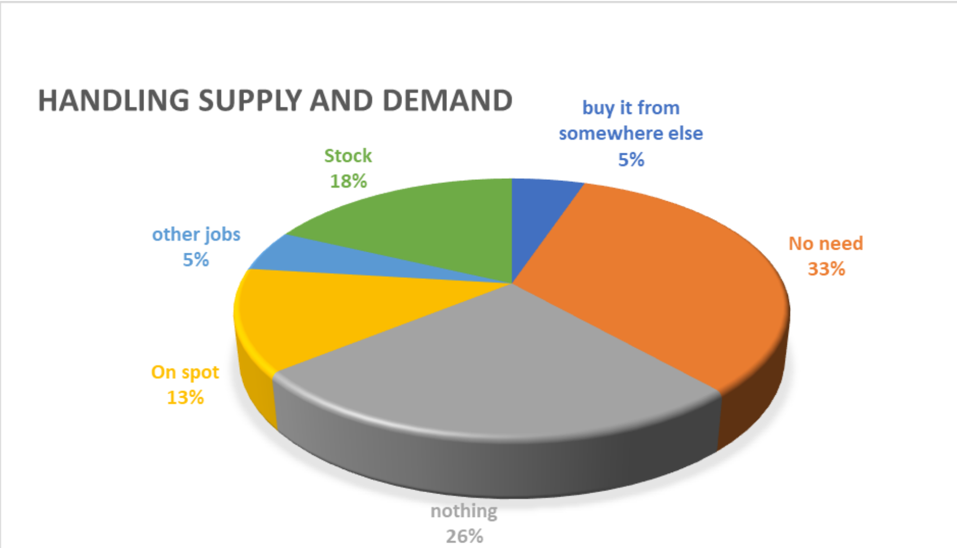

Fig 2.8 Handling supply and demand

~According to statistics most people they think they have no need to manage supply and demand and after that majority think they should do nothing about it and the remaining minorities just do trial and error to solve this.

After observing all the primary data of Jammu locals, we have an idea how important the Operation Management (Newsvendor Model) is.

CHAPTER-3
METHODOLOGY

3.1 Introduction

The newsvendor problem is about finding the optimal amount of supply to order or produce before seeing the actual demand, which is uncertain and varies depending on many factors. For example, a newsvendor must buy newspapers every day without knowing how many customers will show up. If they buy too many, they will waste money and paper. If they buy too few, they will lose sales and profit. This problem is common in many businesses that face uncertain demand and must make supply decisions in advance. The newsvendor problem is a difficult one to solve, as it involves a trade-off between overstocking and understocking. The same problem occurs in other situations, such as when a technology company has to order components with a long lead time and a short product life cycle. If they order too many, they may end up with obsolete inventory. If they order too few, they may miss out on market opportunities. Cisco experienced this problem in 2000-2001, when they overestimated the demand for their products and had to write off billions of dollars in excess inventory.

3.2 Case Study

O'Neill Inc., a sports apparel manufacturer. O'Neill's [1] decision also closely resembles the news vendor's task. We then describe the newsvendor model in detail and apply it to O'Neill's problem. We also show how to use the newsvendor model to forecast several performance measures relevant to O'Neill:

O'Neill Inc. makes clothing, wetsuits, and accessories for different kinds of water sports, such as surfing, diving, waterskiing, wakeboarding, triathlon, and windsurfing. They have products for different levels of users, from beginners to professionals. For example, they have advanced dry suits for cold-water divers who work in the oil industry in the North Sea. O'Neill has two main selling seasons in a year: Spring (from February to July) and Fall (from August to January). Some products are sold in both seasons, but most of them are more suitable for one season than the other. For instance, waterskiing is more popular in the Spring season, while recreational surfing is more in demand in the Fall season. Some products are not affected by fashion trends (for example, standard black neoprene booties), but others have catchy names like "Animal," "Epic," "Hammer," "Inferno," and "Zen," and change their colors and designs according to the preferences of their main customers (young men from California who surf).

O'Neill has its own factory in Mexico, but not all of its products are made there. Some of them are made by TEC Group, a company in Asia that works for O'Neill. TEC Group has some advantages for O'Neill (such as low price, sourcing skills, flexible production, etc.), but they also have a drawback: they need three months to deliver any order. For example, if O'Neill orders something on November 1, they will only get it at their distribution centre in San Diego, California, on January 31, ready to be shipped to their customers. To understand the production problem that O'Neill faces, let's look at a specific wetsuit that surfers use and that has been redesigned for the next spring season: the Hammer 3/2. (The "3/2" means that the neoprene on the suit is 3 mm thick on the chest and 2 mm thick everywhere else.) shows the Hammer 3/2 and the O'Neill logo. O'Neill has decided to let TEC Group make the Hammer 3/2. Because of the three-month lead time of TEC Group, O'Neill must place an order with TEC Group in November, before the spring season starts. O'Neill has estimated that the total demand for the Hammer 3/2 during the spring season will be 3,200 units, based on the sales data of similar products and the opinions of its designers and salespeople. However, this estimate is not very reliable, because there is a lot of uncertainty in the demand. For example, O'Neill knows that half of the time, the actual demand is different from their initial estimate by more than 25 percent of the estimate. In other words, only half of the time, the actual demand is between 75 percent and 125 percent of their estimate. Even though O'Neill's estimate in November is not very accurate, O'Neill will have a much better estimate of the total season demand after seeing the sales data of the first one or two months. Then, O'Neill can tell if the Hammer 3/2 is selling faster or slower than expected. If it is selling slower, O'Neill will probably have too much inventory at the end of the season. If it is selling faster, O'Neill will probably run out of stock. In the second case, O'Neill would like to order more Hammers, but the long lead time from Asia makes it impossible for O'Neill to get those extra Hammers in time. So, O'Neill has to "live or dive" with the single order that they placed in November. Luckily for O'Neill, the Hammer has good profit margins. O'Neill sells the Hammer to retailers for $190, while it pays TEC Group $110 for each suit. If O'Neill has any inventory left at the end of the season, they can usually sell it for $90 per suit. So how many units should O'Neill order from TEC? You might argue that O'Neill should order the forecast for total demand, 3,200, because 3,200 is the most likely outcome. The forecast is also the value that minimizes the expected absolute difference between the actual demand and the production quantity; that is, it is likely to be close to the actual demand. Alternatively, you may be concerned that forecasts are always biased and therefore suggest an order quantity less than 3,200 would be more prudent. Finally, you might argue that because the gross margin on the Hammer is more than 40 percent (190 - 110)/190 =

0.42), O’Neill should order more than 3,200 in case the Hammer is a hit. We next define the newsvendor model and then discuss what the newsvendor model recommends for an order quantity.

Fig 3.1 O’Neill Logo[23].

Fig 3.2 O'Neill Wetsuits Men's Hammer 3/2mm[24].

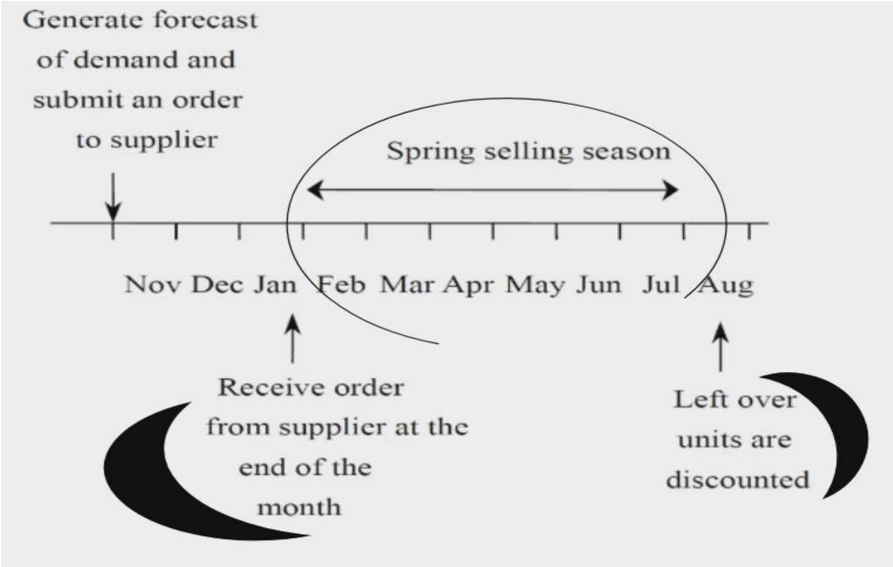

Fig 3.3 O'Neills Business process diagram[1, p. 242].

The value of the inventory that remains at the end of the season depends on the Salvage value, which is the fixed amount that you earn for each unit that you sell after the season. For the Hammer, the Salvage value is 90. However, sometimes the inventory has no value at all, meaning that the Salvage value is 0. Or even worse, sometimes the inventory has a negative value, meaning that you have to pay to get rid of it. This can happen if the product is dangerous and needs special disposal. In that case, the Salvage value is less than 0. To make a good production decision, you need to estimate the demand. O'Neill's initial estimate for the Hammer is 3,200 units for the season. But that is not enough. You also need to know how confident you are in your estimate; you need to measure the error in your estimate. For example, in a perfect world, your estimate would be always right: if you estimate 3,200 units, then 3,200 units is exactly the demand for the season. But your estimate will be wrong sometimes, and the error can be big or small. For example, it is better to be 90 percent confident that the demand will be between 3,100 and 3,300 units than to be 90 percent confident that the demand will be between 2,400 and 4,000 units. Your intuition should tell you that you might want to order a different quantity in those two cases. To sum up, the newsvendor model is a situation where you must make one choice (for example, the order quantity) before something random happens (for example, the demand). There are costs if your choice is too high (for example, you have to sell the inventory that you did not sell during the season for a lower price). There are costs if your choice is too low (you lose the chance to sell more and make more money). The goal of the newsvendor model is to choose the quantity that balances these two costs. To use the model, we need to know our costs and how uncertain the demand is. We already know our costs, so in the next section, we shall focus on how to measure the uncertainty in the demand for the Hammer 3/2 [1].

3.3 Demand forecast

However, I can still edit the file in that path - Master file cannot be made as non-editable file. To do this, we need to understand how much demand uncertainty there is for the Hammer 3/2, which essentially means we need to be able to answer the following question: What is the probability demand will be less than or equal to Q units? for whatever Q value we desire. In short, we need a distribution function. Recall from statistics, every random variable is defined by its distribution function, F (Q), which is the probability the outcome of the random variable is Q or lower. In this case the random variable is demand for the Hammer 3/2 and the distribution function is

$$F(Q) = \text{Prob}\{\text{Demand is less than or equal to } Q\}$$

Because it provides us with a comprehensive understanding of the demand uncertainty we confront, we refer to the distribution function, F (Q), as our demand forecast for convenience. This section's goal is to clarify how we may build our demand forecast by combining data analysis and intuition.

Two types of distribution functions exist. One way to define discrete distribution functions is as a table: There are several potential outcomes, and each one has a corresponding probability. An illustration of a basic discrete distribution function with three possible results is as follows:

Table 3.1 Discrete distribution function

Q	F(Q)
2200	0.25
3200	0.75
4200	1

We will use the Poisson distribution a lot. It is a discrete distribution function, which means it has a limited number of outcomes. The exponential and the normal distributions are different.

They are continuous distribution functions, which means they have infinite outcomes. They are described by one or two parameters. For instance, the normal distribution has two parameters: its mean and its standard deviation. We write the mean as μ and the standard deviation as σ. (μ and σ are Greek letters, mu and sigma.) This is a common way to write them, so we use it too. Sometimes, a discrete distribution function is better for representing demand, and sometimes a continuous distribution function is better. So, we use both kinds of distribution functions. Next, we will look at how to make the forecast. We said earlier that the Hammer 3/2 was changed for the next spring season. So, the sales from the last season may not be a good way to estimate the demand for the next season. There are other things that can affect the demand, like the price and the marketing plan for the next season, the fashion trends, the economy (e.g., are people buying more expensive or cheaper products), the technology changes, and the general popularity of the sport. We asked some people in the company what they think the demand for the Hammer 3/2 will be. We took the average of their answers and got the first forecast of 3,200 units. This is the "intuition" part of our demand forecast. Now we must use O'Neill's data to improve the demand forecast. Table shows the data from O'Neill's last spring season for the surf wetsuits. The data have the original forecasts and the actual demand for each product. The original forecasts were made in a similar way to the 3,200-unit forecast for the Hammer 3/2 for this season. For example, the forecast for the Hammer 3/2 in the last season was 1,300 units, but the demand was 1,696 units

Table 3.2 Showing forecast and actual demand

Product Description	**Forecast**	**Actual Demand**
JR ZEN FL 3/2	90	140
EPIC 5/3 W/HD	120	83
JR ZEN 3/2	140	143

WMS ZEN-ZIP 4/3	170	163
HEATWAVE 3/2	170	212
JR EPIC 3/2	180	175
WMS ZEN 3/2	180	195
ZEN-ZIP 5/4/3 W/HOOD	270	317
WMS EPIC 5/3 W/HD	320	369
JR EPIC 4/3	380	571
EVO 3/2	380	587
WMS EPIC 2MM FULL	390	311
ZEN 4/3	430	239
HEAnoVAVE 4/3	430	274
EVO 4/3	440	623

ZEN FL 3/2	450	365
HEAT 4/3	460	450
ZEN-ZIP 2MM FULL	470	116
HEAT 3/2	500	635
WMS EPIC 3/2	610	830
WMS ELITE 3/2	650	364
ZEN-ZIP 3/2	660	788
ZEN 2MM S/S FULL	680	453
EPIC 2MM S/S FULL	740	607
EPIC 4/3	1020	732
WMS EPIC 4/3	1060	1542
JR HAMMER 3/2	1220	721

HAMMER 3/2	1300	1696
HAMMER S/S FULL	1490	1832
EPIC 3/2	2190	3504
ZEN 3/2	3190	1195
ZEN-ZIP 4/3	3810	3289
WMS HAMMER 3/2 FULL	6490	3673

O'Neill can estimate the actual demand for a product that sells out by looking at the retailers' first orders, before they know the product is out of stock. They do this by phone or fax. (But sometimes people on the phone forget to enter the orders in the computer, so the estimate is not perfect. We will ignore this problem in our analysis.) Some firms may not be able to do this. For example, a store that sells O'Neill's products may not know how many more people would buy the Hammer 3/2 if they had it in stock. But they would know when they ran out of the Hammer and use that to guess how many more they could have sold later. So, even if firm does not see the lost sales, they should be able to make a good guess of the demand.

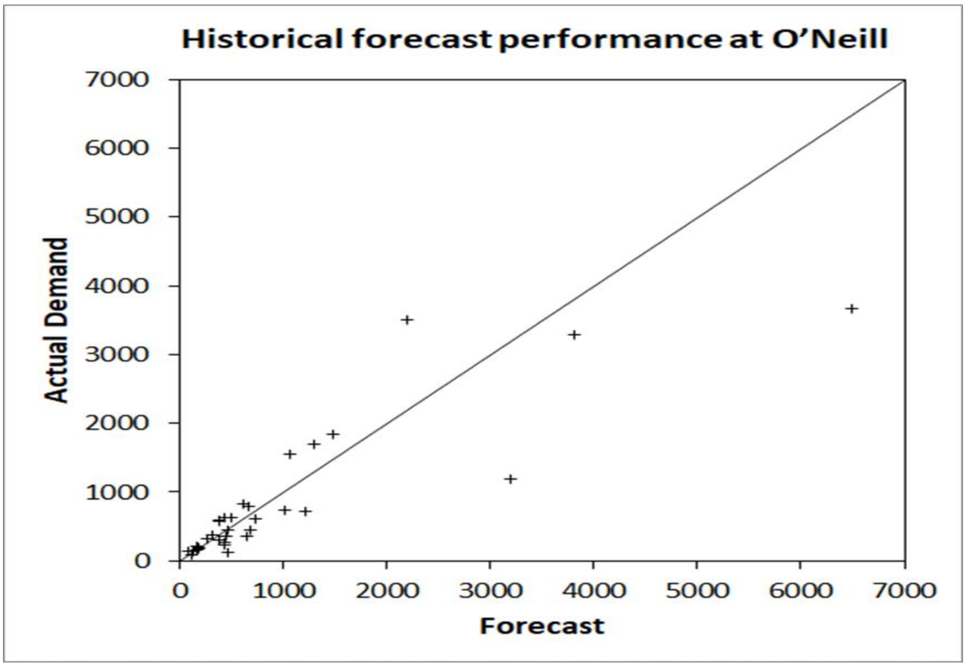

Fig 3.4 Historical forecast

The data shows that there was a range in the forecasts from 90 units at the lowest to 6,490 units at the highest. Significant projection errors were also made by O'Neill. For example, the Women's Hammer 3/2 Full suit was oversold by about 3,000 units, while the Epic 3/2 suit was undersold by roughly 1,300 units. A scatter plot of the actual demand versus the forecasts is shown in Figure. All the observations would fall along the diagonal line if forecasts were perfect.

The forecast errors for some of the smaller products are equally noteworthy, even though the absolute errors for some of the larger products are quite striking. For instance, there was a real need of more for the Juniors Zen Flat Lock 3/2 suit than 150 percent greater than forecast. This suggests that we should concentrate on the relative forecast errors instead of the absolute forecast errors.

Relative forecast errors can be measured with the A/F ratio:

$$\frac{A}{F} RATIO = \frac{(ACTUAL\ DEMAND)}{FORECAST}$$

A forecast that is correct has an A/F ratio of less than 1, whereas a forecast that is too high or too low is indicated by an A/F ratio above 1. The A/F ratios for our data are shown in Table final column.

These A/F ratios give an indication of how accurate the previous season's forecasts were.

Table presents the data sorted in ascending A/F order to demonstrate this argument. The table also shows the A/F rank of each product in order as well as its percentile, or the percentage of products with that A/F rank or below. (For instance, because it is the fifth product out of 33, the product with the fifth A/F ratio has a percentile of 5/33, or 15.2 percent products in the data.) We see from the data that actual demand is less than 80 percent of the forecast for one-third of the products (the A/F ratio 0.8 has a percentile of 33.3) and actual demand is greater than 125 percent of the forecast for 27.3 percent of the products (the A/F ratio 1.25 has a percentile of 72.7). Given that the A/F ratios from the previous season reflect forecast accuracy in the previous season, maybe the current season's forecast accuracy will be comparable. Hence, we want to find a distribution function that will match the accuracy we observe in Table. We will use the normal distribution function to do this. Before getting there, we need a couple of additional results. Take the definition of the A/F ratio and rearrange terms to get

Table 3.3 Representing A/F Ratio

Product Description	Forecast	Actual Demand	A/F Ratio
JR ZEN FL 3/2	90	140	1.56
EPIC 5/3 W/HD	120	83	0.69
JR ZEN 3/2	140	143	1.02
WMS ZEN-ZIP 4/3	170	163	0.96
HEATWAVE 3/2	170	212	1.25

JR EPIC 3/2	180	175	0.97
WMS ZEN 3/2	180	195	1.08
ZEN-ZIP 5/4/3 W/HOOD	270	317	1.17
WMS EPIC 5/3 W/HD	320	369	1.15
JR EPIC 4/3	380	571	1.50
EVO 3/2	380	587	1.54
WMS EPIC 2MM FULL	390	311	0.80
ZEN 4/3	430	239	0.56
HEAnoVAVE 4/3	430	274	0.64
EVO 4/3	440	623	1.42
ZEN FL 3/2	450	365	0.81
HEAT 4/3	460	450	0.98

ZEN-ZIP 2MM FULL	470	116	0.25
HEAT 3/2	500	635	1.27
WMS EPIC 3/2	610	830	1.36
WMS ELITE 3/2	650	364	0.56
ZEN-ZIP 3/2	660	788	1.19
ZEN 2MM S/S FULL	680	453	0.67
EPIC 2MM S/S FULL	740	607	0.82
EPIC 4/3	1020	732	0.72
WMS EPIC 4/3	1060	1542	1.45
JR HAMMER 3/2	1220	721	0.59
HAMMER 3/2	1300	1696	1.30
HAMMER S/S FULL	1490	1832	1.23

EPIC 3/2	2190	3504	1.60
ZEN 3/2	3190	1195	0.37
ZEN-ZIP 4/3	3810	3289	0.86
WMS HAMMER 3/2 FULL	6490	3673	0.57
	Average A/F Ratio		**0.9976**
	St.dev. A/F Ratio		**0.3691**

$$Actual\ demand = \left\{\frac{A}{F} ratio\right\} * Forecast$$

$$Standard\ deviationof\ demand = Standard\ deviation\ of \frac{A}{F} ratio * Forecast$$

Expected actual demand, or expected demand for short, is what we should choose for the mean for our normal distribution, μ. The average A/F ratio in Table is 0.9976. Therefore, expected demand for the Hammer 3/2 in the upcoming season is 0.9976 * 3,200 =3,192 units. In other words, if the initial forecast is 3,200 units and the future A/F ratios are comparable to the past A/F ratios, then the mean of actual demand is 3,192 units. So, let's choose 3,192 units as our mean of the normal distribution. This decision may raise some eyebrows: If our initial forecast is 3,200 units, why do we not instead choose 3,200 as the mean of the normal distribution? Because 3,192 is so close to 3,200, assigning 3,200 as the mean probably would lead to a good order quantity as well. However, suppose the average A/F ratio were 0.90, that is, on average, actual demand is 90 percent of the forecast. It is quite common for people to have overly optimistic forecasts, so an average A/F ratio of 0.90 is possible. In that case, expected actual demand would only be 0.90 * 3,200 =2,880. Because we want to choose a normal distribution that represents actual demand, in that situation it would be better to choose a mean of 2,880 even though our initial forecast is 3,200. Now that we have a mean for our normal distribution, we need a standard deviation. The second equation above tells us that the standard deviation of actual demand equals the standard deviation of the A/F ratios times the forecast. The standard deviation of the A/F ratios in Table is 0.369. (Use the "stdev()" function in Excel.) So, the standard deviation of actual demand is the standard deviation of the A/F ratios times the initial forecast: 0.369 * 3,200 = 1,181. Hence, to express our demand forecast for the Hammer 3/2, we can use a normal distribution with a mean of 3,192 and a standard deviation of 1,181. See for a summary of the process of choosing a mean and a standard deviation for a normal distribution forecast. Now that we have the parameters of a normal distribution that will express our demand forecast, we need to be able to find F (Q). There are two ways this can be done. The first way is to use spreadsheet software. For example, in Excel use the function Normdist(Q, 3192, 1181, 1). The second way, which does not require a computer, is to use the Standard Normal Distribution Function. The standard normal is a particular normal distribution: its mean is 0 and its standard deviation is 1. To introduce another piece of common Greek notation, let φ(z) be the distribution function of the standard normal. Even though the standard normal is a continuous distribution, it can be "chopped up" into pieces to make it into a discrete distribution. The Standard Normal Distribution Function Table is exactly that; that is, it is the discrete version of the standard normal distribution. The format of the Standard Normal Distribution Function Table makes it somewhat tricky to read. For example, suppose you wanted to know the probability that the outcome of a standard normal is 0.51 or lower. We are looking for the value of φ (z) with z = 0.51. To find that value, pick the row and column in the table such that the first number in the row and the first number in the column add up to the z value you seek. With z = 0.51, we are looking for the row that begins with 0.50 and the column that begins with 0.01, because the sum of those two values come to 0.51. (z) is the result of that row's intersection with that column; Table shows that (0.51) ~ 0.6950. Consequently, there is a 69.5 percent chance that a typical normal will have a result of 0.51 or less.

However, it is improbable that our demand projection will follow a typical normal distribution. With our demand estimate being some other normal distribution, how can we utilize the standard normal to get F (Q), or the likelihood that demand will be Q or lower? The process involves converting the quantity of interest, Q, into a corresponding amount for the standard normal. To put it another way, we identify a z such that F (Q) ~ (z) = 0, meaning that the probability demand is smaller than or equal to Q is equivalent to the likelihood that a standard

normal will result in z or less. We refer to that z as the z-statistic. We just look up (z) in the Standard Normal Distribution Function Table to find our answer after we have the right z - statistics.
Use the following equation to translate Q into the corresponding z-statistic:

$$z = \frac{(Q - \mu)}{\sigma}$$

Let's take a case where we are interested in the probability Q 4,000, or the likelihood that demand for the Hammer 3/2 will be 4,000 units or less. Quantity Q 4,000 has a z-statistic of with a normal distribution with mean 3,192 and standard deviation 1,181.

$$z = \frac{(4000 - 3192)}{1181}$$

Therefore, the probability need for the Hammer 3/2 is (0.68), which is the same as the likelihood that the standard normal would have an outcome of 0.68 or less.
The Standard Normal Distribution Function Table indicates that (0.68) ~ 0.7517 (see Table for convenience). Put differently, there is a likelihood of little over 75% that the Hammer 3/2 will be in demand for 4,000 pieces or less. The process of determining the probability that the demand will be less than or equal to some Q (or larger than Q) is summarized in Exhibit
As you may remember, O'Neill has had demand for 50% of their items diverge by more than 25% from their initial projection. Now that we can Verify that the experience matches our normal distribution prediction for the Hammer 3/2. We initially estimated 3,200 units. Therefore, it is implied that demand is either less than 2,400 units or more than 4,000 units when there is a variance of 25% or greater. For Q ~ 2,400, the z-statistic is z ~ (2400 − 3192)/1181 ~ −0.67, and ~ (−0.67) ~ 0.2514 from the Standard Normal Distribution Function Table. (Identify the column with −0.07 and the row with ~0.60.) There is a 75.17 − 25.14 ~ 50.03 percent chance that demand is between 2,400 and 4,000 units if there is a 25.14 percent probability that demand is less than 2,400 units and a 75.17 percent probability that demand is less than 4,000 units. Therefore, O'Neill's original claim about forecast accuracy is in line with our demand projection using normal distribution.
In summary, creating a thorough demand forecast is the aim of this part. It is insufficient to rely on a single "point forecast," such as 3,200 units. We require a distribution function to quantify the potential amount of unpredictability for our forecast.
By fitting a normal distribution to our historical forecast accuracy data, we were able to derive this distribution function [25].

Table 3.4 Distribution Function

z	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8212	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389

3.4 Maximizing Expected Profit

Maximizing expected profit is equivalent to minimizing expected mismatch cost - cost of mismatch between the supply and the demand

Two types of costs

- When we have a stockout, we have an underage cost for every unit that we could have sold (lost opportunity cost), which is equal to the profit from selling a unit.

$$Underage\ Cost = C_u = price - Cost = p - c$$

- When we have a leftover inventory, we have an overage cost for every unit of leftover inventory, which is equal to the loss from selling a unit at salvage value.

$$Overage\ Cost = C_o = Cost - salvage\ value = c - s$$

For O'Neill's Hammer 3/2 wetsuit

- Price is p = $190 per unit
- Cost charged by supplier is c = $110 per unit
- Salvage value is s = $90 per unit
- Cu= $190 - $110 = $80
- Co = $110 - $90 = $20

<u>Balancing Risk and Benefit of Having One More Unit</u>

Fig 3.5 Graph representing expected loss / gain

- Suppose we plan to order Q units. Should we increase Q?
- What is the expected gain/loss from unit number Q + 1?
- Expected gain = C_u*P (demand > Q) =C_u*(1-P (demand ≤Q)) =C_u(1-F(Q))
- Expected loss = C_o* P (demand ≤ Q) = C_oF(Q)
- When Q very small:
- Expected gain from extra unit ~ Cu = $80
- Expected loss from extra unit ~ $0
- It is profitable to increase Q
- As Q increases:
- Expected gain decreases
- Expected loss increases
- At some point expected loss exceeds expected gain; then, increasing Q is no longer profitable
- To maximize expected profit, find Q such that
  expected gain = expected loss

$$C_u (1 - F(Q)) = C_o F(Q)$$

- Solving the equation:
  $C_u - C_u F(Q) = C_o F(Q)$

$$F(Q) = \frac{(Underage\ Cost)}{Underage\ Cost + Overage\ Cost}$$

$$Q = F^{-1}\frac{(Underage\ Cost)}{Underage\ Cost + Overage\ Cost}$$

$$\frac{(Underage\ Cost)}{Underage\ Cost + Overage\ Cost}\ is\ called\ critical\ ratio$$

- Find Q such that P (demand ≤ Q) = critical ratio

Maximizing expected profit from O'Neill's Hammer 3/2 wetsuit

Recall that F(x) is the Normal distribution for the demand forecast of O'Neill's Hammer 3/2 wetsuit with mean $\mu = 3192$ and St. dev. $\sigma = 1181$.

Also recall the costs $C_u = \$80$ and $C_o = \$20$

$$CRITICAL\ RATIO = \frac{(Underage\ Cost)}{Underage\ Cost + Overage\ Cost} = \frac{80}{80+20} = 0.8$$

- ➢ O'Neill should order $Q = F^{-1}(0.8) = 4186$
- ➢ In Excel, =NORMINV (0.8,3192,1181)
- ➢ Why Q much higher than the expected demand u?

- Demand is highly uncertain (σ)
- Potential gain outweighs potential loss (Cu > Co

3.5 Performance Metrics

Newsvendor Model: Lost Sales, Sales, and Leftover

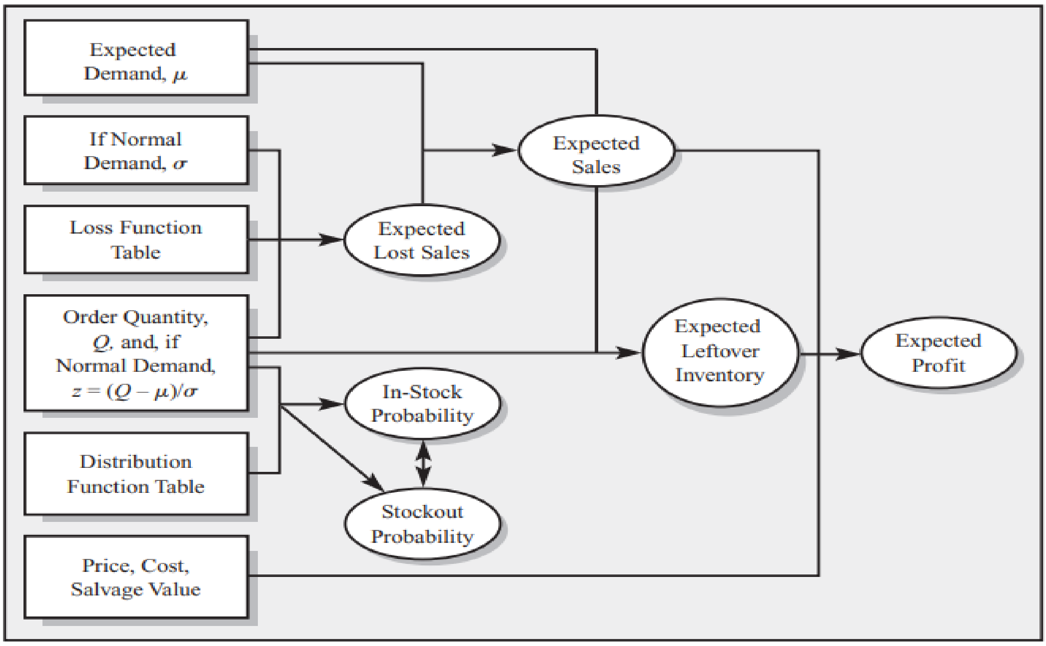

Fig 3.6 Flowchart [1, p. 255].

Recall that μ, = 3192, σ = 1181, and profit maximizing Q = 4186

- ➢ Expected lost sales (expected shortage) = expected amount by which demand exceeds order quantity = (loss function) = 131.84 units
- ➢ In Excel for normally distributed demand:

=σ^2*NORMDIST (Q, μ, σ,0) -(Q-μ) *(1-NORMDIST (Q, μ, σ,1))

- Note that:
- Expected sales + Expected lost sales = Expected demand (u)
- Expected sales + Expected leftover inventory = Q
- Based on this:
- Expected sales = μ, - Expected lost sales = 3192 - 131.84 = 3060.16
- Expected leftover = Q - Expected sales = 4186 - 3060.16 = 1125.84

Revenue, Cost, and Profit

- Expected revenue = Price x Expected sales + Salvage value x Expected leftover inventory

  = 190 x 3060.16 + 90 x 1125.84 = $682,757

- Expected cost = Cost x Q = 110 x 4182 = $460,460

- Expected profit = Expected revenue - Expected cost =

  = $682,757 - $460,460 = $222,297

Maximum Profit and Mismatch Cost

- Another way of calculating Expected profit = Cu x Expected sales - Co x Expected leftover

  = 80 x 3060.16 - 20 x 1125.84 = $222,297

- Maximum profit = (Price - Cost) x μ, = 80 x 3192 = $255,360
- A hypothetical profit with a perfect forecast (crystal ball)
- Mismatch cost = Maximum profit - Expected profit = $255,360 - $222,297 = $33,064
- Alternative way of calculating Mismatch cost =Co x Expected leftover inventory + Cu x Expected lost sales

  = (20 x 1125.84) + (80 x 131.84) = $33,064

- Mismatch cost is the maximum possible gain from improvement in forecasting.
- Maximizing expected profit is equivalent to minimizing mismatch cost. Mismatch Cost as a Percentage of Profit or Revenue.
- Mismatch cost / Maximum profit = 33,064 / 255,360 = 12.95%.
- Assuming Q is chosen to maximize expected profit,
- Mismatch cost / Maximum profit is large when:
- Demand variability, CV = σ / μ, is large - it is hard to match supply and demand

  when demand is less predictable.

- Critical ratio, Cu/ (Cu + Co), is small, i.e., when Cu is relatively low compared to Co -

  in this case, Q is set way below μ, and expected lost sales are large.

➢ Mismatch cost / Expected revenue = 33,064/682,757 = 4.85%.
➢ If net profit for industry concerned is 2-5% of revenue, then mismatch cost is of same order as net profit!

3.6 Service level measure

➢ Newsvendor Model: Service Level Measures
➢ Expected fill rate = percentage of satisfied demand =Expected sales / Expected demand = 3060.16 / 3192 = 95.87%
➢ In-stock probability = F(Q) = 80%
➢ $\frac{C_u}{C_u+C_o}$In Excel, =NORMDIST(Q, σ, μ, 1)
➢ If Q determined by profit maximization, in-stock probability = critical ratio
Stockout probability = 1 - F(Q) = 20%

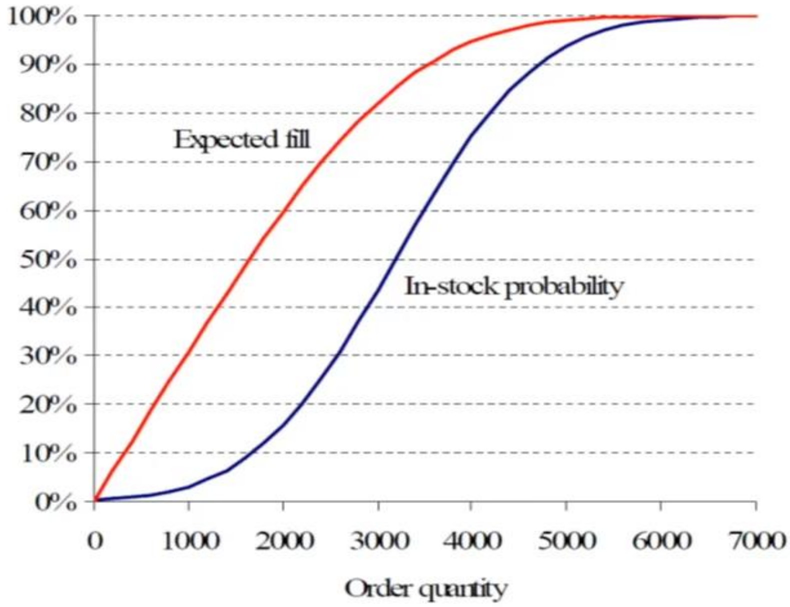

Fig 3.7 Graph representing Expected Fill Rate vs In-Stock Probability

- Suppose Q = 100 and demand can be 80, 90, 100, 110, or 120 with equal probabilities.

➢ Corresponding actual fill rates and in-stock statuses are shown in the second table
➢ Expected fill rate = 0.948
➢ In-stock probability = 0.6
➢ Generally, in-stock probability expected fill rate

Table 3.5 Comparison of Expected and Actual Performance Metrics Before and After Demand Occurs

	Before demand occurs	After demand occurs
Fill rate	Expected percentage of filled demand	Actual percentage of filled demand
In-stock	Probability of being in stock	Either in stock (1) or out of stock (0)

Table 3.6 Showing demand, Sales, Fill rate and In stock

Demand	Sales	Fill rate	In stock
80	80	1	1
90	90	1	1
100	100	1	1
110	100	0.909	0
120	100	0.833	0
	Average	0.948	0.6

Order Quantity for a Desired Service Level

In-stock Probability, Find Q such that the in-stock probability is 99%

- F(Q) = in-stock probability
- Q = F-1(in-stock probability)
- Q=F-1(0.99)

= NORMINV(0.99, μ, σ)

= 5940

- ➢ Expected Fill Rate
- Find Q such that the expected fill rate is 99%
- No each formula
- ➢ Adjust Q in Excel until expected fill rate achieves a desired value (manually or using a Goal Seek)
- ➢ For 99% expected fill rate Q = 5005 [6].

C12 | =C10

	A	B	C	D	E	F	G
1	price	p =	190	Input			
2	cost	c =	110	Input			
3	salvage value	s =	90	Input			
4							
5	Underage cost	Cu = p -c	80				
6	Overage cost	Co = c - s	20				
7	Expected demand	mu =	3192	Input			
8	St. dev. of demand	sigma =	1181	Input			
9	Critical ratio (= in-stock prob.)		0.8				
10	Profit maximizing Q		4186	<-- assuming Normal distribution			
11							
12	Chosen Q	Q =	4186	Input			
13	Expected shortage		131.84	<-- assuming Normal distribution			
14	Expected sales		3060.16				
15	Expected leftover		1125.84				
16	Expected profit		222296.50				
17	Maximum profit		255360.00				
18	Mismatch cost		33063.50				
19	Mismatch cost / Maximum profit		13%				
20							
21	Expected fill rate		95.87%				
22	In-stock probability		80.00%	<-- assuming Normal distribution			
23							
24	Expected revenue		682756.50				
25	Expected cost		460460				
26	Expected profit		222296.50				
27	Mismatch cost		33063.50				
28	Mismatch cost / Expected revenue		4.8%				
29							
30							
31							

Fig 3.8 Excel sheet representing primary data

CHAPTER-4

SYSTEM DEVELOPMENT LIFE CYCLE

4.1 System development life cycle

The following tells us how we made code to solve newsvendor problem by using our understanding of the problem and applying it with IT –

4.1.1 Code-1

Problem identification or requirement analysis:

Understand the problem statement, gather requirements, and identify what needs to be achieved. In this case, it's about calculating profit based on demand, order quantity, selling price and unit cost.

Feasibility study:

Determine if the problem can be feasibly solved given the available resources, time constraints, and technical capabilities. In this case, since it's a simple calculation program, feasibility is likely not an issue.

Design:

Plan how to structure the program, what functions are needed, what variables to use, and how they will interact. This involves deciding on the algorithm and overall architecture. For this program, you'd design the calculate_profit function to perform the profit calculation based on the provided inputs.

Coding:

Write the actual code based on the design. This involves translating the algorithm and structure into a programming language, like the C code provided.

```
#include <stdio.h>

double calculate_profit(int demand, int order_quantity, double selling_price, double unit_cost) {
```

```c
    if (demand < order_quantity) {
        return selling_price * demand - unit_cost * order_quantity;
    } else {
        return selling_price * order_quantity - unit_cost * order_quantity;
    }
}

void main() {
    int demand, order_quantity;
    double selling_price, unit_cost;

    printf("Enter demand: ");
    scanf("%d", &demand);

    printf("Enter order quantity: ");
    scanf("%d", &order_quantity);

    printf("Enter selling price per unit: ");
    scanf("%lf", &selling_price);

    printf("Enter unit cost per unit: ");
    scanf("%lf", &unit_cost);

    double profit = calculate_profit(demand, order_quantity, selling_price, unit_cost);

    printf("Profit: ₹%.2f\n", profit);

}
```

Testing:

Verify that the program behaves as expected under various inputs and conditions. Test for correctness, efficiency, and robustness. This includes checking for input validation, handling edge cases, and ensuring the program runs without errors. In this case, you'd input different demand, order quantities, selling prices and unit costs to see if the profit calculation is accurate. Implementation and maintenance: Deploy the program for use and provide ongoing support, updates, and maintenance as needed. This step involves integrating the program into the intended environment and addressing any issues that arise during use. Additionally, it may involve making enhancements or modifications to the code over time to adapt to changing requirements or improve performance.

Calculate profit function:

- This function takes four parameters: demand, order quantity, selling price, and unit cost.
- It calculates the profit based on the given demand, order quantity, selling price, and unit cost.
- If the demand is less than the order quantity, it calculates profit as (selling price * demand) - (unit cost * order quantity).
- Otherwise, it calculates profit as (selling price * order quantity) - (unit cost * order quantity).
- It returns the calculated profit as a double value.
- main function:
- This is the entry point of the program.
- It declares variables demand, order quantity, selling price, unit cost to store user input and profit to store the calculated profit.
- It prompts the user to enter demand, order quantity, selling price per unit, and unit cost per unit using printf and scanf.
- It calls the calculate profit function with the user-provided values and stores the result in the profit variable.
- Finally, it prints the calculated profit using printf, formatting the output to display the profit with two decimal places and a currency symbol.
- This code essentially calculates and prints the profit based on user-provided input values demand, order quantity, selling price per unit, and unit cost per unit.

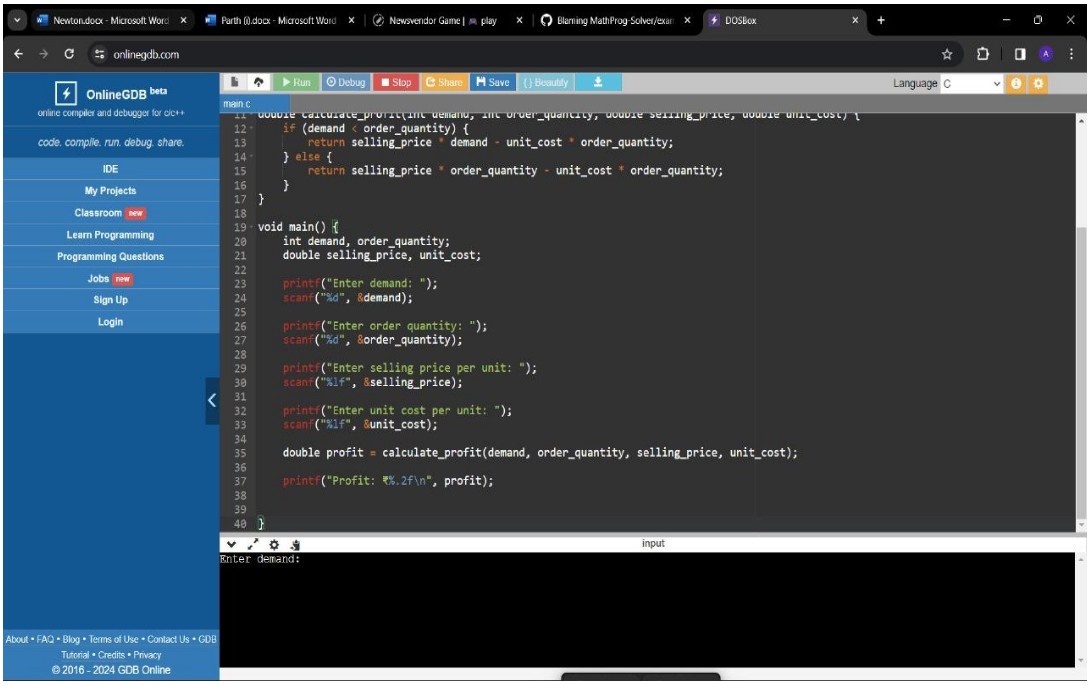

Fig 4.1 Working code -1

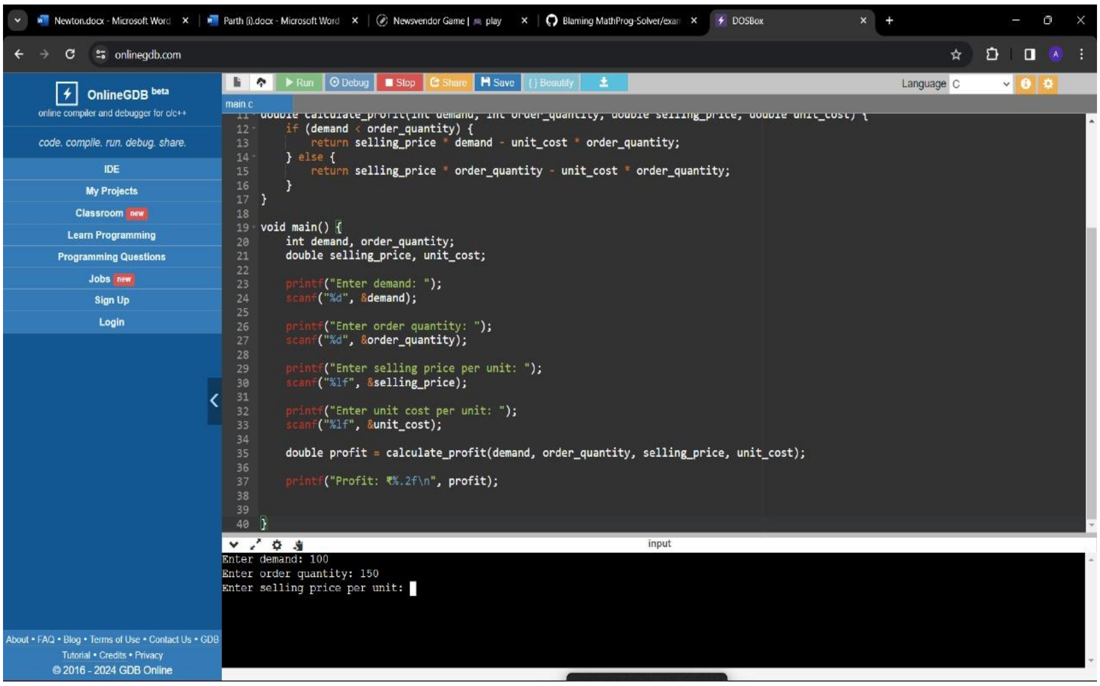

Fig 4.2 Working code -1

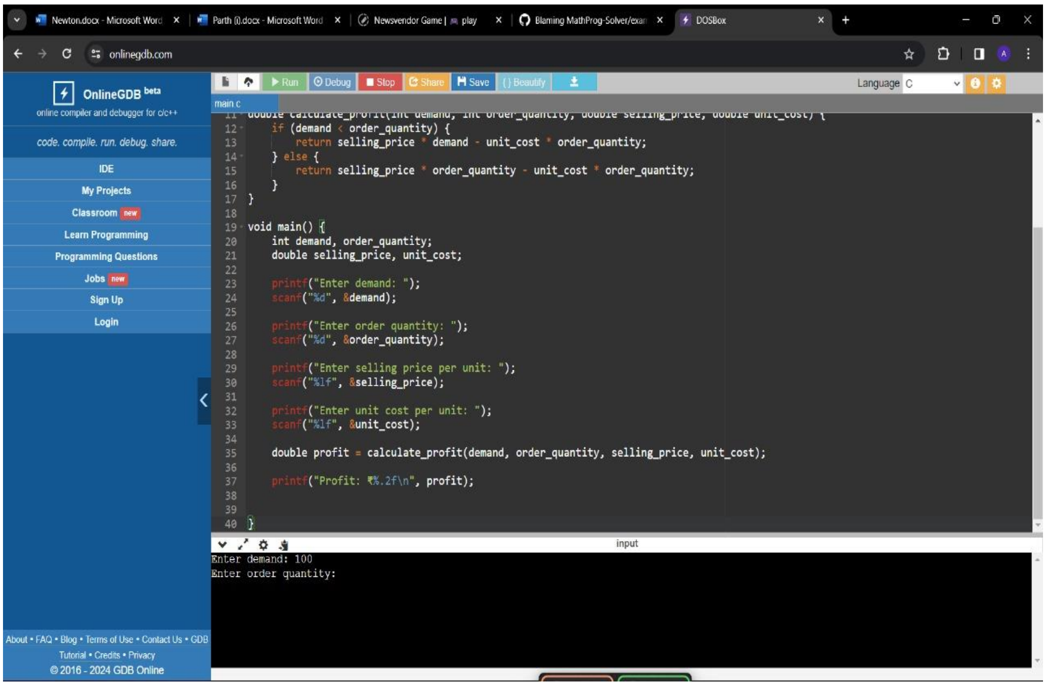

Fig 4.3 Working code -1

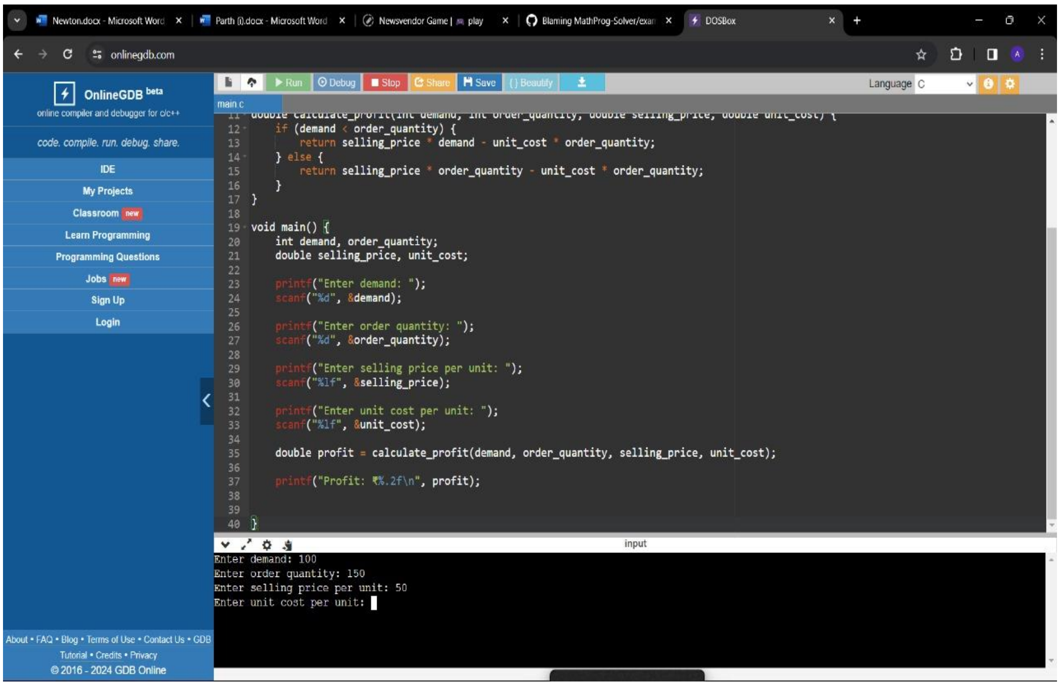

Fig 4.4 Working code -1

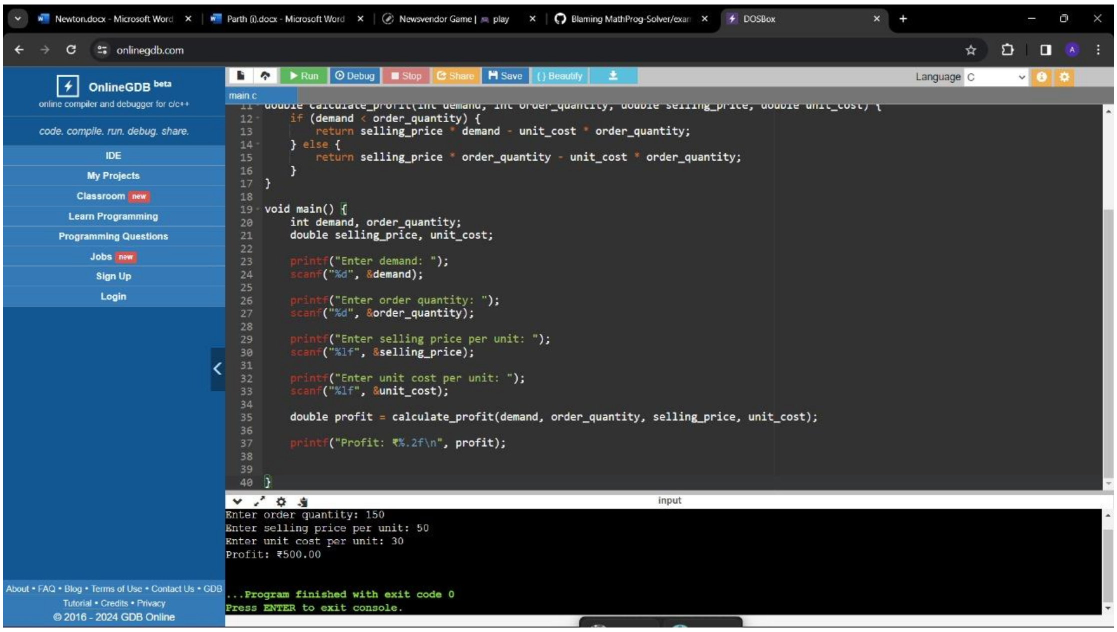

Fig 4.5 Working code -1

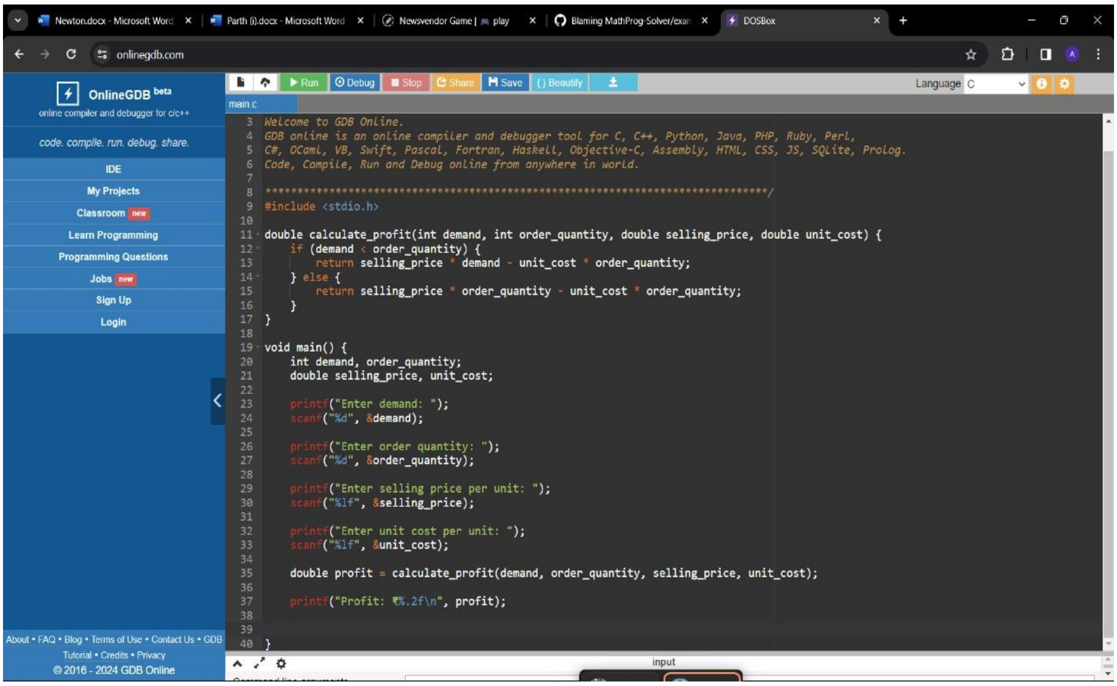

Fig 4.6 Working code -1

4.1.2 Code-2

Problem Identification or Requirement Analysis:

This is the initial stage where the problem is identified, or the requirements of the software are gathered and analysed. It involves understanding the needs of the user and what the desired software should accomplish. In the context of the provided code, the problem identified is to calculate the optimal order quantity.

Feasibility Study:

In this stage, the practicality and financial viability of the proposed solution are evaluated. It's determined whether the problem can be solved within the constraints of time, cost, and resources. For the provided code, it's feasible to calculate the optimal order quantity using the given parameters.

Design:

This involves outlining how the software will work and how components will interact. The function calculateOrderQuantity is designed to calculate the optimal order quantity based on the given parameters. The design phase ensures that the software system will meet the requirements and be robust, reliable, and easy to use.

Coding:

```
#include <stdio.h>

// Function to calculate the optimal order quantity

int calculateOrderQuantity(int demand, int inventory, int salvage, int cost) {

   if (demand > inventory) {

      return 0;

   } else if (demand <= (inventory - salvage)) {

      return demand;

   } else {

      return (inventory + salvage - demand) * cost;

   }

}


void main() {
```

```c
    int demand, inventory, salvage, cost;

    // Input demand, inventory, salvage value, and cost
    printf("Enter the demand: ");
    scanf("%d", &demand);
    printf("Enter the inventory: ");
    scanf("%d", &inventory);
    printf("Enter the salvage value: ");
    scanf("%d", &salvage);
    printf("Enter the cost: ");
    scanf("%d", &cost);

    // Calculate and print the optimal order quantity
    int orderQuantity = calculateOrderQuantity(demand, inventory, salvage, cost);
    printf("Optimal order quantity: %d\n", orderQuantity);
}
```

Testing:

The software is tested to ensure it behaves as expected. In this case, the function calculateOrderQuantity is tested by calling it in the main function with user-provided values. Testing helps identify any bugs or issues that need to be fixed.

Implementation and Maintenance:

The software is put into practical use. Here, the solution is implemented as a C program. After implementation, the software is maintained by updating it as necessary to add new features or fix issues. This could involve modifying the calculateOrderQuantity function or the main function as needed.

Calculate Order Quantity function:

- This function takes four parameters: demand, inventory, salvage, and cost.
- It calculates the optimal order quantity based on the given parameters.

- If the demand is greater than the inventory, it returns 0 because there's not enough inventory to fulfil the demand.
- If the demand is less than or equal to the difference between inventory and salvage value, it returns the demand itself as the optimal order quantity.
- Otherwise, it calculates the order quantity as (inventory + salvage - demand) * cost and returns it.

Main function:

- This is the entry point of the program.
- It declares variables demand, inventory, salvage, and cost to store user input and order Quantity to store the calculated optimal order quantity.
- It prompts the user to enter the demand, inventory, salvage value, and cost using printf and scanf.
- It calls the calculate Order Quantity function with the user-provided values and stores the result in the order Quantity variable.
- Finally, it prints the calculated optimal order quantity using printf.
- This code essentially calculates and prints the optimal order quantity based on user-provided input values for demand, inventory, salvage value, and cost.

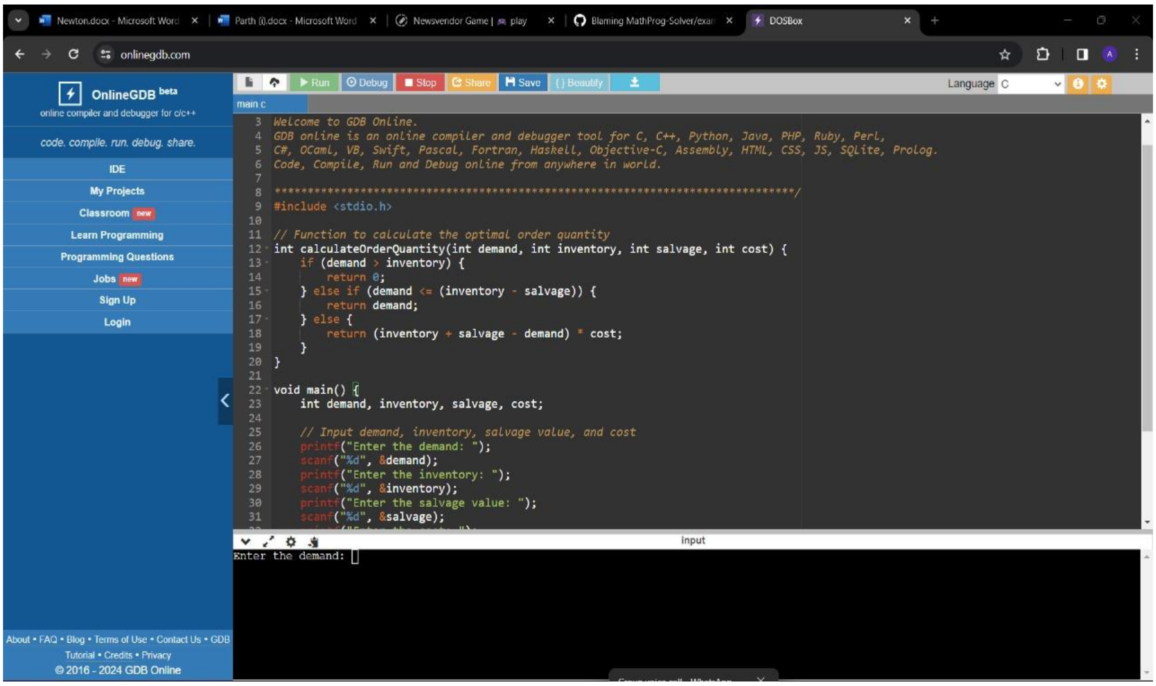

Fig 4.7 Working code -2

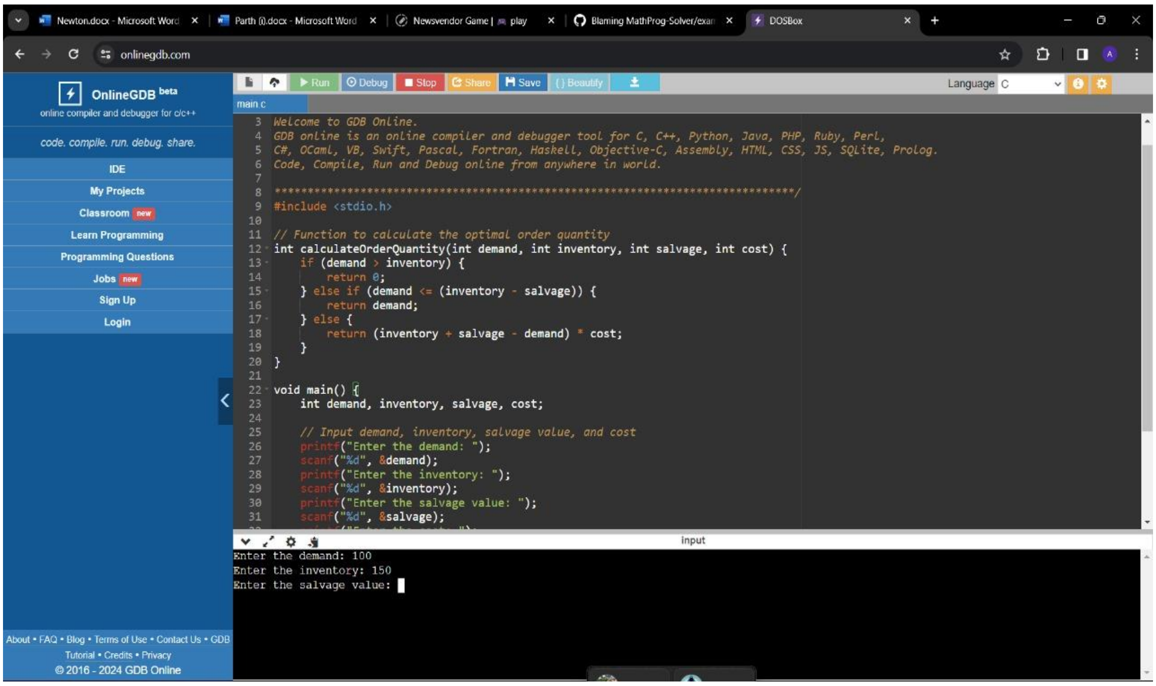

Fig 4.8 Working code -2

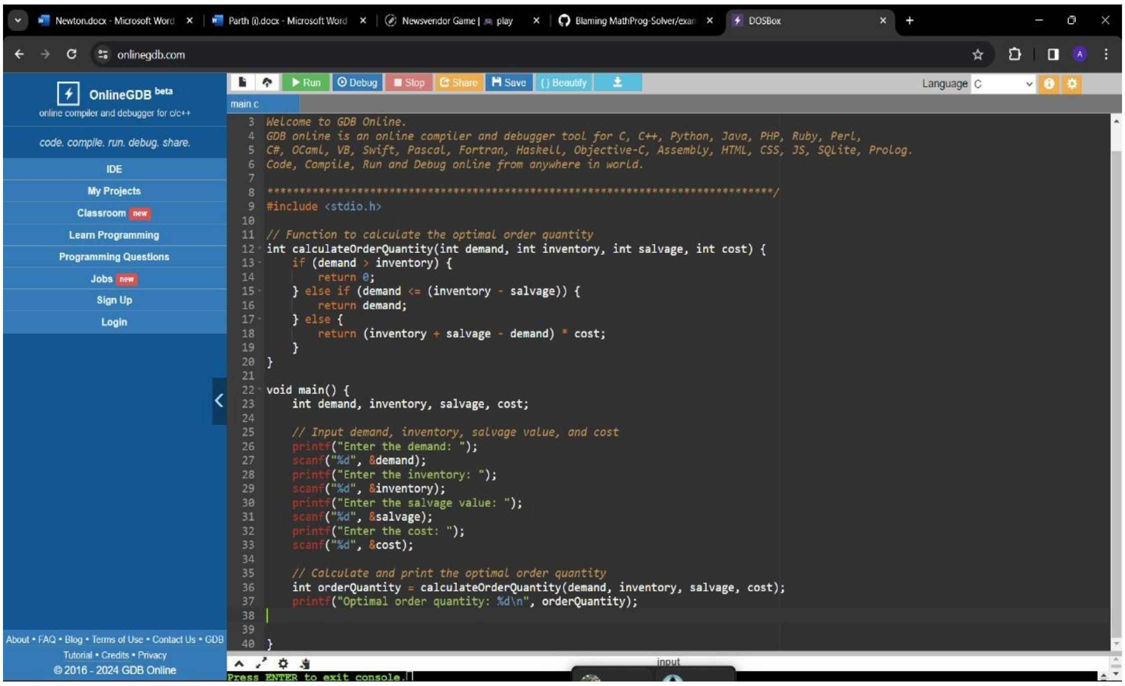

Fig 4.9 Working code -2

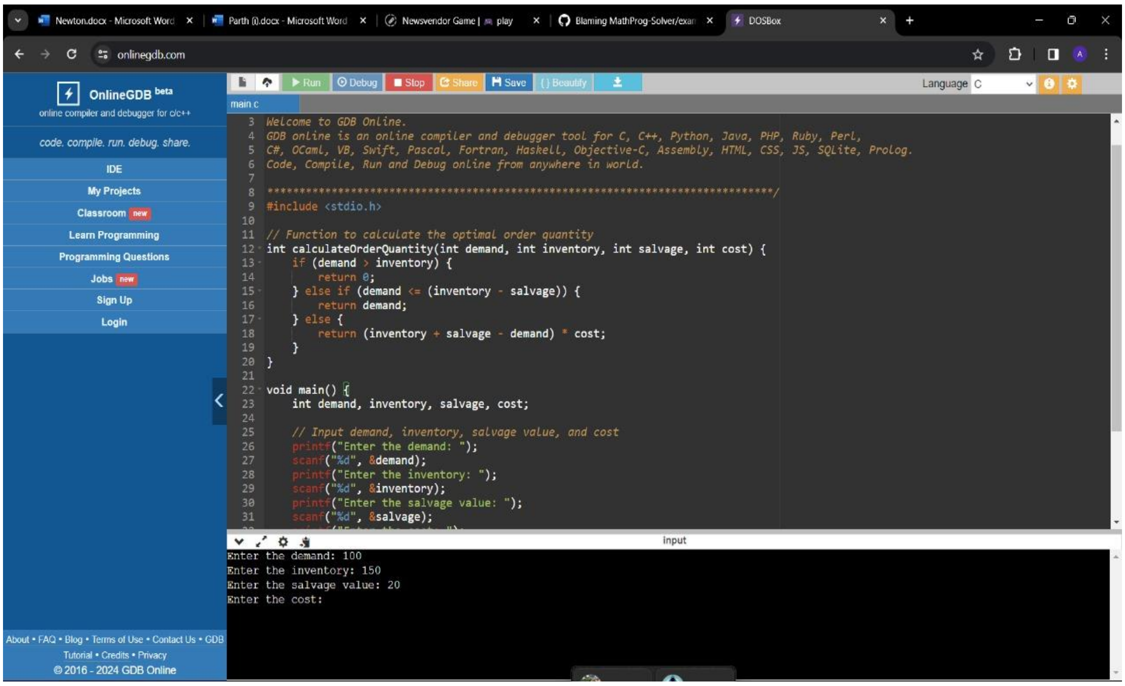

Fig 4.10 Working code -2

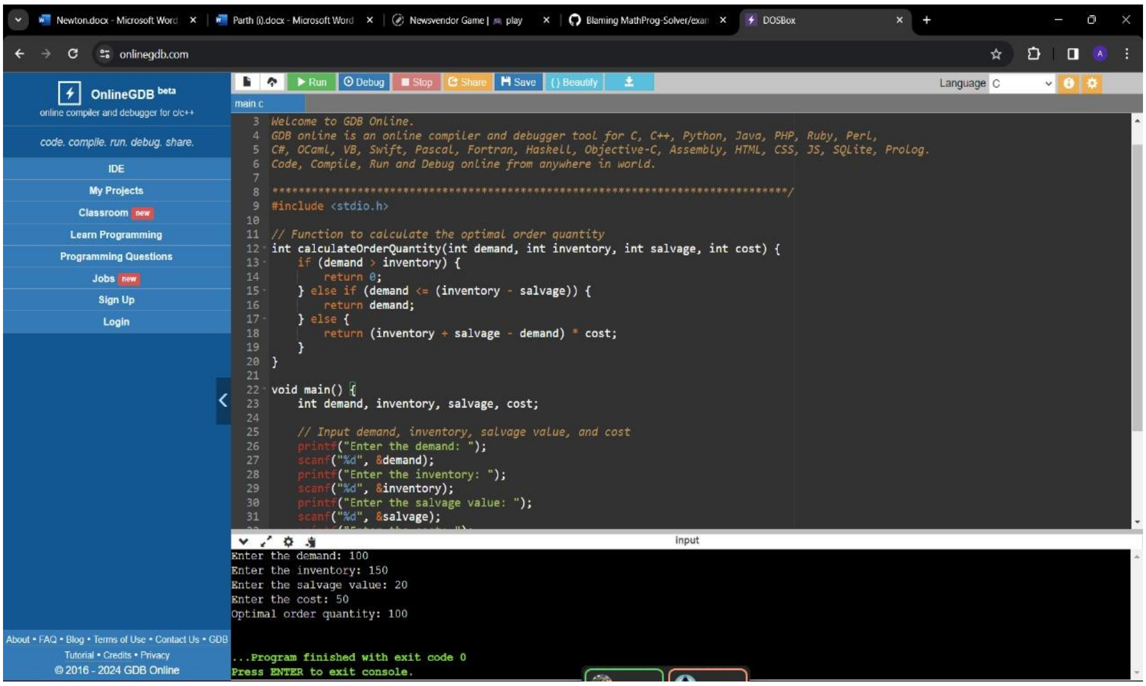

Fig 4.11 Working code -2

4.1.3 Code-3

Problem Identification or Requirement Analysis:

The need for a program to manage an inventory system is identified. The requirements such as adding items, displaying inventory, and freeing memory are defined. The data structure to use (in this case, a linked list) for efficient item management is determined.

Feasibility Study:

The feasibility of implementing the inventory management system using the chosen programming language © is assessed. It's determined whether the requirements can be fulfilled within the constraints of the language and available resources.

Design:

The structure of the program is designed. The InventoryItem struct is defined to store item information. Functions needed for adding items, displaying inventory, and freeing memory are planned. Appropriate data structures and algorithms (linked list for dynamic item storage) are chosen. Memory is allocated dynamically for new items. How to handle memory deallocation to prevent memory leaks is defined.

Coding:

The code for each function is written based on the design. The addItem function is implemented to add items to the inventory. The displayInventory function is implemented to print the current inventory. The freeInventory function is implemented to release allocated memory. The main function is written to demonstrate the usage of the inventory management system.

Testing:

Unit testing is conducted for each function to ensure they work as intended. Edge cases such as adding items, displaying an empty inventory, and freeing memory are tested. It's verified that memory is allocated and deallocated correctly. Potential issues like memory leaks or segmentation faults are checked for.

Implementation and Maintenance:

Once testing is successful, the program is integrated into the production environment. The program is monitored for any runtime errors or issues. Any bugs or user feedback are addressed promptly. The codebase is maintained by updating it as needed, such as adding new features or optimizing performance. The program is continuously improved based on user requirements and technological advancements.

CODE

```
 #include <stdio.h>
#include <stdlib.h>
#include <string.h>
 // Structure to represent an inventory item struct InventoryItem
{ char name[50];
int quantity;
float price;
struct InventoryItem *next;
 };
// Function to add an item to the inventory struct InventoryItem *addItem(struct InventoryItem
*inventory, char itemName[], int quantity, float price)
{ struct InventoryItem *newItem = malloc(sizeof(struct InventoryItem));
if (newItem == NULL)
 { printf("Memory allocation failed.\n");
return inventory;
}
strcpy(newItem->name, itemName);
 newItem->quantity = quantity; newItem->price = price;
newItem->next = inventory;
 printf("Item added successfully.\n");
 return newItem;
}
// Function to display the current inventory void displayInventory(struct InventoryItem
*inventory) { printf("Current Inventory:\n"); printf("%-20s%-10s%-10s\n", "Name",
 "Quantity", "Price");
while (inventory != NULL) { printf("%-20s%-10d%-10.2f\n", inventory-
>name, inventory->quantity, inventory->price); inventory = inventory->next;
}
}
```

```
// Function to free memory used by the linked list void freeInventory(struct InventoryItem *inventory) {
while (inventory != NULL)
{ struct InventoryItem *temp = inventory;
 inventory = inventory->next;
 free(temp);
}
}
int main() {
struct InventoryItem *inventory = NULL;
// Example usage
inventory = addItem(inventory, "Item1", 10, 5.99); inventory = addItem(inventory, "Item2", 5, 8.49); displayInventory(inventory);
 // Free allocated memory
 freeInventory(inventory);
return 0;
 }
```

This version of the program implements an inventory management system using a linked list to store inventory items. Here's a breakdown of the key points:

- Inventory Item Structure: The Inventory Item now includes a pointer to the next item (next) in the list, effectively forming a linked list of inventory items.
- Add Item Function: This function dynamically allocates memory for a new inventory item, initializes its fields with the provided values, and inserts it at the beginning of the linked list. It returns a pointer to the newly added item or the original inventory list if memory allocation fails.
- Display Inventory Function: This function traverses the linked list of inventory items and prints each item's details in a formatted manner.
- Free Inventory Function: This function iterates through the linked list and frees the memory allocated for each inventory item.
- Main Function: In the main function, an inventory pointer (inventory) is initialized to NULL. Two example items are added to the inventory using the add Item function. Then, the current inventory is displayed using the display Inventory function. Finally, the allocated memory is freed using the free Inventory function before the program exits.
- Using a linked list for the inventory offers flexibility in terms of adding and removing items without needing to pre-allocate a fixed amount of memory. However, it comes with the overhead of managing pointers and dynamic memory allocation [4].

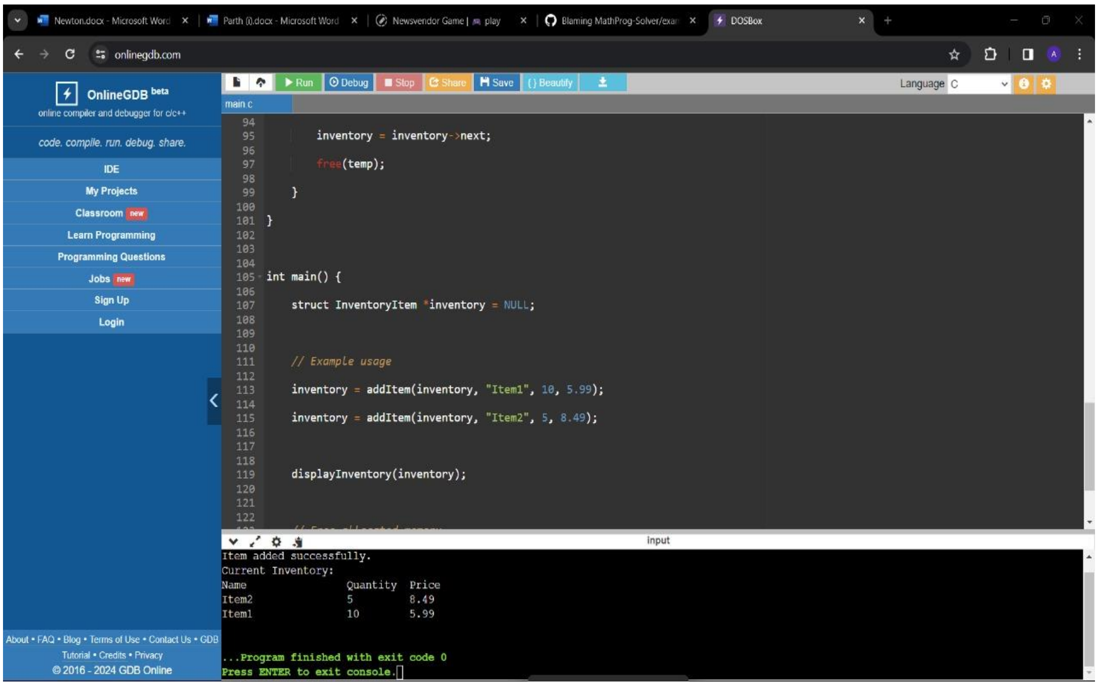

Fig 4.12 Working code -3

CHAPTER-5

RESULTS, DISCUSSIONS, KEY TAKEAWAYS AND FINAL THOUGHTS

5.1 Results and Discussions

The following tells us about the Managerial Insights we gained throughout the chapters –

Managerial Insights - Forecasting

- One-point demand forecast insufficient. Need also a forecast of variability of demand. Construct distribution for demand forecast.
- Keep track of actual demand. It is not the same as unit sales.
- If no stockout, then actual demand = unit sales.
- If stockout, then actual demand may be higher than unit sales. If actual demand cannot be observed, attempt a reasonable estimate.
- Keep track of past forecasts and forecast errors.
- Many firms fail to maintain data needed (who wants to record past mistakes?) or do not realize their importance.
- Profit maximizing order quantity Q expected demand
- If underage cost > overage cost > Q > expected demand.
- If overage cost > underage cost > Q < expected demand.
- Explicit costs not to be overemphasized relative to opportunity costs.
- Overage cost (leftover) is explicit cost, while underage cost (lost sales) is opportunity costs. Overemphasizing former relative to latter leads to ordering less than profit maximizing order quantity.
- Order quantity decision should be separated from forecasting.
- "I forecast 3200, and you order 4186?
- Maximizing expected profit is only one possible objective; appropriate particularly when variability of profit is not major concern.
- If many different products so that realized profit from any one product cannot cause severe hardship, then it is a good objective.
- But if startup firm with a single product and limited capital, then prudent to order less than profit maximizing order quantity.

- Expected profit objective does not consider customer service explicitly.
- Some managers may prefer setting order quantity based on customer service level.

Trade-off: Expected Profit vs Service

- Setting order quantity based on in-stock probability or expected fill rate may decrease expected profit. Fortunately, relatively at top!

Additional Managerial Insights

- Any action that reduces demand variability reduces mismatch cost.
- Any improvement in forecasting translates into higher profits.
- A high critical ratio means there is a large profit margin relative to per unit loss on excessive inventory (e.g., greeting cards) > large optimal order quantity.
- For low critical ratio items (perishability & obsolescence), small optimal order quantity, possibly lower than expected demand.
- Finally, difficulty of deciding on rational order quantities should not invite.

5.2 Conclusion

In exploring the intricate realm of Newsvendor Model for forecasting demand, we embark on a journey at the forefront of Statistic, Mathematics and Information Technology. The newsvendor model is a useful tool for inventory management of perishable products with uncertain demand and fixed prices. The model helps find the optimal order quantity that maximizes the expected profit or minimizes the expected cost, while considering the trade-off between the costs of overstocking and understocking. The model can be applied to various industries and domains, such as fashion, food, healthcare, manufacturing, and real estate. The model can also be extended and modified to incorporate multiple products, multiple periods, multiple sources, and multiple objectives. However, the model also has some limitations and assumptions, such as the demand distribution, the order quantity, and the ignored factors. Therefore, the model should be used with caution and validated with empirical data. The newsvendor model is a classic and fundamental model for operations research and management science, and it provides a valuable insight into the inventory decisions under uncertainty. The newsboy formulation is used to optimize the amount of profit while minimizing the excess materials that hold no value after a given period of time. This formulation can be adapted for different probabilities and distributions of expected sales. Additionally, nuances such as accounting for a salvage price for unsold perishable goods can also be added to the problem for added complexity to mimic a given situation. From that, the salesperson can determine how many of a perishable product should be purchased for resale at a given time to optimize their profits. We made and used different codes to solve newsvendor model and even got the opinions of locals on supply and demand and as we continue to push the boundaries of Statistic, Mathematics and Information Technology, the journey of Newsvendor model as a testament to human ingenuity and the relentless pursuit of excellence in Mathematics.

5.3 Future Scope

- **Software as a service (SaaS)**: We'll work on making a software to make it easily available on market and help businesses cope with the supply-demand issue.
- **Game**: We'll work on making a game so that even kids can get familiar with this and adults/teenagers can take more interest on the issue and learn about it, so it won't trouble them later in life perchance.
- **Inventory optimisation**: Developing specialized inventory management models and algorithms tailored to the unique challenges of e-commerce logistics, such as inventory pooling, order consolidation, and last-mile delivery optimization.
- **Advanced Forecasting Techniques:** Improving demand forecasting accuracy is crucial for effective inventory management. Future research could focus on developing advanced forecasting techniques that leverage big data, machine learning, and predictive analytics to better capture complex demand patterns, seasonality, and external factors influencing demand.

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....***THE END***