MECHANICAL & INDUSTRIAL ENGINEERING DEPARTMENT

IE7200 Supply Chain Engineering

1st Partial Exam Project

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I. Introduction to Supply Chain Management

Supply Chain Management (SCM) is a pivotal aspect of modern business operations, encompassing the efficient coordination of various activities from sourcing raw materials to delivering finished products to consumers. This multifaceted process involves procurement, production, logistics, inventory control, and information management. The essence of SCM lies in optimizing these elements to reduce costs, enhance customer satisfaction, and maintain a competitive edge in the global market.

Effective SCM ensures a seamless flow of goods and information, crucial for minimizing expenses and meeting consumer demand promptly. It not only addresses the operational aspects but also strategically aligns supply chain activities with business goals. This alignment is key in navigating global market complexities, technological advancements, environmental sustainability, and fluctuating consumer demands.

The future of SCM is geared towards embracing technological innovations like automation and blockchain for increased efficiency and transparency. Additionally, sustainability is becoming a core focus, emphasizing eco-friendly practices within supply chains.

In summary, SCM is an essential, dynamic field that significantly impacts a company's efficiency and market presence. Its continuous evolution in response to global trends and challenges underscores its critical role in the success and sustainability of businesses in the 21st century.

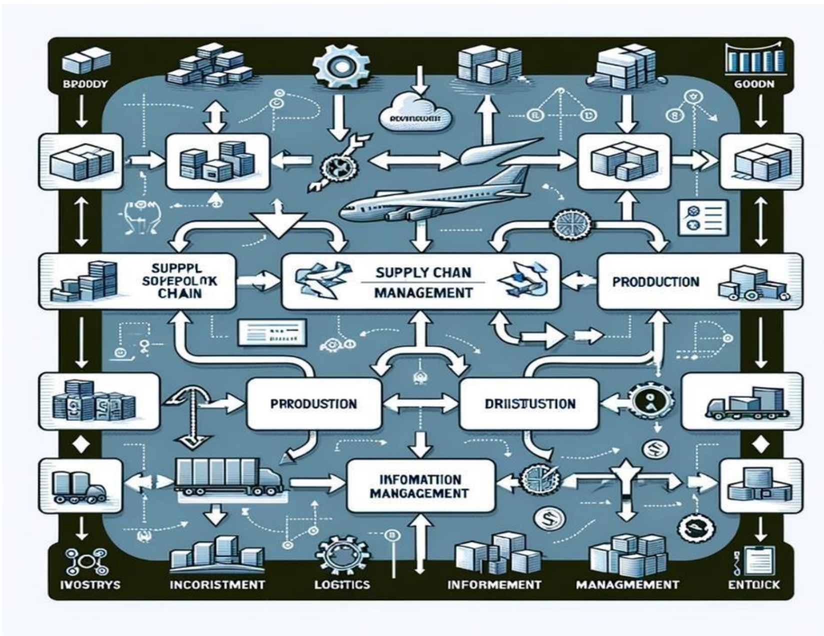

Fig.1 Detailed and informative diagram of Supply Chain Management (SCM) processes.

This diagram illustrates the flow of goods, information, and finances in a supply chain, including key elements such as procurement of raw materials, production, logistics and distribution, inventory management, and information management. Each stage is clearly labeled, and arrows indicate the direction of flow between these elements.

II. Introduction to Push/Pull Systems

Push/Pull systems in supply chain management represent two approaches to material and production control, each responding differently to customer demand.

In a Push system, production is based on forecasted demand. Products are manufactured and pushed to the market with the anticipation that customers will purchase them. This method is typically utilized in scenarios where demand is predictable and stable. The advantage of this approach is the ability to plan and schedule production efficiently, leading to potential economies of scale. However, it can also result in overproduction and high inventory costs if the forecasts are inaccurate.

Conversely, a Pull system is reactive, with production driven by customer demand. In this model, production starts only after a customer order is received, thereby closely aligning production with actual market needs. This approach minimizes the risk of overproduction and excess inventory, ensuring a more streamlined and cost-effective operation. Pull systems are particularly effective in industries where demand is variable and unpredictable.

Many modern businesses adopt a hybrid approach, blending Push and Pull strategies to balance efficiency with responsiveness. The choice between these systems, or the degree to which they are combined, often depends on factors such as product type, market dynamics, and production capabilities.

In summary, Push and Pull systems offer different perspectives on managing supply chain and production processes. While Push focuses on forecast-driven production, Pull emphasizes responsiveness to actual demand, with each system offering its unique set of advantages and challenges. Understanding and applying these concepts effectively is crucial for businesses to optimize their operations and meet market demands efficiently.

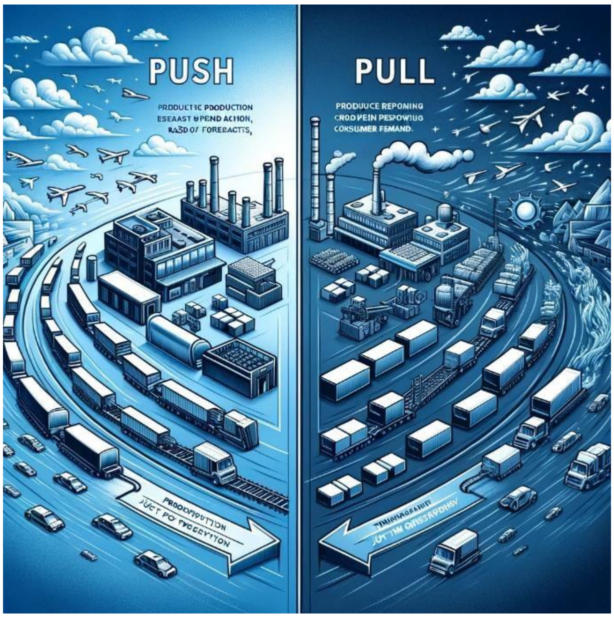

Fig 2. Push and Pull systems in supply chain management.

This image visually contrasts the two approaches: one section depicts the Push system with a production line, and the other shows the Pull system with a more responsive production environment.

- ## Hybrid push-pull

A Hybrid Push/Pull system in supply chain management synergizes the proactive planning of Push systems with the reactive nature of Pull systems. This approach segments the supply chain: initial stages operate on forecast-based Push principles, ensuring efficient production, while the latter stages switch to a Pull method, reacting to real customer demands. This shift typically occurs at a strategic 'push-pull boundary,' optimizing the balance between preparation and responsiveness.

The key advantage of this hybrid model is its ability to mitigate the drawbacks of both pure Push and Pull systems. It reduces the risk of overproduction and surplus inventory common in Push systems and avoids the potential inefficiencies of Pull systems, which may struggle with rapid demand changes.

Determining the optimal push-pull boundary is critical, influenced by product nature, market variability, and cost considerations. This flexible approach allows businesses to adapt to market fluctuations effectively, making the Hybrid Push/Pull system a robust and responsive strategy in modern supply chain management.

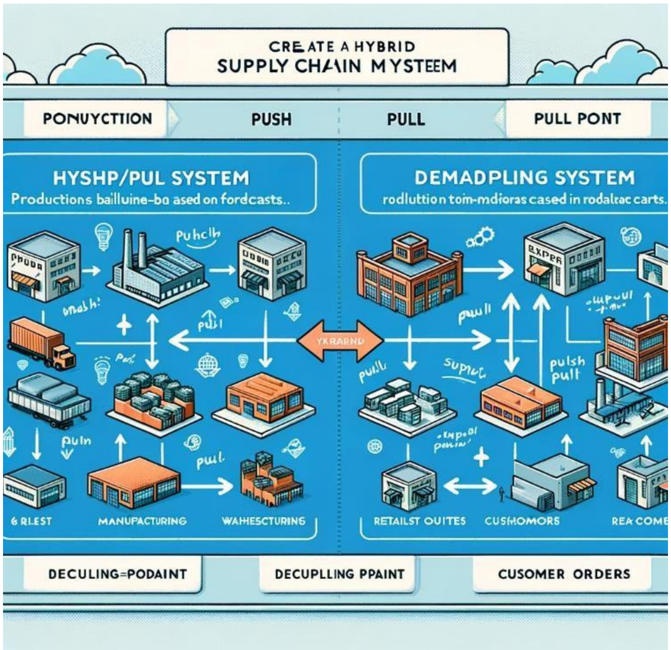

Fig 3. Hybrid Push/Pull system in supply chain management.

Here is a diagram illustrating a Hybrid Push/Pull system in supply chain management. This visual representation highlights the two main sections of such a system:

1. **The 'Push' Section**: This part of the diagram shows production based on forecasts, typically involving manufacturing plants and warehouses. It represents the initial stages of the supply chain where products are produced in anticipation of demand.

2. **The 'Pull' Section**: This section illustrates a demand-driven process. It is more dynamic, often involving retail outlets and responding directly to customer orders. This part of the supply chain reacts to actual sales and consumer demands.

The transition between these two sections is marked by a 'push-pull boundary' or 'decoupling point.' This point signifies where the strategy shifts from forecast-driven production to demand-driven distribution. Arrows in the diagram indicate the flow of goods from manufacturing through to consumer demand.

III. Description of the Systems Dynamics Model –

- **Description of the model-**

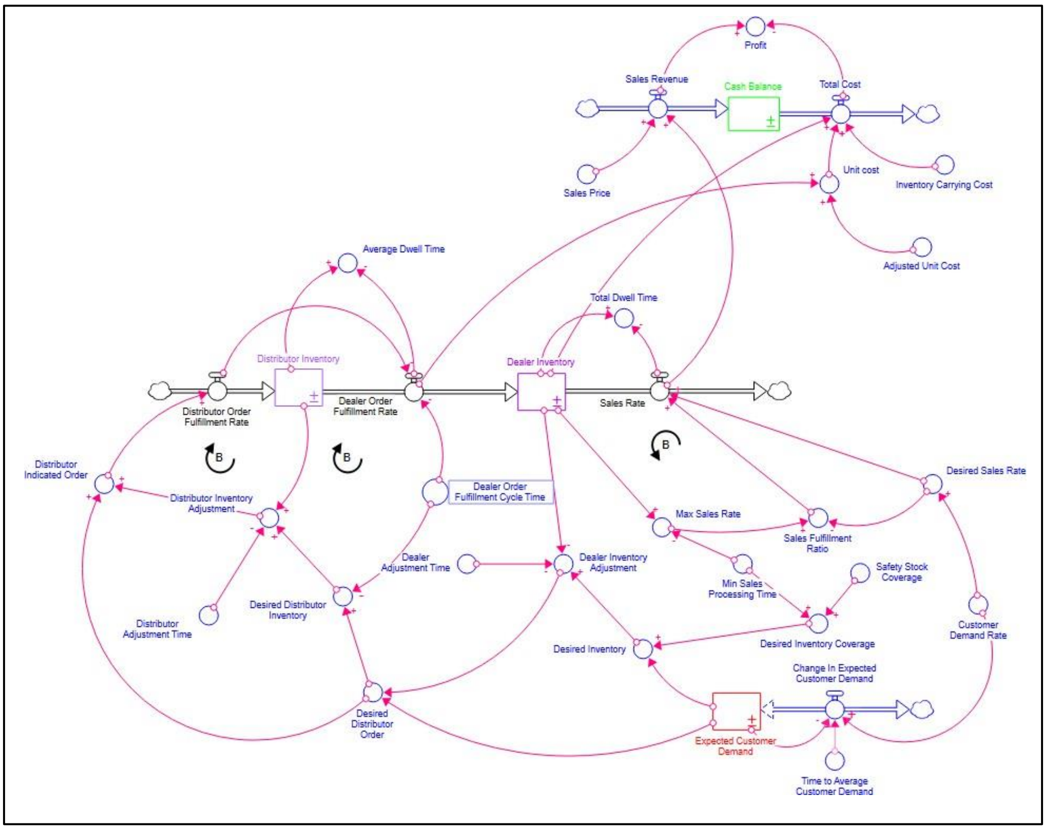

Fig 4. Dynamic representation of the interconnected elements within the supply chain.

The model depicted in the image is a causal loop diagram, which is commonly used in system dynamics to represent the feedback structure of systems. It is specifically focused on supply chain management for a vehicle distribution system. Here's a detailed description of the model components and their relationships:

1. Central Components:

Distributor Inventory & Dealer Inventory: These represent the stock levels at the distributor and dealer respectively. They are central to the model, indicating the flow of vehicles through the supply chain.

Sales Rate: This indicates the rate at which vehicles are being sold to the end customers.

2. Feedback Loops:

- The diagram includes several balancing (B) and reinforcing (R) loops, which are key features of system dynamics models.

Balancing Loops (B): These loops are designed to bring the system to a desired state or equilibrium. They include mechanisms that adjust the inventory based on various factors such as the desired inventory, the order fulfillment rates, and the sales rate.

Reinforcing Loops (R): These loops can lead to exponential growth or decline within the system. In this model, reinforcing loops might represent scenarios where increasing sales lead to increased profits, which in turn might be reinvested to further increase the sales capacity.

3. Inputs and Adjustments:

Distributor Order Fulfilment Rate & Dealer Order Fulfilment Rate: These rates affect how quickly the distributor and dealer can fulfil orders, impacting inventory levels.

Distributor Adjustment Time & Dealer Adjustment Time: These are delays in the system that represent the time taken for the distributor and dealer to adjust their inventory in response to changing conditions.

4. Demand and Sales:

Customer Demand Rate: This is an external input to the system, representing the rate at which customers want to purchase vehicles.

Desired Sales Rate: This is the target rate at which the company aims to sell vehicles.

-**Max Sales Rate:** This is the maximum rate at which the system can sell vehicles, likely limited by production or supply constraints.

5. Costs and Financial Metrics:

Unit Cost & Adjusted Unit Cost: These represent the cost to the company for each vehicle, with adjustments potentially accounting for volume discounts, transportation costs, etc.

Inventory Carrying Cost: The cost associated with holding inventory, which could include storage, insurance, depreciation, and opportunity costs.

Sales Price: The price at which vehicles are sold to customers.

Cash Balance & Profit: These are financial outputs of the system, representing the company's financial health and performance.

6. Inventory Policies:

Safety Stock Coverage: This indicates the amount of extra inventory kept on hand to prevent stockouts.

Desired Inventory & Desired Distributor Order: These are target levels for inventory and orders, aiming to ensure enough stock to meet customer demand without overstocking.

7. Time Delays:

Average Dwell Time: The average time that vehicles stay within the system before being sold.

Dealer Order Fulfilment Cycle Time: The time it takes for the dealer to complete an order fulfilment cycle.

Min Sales Processing Time: The minimum time it takes to process a sale, likely impacted by administrative tasks.

8. Market Dynamics:

Change in Expected Customer Demand & Time to Average Customer Demand: These variables represent how the company anticipates and reacts to changes in market demand over time.

This causal loop diagram is a dynamic representation of the interconnected elements within the supply chain. Each variable and loop impact the system, and changes to one part can have ripple effects throughout the entire system. In analysing such a model for supply chain efficiency, one would simulate various scenarios to understand the impact of different inputs on the outputs and identify leverage points for improving system performance.

Why this model is hybrid Push/Pull?

Fig 4 is a hybrid push-pull supply chain model, which synergistically blends the forecast-oriented push approach with the demand-responsive pull approach within its structure. The push component is reflected in the premeditated determination of inventory levels, such as the Desired Distributor Inventory, which are predicated on projected demand assessments. This proactive stance facilitates the flow of vehicles from production through to the distributor, pre-emptively aligning supply with expected market demand.

Simultaneously, the model incorporates a pull strategy, discernible through the real-time adaptation to customer purchasing patterns, as evidenced by the Customer Demand Rate's direct influence on the Dealer Inventory and Sales Rate. This demonstrates the model's responsive nature, where the actual consumer demand exerts a "pull" on the supply chain, dictating the pace at which inventory is replenished and managed, particularly visible in the Dealer Order Fulfilment Rate and the Dealer Inventory Adjustment mechanisms.

The confluence of both strategies within a singular operational framework is what characterizes this model as a hybrid push-pull system. It capitalizes on the predictive nature of the push system to maintain a baseline of supply readiness while simultaneously embracing the agility of the pull system to adjust supply chain activities in accordance with real-time sales and demand data. This dual-faceted approach aims to strike a balance between maintaining sufficient stock to meet forecasted demand and adapting inventory replenishment to the actual sales trends, thereby optimizing overall supply chain efficacy and customer satisfaction. This hybrid model is designed to minimize overstocking and understocking risks, reduce waste, and streamline operations, thus contributing to a more cost-effective and customer-centric supply chain.

Analysis of the current model -

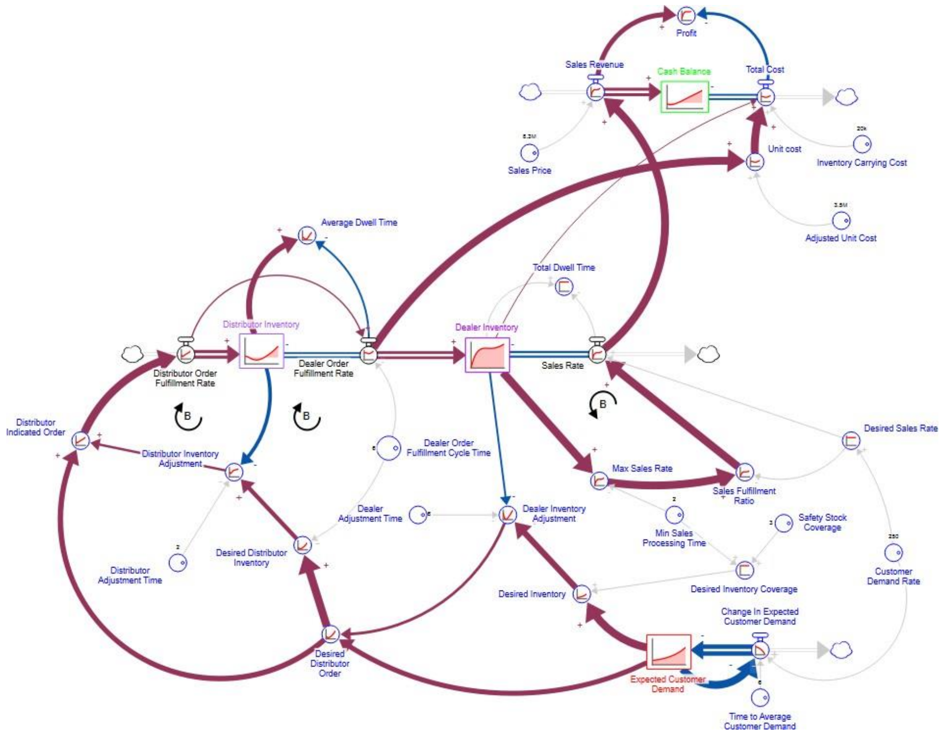

Fig 5. System Dynamics Model of Supply Chain Management with Feedback Loops and Performance Metrics Visualization

1. Inventory Levels:

- Safety Stock Coverage: At 3 weeks, reducing this to, say, 2 weeks could potentially decrease the Dealer Inventory by approximately 1/3 (assuming linear relation), which in this case could be around 2.02k units. This reduction would decrease the Inventory Carrying Cost by about 40.4k NGN/week (2.02k units * 20k NGN/unit).
- Desired Inventory and Order Fulfillment: Lowering the Dealer and Distributor Inventory could improve the Cash Balance by reducing the capital tied up in inventory. For instance, each 1k reduction in Distributor Inventory could free up 3.5 billion NGN (1k units * 3.5 million NGN/unit).

2. Lead Time Reduction:

- By reducing the Dealer and Distributor Adjustment Time from 6 weeks to 4 weeks, the responsiveness to market changes improves. This could potentially increase the Expected Customer Demand fulfillment rate and reduce the Total Dwell Time, contributing to an increased Sales Rate and potentially higher Profit margins. The reduction in lead times can also decrease inventory levels due to more efficient turnover, impacting the holding costs.

3. Demand Forecasting:

- Accurate forecasting that brings Expected Customer Demand closer to actual demand can reduce both overstock and stock outs. Even a 10% improvement in forecasting accuracy can lead to more effective inventory management, potentially increasing sales if demand is higher than expected or reducing Inventory Carrying Costs if demand is lower.

4. Cost Reduction:

- If the Adjusted Unit Cost of 3.5 million NGN could be reduced by even 5% through better negotiations or efficiency gains, this would result in savings of 175,000 NGN per vehicle. Across an expected demand of 2.02k units/week, this represents a potential cost saving of 353 million NGN/week.

5. Process Optimization:

- Decreasing the Min Sales Processing Time from 2 weeks to 1 week could improve cash flow and responsiveness. Similarly, reducing the Dealer Order Fulfillment Cycle Time from 6 weeks to 4 weeks could enhance the Sales Fulfillment Ratio, potentially increasing the Sales Rate.
- This could shorten the cash-to-cash cycle time, potentially increasing the Cash Balance due to quicker returns on sold inventory.

6. Price Optimization:

- If a price adjustment leads to a change in demand, a sensitivity analysis would be required. For instance, a 5% increase in Sales Price could lead to additional profit if the demand is inelastic. On a weekly basis, this could potentially increase the Sales Revenue by 415 million NGN (5% of 8.3 billion NGN).

7. Dynamic Replenishment:

- A more responsive replenishment system could reduce the need for high levels of safety stock by more closely aligning inventory with actual sales. Even a 10% reduction in excess inventory due to better replenishment could significantly impact cash flow and carrying costs.

8. Technology and Automation:

- An investment in technology could lead to long-term savings, though it's difficult to estimate without specific costs. Typically, automation can lead to a reduction in manual processes and errors, which could, for example, improve the Distributor Order Fulfillment Rate by 10-20%.

9. Supplier Management:

- Better supplier terms could reduce the cost of goods sold. A 2% reduction in procurement costs due to improved supplier management could have a substantial impact on the Adjusted Unit Cost, leading to increased Profit margins.

10. Customer Relationship Management:

- Understanding customer needs could lead to a more accurate demand forecast and a better match between production and sales, thereby reducing inventory carrying costs and improving the Sales Rate.

11. Lean Practices:

- Implementing lean practices could lead to a 5-10% reduction in waste throughout the supply chain. This could lower Total Cost and improve Profit through increased efficiency.

IV. Description of the Scenarios to be Analysed

This section delves into strategic adjustments within the supply chain of Stella model, aiming to elevate both efficiency and profitability. By scrutinizing each key area of the supply chain, we propose targeted scenarios for improvement. These scenarios are meticulously analysed to forecast their potential impact on the supply chain's performance.

Scenario 1: Accelerated Dealer Adjustment Time

Change: Reduce Dealer Adjustment Time from 6 weeks to 3 weeks.

Impact: Faster dealer response to inventory levels, leading to a more dynamic adjustment to sales trends.

Scenario 2: Enhanced Demand Forecasting

Change: Implement advanced demand forecasting techniques to reduce Time to Average Customer Demand from 6 weeks to 4 weeks.

Impact: More accurate and timely response to market demand and increasing sales fulfilment ratio from 15.9 to 22.5 Dimensionless.

Scenario 3: Cost Reduction through Supply Chain Optimization

Change: Conduct a supply chain audit to identify areas where the Adjusted Unit Cost can be reduced, targeting a reduction from 3.5 million NGN/Units to 3.3 million NGN/Units.

Impact: Direct reduction in cost of goods sold potentially increasing profit margins which can be seen by unit cost reduction from 16.2 billion NGN/weeks to 15.2 billion NGN/weeks.

Scenario 4: Inventory Carrying Cost Reduction

Change: Implement lean inventory techniques to decrease Inventory Carrying Cost from 20,000 NGN/Week to 15,000 NGN/Week.

Impact: Reduction in the weekly costs associated with holding inventory results in total cost reduction from 16.2 billion NGN/weeks to 14.2 billion. NGN/weeks.

Analysis of the Described Scenarios

Scenario 1 Analysis: Accelerated Dealer Adjustment Time

The reduced adjustment time could decrease the need for safety stock, as dealers would be able to respond more quickly to changes in demand, lowering inventory carrying costs. This could result in lower total costs and higher profits and thus increase in profit from 12.8 billion to 16.8 billion with cash balance from 98.7 billion to 148 billion. However, careful analysis of the dealer's capacity to handle a faster turnover is necessary to avoid potential overstrain.

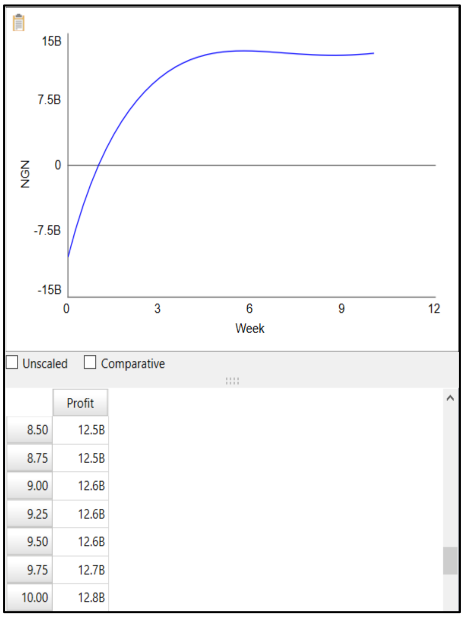

Fig.6. Initial Profit

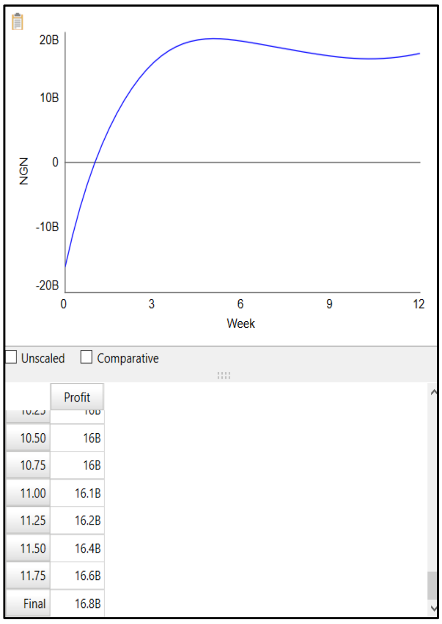

Fig.7 Updated Profit

Scenario 2 Analysis: Enhanced Demand Forecasting, Implementing advanced demand forecasting techniques to reduce the Time to Average Customer Demand from 6 weeks to 4 weeks represents a strategic enhancement in the supply chain's responsiveness and efficiency. This change focuses on leveraging predictive analytics, artificial intelligence, and machine learning algorithms to analyse historical sales data, market trends, and consumer behaviour patterns. The goal is to achieve a more nuanced understanding of demand fluctuations and to anticipate customer needs with greater accuracy.

The direct consequence of more accurate demand forecasting and enhanced responsiveness is an increase in the sales fulfillment ratio, from 13 to 17.8 dimensionless. This metric reflects the company's ability to meet customer orders from available stock without delay. A higher fulfillment ratio indicates that a greater proportion of customer demand is being satisfied efficiently, leading to reduced backorders, fewer lost sales, and improved customer satisfaction. This efficiency directly contributes to revenue growth and market share expansion, as customers are more likely to return to a brand that reliably meets their needs.

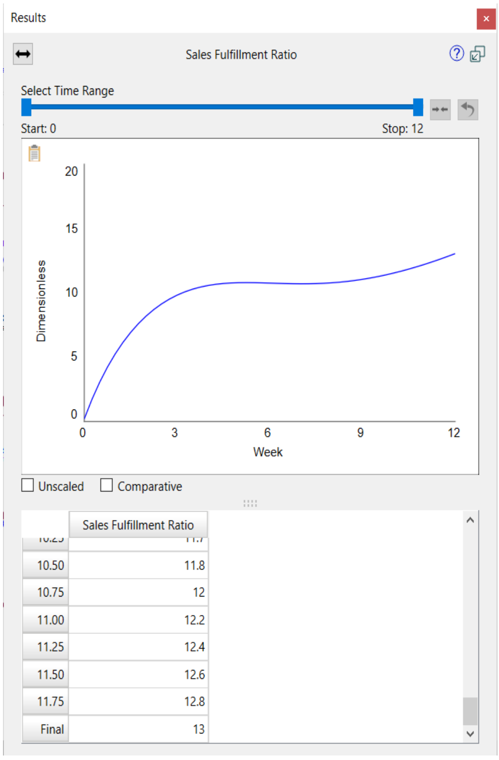

Fig.8 Initial Sales Fulfillment ratio

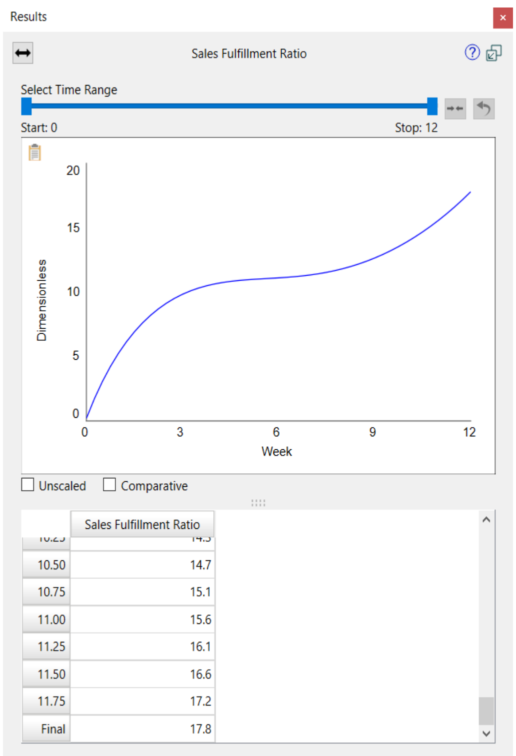

Fig.9 Updated Sales Fulfillment ratio

Scenario 3 Analysis: Cost Reduction through Supply Chain Optimization

Conducting a supply chain audit to identify opportunities for cost reduction targets lowering the Adjusted Unit Cost from 3.5 million NGN (Nigerian Naira) per unit to 3.3 million NGN per unit. This strategic approach aims to dissect and analyse every component of the supply chain operations to uncover inefficiencies, redundant processes, or areas where cost-saving measures can be implemented without compromising quality or delivery timelines.

The shift from a unit cost of 16.2 billion NGN per week to 13.18 billion NGN per week represents a substantial improvement in financial performance. This reduction in weekly costs, when extrapolated over a fiscal year, can lead to significant savings and enhanced financial health for the company. Improved financial performance not only strengthens the company's balance sheet but also attracts potential investors and supports further expansion and growth initiatives.

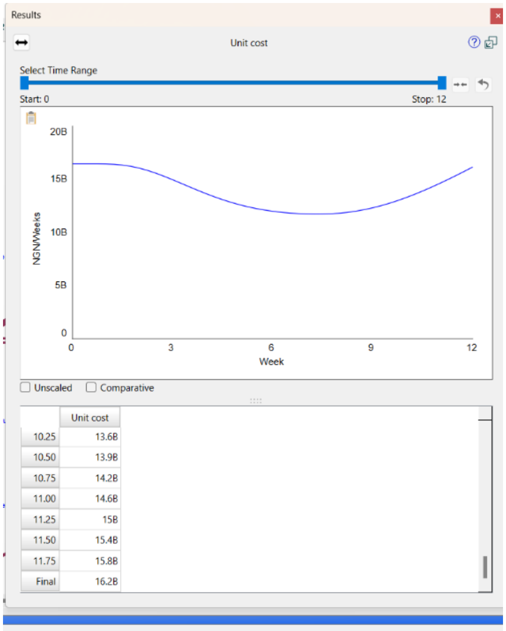

Fig.8 Initial Unit Cost

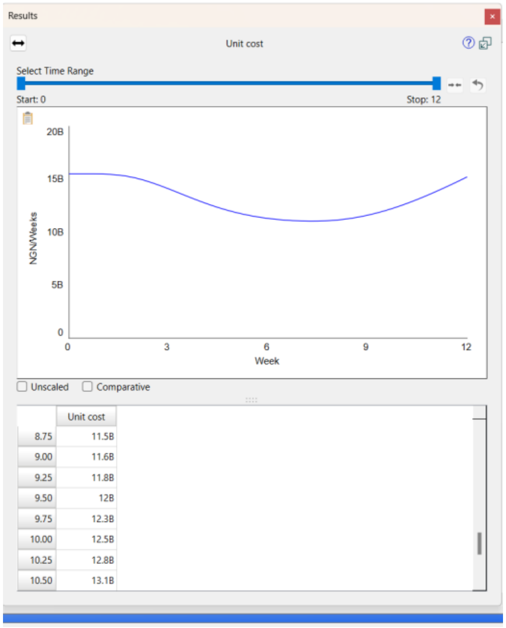

Fig.9 Updated Unit Cost

Scenario 4 Analysis: Inventory Carrying Cost Reduction

Implementing lean inventory techniques to decrease Inventory Carrying Cost from 20,000 NGN/Week to 15,000 NGN/Week is a strategic initiative aimed at enhancing the efficiency and cost-effectiveness of inventory management. Lean inventory techniques, such as Just-In-Time (JIT) inventory, Kanban systems, and demand forecasting, focus on minimizing excess stock and reducing waste while ensuring that production processes are not disrupted by shortages. This approach not only reduces the physical space required for storage but also minimizes the costs associated with insurance, obsolescence, depreciation, and capital tied up in inventory.

The reduction in inventory carrying costs contributes to a broader total cost reduction in the company's operations, decreasing from 16.2 billion NGN/weeks to 14.2 billion NGN/weeks. This substantial decrease in operational costs can significantly improve the company's overall financial health, allowing for reallocation of resources towards growth initiatives, R&D, or price competitiveness in the market.

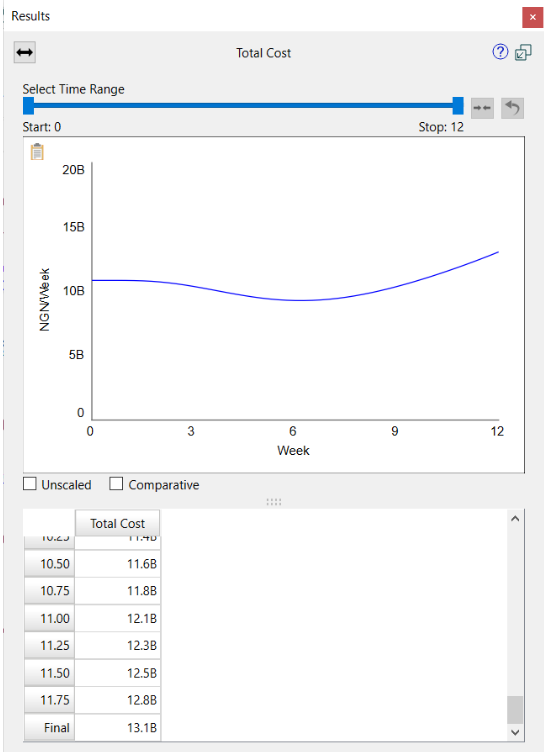

Fig.8 Initial Total Cost

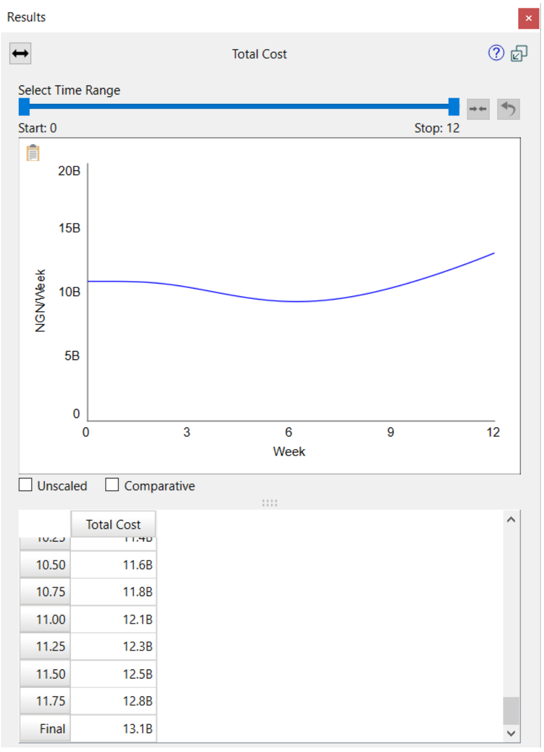

Fig.9 Updated Total Cost

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VI. Appendix

Title	Initial Value
Dealer Order Fulfillment Cycle Time	8
Distributor Adjustment Time	2
Minimum Sales Processing Time	2
Safety Stock Coverage	3
Customer Demand Rate	250
Adjusted Unit Cost	3,500,000
Inventory Carrying Cost	20,000
Sales Price	8,300,000
Time to Average Customer Demand	6

Table 1: Stock Formula Value for Hybrid Push- Pull Model

Title	Formula
Distributor Inventory Adjustment	Desired Distributor Inventory-Distributor Inventory)/Distributor Adjustment Time, Units: Units/Week
Distributor Indicated order	Distributor Inventory Adjustment + Desired Distributor Order
Desired Distributor Order	MAX (0, Expected Customer Demand + Dealer Inventory Adjustment)
Desired Distributor Inventory	Dealer Order Fulfilment Cycle Time * Desired Distributor Order
Dealer Inventory Adjustment	(Desired Dealer Inventory-Dealer Inventory)/Dealer Adjustment Time
Desired Inventory	Desired_Inventory_Coverage * Expected_Customer_Demand
Desired Sales Rate	Customer Demand Rate
Sales Fulfillment Ratio	SAFEDIV(Max_Sales_Rate, Desired_Sales_Rate)
Max Sales Rate	Dealer Inventory/Min Sales Processing Time
Dealer order fulfillment	DELAY3(Distributor_Order_Fulfillment_Rate, Dealer_Order_Fulfillment_Cycle_Time)
Total Dwell Time	Safediv (Dealer Inventory, Sales Rate),
Average Dwell Time	Safediv (Distributor Inventory, Dealer Order Fulfilment Rate)
Unit Cost	Adjusted Unit Price * Dealer Order Fulfilment Rate
Profit	Sales Revenue-Total Cost

Table 2: Flow Formula Value for Hybrid Push- Pull Model

Title	Equation
Distributor inventory	Distributor Order Fulfilment Rate - Dealer Order Fulfilment Rate
Dealer Inventory	Dealer Order Fulfilment Rate-Sales Rate, Desired Dealer Inventory
Expected Customer Demand	Smth3 (Customer Demand Rate, Time to Average Customer Demand)
Cash Balance	Sales Revenue-Total Cost

Table 3: Converter Formula Value for Hybrid Push- Pull Model