Optimizing Warehouse Operations with Strategic Inventory Replenishment

Executive Summary

The purpose of this project is to evaluate how four different stock replenishment strategies impact the operational and financial performance of a distribution warehouse. The analysis examines warehouse utilization, order fulfilment and financial metrics such as net profit, revenue and cost to serve. The objective is to identify the strategy that achieves the optimal balance between a lean inventory, high order fulfilment and sustainable profitability.

The strategies examined are:

1. **Weekly Scheduled Orders** - consolidated replenishment on a fixed weekly schedule.
2. **Just-in-Time (JIT)** - ordering stock only when needed to meet immediate demand.
3. **Hybrid A** - JIT for high-priority products (Classes A & B), weekly for lower priority (Class C)
4. **Hybrid B** - JIT for the highest priority products (Class A), weekly for all others (Classes B & C)

The findings are based on a 90-day simulated dataset of a B2C distribution warehouse. Demand patterns varied by product class, while warehouse capacity and the profit margin for each product were kept constant throughout the period.

Key findings

- **Warehouse utilization** averaged ~55% for all strategies, but stability varied: JIT kept levels stable; weekly deliveries caused large swings.
- **Net profit** ranged narrowly from £94.2K (JIT) to £98.4K (weekly).
- **Missed orders/revenue leakage** was highest under the weekly delivery strategy (1.99%/£10,986) and lowest under Hybrid A (0.60%/£1,232).
- Weekly replenishment had the lowest **logistical cost** due to fewer **inbound deliveries** (19 total) and higher **truck utilization** (70.5%)

Recommendations

Adopt a modified hybrid replenishment strategy (based on either A or B) where additional safety stock is held for product classes that are frequently sold out. This would improve utilization of warehouse capacity, boost truck utilization, and reduce missed sales without substantially increasing logistical costs.

Introduction

Efficient inventory management is essential for the long-term success of any business operation. Holding too little stock increases the risk of stock outs, which can lead to lost revenue, dissatisfied customers, and damage to brand reputation. Conversely, holding excess stock ties up working capital, drives up storage costs, and can reduce operational efficiency. Therefore, maintaining optimal stock levels requires a balance to ensure sufficient product availability without incurring unnecessary costs. This makes the choice of inventory replenish strategy a key driver of business performance and forms the basis of the present study.

This project explores how different replenishment strategies influence the daily operations of a B2C (business-to-consumer) distribution warehouse in a simulated environment. In this model, the warehouse purchases items in bulk from an upstream supplier, stores and manages inventory, and fulfils orders through daily outbound deliveries. This setup reflects a common B2C logistics model where distribution warehouses play a critical link between suppliers and end customers. To achieve this role, the warehouse must operate within a set of goals and constraints.

The main objectives are to achieve a high order fulfilment rate, maintain lean inventory levels, and ensure profitability. These goals are balanced against its limitations. The warehouse's maximum capacity is 2,000 units, outbound deliveries are made daily, and the demand patterns vary across product classes. Additionally, the vehicles used for inbound and outbound deliveries are subject to capacity limits and both storage and deliveries incur costs. Together, these factors create the operational frame within which the different replenishment strategies must perform.

These goals and constraints are informed by established principles in logistics and supply chain theory including inventory management models, ABC classification and demand forecasting. The next section explores the theoretical background to better contextualize the framework for the replenishment strategies tested in this project.

Theoretical Background

Effective inventory and cost management are essential for running an operation that balances service level with profitability. This section introduces four key concepts that together provide the framework for such an operation.

Lean Inventory Management

Changing the inventory levels can affect both revenue and operating costs. Optimizing the distribution of products can increase sales revenue by improving product availability, whereas reducing inventory as a whole can lower operating costs such as those from storage. Furthermore, more efficient inventory management can reduce labour requirements, further lowering operational costs. There are efficiency metrics that can indirectly measure these changes in revenue and operating costs.

One such metric is **Inventory Turnover Ratio** (ITR). This metric measures operational efficiency by comparing the cost of goods sold to the average value of the inventory and is defined as:

$$ITR = \frac{Cost\ of\ Goods\ Sold\ (COGS)}{Average\ Value\ of\ Inventory}$$

The formula above shows how inventory levels and product sales together influence profitability and operational efficiency. Holding inventory constant but selling more goods results in a higher ITR, and conversely, selling the same quantity of goods, while holding less inventory also increases the ITR. A high ITR generally means faster movement of goods and more efficient use of capital making it an important measure when evaluating lean inventory practices.

Lean inventory management aims to minimize waste, reduce costs and improve cash flow by only holding the necessary inventory to meet demand. It relies on continuous improvement, waste elimination, and using a **pull-based supply chain** (one where goods are only ordered or produced when required by the customer). A key method in achieving this is **Just-in-Time (JIT)** replenishment strategy where stock arrives only when it is needed. This will be explored in more detail alongside other replenishment strategies, demand forecasting and the impact of lead times on supply chain performance.

Inventory Replenishment Strategies

A business may use different methods to replenish inventory depending on the type of goods and needs of the market. Broadly speaking, there are three main stock replenishment methods:

1. Periodic Replenishment

2. Top-up Orders
3. Reorder Point (ROP) Orders

Periodic Replenishment is when orders are placed at a regular, fixed schedule (such as weekly or monthly) regardless of current stock levels. This is an example of a **push-based supply chain** because the products are ordered or produced in anticipation of consumer demand and not as a response to it. This is a simple and predictable method, but may result in stock outs or too much stock if there are fluctuations in demand.

Top-up Orders is when inventory is checked on a schedule (or during quiet periods) and the stock is topped up to a maximum level whenever it is below a pre-defined minimum. This is a **pull-based supply chain** because it is based on actual inventory consumption. This method reduces the risk of overstocking, but may still be vulnerable to stock out if demand spikes unexpectedly.

Finally, **Reorder Point (ROP) Orders** is when a replenishment order is triggered as soon as stock falls below a predefined reorder point. This is another example of a pull-based supply chain because it is reactive to actual consumer demand. ROP is well suited to a Just-in-Time (JIT) strategy and can make efficient use of inventory space. However it relies on good communication and quick transportation between the supplier and the receiver to meet demand.

While these methods form the foundations of inventory management, their effectiveness depends on how well business can account for variability in supply and demand. Key concepts that can influence replenishment include:

- **Safety stock** - Buffer inventory held to protect against unexpected spikes in demand.
- **Lead Time -** The period between placing an order and receiving it. This is important to consider when setting reorder points or order quantities.
- **Demand Forecasting -** Using historical data or trends to predict future demand.

In general, push based methods rely on forecasting to accurately predict the demand, whereas pull based methods respond to past demand. However, with no safety stock, accurate forecasting and short lead times, a pull-based system (particularly ROP) can operate as a JIT strategy by delivering exactly the right amount of stock precisely when it is needed.

Businesses typically stock many different products, each with a different demand pattern and value. Because of this, they may employ multiple replenishment strategies to ensure the right balance of availability and operational efficiency. One way to determine which strategy suits each product is through ABC inventory classification.

ABC Inventory Classification

ABC Inventory Classification is a way of categorizing products into three categories - A, B or C - based on their relative importance to the business. Following the **Pareto Principle**, it is often revealed that a small proportion of products (Class A products) account for a large proportion of total value, while a large percentage of low-value products (Class C products) contribute only a small proportion.

As high value goods, **Class A** products require stricter management and benefit most from JIT inventory replenishment. These goods tend to have a high and consistent demand. Conversely, **Class C** products do not require tight controls, and benefit from periodic restocking due to their sporadic demand. As an intermediary group, **Class B** products moderate-value items with variable demand. They require balanced inventory controls to avoid stock outs, but without the intensive management of Class A products.

In summary, ABC classification analysis helps businesses apply limited resources in the most efficient way by placing more attention on high-value products while still meeting the demand for low-value items.

Cost to Serve Modelling

Another way a business can optimize its supply chain operations is by considering **Cost to Serve (CTS) Modelling**. CTS represents the total cost incurred to deliver a product to a customer, including all direct and indirect costs. It can be calculated by product or by customer to identify which products or customers are the most profitable (or costly) to serve.

CTS gives a more nuanced breakdown of costs than simply examining the gross margin, enabling businesses to focus resources on the more profitable products or customers. Furthermore, it can identify which parts of the operation are driving up costs and can be optimized, as well as identifying products or customers that are unprofitable under current conditions and may not be worth pursuing.

In the context of this study, CTS is an important factor to consider when choosing a stock replenishment strategy. For example, a strategy might excel at meeting demand, but be too expensive to implement for certain products or suppliers making it less viable in practice.

Methodology

This study evaluates how different replenishment strategies meet the operational needs of a warehouse using simulated data. Simulation allows controlled scenario testing and fair comparisons between strategies, whereas detailed real-world warehouse operational data is rarely publicly available due to its sensitive nature. This section provides an overview of the data simulating process and any assumptions made. A more detailed step-by-step explanation, along with the code used, can be found in the Jupyter Notebooks in the GitHub repository.

The simulation models a small distribution warehouse for an e-commerce site over a 90-day period. The warehouse carries 15 different products evenly distributed over three pre-defined sale-speed categories . These groups differ in both sale-speed and profit margin which approximates a simplified ABC categorization framework (see Appendix A for full product details).

Inventory Flow

A key part of the simulation is **inventory flow** where products enter and leave the warehouse. For simplicity, it is assumed that each order consists of only one product. Inventory flow is modeled daily on a per product basis by considering:

1. Demand (the number of orders for each product)
2. Inventory level (the number of items remaining after considering inbound and outbound flows)
3. Outbound items (the actual number of items that leave the warehouse to meet demand)
4. Inbound items (the number of items delivered to the warehouse by the supplier)

Every day, the **demand** for each item is simulated stochastically to mimic customer orders. For each category of product, a different probability distribution is used to model different demand patterns. See Appendix B for more details of how demand is simulated for each product class.

Each day, the simulated demand is subtracted from the **inventory level** and the corresponding number is recorded as **outbound items**. If the demand exceeds the available inventory, the short fall is treated as missed sales and recorded as **unmet demand**.

The quantity and timing of **inbound items** depend on the replenishment strategy with two main approaches tested: weekly periodic replenishment and Just-in-Time (JIT). Both strategies assume a fixed lead time of three days. Under the **weekly deliveries** strategy, orders are placed every Friday and arrive the following Monday. In the **JIT strategy**, deliveries are triggered when inventory levels of a product fall below the reorder point. More details on each replenishment strategy are found in Appendix C.

In addition to the two main strategies, hybrid strategies were also considered. These strategies combine periodic replenishment with JIT to better align replenishment methods with product characteristics. In this framework, Class A products are replenished with JIT, Class C products by periodic deliveries, and Class B may follow either approach. The strategies are summarized in the table below.

Table 1: Replenishment method by product class and strategy

	Class A	**Class B**	**Class C**
Pure JIT	JIT	JIT	JIT
Hybrid A	JIT	JIT	Weekly
Hybrid B	JIT	Weekly	Weekly
Pure Weekly	Weekly	Weekly	Weekly

Warehouse Operations

Product-level data can be aggregated by day (and strategy) to provide an overview of total daily inventory flow in and out of the warehouse. From this aggregated table, **key performance indicators** (KPIs) can be calculated deterministically, including warehouse utilization, number of inbound and outbound shipments, delivery vehicle utilization, required human operatives to handle the workload, and the expected number of errors. These KPIs form the basis for comparing the effectiveness of different replenishment strategies in optimizing warehouse operations.

Warehouse utilization measures how much warehouse storage is currently occupied. It is defined as the proportion of total inventory relative to the maximum warehouse capacity. Importantly, the total inventory level cannot exceed the maximum warehouse capacity. A metric similar to warehouse utilization is **storage capacity utilization**, defined as the ratio of unit-days (the number of days units occupy storage) to the total available unit-days of the warehouse. This gives a more nuanced view of how the space is used over time.

Inbound and outbound shipments refer to the number of delivery vehicles, whether fully or partially loaded, that arrive or depart from the warehouse. **Vehicle utilization** is calculated as the ratio of items transported to the carrying capacity of the respective vehicle type.

Utilization metrics are important KPIs for operational efficiency. High utilization means more cost effective use of resources while lower utilization points to wasted space or excess overheads. See Appendix D for more details on warehouse and vehicle utilization.

The human side of the operation is captured through *staff count* and *error* columns. **Staff count** is the number of operatives needed for the amount of work. **Errors** represent avoidable mistakes made during shifts. In the model, the errors do not destroy items or delay shipments but do incur a small financial cost. These variables are included for completeness, but have minimal impact on the final conclusions. See the notebook for more details about how these are calculated.

Finances

Financial metrics are central to evaluating the success of a replenishment strategy. The product table (Appendix A) provides wholesale and retail prices, while the costs table (Appendix E) lists the operational costs. Together, these allow the calculations of key measures such as gross profit, net profit and cost to serve on a per strategy basis.

The following formulas are used in the analysis:

- $Gross\ Profit\ =\ Revenue\ -\ Cost\ of\ Goods\ Sold$
- $Net\ Profit\ =\ Gross\ Profit\ -\ Operational\ Costs$
- $Operational\ Cost\ to\ Serve\ =\ Net\ Profit\ \div\ Total\ Orders\ Fulfilled$

In the model, products retain the same profit margin across all strategies. To emphasize the differences between the competing strategies, this report uses **operational cost to serve** rather than the broader cost to serve measure.

Revenue leakage is also included as the total revenue lost due to stock not being available to fulfill orders.

Tools

The code for the simulation was written in Python (Jupyter Notebooks). Pandas handled table manipulation, while NumPy and SciPy generated the demand distributions. Visualizations were produced using Matplotlib and Seaborn. The final outputs were written to a PostgreSQL relational database using SQLAlchemy, and presented in a Power BI dashboard available here.

See Notebooks for full details.

Results

The result section evaluates the effectiveness of the four inventory replenishment strategies. The goal is to understand how each strategy affects profitability, order fulfillment and operational efficiency.

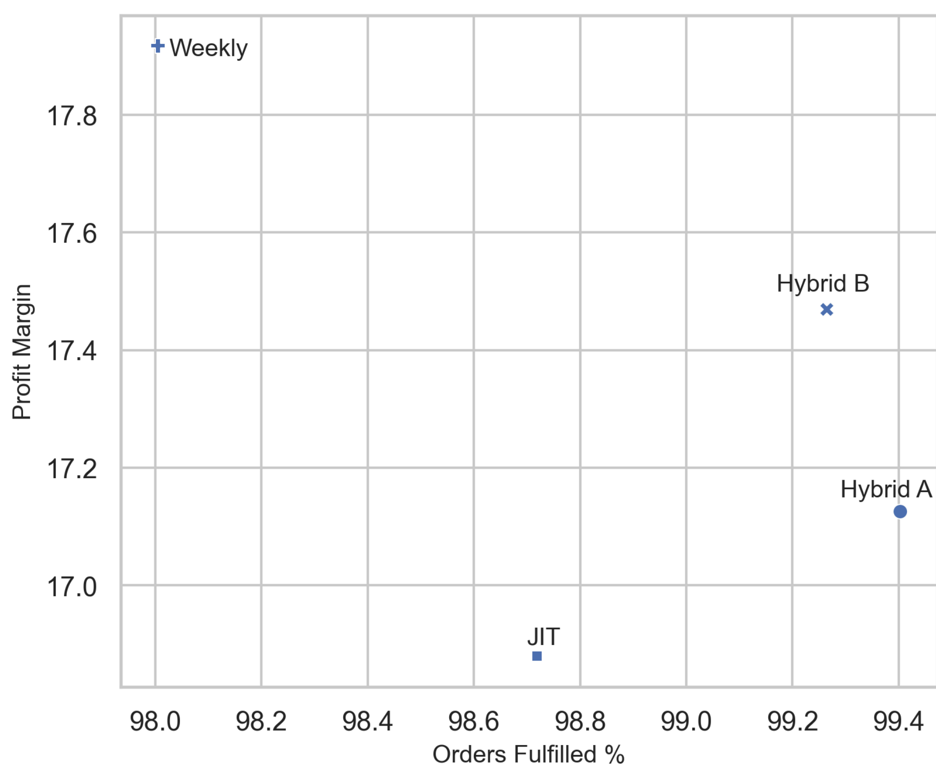
High Level Summary

The high level summary provides a broad overview of the effects of each strategy, focusing on both profitability and service level.

Table 2: Profitability and service level metrics by strategy

Strategy	Net Profit (£)	Revenue (£)	Profit Margin (%)	Fulfilled Orders	Fulfilled Orders (%)	Revenue Leakage (£)
JIT	94,199.89	558,071.00	16.9	13,559	98.7	2,230.00
Hybrid A	95,742.82	559,069.00	17.1	13,653	99.4	1,232.00
Hybrid B	97,625.70	558,851.00	17.5	13,634	99.3	1,450.00
Weekly	98,421.22	549,315.00	17.9	13,461	98.0	10,986.00

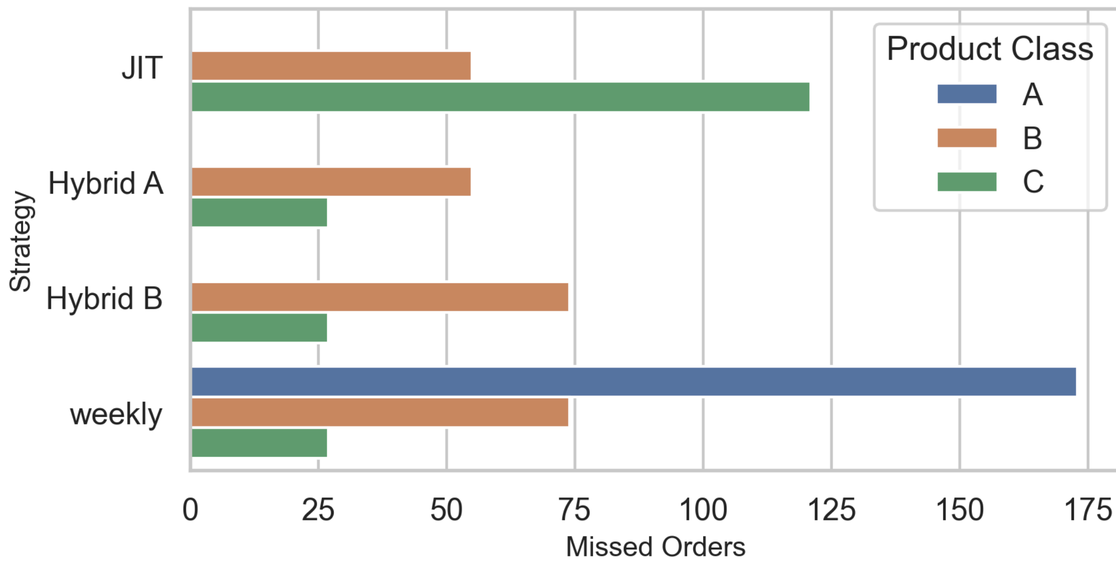
Chart 1: Profit margin by orders fulfilled



The *weekly* replenishment strategy achieved the highest profitability margin (17.9%) but resulted in the lowest service level (98% of demand met). *Hybrid A* provided the best service level (99.4% of demand met), while *Hybrid B* offered a good balance of profitability (17.5%) and service level (99.3% of demand met). In contrast, the pure *JIT* strategy underperformed on both metrics with below average service level (98.7% of demand met) and low profitability (16.9%).

Under ABC inventory management not all missed sales are equal. The chart below shows missed orders by product class per strategy

Chart 2: Missed orders by product class



Not only are most orders missed under the *weekly* strategy, most of these orders are for high value Class A products. This drives a disproportionate revenue leakage because each missed Class A product represents a significant loss making it unsuitable choice. The *JIT* strategy is well suited to the demand of Class A products, but does not adequately keep up with the demand for the low-value Class C products. Therefore, the hybrid strategies perform the best overall. However, under every strategy there are missed sales indicating that some adjustments are necessary to meet demand completely.

Operational Efficiency

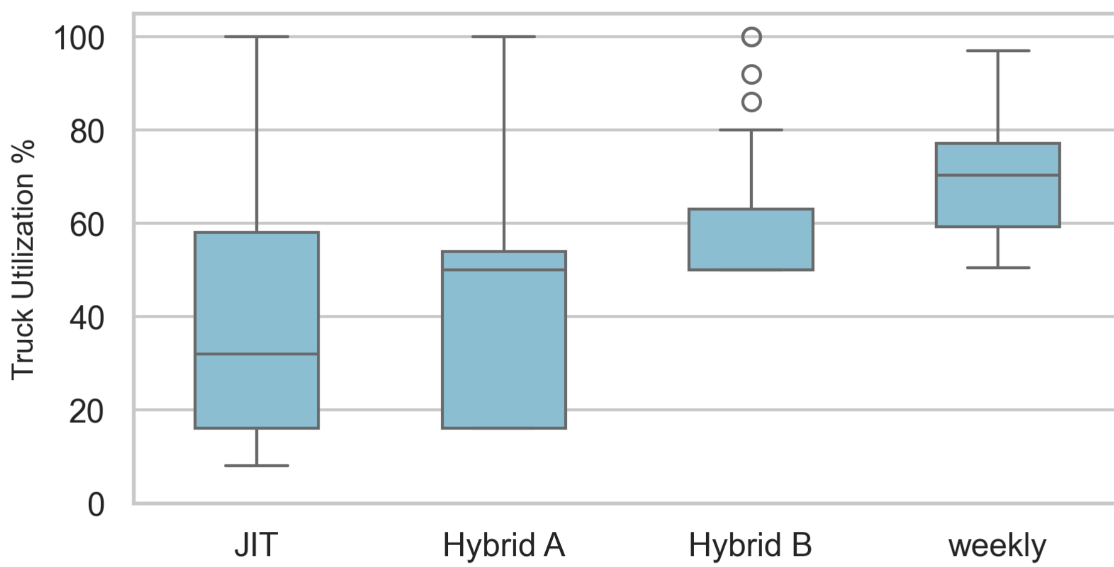
Despite having the lowest revenue, the *weekly* strategy achieved the highest profit. This indicates the lower logistical costs outweighed the revenue difference, meaning more efficient resource utilization.

Table 3: Operational efficiency by strategy

Strategy	Total Inbound Units	Inbound Shipments	Average Units per Shipment	Avg. Truck Utilization (%)	Avg. Warehouse Utilization (%)
JIT	12,910	66	195.6	38.1 ± 24.3	55.7 ± 9.7
Hybrid A	13,100	58	225.9	44.1 ± 23.1	54.0 ± 9.2
Hybrid B	13,080	43	304.2	60.0 ± 15.1	56.1 ± 11.3
Weekly	12,730	19	670.0	70.5 ± 14.1	54.4 ± 19.0

Under the *weekly* replenishment strategy, the products are consolidated into fewer fuller shipments (19 shipments) which reduces the shipping costs. However, this approach also concentrates risk and leaves the operation vulnerable to stock outs towards the end of the week. **Note**: the trucks for *weekly* are larger than those of the other strategies (see Appendix D).

Chart 3: Truck utilization by strategy



The *weekly* strategy is more efficient at consistently utilizing inbound truck space (average utilization 70.5%). *JIT* and *Hybrid A* are the worst performing, but also vary the most. This presents the opportunity to leverage underutilized trucks by including extra safety stock selectively. This will smooth out variability without incurring significant extra costs.

Across all the strategies, the warehouse was underutilized (average around 55%). However, the *weekly* strategy shows more variation over the simulation period. This is consistent with periodic replenishment where the stock arrives at the beginning of the week and inventory levels peak before depleting over the course of the week. The *JIT* and *Hybrid A* (more JIT-aligned) strategies are more consistent with smaller, targeted replenishment occurring throughout the week.

Inventory Turnover Ratio (ITR) and Missed Sales are shown in the table below. Hybrid strategies are combinations of the two pure strategies and are therefore omitted to avoid repetition.

Table 4: ITR and missed sales by product class and strategy

	A		**B**		**C**	
Strategy	**ITR**	**Missed Sales (%)**	**ITR**	**Missed Sales (%)**	**ITR**	**Missed Sales (%)**
JIT	10.5	0.00	16.4	1.49	15.1	6.57
Weekly	12.7	2.11	13.4	2.01	9.7	1.47

Under the *JIT* strategy, ITR is generally higher, though Class C products perform better under the *weekly* strategy. ITR is also artificially inflated by frequent stock outs, indicating some products were consistently understocked. In practice, lean principles prioritize meeting demand over maximizing the turnover ratio, so the preferred strategy is the one that minimizes missed sales, even if it lowers ITR.

From this perspective, the *Hybrid A* strategy (*JIT* for A and B, *weekly* for C) performs the best. Nonetheless, it is not necessarily a matter of lowering ITR to reduce missed sales. With appropriate order quantities, reorder points and safety stock, it may be possible to maintain a lean inventory while still meeting demand. This achieves a balance between efficiency and service level.

Operational Costs

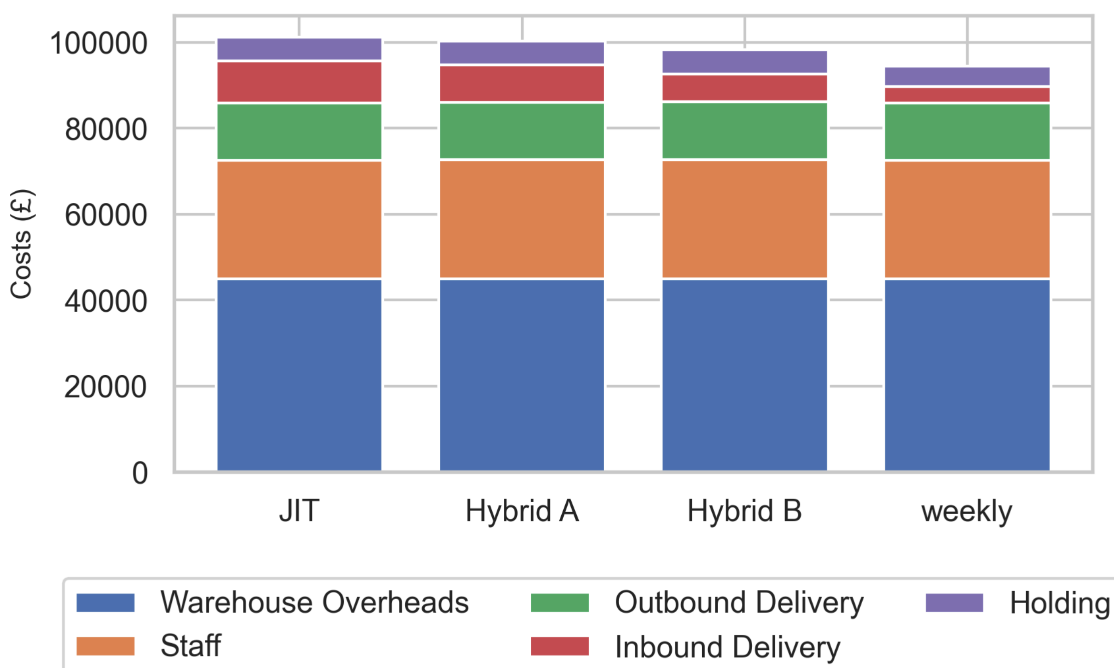
While operational efficiency shows how efficiently the operation was managed, it does not capture the full picture. Every part of the order fulfillment procedure carries an associated cost.

Table 5: Logistical costs and CTS by strategy

Strategy	Fulfilled Orders	Logistical Costs (£)	Missed Profit (£)	Cost to Serve (£)	Adjusted Cost to Serve (£)
JIT	13,559	101,707	1,385.50	7.50	7.60
Hybrid A	13,653	100,856	693.50	7.39	7.44
Hybrid B	13,634	98,869	797.50	7.25	7.31
Weekly	13,461	95,057	3,814.50	7.06	7.35

Logistical costs are lowest under the *weekly* strategy (£95,057) and highest under the *JIT* strategy (£101,707). This difference is driven by the frequency of inbound shipments, with *weekly* having the fewest (19) and *JIT* having the most (66). The break down of costs is shown below (errors are omitted from the chart because they were negligible):

Chart 4: Logistical cost break down by strategy



The single largest expense is warehouse overheads (representing rent, utilities and machinery) which is fixed across all strategies. The other major expenses are staffing costs and outbound deliveries which vary only slightly (less than 1%) between strategies.

The difference in expenditure between strategies is mainly shown by the inbound delivery costs (ranging from £3,800 and £9,900 for *weekly* and *JIT* respectively), and to a lesser extent inventory holding costs (between £4,832 for *weekly* and £5,664 for *Hybrid B*). This reduction in costs enables the *weekly* strategy to be more profitable while turning over less money. However, this increased profitability comes at the expense of service level, and is not conducive for healthy long-term growth.

Operational cost to serve is defined as the average operational cost of fulfilling an order, excluding COGS to focus on efficiency. Despite fulfilling the fewest orders, the *weekly* strategy is the cheapest (£7.06) due to its lower overall shipping frequency. *JIT* is the most expensive strategy (£7.50) due to frequent inbound deliveries. The hybrid strategies fall between these two extremes with *Hybrid A* (£7.39) being slightly more expensive than *Hybrid B* (£7.25).

However, operational cost to serve alone does not capture the impact of missed sales. Adjusted cost to serve incorporates service level by penalizing strategies that leave revenue unrealized.. *Weekly* is the most affected (£7.06 → £7.35) due to the high share of missed Class A sales. After service level is considered, *Hybrid B* emerges as the cheapest option (£7.31), striking a good balance between logistical efficiency and service level.

Table 6: Cost structure by strategy (% of revenue)

Strategy	COGS	Operations	Net Profit
JIT	64.9	18.2	16.9
Hybrid A	64.8	18.0	17.1
Hybrid B	64.8	17.7	17.5
Weekly	64.8	17.3	17.9

Overall, operational costs do not make up a significant portion of revenue and vary only slightly between strategies. Since most costs are fixed (e.g. warehouse overheads), the priority should be to utilize resources more effectively, even if this slightly increases operational costs. Doing so ensures a higher level of service and reduces missed sales which is overall better for the business than cutting operational costs.

Final Summary

The purpose of this investigation was to examine how four different replenishment strategies affected the operations of a small distribution warehouse over a 90 day period. The warehouse had a fixed storage capacity of 2,000 units which served as a key constraint. Efficient use of this limited capacity was important to meeting demand and minimizing missed sales. Underutilizing the space, especially when stock outs occurred, represents mismanagement of resources as the fixed cost of operating the warehouse remained constant no matter how much capacity was used.

Table 7: Storage capacity utilization and missed sales by product class and strategy

	Storage Capacity Utilization (%)				Missed Sales			
Strategy	**A**	**B**	**C**	**Total**	**A**	**B**	**C**	**Total**
JIT	39.0	11.1	5.7	55.7	0	55	121	176
Hybrid A	39.0	11.1	9.4	59.5	0	55	27	82
Hybrid B	39.0	13.4	9.4	61.8	0	74	27	101
Weekly	31.6	13.4	9.4	54.4	173	74	27	274

Across all strategies, the warehouse operated below optimal stock levels (54.4 - 61.8%). While different strategies reduced missed sales to different degrees, the overall number of missed sales remained high compared to available storage (82-274). This indicates that understocking is a significant constraint in the operation.

Under the most successful replenishment strategy, *Hybrid A*, the stock of Class A products (39% of capacity) was enough to fully meet customer demand. However, Class B and Class C products were understocked (11.1% and 9.4% of capacity respectively) resulting in missed sales. This highlights an opportunity to improve fulfilment without exceeding storage capacity. With minor adjustments, such as holding more safety stock and ordering larger quantities, the warehouse could have met total demand without a significant increase in costs. Doing so would reduce the effective cost to serve per order by spreading fixed warehouse overheads across a larger volume of fulfilled sales.

Although the periodic replenishment strategy stocked slightly more Class B products than the JIT strategy (13.4 vs. 11.1), there were also more missed sales under this strategy (74 vs 55). This underscores the importance of adjusting replenishment strategies to meet both the available storage and demand patterns.

Conclusion

The purpose of the simulation was to examine how the choice of replenishment strategy impacted the operations of a small distribution warehouse with fixed capacity. Performance was evaluated across key metrics such as warehouse utilization, order fulfillment, net profit and cost to serve. The strategies tested were push-based periodic deliveries, pull-based JIT-style deliveries and two hybrid strategies which combined elements of both strategies based on product class.

The strategies that performed the best were the hybrid strategies with *Hybrid A* (JIT for Classes A and B, Periodic for C) meeting demand most consistently and *Hybrid B* (JIT for Class A, Periodic for Classes B and C) offering the best balance between profitability and service level. This shows that JIT is important for high value products while low value products benefit most from periodic replenishment. Class B products were handled better by JIT, but at the expense of increased operational costs.

However, these strategies could be improved. The warehouse capacity was underutilized across all strategies despite the fixed costs. Holding more stock could raise service level and profitability without major extra costs. Achieving consistent utilization first ensures the business grows into its existing resources, providing a stronger basis for future expansion rather than scaling operations down to meet the current demand.

Furthermore, this investigation relied on heuristically derived order quantities and reorder points, but in practice more systematic approaches could be applied. For example, techniques such as **Economic Order Quantity** (EOQ), safety stock calculations and dynamic reorder points could allow finer control over inventory levels. Incorporating these parametres into the simulation would likely further optimize warehouse operations.

Limitations

There are some limitations to the strength of these conclusions. The model was a simulation with simplifications and not based on empirical data. Each product belonged to a product class with all members of that class sharing the same demand patterns with no variation throughout the simulation period. Furthermore, lead times never deviated and were consistent every time and there was no risk of disruptions. The simulation also did not allow for order delays, with any order not being fulfilled on the day counted as a missed order. Costs such as transport, staffing and warehouse overheads were treated as fixed and linear whereas in practice they may scale non-linearly. These simplifications mean that the results are best viewed as indicative of general trends rather than precise operational forecasts.

Future Expansion

The current simulation provides a basic framework that can be expanded on to better model reality.

A future version of the simulation may contain:

- A larger and more realistic product range. Increase the number of SKUs from 15 to 100, with uneven product classes (15 for Class A, 35 for Class B and 50 for Class C). Demand distributions would partially overlap rather than forming three distinct bands creating a more representative demand structure.
- Variable demand patterns. Introduce product level demand fluctuations and more in depth seasonality, trends and random shocks to demand to model real-world uncertainty.
- Stochastic lead times and disruptions. Allow delivery times to vary and include the possibility of late shipments. This would test strategy resilience.
- Order delays. Instead of counting all unfulfilled orders as lost, incorporate the option of fulfilling back orders. Also allow orders to be deferred to the next day if vehicle capacity is exceeded to avoid dispatching an additional truck or van for a small amount of orders.
- Economic Order Quantity (EOQ) and other optimizations. Replace heuristic order quantities with formal inventory models allowing strategies to be fine-tuned.
- Improved demand forecasting. Replace the seven-day moving average with more sophisticated methods (e.g. exponential smoothing, ARIMA or machine-learning) to allow strategies to anticipate demand more accurately.

Appendices

Appendix A - Product Details

Table 8: Product information

Product ID	Product Name	Wholesale Cost (£)	Retail Price (£)	Storage Cost per Day (£)	Product Class
P001	Bluetooth Headphones	28.00	40.00	0.07	A
P002	4K Streaming Stick	36.00	55.00	0.05	A
P003	Smartwatch Lite	50.00	74.00	0.06	A
P004	Budget Tablet	52.00	75.00	0.08	A
P005	Mini Speaker	35.00	50.00	0.06	A
P006	Wireless Mouse	12.00	24.00	0.04	B
P007	Leather Phone Case	8.00	16.00	0.03	B
P008	USB Hub	8.00	17.00	0.03	B
P009	Laptop Sleeve	9.00	18.00	0.04	B
P010	Stylus Pen	7.00	14.00	0.03	B
P011	Webcam Privacy Cover	3.00	10.00	0.02	C
P012	Screen Cleaning Cloth Pack	3.00	12.00	0.02	C
P013	Phone Stand	3.50	11.00	0.03	C
P014	Sticker Pack	4.00	14.00	0.01	C
P015	Pack of 12 Pencils	2.50	8.00	0.02	C

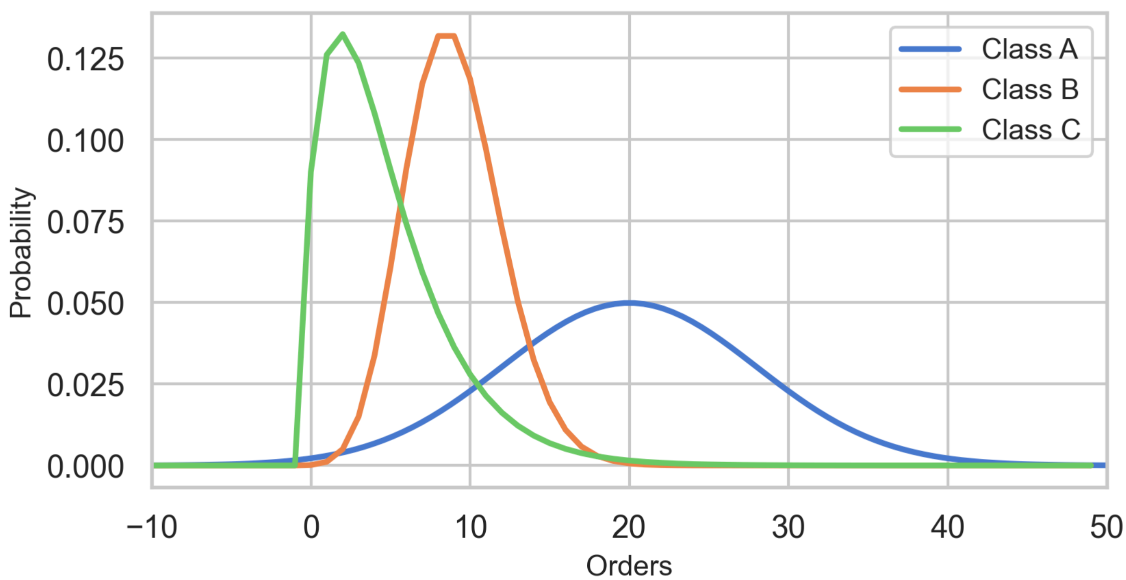
Appendix B - Demand Distributions

The daily demand for each product are calculated from the following probability distributions:

- Fast moving products (analogous to Class A) are drawn from a normal distribution, representing high and consistent demand.
- Medium moving products (Class B) are drawn from a Poisson distribution to reflect a steady but lower demand.
- Slow moving products (Class C) are drawn from a negative binomial distribution. This shows low and erratic demand.

It is important to note that these distributions do not perfectly replicate real demand but provide a reasonable framework for distinguishing between product classes. Furthermore, all items within a class share the same demand behaviour to allow clearer comparisons between strategies. In the real world, demand patterns can differ even within the same ABC class.

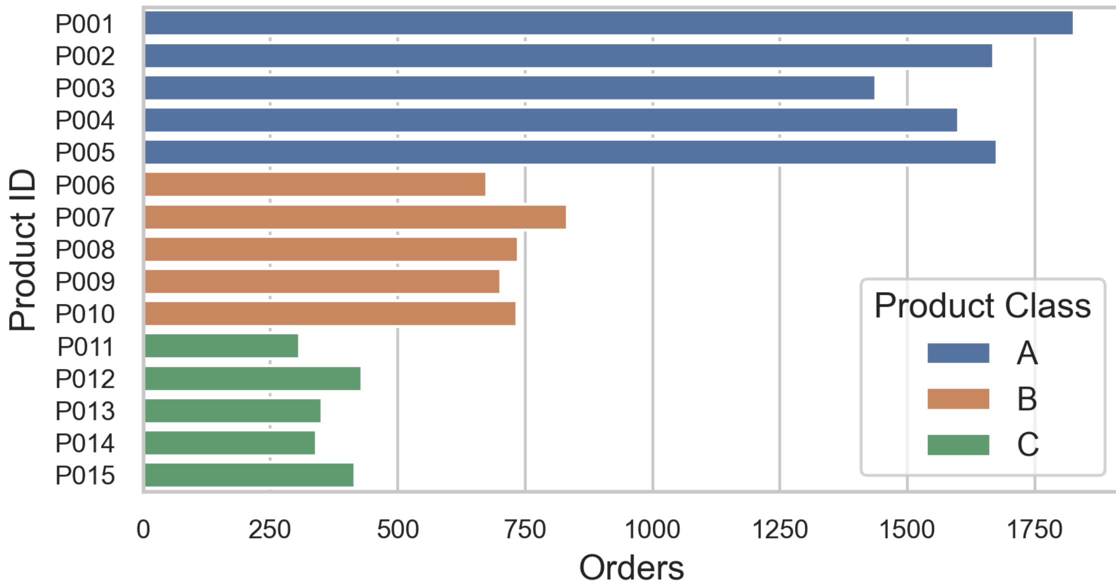
Chart 5: Base demand distributions



To introduce variation, each product's daily demand has a 10% chance of being either 20% bigger or 30% smaller than its expected value. The base distribution is further modified by adding a smaller normal distribution centred around zero to simulate day-to-day fluctuations in demand. Additionally, demand is more likely to be higher in the first week and lower in the last week of each month. Importantly, the final demand cannot be negative and must be at least zero. Together, these modifications create more unpredictable demand patterns that better reflect real-world scenarios.

The generated demand for each product is shown in the chart below:

Chart 6: Total orders per product ID



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Appendix C - Replenishment Strategies

For **weekly deliveries**, the order quantity is seven times the seven-day moving average of demand as of the order date (simulating demand forecasting), rounded up to the nearest ten to simulate minimum order quantities.

For the **JIT strategy**, the reorder point for each product is set to 35% of its initial stock. The order quantity depends on the products' ABC category: 250 units for Class A, 80 units for Class B and 40 units for Class C. These numbers were chosen heuristically as a starting point and could be further optimized.

Note on terminology: The JIT strategy outlined here follows the JIT principle of replenishing stock in response to demand rather than on a fixed schedule. However, it is more accurately a reorder point model with safety stock. This type of model i s often used as a practical approximation of JIT in situations where perfect synchronization between supply and demand cannot be achieved.

Appendix D - Warehouse and Logistics Assumptions

In the simulation, the warehouse has a total storage capacity of 2,000 units. For modelling purposes, it is assumed that all products are the same size (i.e. one unit). Therefore, daily warehouse utilization is calculated as the total items in inventory divided by 2,000.

For **outbound shipments**, orders are dispatched in vans that have a carrying capacity of 100 units each. It is assumed that sufficient vans are always available. This represents a flexible contractor system where vans are hired as needed with each contractor providing their own vehicle.

For **inbound shipments**, the vehicle type depends on the replenishment strategy. The weekly consolidated deliveries use large trucks with a capacity of 1,000 units, whereas other strategies use smaller trucks with carrying capacities of 500 units. The cost of delivery with a larger truck is £200, whereas the smaller one is £150, making the larger trucks more economical when fully loaded.

There is also no order deferral in the simulation. This means that all inbound and outbound units will ship regardless of how well they utilize vehicle space. For example, 101 outbound units will require 2 vans to ship. In reality, the extra order would be deferred until the next day to make better use of resources.

Appendix E - Financial Costs

Table 8: Costs associated with each item

Item	Cost (£)
Error	5
Worker (per day)	120
Outbound delivery contractor	75
Large truck delivery	200
Small truck delivery	150
Warehouse overheads (per day)	500