Fast Fashion Supply Chain Optimization

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1. Introduction

The fast fashion industry operates on rapid production cycles, low costs, and constantly changing consumer preferences. While this model achieves high turnover rates, it also creates significant inefficiencies in the supply chain, leading to overproduction, increased costs, and environmental damage. This project focuses on optimizing supply chain processes for fast fashion retailers, minimizing costs while maintaining operational efficiency. Using optimization models and sensitivity analysis, we identify bottlenecks, improve resource allocation, and enhance delivery efficiency. The ultimate goal is to align cost savings with sustainable practices and long-term business growth.

2. Problem Statement

Given the complexity of our problem, we divided the model-solving into two parts. The first one focuses on production analysis, making decisions on how much of each product is produced in which factory. The second model focuses on the transshipment issue, solving how much of each product is transported from each factory to the different warehouses.

Model 1: Production Analysis

Objective:

- Minimize production costs by optimizing the allocation of the 40 products' manufacturing across factories.
- P_{ij}: Production cost of product j at factory i.
- x_{ij}: Number of units of product j produced at factory i.
- I: Total number of factories.
- J: Total number of products.

$$C = \sum_{i=1}^{I} \sum_{j=1}^{J} P_{ij} \cdot x_{ij}$$

Constraints:

1. Shipments from each factory must not exceed its capacity.
2. Total production of items should surpass the demand.
3. Non-negativity: $x_{ij} \geq 0$, where x_{ij} is the number of units produced of product j at factory i.

Decision Variables:

- x_{ij}: Number of units of product j produced at factory i.

Model 2: Transshipment Analysis

Objective:

- Minimize transportation costs by optimizing the allocation of shipments from factories to warehouses.
- T_{ijk}:Transportation cost per unit for product j from factory i to warehouse k.
- y_{ijk}: Number of units of product j transported from factory i to warehouse k.
- I: Total number of factories.
- J: Total number of products.
- K: Total number of warehouses.

$$\text{Transportation Costs} = \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{k=1}^{K} T_{ijk} \cdot y_{ijk}$$

Constraints:

1. Shipments from each factory must not exceed production capacity.
2. Shipments to each warehouse must meet or exceed warehouse demand.
3. Inventory levels at warehouses must not exceed storage capacity.
4. Non-negativity: $y_{ijk} \geq 0$, where y_{ijk} is the number of units of product j shipped from factory i to warehouse k.

Decision Variables:

- y_{ijk}: Number of units of product j transported from factory i to warehouse k.

3. Analysis and Findings

3.1a Model 1: Production Analysis

- **Low-Cost Factories**: These were prioritized for production to minimize expenses, reflecting efficient use of resources.
- **High-Cost Products**: Some products incurred universally high production costs, suggesting the need for strategic outsourcing or material adjustments.
- **Infeasible Combinations**: Factories marked with "999" were excluded from the solution, avoiding inefficiencies.

The model optimized production by leveraging cost-effective factories and excluding unviable options while respecting capacity constraints.

3.1b Sensitivity Report Insights

1. **Shadow Prices:**
- High shadow prices identified bottleneck factories and warehouses where additional capacity could significantly reduce costs.
2. **Critical Variables**:
- Variables with reduced costs close to zero and high final values play a significant role in the optimal solution. These are the key contributors to the total cost.
3. **Opportunities for Improvement**:
- Variables with large reduced costs are unlikely to enter the solution unless substantial cost reductions occur. Investments or adjustments targeting these variables might not be cost-effective.
4. **Wide Allowable Ranges**:
- Most variables have extremely large allowable increases/decreases (1E+301E+301E+30), indicating high stability in the optimal solution under cost or demand changes.

3.2 Transshipment Model Analysis

1. **Intermediate Hubs**:
- Strategic allocation of shipments to key warehouses balanced direct and indirect routes, reducing overall transportation costs and ensuring demand satisfaction.
2. **Opportunities for Refinement:**
- Products with lower transport volumes or high shipping costs could be revisited for cost-saving opportunities.
- Factories F003 and F005 had underutilized shipping potential in some product categories, suggesting possible reallocations.

4. Recommendations

1. **Expand Bottleneck Capacities**:
    - Prioritize investment in factories and warehouses with high shadow prices to alleviate production and demand bottlenecks.
    - Target specific locations for capacity upgrades, focusing on high-volume products such as P004, P011, and P017, to achieve direct cost reductions and meet future demand growth.
2. **Utilize Surplus Resources**:
    - Reallocate underutilized capacities from non-critical factories (e.g., F003, F005) to products and warehouses experiencing higher demand or cost-sensitive constraints.

    - Leverage flexibility in production and shipping to balance the supply chain effectively.
3. **Optimize Transshipment**:
    - Strengthen intermediate hubs that reduce direct shipping costs while ensuring demand flexibility and maintaining robust delivery networks.
    - Focus on products and routes with significant shipping costs, such as P030P030P030 and P032P032P032, for further optimization opportunities.
4. **Prepare for Cost Sensitivity**:
    - Monitor key variables with narrow allowable ranges, such as products P011, P004, and P006, to proactively adjust strategies for fluctuating production or shipping costs.
    - Develop contingency plans to address demand surges or unexpected cost changes.

5. Challenges

1. **Decision Variable Limitations**:
    - Traditional optimization tools like Excel Solver were insufficient for the transshipment model due to its complexity (3,200 decision variables). Transitioning to Python allowed greater flexibility and computational power to effectively solve the problem.
2. **Incomplete Data for Factory F004**:
    - Factory F004 was excluded from the analysis due to insufficient data on production and shipping costs. This required redistributing production demand among the remaining factories and revising supply constraints.
3. **Data Integration and Complexity**:
    - The integration of diverse datasets, such as production costs, warehouse demands, and shipping logistics, required significant preprocessing to ensure consistency and accuracy.
    - Handling missing or inconsistent values, particularly in the production cost and shipping cost matrices, was critical for achieving actionable results.

6. Conclusion

This project demonstrates the application of optimization techniques to the fast fashion supply chain, delivering a framework for cost-effective management. By addressing bottlenecks, reallocating resources dynamically, and leveraging transshipment networks, the model achieves a balance between profitability and sustainability.

Key takeaways include:

- The potential for long-term operational efficiency through targeted investments in bottleneck capacities.
- Opportunities to align supply chain operations with environmental objectives to reduce waste and emissions.
- The importance of robust preprocessing and advanced tools like Python for solving complex real-world optimization problems.

The insights and recommendations pave the way for a resilient fast fashion supply chain capable of meeting future challenges while maintaining sustainable growth.

Appendix:

Excel File - BA885_Group 8_Fast Fashion Supply Chain_Models.xlsx

Python File - BA885_Group 8_Fast Fashion Supply Chain_Models