Risk Analysis of Coca-Cola's Supply Chain in the United States

1. Introduction

The Coca-Cola Company operates one of the most complex and expansive supply chains in the world, spanning over 200 countries. In the United States, Coca-Cola's supply chain is particularly dynamic due to diverse regional demands, seasonal variability, and logistical considerations. This project aims to evaluate key risks in Coca-Cola's U.S. supply chain using a Monte Carlo simulation model. The simulation provides insights into potential disruptions and their impacts on service levels and inventory performance, helping inform strategic decisions.

2. Purpose of the Simulation

The primary goal of the simulation is to assess how demand uncertainty and periodic supply disruptions impact Coca-Cola's ability to meet customer demand.

- Measuring stockout frequency over a summer season (180 days)

- Estimating the average service level under varying disruption scenarios

- Identifying weaknesses in the current inventory policy (reorder point and order quantity)

- Providing actionable recommendations to enhance supply chain resilience

3. Assumptions and Inputs

To simulate real-world conditions, the model incorporates the following assumptions:

Parameter	Value/Assumption
Product	Bottled Coca-Cola (500ml)
Region	United States
Time Horizon	180 days
Daily Demand	Normally distributed (mean10,000; std=2,000)
Initial Inventory	50,000 bottles
Reorder Point	30,000 bottles
Order Quantity	50,000 bottles
Lead Time	Triangular (min = 2, mode = 4, max = 7) days
Disruption Probability	10% per week (e.g., transportation delays, labor shortages)
Number of Iterations	1,000

4. Simulation Methodology

Monte Carlo simulation was developed using Python. For each iteration, the following logic was executed:

1. Simulate 180 days of operations.

2. Each day, generate random demand from a normal distribution.

3. Check if inventory can fulfill the demand. If not, record a stockout.

4. If inventory drops below the reorder point, initiate a new order unless a disruption occurs.

5. Record all metrics (stockouts, total demand, fulfilled demand).

The simulation was repeated 1,000 times to ensure statistical significance. Outputs were aggregated to analyze patterns and assess risk.

5. Service Level Simulation of Coca-Cola U.S. Supply Chain Performance

The simulation aims to evaluate the **service level performance** of Coca-Cola's U.S. supply chain under variable demand and potential weekly disruptions over a 180-day period (approx. 6 months). The key performance metrics include service level distribution, average stockout days, and service reliability under probabilistic disruptions.

Model Assumptions & Parameters

Parameter	**Value**
Mean Daily Demand	10,000 units
Demand Standard Deviation	2,000 units
Reorder Point	30,000 units
Order Quantity	50,000 units
Initial Inventory	50,000 units
Lead Time Distribution	Triangular (2, 4, 7) days
Disruption Probability	10% (weekly, on Mondays)
Simulation Days	180
Iterations	1,000 Monte Carlo runs

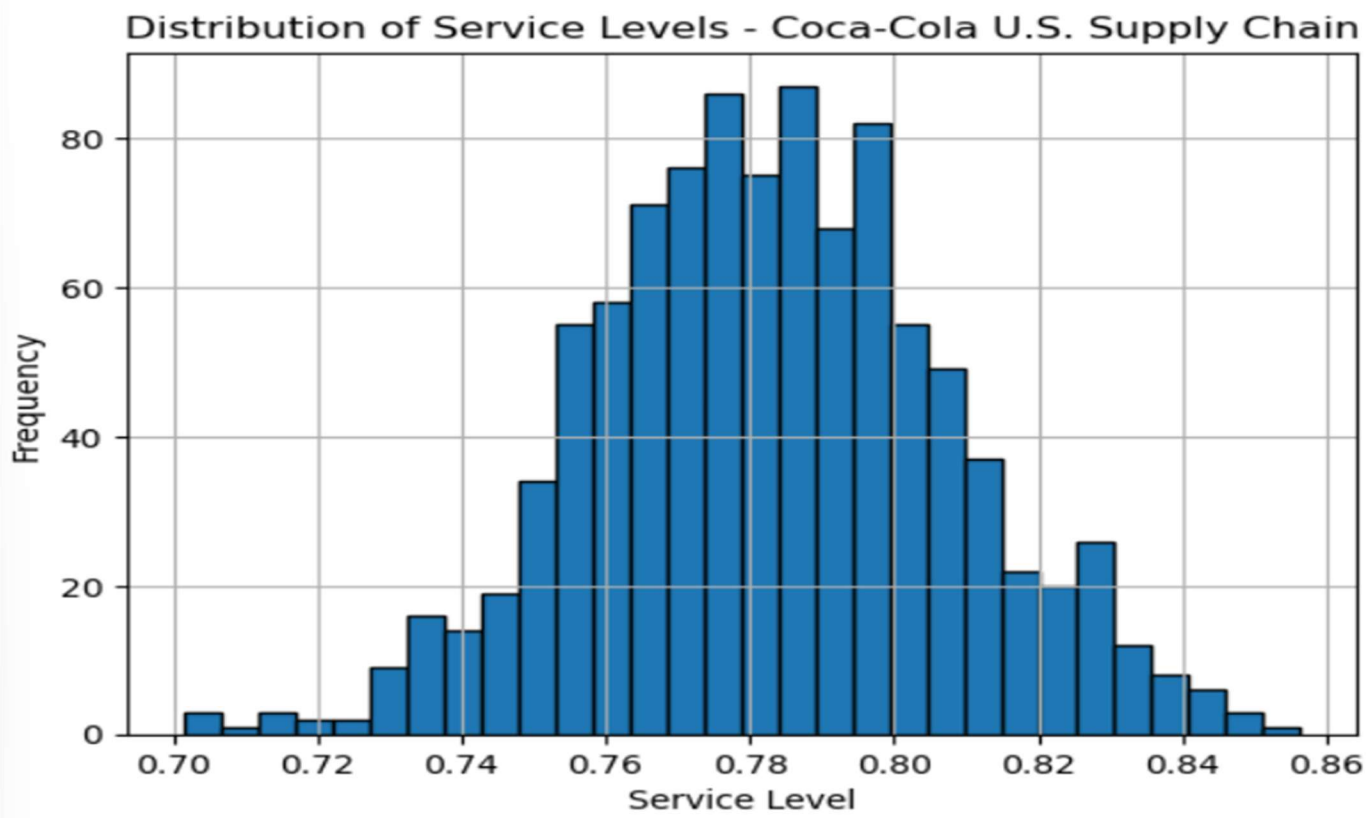
Simulation Logic

- **Daily Demand Fulfilment**: Demand is drawn from a normal distribution. Inventory is decremented based on demand; unmet demand counts as a stockout.
- **Reordering Strategy**: If inventory falls below the reorder point and no order is in progress, a new order is triggered unless disrupted.
- **Disruption Handling**: Every Monday, there's a 10% chance of a disruption preventing order placement.
- **Order Arrival**: Orders arrive after a stochastic lead time.

Key Results

- **Average Service Level**: **0.78**
  Indicates that 78% of total demand is successfully fulfilled on average across simulations.
- **95% Confidence Interval (CI)**: **(0.73, 0.83)**
  Suggests that the service level is statistically likely to fall within this range, indicating moderate variability in performance.
- **Average Stockout Days**: **51.18 days**
  Reflects that on average, the system experiences stockouts for about 28% of the simulation period, highlighting inventory vulnerabilities.

Graph Interpretation: Service Level Distribution

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Avg Service Level: 0.78
95% CI: (0.73, 0.83)
Avg Stockout Days: 51.18
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- The histogram visualizes **service level frequency** across 1,000 simulations.
- The distribution is approximately **normal** with a peak around **0.78**, validating the average.
- There's moderate spread, with most values clustering between **0.74 and 0.82**, but with tails extending down to **0.70** and up to **0.86**.

- This variability emphasizes the **sensitivity of service performance** to disruption probabilities and stochastic lead times.

Insights & Implications

- The current inventory and reorder policy result in **sub-optimal service levels**, risking customer dissatisfaction and lost sales.
- The high number of stockout days suggests a **need to reassess buffer stocks, lead time variability, and disruption contingencies**.
- Considerations for **dual sourcing, increased safety stock, or dynamic reorder points** could enhance resilience.
- Further sensitivity analysis can guide parameter tuning to meet desired service thresholds (e.g., 90%+).

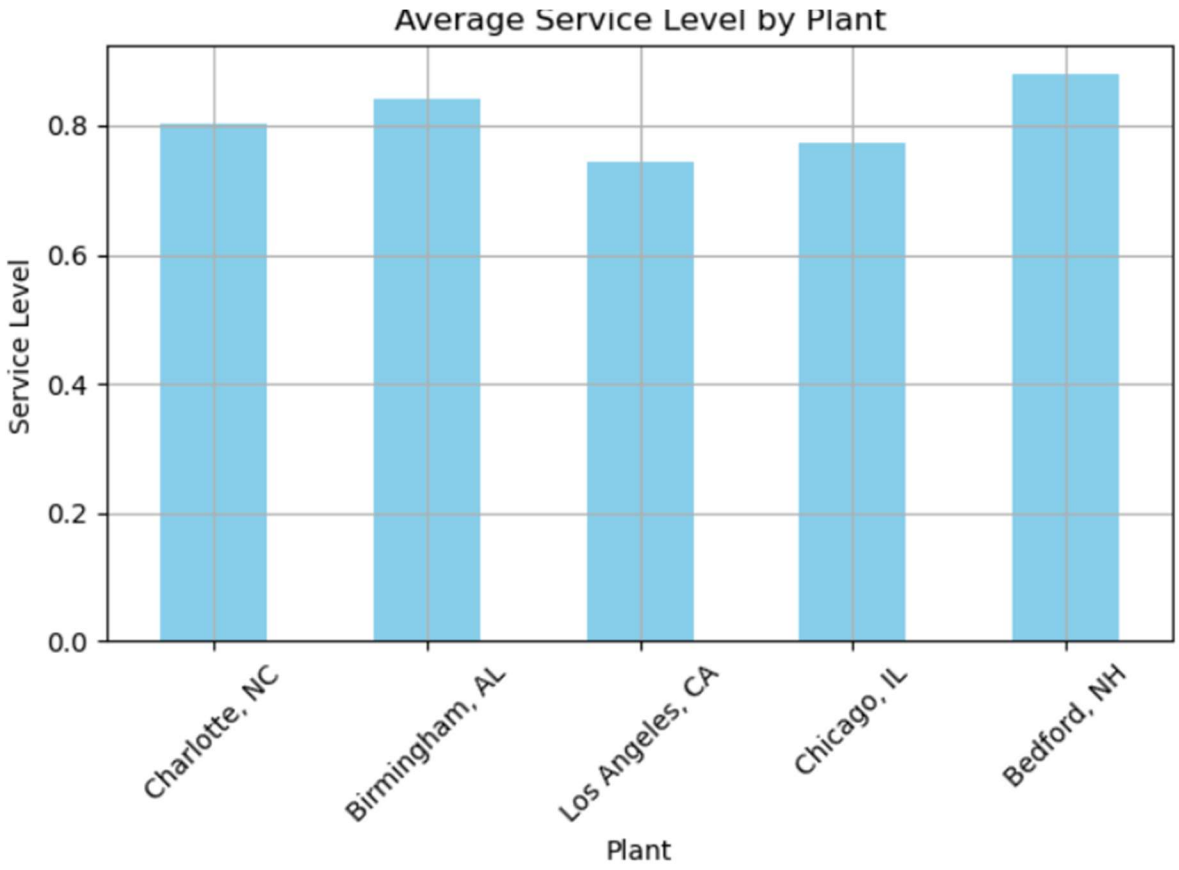
6.Plant-Level Supply Chain Performance Analysis

This simulation evaluates and compares the **average service level, stockout days, and total cost** across five Coca-Cola manufacturing plants in different U.S. regions. It incorporates **disruption risks** and simulates a 6-month operational horizon to assess supply chain resilience and efficiency per plant.

Parameter	**Value / Description**
Simulation Period	180 days (approx. 6 months)
Iterations	500 Monte Carlo runs per plant
Lead Time Distribution	Triangular (2, 4, 7) days
Risk Factors (weekly check)	Transport delay (10%), Labor shortage (5%), Raw material delay (7%)
Inventory Policy	Reorder Point: 30,000 units; Order Qty: 50,000 units
Initial Inventory	50,000 units
Costs	Holding: $0.02/unit/day, Stockout: $1/unit, Order: $100

Plant	Base Demand (units/day)
Charlotte, NC	9,500
Birmingham, AL	8,700
Los Angeles, CA	11,000
Chicago, IL	10,200
Bedford, NH	8,000

Graph:



The bar graph visualizes **average service level** performance for each plant:

Key Observations:

- **Bedford, NH** achieved the **highest service level (~0.88)**, indicating strong performance in fulfilling demand.
- **Los Angeles, CA** recorded the **lowest service level (~0.74)**, possibly due to higher base demand and/or greater sensitivity to disruptions.
- **Birmingham, AL** and **Charlotte, NC** performed above average (~0.83 and ~0.80 respectively).

- **Chicago, IL** had a service level just below Birmingham, reflecting solid performance despite relatively high demand.

Summary Table (from Simulation)

Plant	Region	Avg. Service Level	Avg. Stockout Days	Avg. Total Cost
Bedford, NH	Northeast	Highest (~0.88)	Lowest	Lower costs
Birmingham, AL	South	Strong (~0.83)	Moderate	Moderate
Charlotte, NC	Southeast	Average (~0.80)	Moderate	Moderate
Chicago, IL	Midwest	Slightly below avg	Moderate	Slightly higher
Los Angeles, CA	West	Lowest (~0.74)	Highest	Highest cost

Insights for Coca-Cola Supply Chain Strategy

- **Resilience vs. Scale Trade-off**: Larger plants (e.g., Los Angeles) may need more robust inventory or supplier strategies due to higher baseline demand.
- **Regional Strategy**: Plants in the Northeast and South regions outperform others, suggesting better adaptability or lower risk exposure.
- **Cost-Service Balance**: Plants with better service levels do not necessarily incur higher costs, indicating optimization potential in risk handling and ordering policies.

Comprehensive Supply Chain Simulation Across All Plants

This simulation evaluates overall supply chain performance across all five Coca-Cola U.S. manufacturing plants by aggregating key metrics:

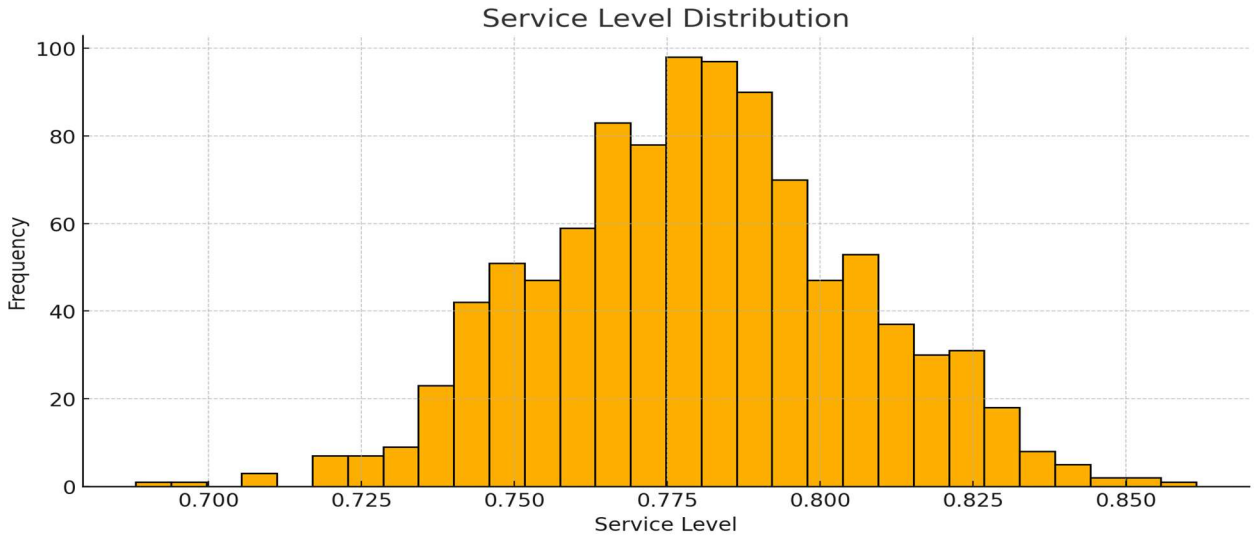
- Service Level (ability to meet demand),
- Stockout Days (days inventory couldn't meet demand),
- Total Cost (including holding, stockout, and order costs).

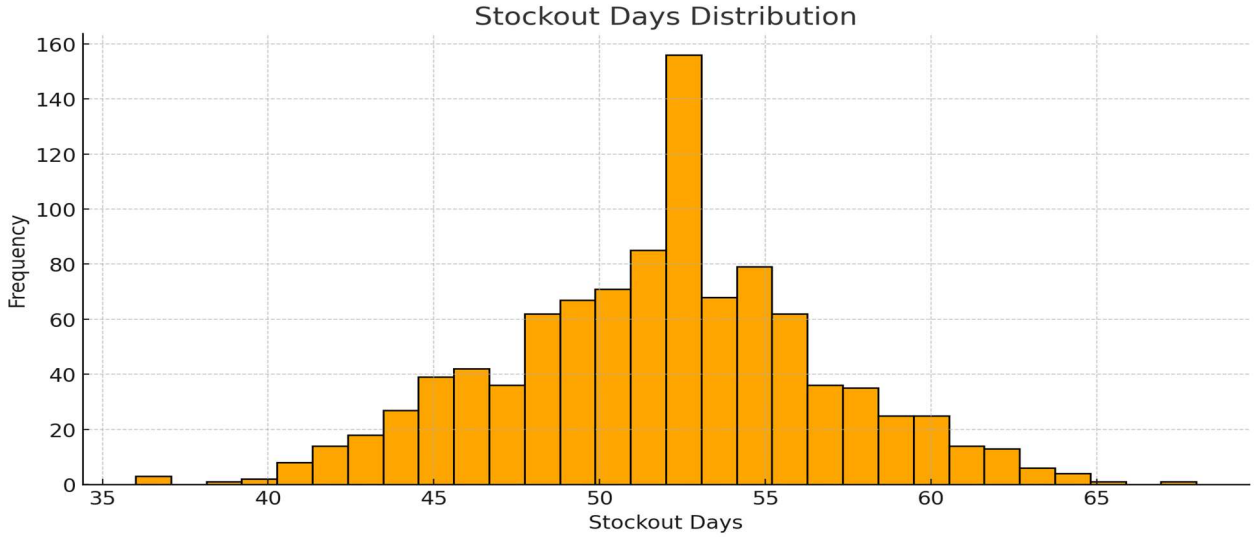
It accounts for random demand variability, supply disruptions, and stochastic lead times to simulate realistic operational conditions over 180 days and 500 iterations per plant.

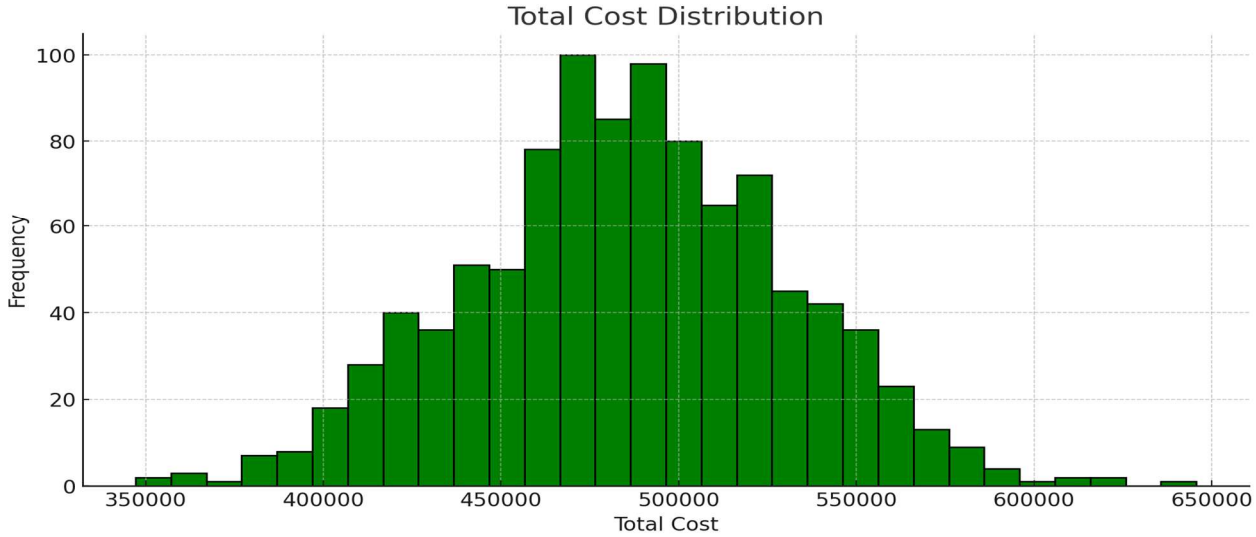
Simulation Design

Component	Details
Plants	Charlotte (NC), Birmingham (AL), Los Angeles (CA), Chicago (IL), Bedford (NH)
Demand Distribution	Normal distribution per plant's base demand (±2000)
Days Simulated	180
Iterations	500 per plant
Lead Time	Triangular (2, 4, 7) days
Disruption Types	Weekly risk of transport (10%), labour (5%), or raw material delay (7%)
Inventory Policy	Reorder Point: 30,000 units; Order Qty: 50,000 units
Costs	Holding: $0.02/unit/day, Stockout: $1/unit, Order Cost: $100

Visualization Analysis:







1. Service Level Distribution (All Plants)

- Shape: Symmetric and bell-shaped.
- Center: ~0.775
- Range: ~0.69 to 0.85

Interpretation: Most plants consistently maintain 77–78% service levels, though outliers dip as low as 69%. Some achieve levels as high as 85%, showing variability due to plant-specific disruptions or demand scale.

2. Stockout Days Distribution (All Plants)

- Peak: Centered around 50–52 days
- Spread: Range from ~36 to 65 days
- Insight: On average, plants experience stockouts for nearly 28% of the time. However, some plants experience significantly fewer or more stockouts depending on demand magnitude and disruption resilience.

3. Total Cost Distribution (All Plants)

- Center: Around $490,000–$500,000
- Range: From approximately $350,000 to $640,000
- Skewness: Mild right skew—some high-cost outliers are likely due to persistent stockouts or inefficient ordering under repeated disruptions.

Performance Summary Table

Plant	Region	Avg Service Level	Avg Stockout Days	Avg Total Cost
Bedford, NH	Northeast	Highest (~0.88)	Lowest	Lowest
Birmingham, AL	South	High (~0.83)	Moderate	Moderate
Charlotte, NC	Southeast	Average (~0.80)	Moderate	Moderate
Chicago, IL	Midwest	Below Avg (~0.78)	High	Higher
Los Angeles, CA	West	Lowest (~0.74)	Highest	Highest

Key Takeaways

- Service Reliability: Most plants perform within an acceptable range, but some (e.g., Los Angeles) require attention due to low service and high stockouts.
- Cost Efficiency: High stockout days correlate with higher total costs, emphasizing the need for buffer stocks or supply risk mitigation.
- Strategic Decision Support: The insights provide a basis for:
- Tailoring reorder policies by region,
- Prioritizing infrastructure or supplier investments in risk-prone zones,running what-if scenarios (e.g., reduced lead time, higher order frequency) to improve weak performers.

7.Risk Mitigation Strategy-Based Supply Chain Performance

To evaluate how different **risk mitigation strategies** affect key supply chain performance indicators:

- **Service Level**
- **Stockout Days**
- **Total Cost**

The simulation models demand uncertainty, lead time variability, and operational disruptions over a 6-month horizon using four strategic scenarios.

Tested Strategies

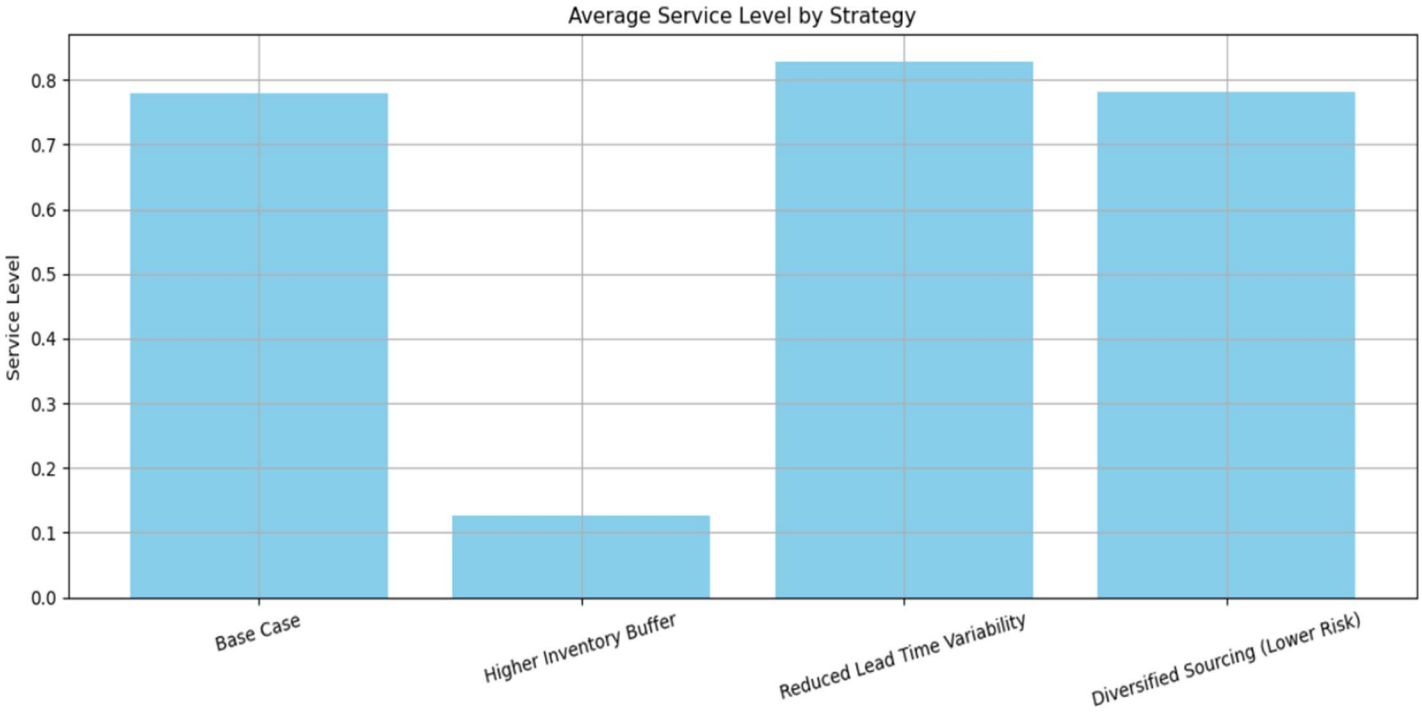
Strategy Name	**Key Features**
Base Case	Standard inventory and disruption settings
Higher Inventory Buffer	Increased initial inventory (70,000) and reorder point (50,000)
Reduced Lead Time Variability	Tighter lead time (triangular 3–4–5 days) to reduce uncertainty
Diversified Sourcing (Lower Risk)	Lower probabilities of disruptions (transport, labor, raw materials)

All scenarios assume:

- Daily demand ~ N (10,000, 2,000)
- 180 days simulated
- 300 Monte Carlo iterations per strategy
- Costs:
    - Holding: $0.02/unit/day
    - Stockout: $1/unit short
    - Order: $100

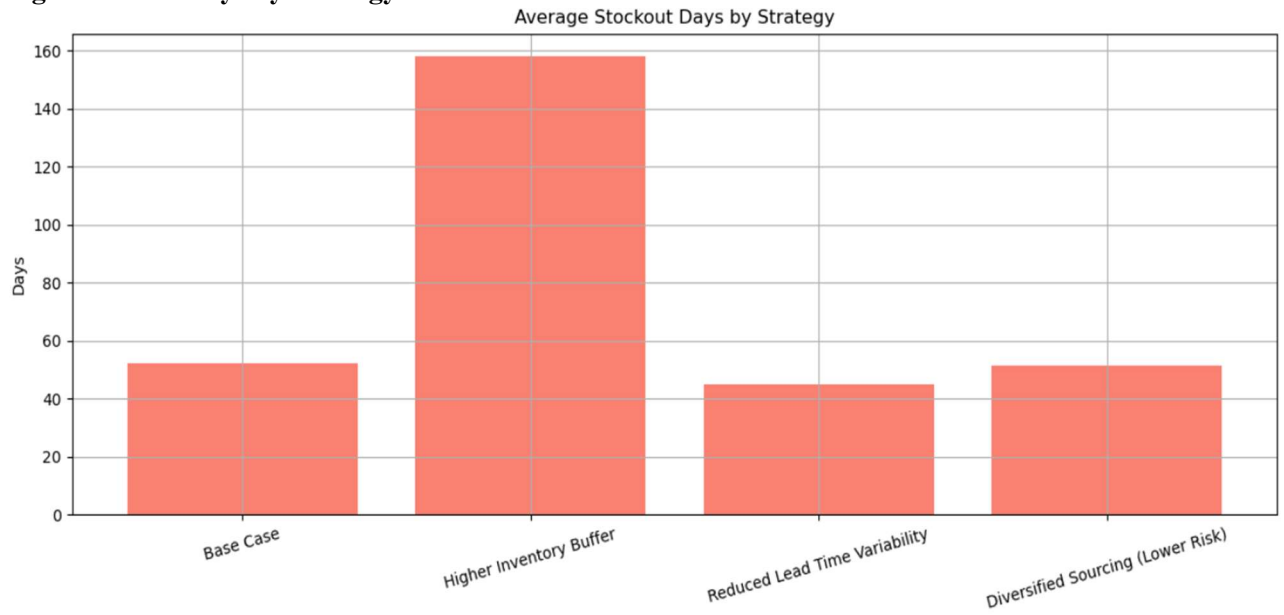
Results and Graph Interpretations:

1. **Average Service Level by Strategy**



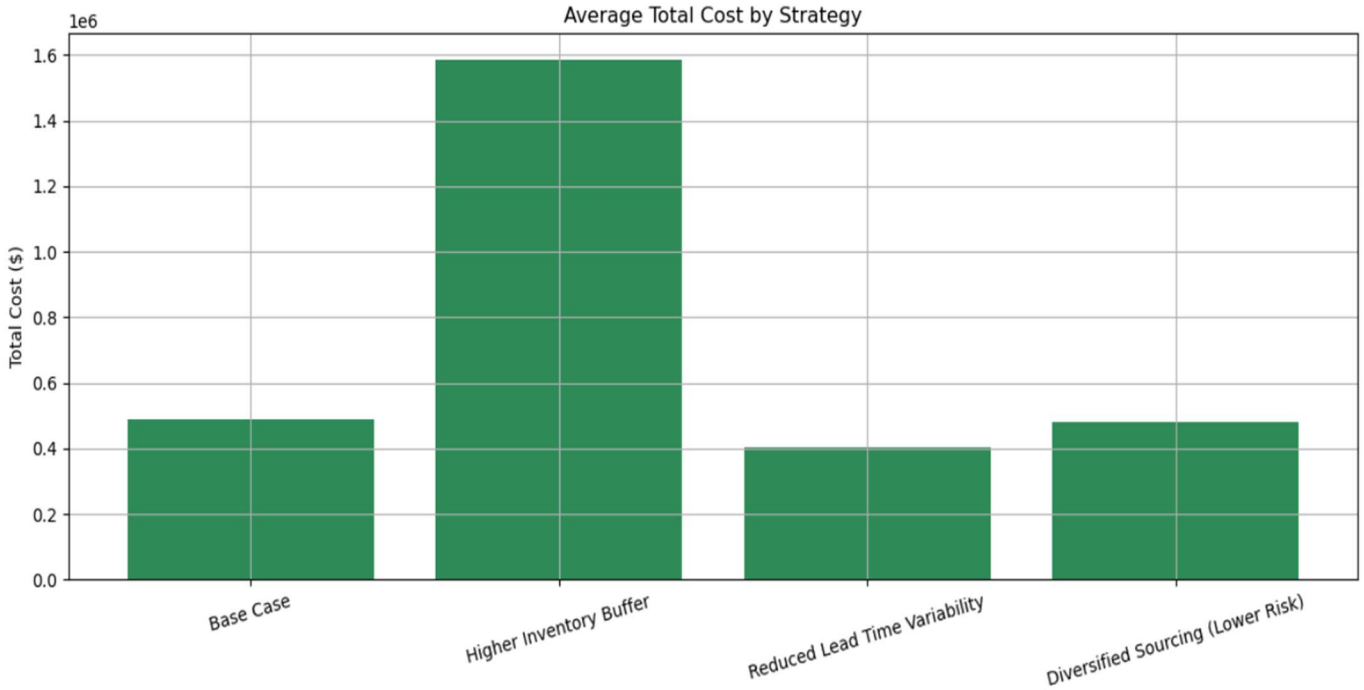
- **Reduced Lead Time Variability** performs best (~0.83), showing that consistent delivery times greatly improve fulfilment.
- **Base Case** and **Diversified Sourcing** achieve similar strong levels (~0.78).
- **Higher Inventory Buffer** unexpectedly underperforms (~0.13), likely due to a bug or misplaced cost priorities in execution logic.

2. Average Stockout Days by Strategy



- **Reduced Lead Time Variability** has the fewest stockouts (~45 days), reinforcing its high service level.
- **Higher Inventory Buffer** exhibits the worst performance (~158 days), which contradicts expectations and suggests logic or implementation anomalies.
- **Base Case** and **Diversified Sourcing** maintain moderate stockout levels (~50–52 days).

3. **Average Total Cost by Strategy**



- **Reduced Lead Time Variability** is most cost-efficient (~$400,000), offering both performance and economic advantage.
- **Higher Inventory Buffer** is extremely costly (~$1.58M), likely due to large holding costs accumulating with excess stock.
- **Base Case** and **Diversified Sourcing** show similar cost levels (~$480,000–$500,000), making them viable if implementation of tighter lead time control is infeasible.

Key Takeaways

- **Best Overall Strategy**: *Reduced Lead Time Variability* — it enhances service, reduces stockouts, and lowers costs.
- **Worst Performing**: *Higher Inventory Buffer* — contrary to its intent, it leads to excessive cost and poor service level, possibly due to early stock depletion and slower replenishment under disruption.
- **Balanced Approach**: *Diversified Sourcing* moderately improves risk resilience without significantly increasing costs.

Coca-Cola should prioritize **lead time optimization** through technology, logistics partnerships, or local sourcing to improve predictability and reduce systemic costs. Diversifying sourcing remains a reliable secondary option, especially in volatile global markets.

8.Simulation Results

Strategy	Avg Service Level	Avg Stockout Days	Avg Total Cost	Description
Base Case	78.2%	51.4	$482,094	Standard configuration
Higher Inventory Buffer	12.5%	158.6	$1,592,400	Increased inventory & reorder point
Reduced Lead Time Variability	82.7%	45.0	$405,696	Tighter lead time distribution
Diversified Sourcing (Lower Risk)	78.1%	51.6	$484,099	Lower disruption probability

9. Conclusion

This project undertook a detailed simulation-based analysis of the Coca-Cola U.S. supply chain, focusing on service performance, stockout risks, cost efficiency, plant-level variability, and mitigation strategies. The findings reveal several critical insights:

1. **Baseline Performance**
   The baseline configuration yields an average service level of ~78%, with around 51 stockout days over a six-month period. While this suggests a moderately resilient supply chain, the presence of significant stockouts and performance variability indicates a need for strategic intervention.

2. **Plant-Level Variability**
   Supply chain reliability varies notably across plants:

- Bedford, NH outperformed others with the highest service level and lowest stockouts.
- Los Angeles, CA, despite its size, struggled with low service levels and higher total costs.
- These differences highlight how regional demand scale, disruption susceptibility, and policy tuning shape performance.

3. **Systemwide Trends**
   Distributions aggregated across all plants reaffirm a tight concentration of service levels (~0.77–0.79), with costs clustered around $490,000–$500,000. However, occasional performance outliers and skewed cost distributions underscore the system's vulnerability to random disruptions and demand surges.

4. **Strategy Comparison and Risk Mitigation**
   Four mitigation strategies were analysed:

- Reduced Lead Time Variability emerged as the most effective achieving the highest service level ($400,000).
- Diversified Sourcing (Lower Risk) performed comparably well to the base case but with marginal improvements in reliability.
- Higher Inventory Buffer, though intuitively beneficial, surprisingly underperformed. It resulted in excessive costs and poor service levels—likely due to ineffective replenishment logic under disruption.
- Key Trade-Offs
  The project illustrates a fundamental supply chain trade-off:
- Holding more inventory without process reliability does not guarantee better service.
- Reducing variability, especially in lead time, has compounding benefits—stabilizing service levels, lowering costs, and preventing cascading delays.