ENHANCING PERISHABLE SUPPLY CHAIN EFFICIENCY AND DETERMINING SUITABLE INVENTORY POLICY

Project Report

Submitted in partial fulfillment of the requirements for the award of the degree of

Bachelor of Technology
in
Production Engineering

by

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I. CERTIFICATE

This is to certify that the report entitled "**ENHANCING PERISHABLE SUPPLY CHAIN EFFICIENCY AND DETERMINING SUITABLE INVENTORY POLICY** " is a bonafide record of the Project done by **SAGI MOHIT VARMA** (*Roll No*.: B200390PE),**VADAM SANJEEVA KUMAR**(*Roll No*.: B200400PE), **KANAPARTHI VIVEK** (*Roll No*.: B200398PE) ,**ADITHYA KIRAN R**(*Roll No*.: B200396PE),under my supervision, in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Production Engineering from National Institute of Technology Calicut, and this work has not been submitted elsewhere for the award of a degree.

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II. ACKNOWLEDGMENT

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Their dedication to quality, intelligent contributions, and relentless work not only made this project possible but also contributed considerably to its success. Each member brought a unique viewpoint and skill set to the table, resulting in a dynamic and effective team

We would also like to thank the NATIONAL INSTITUTE OF TECHNOLOGY CALICUT for providing me with the necessary resources and facilities to carry out this project. We are grateful to my department's staff and faculty members for their support and encouragement.

Sincerely,
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ABSTRACT

This study compares a traditional Supply Chain Economic Order Quantity (EOQ) model with a mathematical model for Vendor Managed Inventory (VMI) to see which is more effective for perishable goods in the Fast-Moving Consumer Goods (FMCG) industry. The research uses simulation to investigate two different demand distributions: uniform and normal, taking into account variables like lead time, demand unpredictability, and inventory holding costs. The model seeks to determine the best inventory management tactics by examining fixed warehousing and transportation costs in addition to factors like packaging quantities and storage expenses. By optimising shipment timetables and setting appropriate minimum and maximum stock criteria, the main goal is to reduce overall costs throughout the supplier-customer connection. Different entities in the supply chain must work together and share information, as the study's focus on integrating VMI as a decision support system highlights.

The findings demonstrate that VMI outperforms the conventional EOQ model in terms of inventory optimisation which results in the cost reduction of 27% for normal and 29.4 % for uniform as per the case we studied in this project, resulting in notable improvements in supply chain efficiency overall. Highlighting the benefits of using VMI, the study provides a sound foundation for making decisions about the best inventory parameters. This work advances perishable FMCG product management and supply chain optimisation techniques by clarifying the improved performance of VMI over traditional approaches.

Keywords - Vendor Managed Inventory (VMI), Economic Order Quantity (EOQ), Fast-Moving Consumer Goods (FMCG), inventory management

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LIST OF ABBREVIATIONS

EOQ	Economic Order Quantity
VMI	Vendor managed Inventory
VMR	Vendor Managed Replenishment

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CHAPTER 1

INTRODUCTION

Perishable goods, characterized by their limited shelf life and sensitivity to external factors such as temperature and humidity, pose unique challenges to supply chain managers. Effective management of perishable goods demands a delicate balance between ensuring product availability while minimizing the risk of overstock and subsequent wastage. The efficient allocation of resources and optimization of inventory play pivotal roles in ensuring business success and maintaining competitive advantage. The perishable goods industry, particularly the dairy sector, faces unique challenges in managing inventoryeffectively to ensure product freshness, reduce wastage, and enhance overall supply chain sustainability. The project at hand is driven by the imperative to address these challenges and achieve specific objectives aimed at optimizing the management of perishable dairy products.

Since inventory management impacts the total cost and effectiveness of the system, it is an essential part of every supply chain. Inventory excessive expenditure, stockouts, and ultimately unsatisfied customers are the outcomes of ineffective inventory management. The inventory management approach known as Vendor Managed Inventory (VMI), which transfers inventory management duties from the supplier to the consumer, has become more popular in recent years. So that the buyer is able to focus on other aspects of their business, the supplier is in charge of keeping an eye on the consumer's inventory levels and determining when and how much to supply.

1.1 Background

The perishable nature of dairy products necessitates a strategic approach to inventory management to prevent spoilage and financial losses. The timely delivery of fresh goods to customers is crucial for maintaining customer satisfaction and loyalty.

Traditional supply chain management (SCM) practices have long been employed to manage inventory levels and meet customer demand. Under the traditional SCM model, each entity within the supply chain – from manufacturers to distributors to retailers – maintains its inventory levels based on demand forecasts and historical sales data. However, this approach often leads to challenges such as bullwhip effects, inventory imbalances, and stockouts due to inaccurate demand forecasts and information delays across the supply chain.

Vendor-managed inventory (VMI) represents an alternative approach to inventory management, characterized by a collaborative relationship between suppliers and retailers. In the VMI model, the supplier assumes responsibility for monitoring and replenishing inventory levels at the retailer's location based on real-time demand data shared by the retailer. This collaborative approach aims to improve inventory visibility, reduce stockouts, and enhance overall supply chain efficiency by aligning inventory levels more closely with actual demand. In light of these considerations, our project focuses on implementing the technique Vendor Managed Inventory (VMI), to revolutionize the way perishable inventory is handled in the dairy supply chain.

The size of shipments creates a dilemma between suppliers and buyers concerning the average costs associated with warehousing and shipping. The primary objective is to minimize the total average cost, which comprises both shipping and warehousing expenses, by optimizing the frequency and volume of shipments.

Suppliers typically favour sending large shipments to maintain stock levels close to maximum capacity, allowing for gradual depletion as demand dictates before replenishing. In this scenario, the buyer retrieves inventory from the warehouse on a daily basis as needed, while the supplier receives notifications about consumption on a weekly basis from the third-party warehousing facility, which reports cumulative weekly usage in one instance.

The warehousing cost constitutes a significant portion of the buyer's inventory holding expenses. It encompasses various operational aspects such as storage space, material handling, insurance coverage, obsolescence, and shrinkage. This cost includes both fixed and variable components. The fixed cost represents a monthly warehouse fee that the buyer must pay irrespective of the average inventory level, while the variable costs, including storage fees, insurance charges, and handling fees, are contingent upon the average monthly inventory level.

1.2 Objectives of The Study

1. Comparing the effectiveness of the Vendor Managed Inventory (VMI) model against the traditional Supply Chain Economic Order Quantity (EOQ) model for perishable goods.

2. To suggest an inventory policy based on fluctuating demand characteristics, to fix process parameters and to identify the responsible party(buyer/supplier) who should bear the costs.

3. Minimize the average total supply chain cost by optimizing the shipment supply.

The project seeks to explore and compare the efficacy of traditional SCM and VMI in managing the supply chain of perishable goods. Central to this exploration is the utilization of demand data exhibiting both normal and uniform distributions. By simulating demand scenarios under these distributions, we aim to analyze the performance of each approach in meeting customer demand, minimizing stockouts, and reducing inventory holding costs. The findings from data analysis, case studies, and the challenges faced in the perishable goods industry will also be presented, culminating in conclusions andfuture recommendations for further improvements.

CHAPTER 2

LITERATURE REVIEW

Table.1. Literature Review

S.no	Research Paper	Contribution
1	Akindote,2023 **Digital Era: Navigating VMI and Supply Chain for Sustainable Success.**	It emphasizes the importance of integrating sustainability into VMI and supply chain management practices by leveraging emerging technologies like IoT, blockchain, AI, machine learning, and RPA to improve operational performance, reduce costs, and create lasting value.
2	Reki et al. (2023) **A machine learning model with linear and quadratic regression for designing pharmaceutical supply chains with soft time windows and perishable products.**	Develops a mathematical model for PSCND that minimizes total cost and delivery penalties due to schedule violations involving STWs. The suggested model leads to an efficient PSC by reducing costs, decreasing shortages, and increasing customer satisfaction with STW consideration.
3	Alan et al.(2023) **Vendor Managed Inventory and Strategy: Case Study of Global Supply Chains.**	The paper defines the bullwhip effect as a phenomenon of demand variance amplification, leading to a misinterpretation or exaggeration of information in supply chains.The bullwhip effect, can also impact other industries. It strains operations by raising safety stocks and demanding additional production and storage resources.

4	Wangsa et al.(2020) **A sustainable vendor-buyer inventory system considering transportation, loading and unloading activities**	This addresses the impact of loading and unloading activities on optimal order quantity, lead-time, and total emission quantity, contributing to the field of sustainable vendor-buyer inventory systems
5	Liu et al.(2020) **Scheduling the distribution of blood products:** **A vendor-managed inventory routing approach**	The study contributes to the field by examining the effects of demand variations on performance indicators, showcasing the potential impact of changing demand on the blood supply chain. This paper aims to optimize blood product scheduling by constructing a Vendor-Managed Inventory Routing Problem (VMIRP) model, minimizing operational costs
6	Praveen et al .(2020) **Inventory Management using Machine Learning.**	Introducing a hybrid methodology that integrates multi-criteria decision making (MCDM) techniques with different machine learning algorithms for inventory analysis.The proposed hybrid methodology can help businesses make informed decisions regarding stock levels and meet the demands of various products.
7	Maioa et al.(2019) **The effectiveness of Vendor Managed Inventory in the last-mile delivery: an industrial application**	The study explores the dynamics of replenishing consumer goods in mega city networks, focusing on Nanostore-dense areas. It highlights the comparative advantages of Vendor Managed Inventory (VMI) over traditional Customer Managed Inventory systems, demonstrating potential cost savings and efficiency gains.

8	Sabila et al.(2018) **Inventory Control System by Using Vendor Managed Inventory (VMI)**	It explores the benefits of Implementing VMI offers to stores by ensuring high availability of products and provides an opportunity for distributors to improve the efficiency of their product marketing. It also helps in maintaining the availability of fluctuating demand and demand uncertainty.
9	Otsuka et al.(2018) **Quality design method using process capability index based on Monte-Carlo method and real-coded genetic algorithm**	Variability in the depiction and feature of products has existed an main issue investigated what points to the equally main type of the feature of output delivery and stock administration
10	Jaber et al.(2016) **Vendor managed inventory with consignment stock agreement for a supply chain with defective items**	This research examines how varying levels of defective items, storage expenses, and disposal methods influence the suggested storage plan and overall supply chain expenses. It focuses on analyzing the sensitivity of both financial and non-financial aspects of holding costs, offering a comprehensive comparison with previous works.
11	Qing et al.(2014) **Coordinating contracts for fresh product outsourcing logistics channels with power structures**	The research has surveyed the helpful effect of management service kind on amount size and characteristic increases on account of arrangement as a mechanism to overcome channel capacity forms or determinantal human attitude.

CHAPTER 3

CHALLENGES FACED BY PERISHABLE SUPPLY CHAIN

Perishable Fast-Moving Consumer Goods (FMCG) products face a major obstacle: high total supply chain costs. These costs strain profitability and lead to product spoilage. Shipment size and warehousing costs significantly impact both suppliers and retailers.

Larger shipments reduce per-unit transportation costs for suppliers, but require higher upfront investment and increase spoilage risk at the retailer level. Smaller, more frequent deliveries benefit retailers with reduced warehousing costs, fresher products, and improved demand responsiveness, but come at the expense of higher transportation costs.

Suppliers can lower their shipping expenses per unit by sending larger shipments. Nevertheless, this necessitates a larger initial investment to complete the shipments, resulting in a greater amount of capital being tied up. In addition, the presence of larger shipments at the retailer level increases the likelihood of deterioration caused by excessive inventory or improper handling.

Conversely, shops gain advantages from receiving delivery more often and in lower quantities. These deliveries help to decrease warehousing expenses by requiring less storage space due to the reduced inventory. In addition, smaller shipments result in quicker product turnover, reducing the risk of spoilage and enabling merchants to more often modify orders to align with swings in demand. Nevertheless, these advantages are accompanied by the drawback of elevated transportation costs resulting from the greater volume of deliveries.

Ensuring a continuous cold chain logistics across the whole supply chain incurs significant costs for both suppliers and retailers. Both parties necessitate specialised storage facilities, which has an impact on the overall expenses. It is essential to strike a balance between the costs associated with maintaining inventory and the need to minimise stockouts. Both suppliers and merchants are under pressure to maintain low inventory levels while still guaranteeing that there is enough merchandise available. Excessive inventory leading to spoilage introduces an additional level of financial worry.

The exorbitant prices associated with the supply chain provide a challenging predicament. Companies under pressure to increase prices in order to compensate for these expenses, however, this might lead to a decrease in consumer demand. The profit margins for perishable products are often lower than those for non-perishables, which emphasises the importance of effective cost management.

To overcome these obstacles, implementing collaboration, adopting technology, utilising inventive packaging, and exploring alternate distribution methods are effective strategies. Companies can achieve effective and profitable management of their perishable items in a high-cost supply chain environment by optimising transportation, minimising handling, enhancing forecasting, and prolonging shelf life.

3.1 RESEARCH GAPS FROM THE LITERATURE

Inaccurate Demand Forecasting:

Errors in predicting demand can result in excessive inventory or shortages, causing disruptions in the fragile equilibrium of perishable product supply chains. Overestimating demand leads to an abundance of inventory, which in turn raises holding costs and poses a danger of product deterioration. On the other hand, if demand is underestimated, it might result in stockouts, which can harm consumer satisfaction and brand reputation.

Accurate demand forecasting is essential for optimising inventory levels, reducing waste, and satisfying customer expectations. Companies may increase forecast accuracy and enhance supply chain responsiveness by utilising historical data, industry trends, and advanced analytics.

Limited Understanding of VMI Impact:

The effects of Vendor Managed Inventory (VMI) go beyond only inventory quantities and include the enhancement of cooperation, effectiveness, and promptness across the entire supply chain. Nevertheless, numerous stakeholders may possess a restricted comprehension of the complete extent and possible advantages of VMI. Establishing trust between the purchaser and the vendor is crucial for the effective deployment of Vendor Managed Inventory (VMI). This entails promoting clear communication, openly sharing information, and matching goals to optimise mutual advantages. Through the establishment of a cooperative alliance, both entities can maximise inventory levels, save expenses, and improve the consumer delight.

Insufficient Analysis of VMI Challenges:

The introduction of VMI in perishable supply chains poses distinctive obstacles as a result of the characteristics of perishable items, such as their limited shelf life and unpredictable swings in demand. However, there is sometimes a lack of thorough study of these issues and their consequences for the effectiveness of VMI.

A thorough examination is crucial for comprehending how VMI might be modified to meet the particular requirements and limitations of perishable products. This entails assessing variables such as demand variability, lead times, and inventory holding costs in order to create customised Vendor Managed Inventory (VMI) plans that optimise efficiency and mitigate risk.

Lack of Risk Analysis in VMI:

Insufficient assessment of potential hazards in VMI implementation might result in operational disruptions and economic losses. In order to maintain successful Vendor Managed Inventory (VMI) management, it is crucial to identify and address risks such as stockouts, excessive dependence on suppliers, and problems related to data security.

To conduct a thorough risk analysis, risks must be evaluated at every level of the VMI process, and proactive measures should be taken to reduce detected risks. These actions may involve expanding the range of suppliers, implementing strong data security measures, and creating backup plans for potential disruptions in the supply chain.

Limited Discussion on Supply Chain Parameters:

The total cost and efficiency of supply chain activities are greatly influenced by important factors such as replenishment batch size, supplier delivery delay, and transportation lead times. However, there is sometimes a dearth of thorough discourse and examination of these characteristics. Examining supply chain factors is crucial for comprehending cost ramifications, streamlining lead times, and augmenting overall supply chain efficacy. Companies can find potential for cost savings, process improvements, and greater alignment with customer demand by assessing characteristics such as order frequency, batch sizes, and shipping durations.

3.2 COSTS INVOLVED IN PROPOSING AN INVENTORY DECISION MODEL

Warehousing cost refers to the expenses incurred in storing and managing inventory, which is a part of the overall inventory holding cost borne by the buyer. The cost refers to the expenses that the buyer must bear for the storage space, material handling, insurance, deterioration, shrinkage, and other related factors.

The cost of warehousing consists of a fixed price that customers must pay each month, regardless of their average inventory level. Additionally, there are variable costs such as storage expenses, insurance, and handling fees, which depend on the average monthly inventory level. The figure depicted in Fig. 1 illustrates the relationship between shipment size and average warehousing cost. As the cargo size increases, the average inventory level in the warehouse also increases, leading to an escalation in warehousing cost. Kindly be aware that the term "shipment size" refers to the quantity of units required for a specific period of time, typically measured in weeks.

In our scenario, the responsibility for covering the shipping expenses lies with the supplier. These costs are fixed and are already incorporated into the unit price provided for the product. Due to the fixed pricing, smaller and more frequent shipments will decrease the supplier's margin of profit. There is a diverse range of fixed shipping costs, including fees for custom clearance, hazardous materials (where applicable), and transport surcharges. Additionally, there is a variable shipping fee that is dependent on the size of the item, which includes delivery charges and a fuel premium. Larger shipment sizes result in a decrease in the average shipping cost per unit due to the allocation of fixed costs among a greater number of products. Figure 1 illustrates the mean shipping expense associated with the size of the shipment.

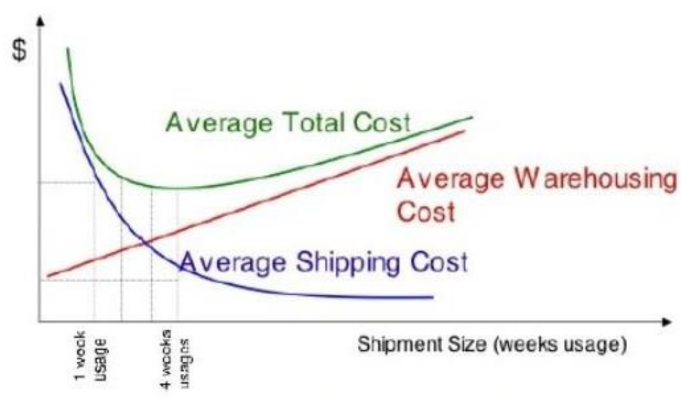

Fig.1 Average Warehousing Cost, Average Shipping Cost and Average Total Cost based on Shipment Size

(Source: “A Mathematical Approach to Vendor-Managed Inventory”)

From the model, it was deduced that shipment size caused a conflict of interest between supplier and buyer in terms of average warehousing and shipping cost. The aim of the inventory decision model was to reduce the average total cost which is the sum of average shipment cost and average warehousing cost by optimizing the shipment supply.

CHAPTER 4

METHODOLOGY

The proposed decision support system utilises an ensemble model, as depicted in Figure 2, to gather coordination information and prior sales data from both customers and suppliers. This data is utilised to generate the anticipated demand. The dataset in this work was constructed using probability distributions.

The inventory decision model will determine factors such as total inventory costs, optimum service levels, marginal costs, minimum and maximum stock levels based on the demand and its changes.

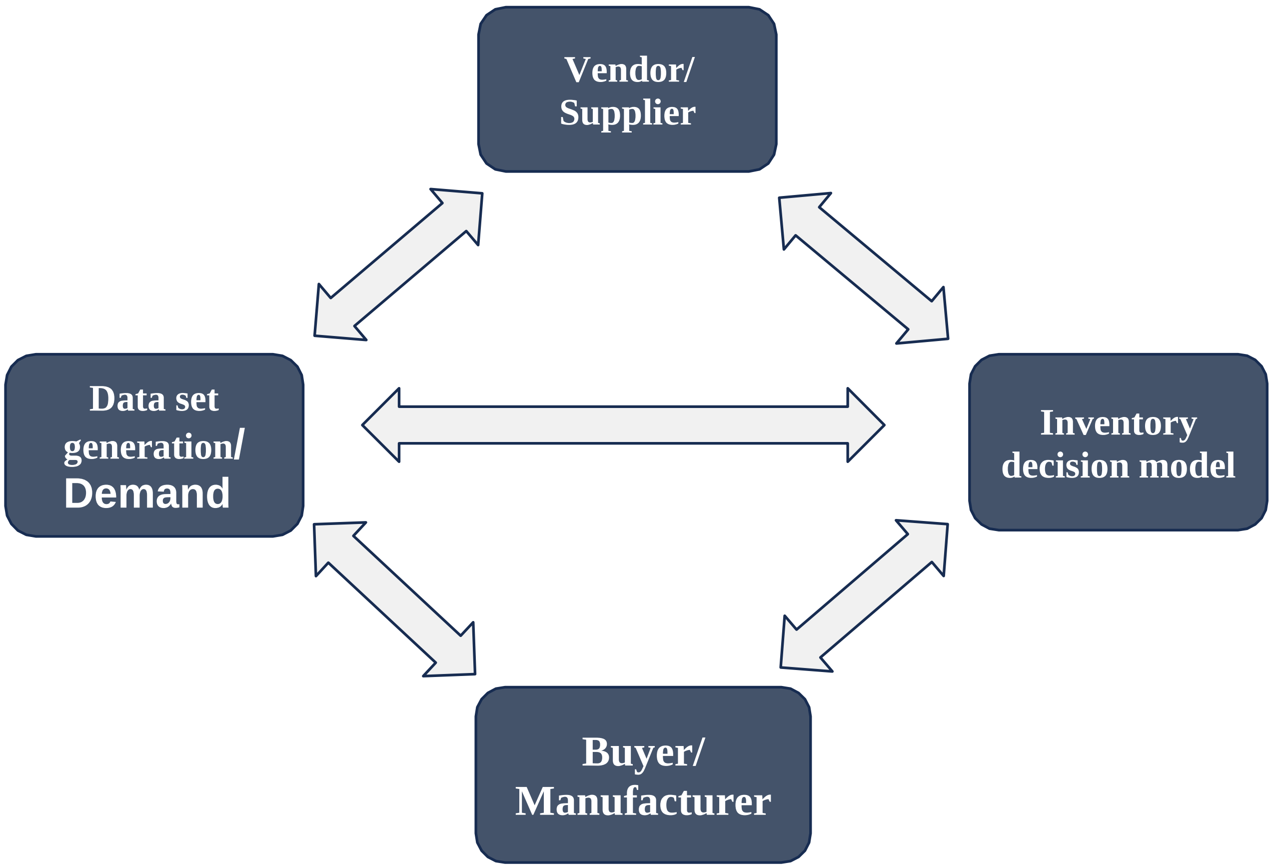

Fig.2. Ensemble Model

4.1 DATA SET GENERATION

The data generation procedure includes choosing 12 data points from an initial dataset obtained from the demand dataset of a fast-moving consumer goods (FMCG) product. It has been utilised for determining the parameters of the distribution and subsequently generate fresh data points. The generated data is expanded to include 52 data points for each distribution.

Table.2. Monthly Demand Data

Monthly Demand Data
450
360
345
366
259
210
219
249
186
45
167
156

This study utilises two types of distributions, specifically the Normal distribution and the Uniform distribution, to generate the subsequent dataset. The Normal distribution and the uniform distribution are both important in terms of modelling and predicting various demand patterns and variability for a commodity.

4.2 UNIFORM DISTRIBUTION MODEL

The concept of uniform distribution in mathematics refers to a situation where each possible event within a certain range has an equal likelihood of occurring. Within the realm of supply chain management, the utilisation of uniform distribution signifies that the likelihood of demand or lead times occurring is evenly distributed throughout all intervals within a particular range.

A situation where a uniform distribution could be suitable is when dealing with items or services that have regular and predictable demand patterns over a period of time. For instance, common household commodities such as salt or sugar may maintain a consistent level of demand throughout the year, unaffected by seasonal influences or market movements. Similarly, in supply chains with regular and predictable wait times for order fulfilment, the time it takes for products to move from the point of order placing to delivery can be modelled using a uniform distribution. This is especially pertinent in businesses characterised by established production processes and dependable transportation networks.

For generating Uniform Distribution model,

$$X_t = a + (b - a) \text{ x } U \dots \dots eq(4.1)$$

Where,

U is a random number between 0 and 1.

a = lower Limit of demand,

b = Upper Limit of demand

The uniformly distributed demand data that is generated from the raw data is.,

Table.3. Uniformly Distributed Data

Uniformly Distributed Demand Data	
313	241
730	562
238	104
1058	424
640	275
239	210
536	446
340	216
456	319
446	214
379	537
481	388
475	618
346	692
725	26
85	626
509	161
538	362
294	181
132	723
336	285
247	213
244	608
181	366
565	409
56	1086

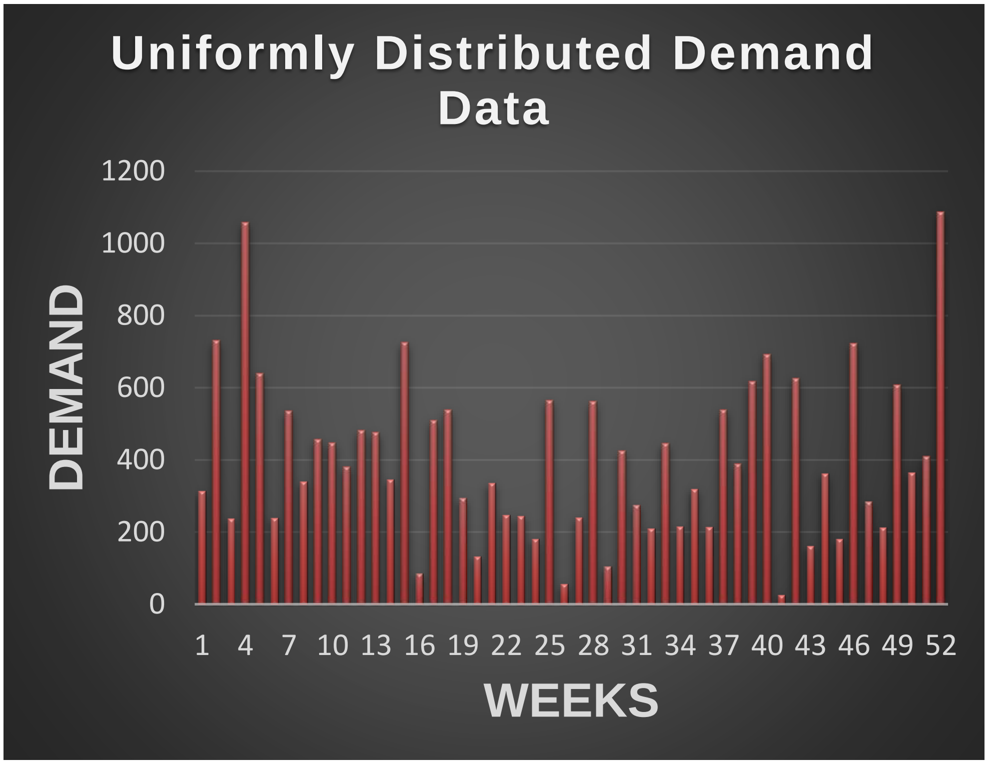

Fig.3.Uniformly Distributed Demand Data

4.2.1 TESTING OF GENERATED UNIFORM DEMAND DATA

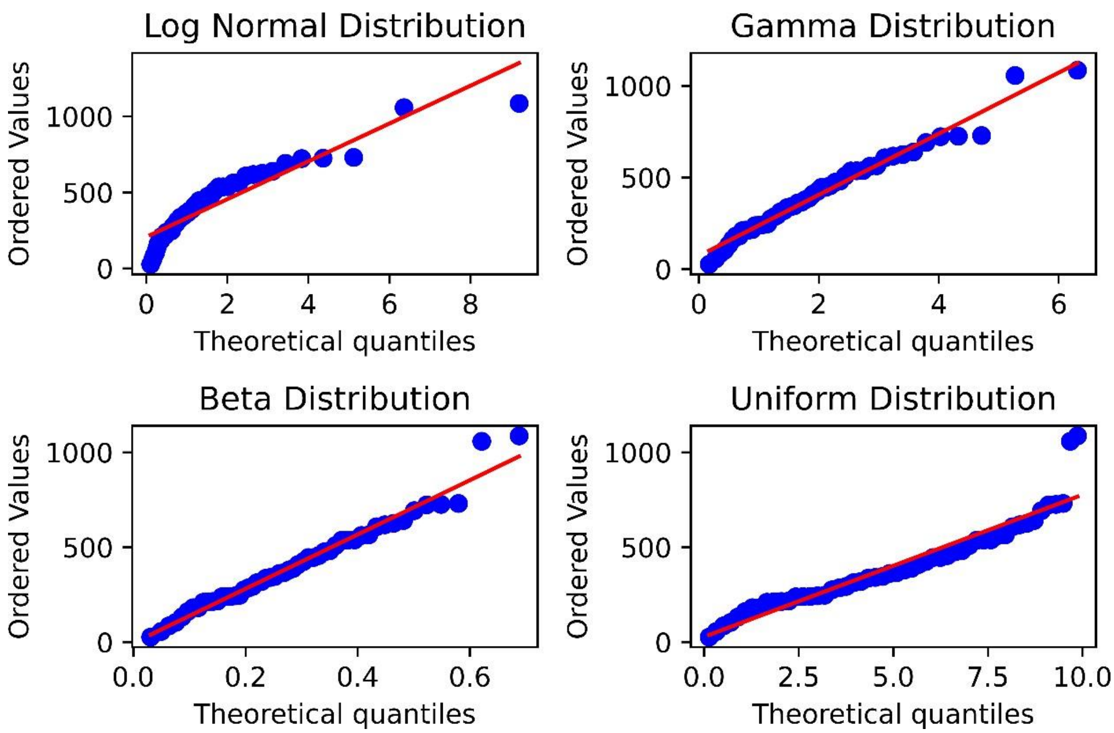

Fig.4. Kolmogorov smirnov goodness of fit test(Uniform)

4.3 NORMAL DISTRIBUTION MODEL:

The normal distribution is frequently used in supply chain management for products that demonstrate consistent and predictable demand patterns across time. This distribution is appropriate for products that have a steady and predictable level of demand, with very little variation. This allows for precise forecasting and planning. Normal distribution may be relevant to products such as staple commodities (e.g., basic food items), household supplies, and certain drugs that have consistent consumption patterns.

Furthermore, the normal distribution is valuable for representing lead times in procurement and production operations, under the assumption of a steady and predictable movement of items throughout the supply chain. It is worth mentioning that although normal distribution may be a suitable approximation for certain products, other things with higher levels of demand fluctuations may necessitate the use of different distribution models in order to effectively account for their variability and uncertainty.

Here the data is generated by following Empirical Continuous Distribution, and later upon by testing it is conformed as normally distributed demand data.

$$X_1 = x_a + \frac{R_1 - y_a}{y_b - y_a}(x_b - x_a) \ldots\ldots eq(4.2)$$

Where, R_1= Random number between 0 and 1

The Normally Distributed Demand data that is generated from the raw data is.,

Table.4. Normal Distributed Demand Data

Normal Distributed Demand Data	
87	326
524	322
271	664
464	414
685	505
269	212
528	354
314	322
183	160
311	374
725	524
524	437
184	325
358	448
216	212
328	281
508	446
371	269
555	649
492	323
629	308
285	463
237	356
428	233
446	285
273	208

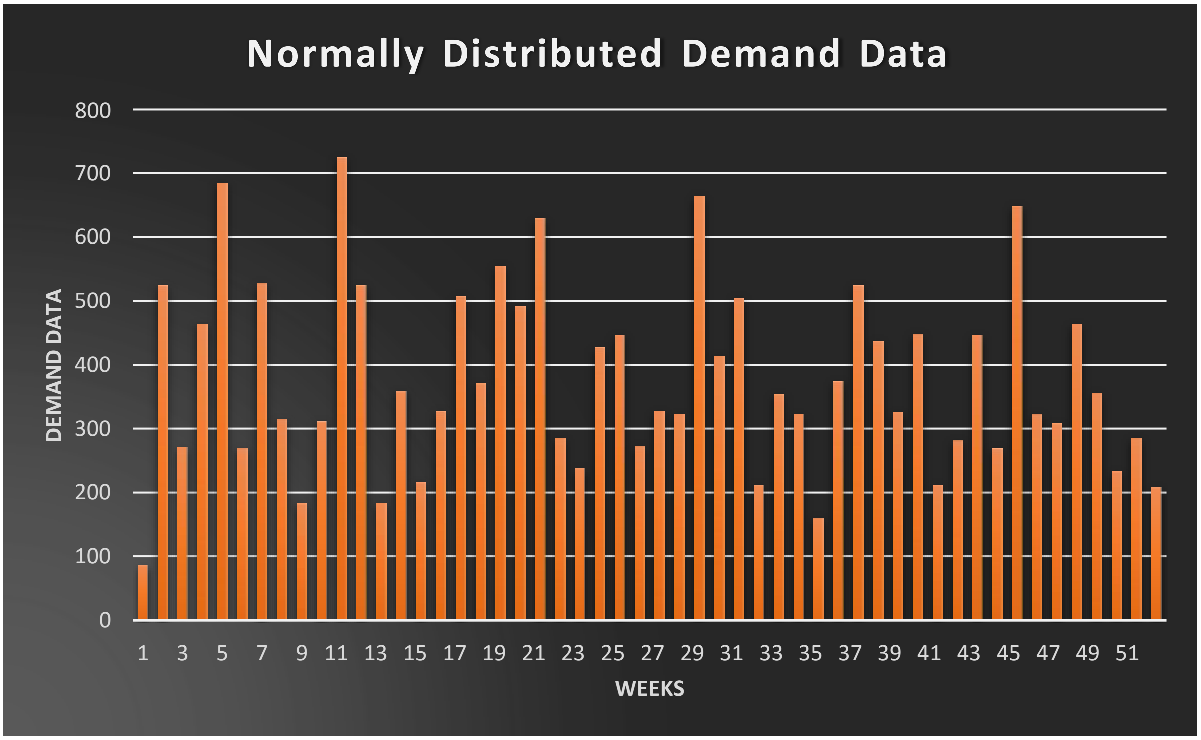

Fig.5.Normally Distributed Demand Data

4.3.1 TESTING OF GENERATED NORMALLY DISTRIBUTED DEMAND DATA:

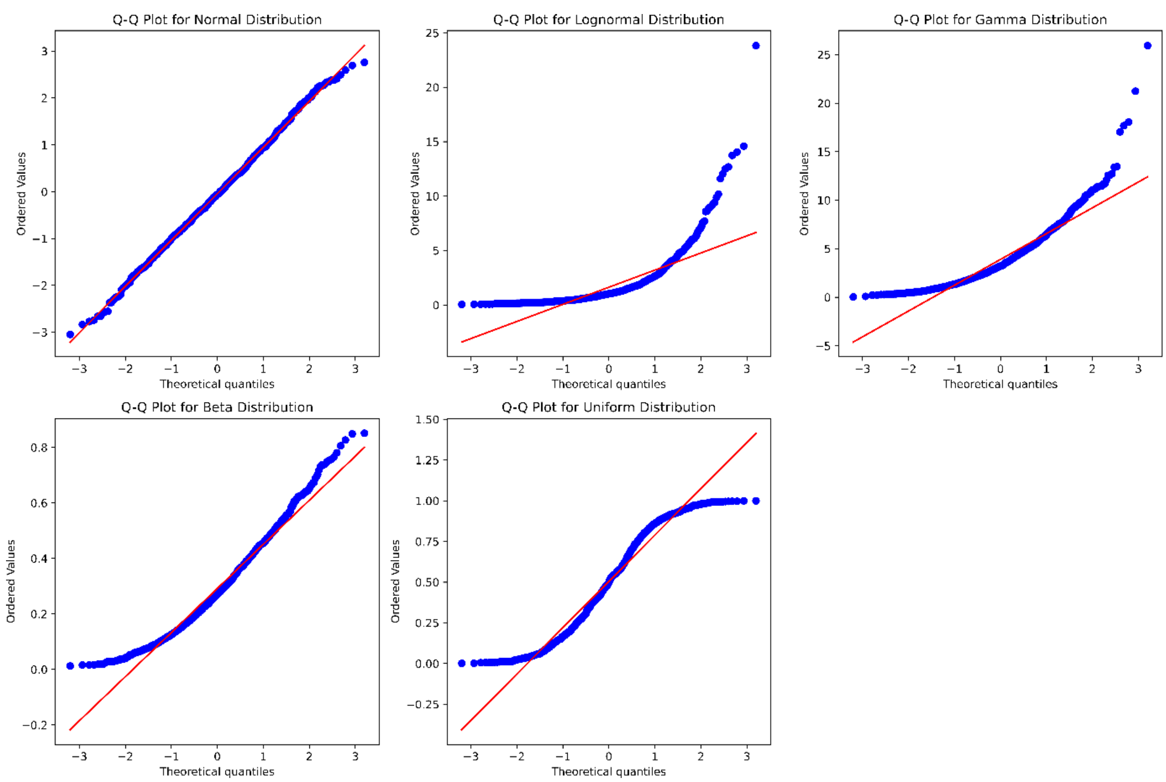

Fig.6. Kolmogorov smirnov goodness of fit test (Normal)

CHAPTER 5
INVENTORY MODEL DECISION

5.1 VMI MODEL

This investigation explores a mathematical model developed by Sirin (2013) in his paper titled "A Mathematical Approach to Vendor-Managed Inventory with Consignment". The model demonstrated that the size of the shipment led to a conflict of interest between the provider and buyer in relation to the average costs of warehousing and shipping. The objective of the inventory decision model was to minimise the average total cost, which is the combined cost of shipping and warehousing, by optimising the supply of shipments.

The size of the shipment introduces a conflict of interest between the supplier and the buyer about the average costs of warehousing and transportation. The objective is to minimise the overall average cost, which is the sum of the average shipping cost and the average warehousing cost, by optimising the supply of shipments. Figure 1 illustrates the relationship between the total average cost and the optimal shipping size in weeks, which minimises the average total cost.

Suppliers typically prefer to deliver a large cargo in order to maintain stock levels close to the maximum capacity. They then wait for the stock to decrease, according to demand needs, until it reaches the minimum stock level before replenishing. In our situation, the buyer retrieves the committed product from the warehouse facility on a daily basis, as necessary. The supplier is informed about the weekly consumption through a third-party warehousing facility, which reports the total weekly usage in one go.

The transportation time refers to the duration it takes for items to be recorded in the inventory reports of a warehousing facility, starting from the moment the goods are dispatched from the supplier's dock. On average, this process takes one week.

The inventory holding per shipment frequency, which depends on the minimum stock level and shipment size and is the primary factor in warehousing costs, is shown in Fig.7.

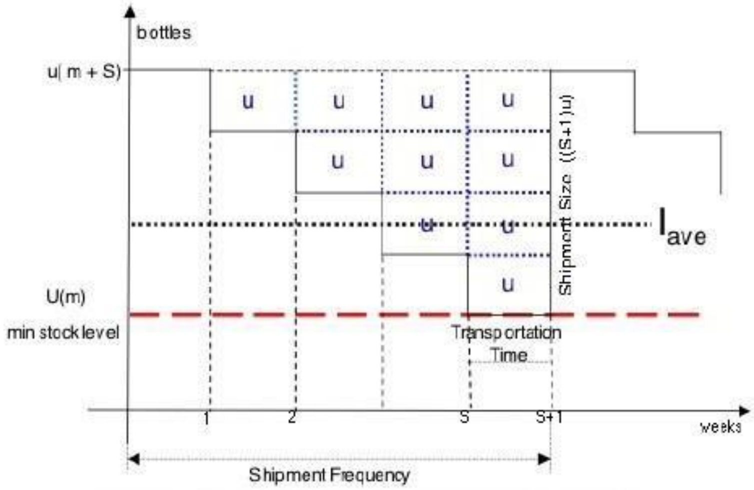

Fig.7. Inventory holding per shipment frequency

(Source: “A Mathematical Approach to Vendor-Managed Inventory with Consignment”.)

Following notations are used throughout the model to define the parameters as well as different costs involved,

m	minimum stock level (weeks)
M	maximum stock level (weeks)
u	weekly usage (units/week)
S	number of weeks to hit min stock level after replenishment
$S+1$	shipment frequency (weeks)
$u(S+1)$	shipment size (units)
k	storage cost per box ($)
b	number of units in a box (units)
FC_w	monthly fixed warehouse cost ($)
W_{ave}	average (weekly) warehousing cost per shipment frequency ($)
FC	Fixed shipping cost per shipment
VC	Variable shipping cost/shipment
SC_{ave}	Weekly average shipping cost

- Buyers within supply chains encounter a wide range of expenses related to warehousing, which is a result of the complex process of storing and controlling inventory. Warehousing expenses consist of several components, such as the rental of storage space, purchasing of material handling equipment and labour, insurance premiums to protect against potential losses, costs associated with goods becoming obsolete, and losses due to theft or damage.

  Every individual element contributes to the total cost of warehousing, demonstrating the intricate interaction of components required to sustain an operational storage facility. The costs can be classified into fixed and variable components. Fixed costs are expenses that do not change based on the amount of products held. These costs include things like the basic rental rates for warehouse space and insurance payments. On the other hand, variable costs change depending on the amount of inventory retained. These costs include fees for storing excess inventory, higher labour costs for managing larger quantities of items, and insurance premiums that are modified dependent on the value of the inventory.

  Average Warehousing cost is calculated as,

$$W_{ave} = \frac{1}{2}(2um + us)\frac{k}{b} + \frac{FC_w}{4} \ldots \ldots (eq. 5.1.1)$$

- Shipping costs represent a significant component of the overall expenses incurred by suppliers within the supply chain. These costs are often embedded within the listed unit price of the product and are borne by the supplier. However, the structure of shipping costs and their impact on profitability can vary depending on various factors.

  One key consideration is the trade-off between shipment size and profit margins. Smaller and more frequent shipments, while ensuring prompt delivery and inventory replenishment, can erode the profit margin of the provider. This is because the fixed expenses associated with each shipment, such as customs clearance, hazardous material fees, and transportation surcharges, remain constant regardless of shipment size.

  Additionally, variable costs such as delivery fees and fuel surcharges add to the overall expense, further reducing profitability. Conversely, larger shipments offer economies of scale, thereby lowering the average unit shipping cost.

By consolidating multiple orders into a single shipment, suppliers can spread out fixed expenses across a larger volume of goods, effectively reducing the per-unit shipping cost. This can help mitigate the impact of shipping expenses on profit margins and enhance overall cost-effectiveness in supply chain operations.

Average Shipping costs are described as,

$$SC_{ave} = \frac{FC}{S+1} + (VC \text{ x } u) \ldots . eq(5.1.2)$$

Average total cost per shipment frequency is defined as the sum of Average Warehousing cost and Average Shipping cost,

$$AC = W_{ave} + SC_{ave}$$

$$AC = \left[\frac{1}{2}(2um + us)\frac{k}{b} + \frac{FC_w}{4}\right] + \left[\frac{FC}{S+1} + (VC \text{ x } u)\right] \ldots \ldots eq(5.1.3)$$

SC: Total shipping cost per shipment frequency

FC: Fixed shipping cost per shipment

VC: Variable shipping cost/shipment

SC_{ave}: Weekly average shipping cost

- Marginal cost (MC) serves as a fundamental concept in economics and production analysis, representing the incremental cost associated with producing one additional unit of output. Mathematically, it is expressed as the derivative of the total cost (TC) function with respect to the quantity produced. By calculating the rate of change in total cost per unit change in quantity, marginal cost provides valuable insights into production efficiency, pricing strategies, and optimal resource allocation. Understanding marginal cost dynamics is essential for businesses to make informed decisions regarding production levels, pricing decisions, and overall profitability in competitive markets.

MC will represent the additional cost of shipping one more week of supply.

$$TC = AC \text{ x } (S + 1)$$

$$MC = \frac{\partial TC}{\partial S}$$

$$MC = \frac{k}{2b}(2um + 2uS + u) + \frac{FC_w}{4} + VC \text{ x } u \ldots \ldots . eq \text{ (5.1.4)}$$

- When marginal cost equals average cost, the average cost is minimized because the additional cost of producing one more unit is in equilibrium with the average cost across all units. This indicates an efficient allocation of resources, where the cost per unit is optimized.

  Furthermore, the relationship between marginal cost and average total cost is pivotal in understanding cost dynamics. If marginal cost is less than average cost, each additional unit produced contributes less to the average cost, causing it to decline. Conversely, if marginal cost exceeds average cost, the opposite effect occurs, leading to an increase in average total cost.

  Solving equations simultaneously will result in returning the optimal shipment frequency (S+1) and time period to reach minimum stock level after replenishment (S) leading to minimum total cost for the system,

$$S = \sqrt{\frac{2 \text{ x } b \text{ x } FC}{u \text{ x } k}} - 1$$

- The minimum stock level (m) is critical for calculating the average inventory level and inventory turnover, in addition to the shipment size. It serves as a safeguard against potential deficiencies and disruptions in the distribution network, as well as unforeseen surges in use. In order to account for unpredictable replenishment needs, the minimum stock level should be sufficient to cover the buyer's consumption throughout both the supplier's manufacturing lead time and transit time.

  The maximum stock level (M) plays a pivotal role in optimizing shipment frequency (S+1) and mitigating the risks associated with overstocking. By ensuring that M is greater than or equal to the sum of the minimum stock level and the optimal number of weeks required to reach the minimum stock level following replenishment (S), businesses can maintain a balance between inventory levels and demand fluctuations.

This proactive approach helps minimize costs associated with excess inventory, such as expiration and holding costs, while enhancing operational efficiency and responsiveness within the supply chain.

$$M \geq m + S$$

5.2 EOQ MODEL

The Economic Order Quantity (EOQ) model is highly significant in the field of supply chain management. It is a crucial tool for calculating the most efficient order quantity that minimises overall inventory expenses, by finding the right balance between costs of holding inventory and costs of placing orders.

By computing the Economic Order Quantity (EOQ), organizations may guarantee effective inventory management, preventing instances of stockouts while minimizing surplus inventory levels. This strategy enables cost reductions by optimizing procurement processes and minimizing carryingcosts linked to excessive inventories.

Furthermore, the EOQ model improves supply chain efficiency by optimizing the schedules for replenishing inventory, enhancing the allocation of resources, and managing cash flow more effectively. The application of this framework extends to a wide range of businesses and sectors, offering a structured approach to decision-making in inventory control and procurement strategies. The EOQ model allows firms to enhance operational efficiency, cost-effectiveness, and competitiveness in the constantly evolving discipline of supply chain management.

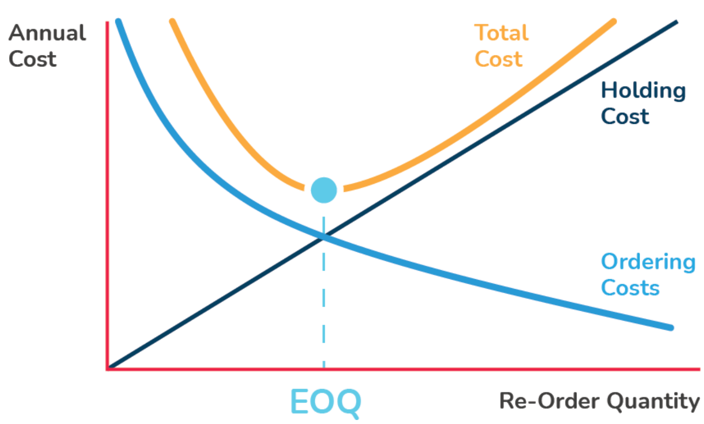

Fig.8. EOQ model

$$EOQ = \sqrt{\frac{2DS}{H}} \quad ....eq(5.2)$$

where:

S=Order costs (per order, generally including shipping and handling)

D=Annual Demand (quantity sold per year)

H=Holding costs (per year, per unit)

5.3 COST CONSIDERATIONS

Table.5. Cost considerations

***b*(No of units in a box)**	10
***FC*(Monthly Warehouse Fee)**	150000
***k*(Storage cost per box)**	600
FC / shipment	23700
VC	3733
***m* (min stock level)**	1

For calculating the costs involved for VMI, the total 52 demand data points are made into 17 shipments. The EOQ model determines the optimal order quantity that a buyer/customer should acquire to minimize their total inventory expenses, which encompass order costs, shortage costs, and storage costs.

Additionally, a comparison is made between the VMI and EOQ models, and the inventory strategy that results in the lowest total cost is regarded to be the superior model.

CHAPTER 6

RESULTS AND DISCUSSION

The weekly demand data obtained from the distribution model equations performed a key part in the Vendor Managed Inventory (VMI) system by enabling the determination of the most efficient shipment frequency and quantity. Through the utilisation of this data, the VMI system effectively controlled inventory levels, guaranteeing prompt restocking while reducing surplus stock or shortages. In addition, the costs related to warehousing and shipping were carefully calculated, allowing for a thorough examination of how costs change in relation to oscillates in demand.

Furthermore, a comprehensive evaluation was conducted to determine the overall charges of implementing the VMI system, which included both direct costs and indirect costs related to inventory management. By conducting a thorough analysis, we have determined the point at which the overall cost is minimised, indicating the most efficient balance between the costs of keeping inventory and fulfilling orders. The thorough assessment offered significant perspectives for decision-makers, informing strategic efforts to improve the efficiency and cost-effectiveness of the supply chain.

Total cost for the VMI implied distribution models can be calculated as

1.<u>Uniform distribution model</u>

generated demand	Uniform demand(u)	S	S+1	I =1/2(S+1) (2um+uS)	I_avg=1/2 (2um+uS)
313					
730					
238	1280.487764	-0.2145	0.78546	897.8879929	1143.131875

W	SC	shipment size	M (max stock	TC
83328.14867	3778261.755	1005.775986	0.785463176	3861589.903

Fig.9.Sample Calculation For Uniform Distribution model

2.Normal Distribution model

normal generated data	Normal distributed demand	S=(√((2*b*FC_sc))/(u*k	S+1	I =1/2(S+1) (2um+
87				0
524				
271	882.1079708	-0.053648069	0.9464	812.3922906

I_avg=1/2 (2um+uS)	W= 1/2(S+1) (2um+uS)k/	Shipping Cost,SC=F_s	TC=W+SC
858.446276	84231.73483	3139950.841	3224182.576

Fig.10.Sample calculation for normal distribution model

Utilising the data that is at present, it is possible to reach the conclusion that there is an apparent relationship between the cost functions and the demand data, since both reflect a comparable pattern. This conclusion can be drawn from the comparison of total costs between the two distributions, which is illustrated in figure 11. Through the fact that it exhibits a proportionate relationship to the demand data, this demonstrates that the total cost function has an unbreakable connection to the actual demand data.

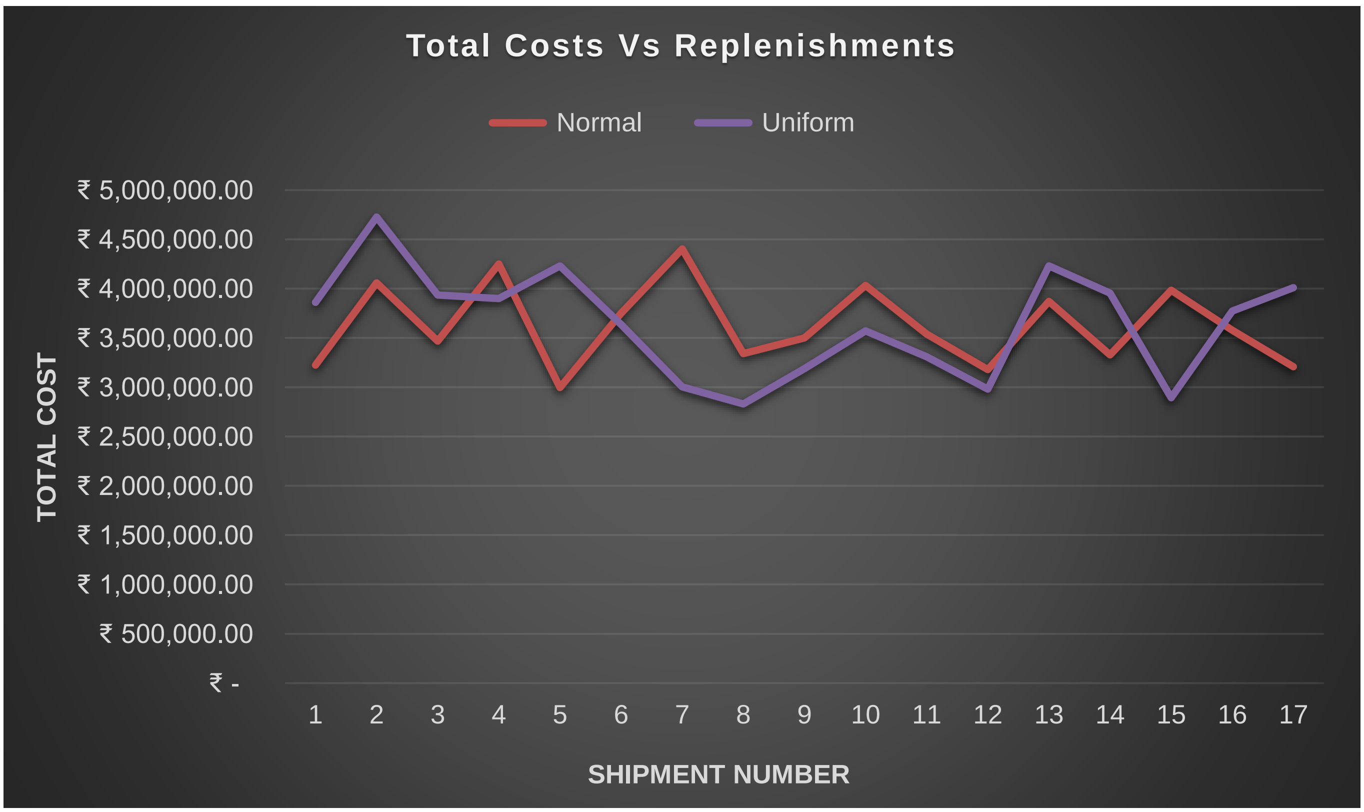

Fig.11. Total Cost relation with replenishments for the normal and uniformly distributed demand

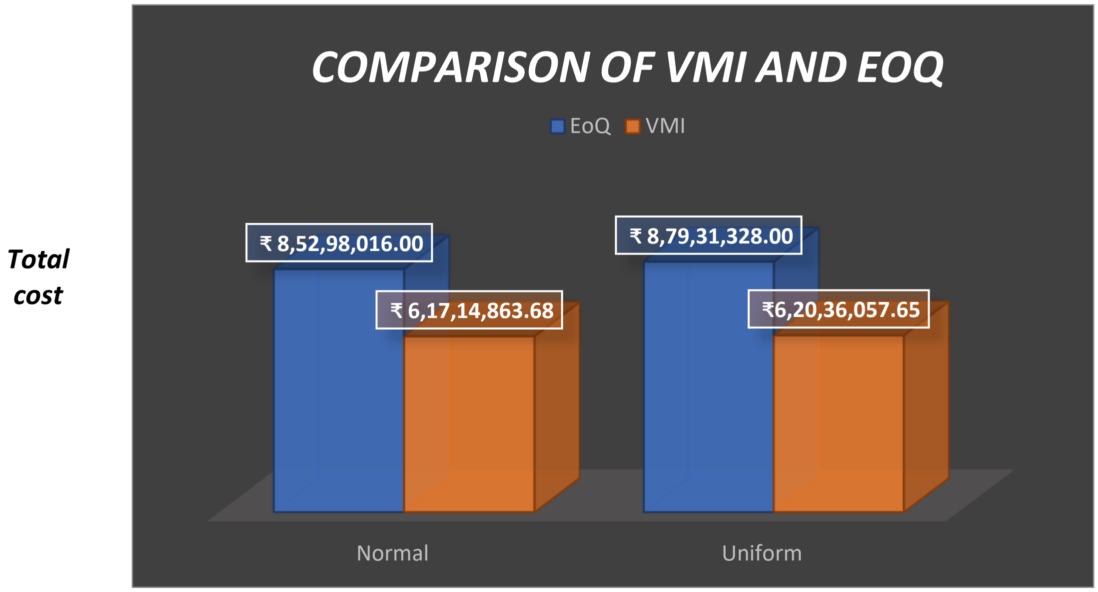

Fig.12. Total Cost comparisons for EOQ and VMI for normal and uniformly distributed data

After thoroughly analysing all costs associated with both the Vendor Managed Inventory (VMI) and Economic Order Quantity (EOQ) models, it is clear that the VMI model is the better choice for achieving cost reduction. This conclusion arises from a thorough assessment of the connection between different models, as depicted visually in Figure 12.

The data shows a strong association that supports the VMI model as the most effective in reducing total expenses in the supply chain framework. By adopting VMI, organisations can take advantage of its inherent efficiencies, easier inventory management, and improved coordination between suppliers and buyers. This strategic change not only improves cost efficiency but also promotes flexibility and quick response, positioning organisations for long-term success in rapidly changing market conditions.

The overall cost of inventory management consists of the costs associated with warehousing and shipping. The Economic Order Quantity (EOQ) model was assessed using two types of data: normal distributed and uniformly distributed. The total cost values obtained were ***Rs. ₹8,52,98,016.00*** and ***Rs.8,79,31,328.00*** respectively. Conversely, the Vendor Managed Inventory (VMI) model provides distinct reports for warehousing and shipping expenses. The normal distributed data incurred a warehousing cost of ***Rs. 14,24,612.292*** and a shipping cost of ***Rs. 6,02,90,251.39***, resulting in a total cost of ***Rs. 6,17,14,863.68***. Similarly, for uniformly distributed data, the warehousing cost was ***Rs. 14,29,828.306*** and the shipping cost was ***Rs. 6,06,06,229.34***, resulting in a total cost of ***Rs.6,20,36,057.65.***

Both cases clearly demonstrate that the transportation cost comprises approximately 97.6% of the whole cost, whereas the warehousing cost constitutes a negligible proportion of the overall cost.

The cost of inventory management is substantially reduced under the Vendor Managed Inventory (VMI) model compared to the Economic Order Quantity (EOQ) approach. The VMI model is characterized by its high efficiency and streamlined nature, since it empowers the vendor to assume responsibility for monitoring and maintaining the inventory levels of the customer. As a consequence, the probability of experiencing stockouts or having excessive inventory is diminished, hence mitigating the need for costly urgent orders or storage costs.

The VMI model effectively decreases the overall cost of inventory management by minimising such instances. On the other hand, the EOQ model, which depends on the buyer to calculate the most efficient order quantity, might lead to excessive or insufficient inventory, resulting in increased costs. Hence, the VMI model presents a more economical and efficient method for inventory management.

CHAPTER 7
CONCLUSION

After conducting a comprehensive comparison between the Vendor Managed Inventory (VMI) model and the Economic Order Quantity (EOQ) model, it is clear that implementing the VMI strategy offers a more beneficial alternative for minimising total costs. The choice is based on a thorough cost comparison analysis, which shows that the VMI approach regularly results in lower total costs compared to the EOQ model. By adopting a Vendor Managed Inventory (VMI) system, the supplier assumes the responsibility of monitoring inventory levels and restocking goods, hence reducing the potential hazards of excessive inventory and stock shortages. As a result, the costs associated with holding and organising expenses are decreased, resulting in a more efficient and economical operation. Therefore, it is highly advisable for firms to thoroughly examine implementing a Vendor Managed Inventory (VMI) method in order to enhance the efficiency and cost-effectiveness of their supply chain.

Furthermore, this Decision Support System (DSS) model shows potential for wider use across a range of Fast-Moving Consumer Goods (FMCG) products, as long as the necessary demand data is accessible. The adaptability and diversity of this technology enable firms to extract important insights and recommendations specifically designed for optimising inventory management procedures. The DSS model uses thorough analysis of demand data to determine the most efficient order quantities and reorder points for a wide range of FMCG products. Utilising these insights not only reduces costs but also strengthens protection against the possibility of running out of stock, therefore improving overall operational effectiveness. Moreover, the DSS model’s flexibility to be customised allows it to be aligned with the specific needs and characteristics of different FMCG products, highlighting its essential function as a tool for improving profitability and operational excellence in the FMCG business.

Essentially, FMCG firms have to embrace the VMI model, which is supported by a strong DSS architecture, in order to remain viable in today’s competitive environment. Organisations may achieve continuous success and resilience in the face of changing market dynamics and consumer demands by actively embracing teamwork, using technology, and optimising supply chain techniques.

CHAPTER 8

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