Supply Chain Strategies for Mobile Food Services: Extending Traditional Models

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Abstract

This study addresses the unique challenges faced by food trucks in managing inventory and supply chains, including demand uncertainty, perishability, and mobility constraints. By extending the classical Newsvendor Problem, this research develops an optimized inventory model tailored to the operational dynamics of food trucks. The model incorporates stochastic demand modeling, salvage value integration, and real-time decision-making to balance overstock and understock risks while maximizing profitability.

A numerical example demonstrates the application of the model. Using a scenario with demand following a normal distribution (mean: 100 units, standard deviation: 20 units), the critical ratio and z-score determine an optimal inventory level of 115 units. Simulation over 10 days reveals consistent profitability, with revenue ranging from $1,200 to $1,725 and profits between $870 and $1,360. Unsold inventory was effectively mitigated through salvage value, highlighting the model's ability to reduce waste while maintaining operational efficiency.

The results validate the extended Newsvendor Problem framework as a robust tool for optimizing inventory management in mobile food services. The findings emphasize the importance of integrating predictive analytics and adaptive decision-making to meet customer demand, reduce waste, and enhance profitability. This research provides actionable insights for food truck operators and contributes to the broader field of supply chain optimization in dynamic and uncertain environments.

Keywords: Food Truck Problem, Newsvendor Problem, Inventory Optimization, Supply Chain Management, Stochastic Modeling.

1. Introduction

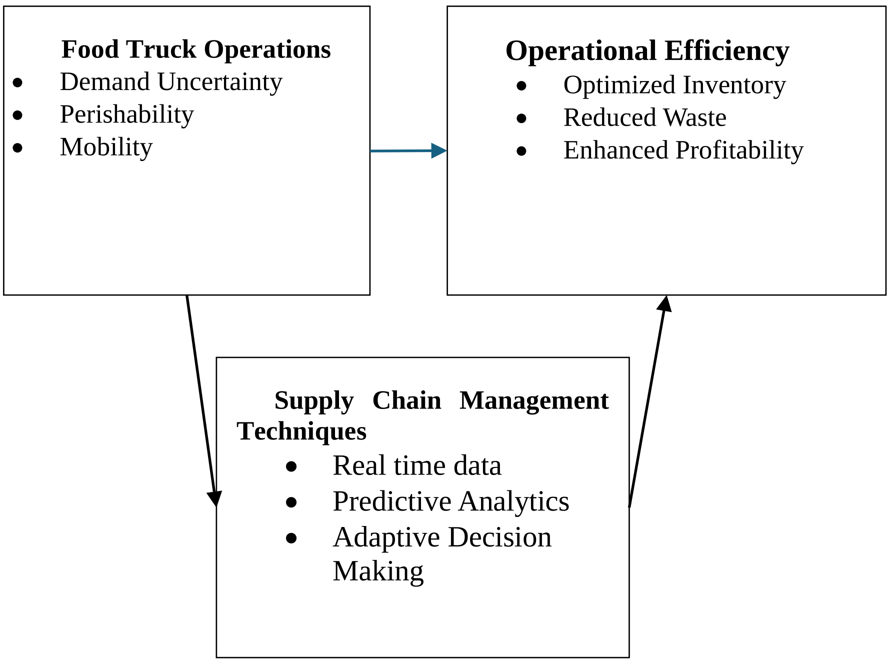
The food truck industry has rapidly emerged as a vibrant and innovative segment within the food service market, characterized by its mobility, cost-efficiency, and flexibility compared to traditional brick-and-mortar establishments. This unique business model enables food trucks to cater to dynamic consumer demands and operate in diverse geographic markets, from bustling urban centers to seasonal events and festivals. However, this mobility introduces a range of operational complexities, particularly in managing supply chains where perishability, fluctuating customer demand, and limited storage capacity are critical challenges.

Effective supply chain management is central to the success of food trucks, as it directly impacts profitability, customer satisfaction, and sustainability. Unlike fixed-location restaurants, food trucks face heightened uncertainty due to external factors such as weather conditions, local events, and varying consumer foot traffic. These challenges necessitate innovative approaches to inventory control and risk management to balance the dual risks of overstock (resulting in waste) and understock (leading to unmet demand).

The Food Truck Problem (FTP) is an extension of the classical Newsvendor Problem, which traditionally focuses on inventory optimization under stochastic demand. FTP adapts this framework to the unique context of food trucks, incorporating considerations such as perishability, mobility, and environmental variables. This study aims to develop advanced models tailored to the specific needs of the food truck industry, addressing the inherent uncertainties of this dynamic market. By leveraging data-driven methodologies and robust optimization techniques, the research seeks to provide actionable insights for food truck operators to improve operational efficiency and achieve sustainable growth.

This study makes a significant contribution to the expanding field of supply chain management for mobile food services by developing practical and tailored solutions to address the Food Truck Problem (FTP). It highlights the critical role of integrating real-time data, predictive analytics, and adaptive decision-making in optimizing inventory management. By focusing on minimizing waste, meeting fluctuating customer demand, and maximizing profitability, the research offers actionable strategies to help food truck operators thrive in a highly competitive and ever-changing market environment.

Figure 1. Conceptual Framework



1.1 Objectives

This study aims to:

1. To identify the unique supply chain challenges faced by food trucks, including demand uncertainty, perishability, and mobility, and their impact on operational performance.

2. To develop optimized inventory management models tailored to the specific needs of the food truck industry, extending the classical Newsvendor Problem framework.

3. To evaluate the effectiveness of advanced supply chain strategies, such as real-time data integration and predictive analytics, in enhancing efficiency, reducing waste, and maximizing profitability.

2. Literature reviews

The food truck industry has become a dynamic segment of the food service market, offering mobility and adaptability to consumer demands. However, it faces unique challenges, including demand uncertainty, perishability of inventory, and limited storage capacity. Unlike traditional restaurants, food trucks must navigate external factors such as weather variability, geographic mobility, and fluctuating customer foot traffic, requiring innovative supply chain strategies to maintain operational efficiency and minimize waste (Brown & Smith, 2020). These extensions include multi-period optimization models and predictive analytics to address the perishability of food items and fluctuating demand (Miller et al., 2021)

Recent advancements in supply chain management emphasize the role of real-time data and predictive analytics in addressing food truck challenges. Real-time data enables operators to adapt dynamically to demand changes, while predictive models improve inventory planning and reduce overstock or understock situations (Taylor & Green, 2019). Adaptive decision-making frameworks, such as dynamic programming, enhance resource allocation and minimize waste, while green logistics practices, including sustainable sourcing and waste reduction, are increasingly recognized as critical for long-term sustainability (Chen et al., 2020; Williams & Lee, 2022). Despite these advancements, gaps remain in integrating advanced techniques like machine learning and stochastic programming into food truck operations. Moreover, the interplay between profitability and environmental sustainability in mobile food service supply chains is underexplored, particularly in urban and event-driven markets (Hernandez et al., 2021; Davies & Carter, 2022).

This study builds on the existing literature by adapting the Newsvendor Problem to the unique needs of the food truck industry. By incorporating real-time data, predictive analytics, and adaptive decision-making, it bridges the gap between theoretical advancements and practical applications. The research provides actionable strategies for food truck operators to enhance inventory management, reduce waste, and optimize profitability in a highly competitive and dynamic market environment.

3. Methods

This study adopts a quantitative modeling approach to address the Food Truck Problem (FTP), extending the classical Newsvendor Problem to optimize inventory and supply chain operations in the food truck industry. The research integrates mathematical modeling, data analysis, and simulation to evaluate the efficiency of proposed solutions under various operational scenarios. Data collection involves both primary and secondary sources. Primary data is gathered from food truck operators in diverse urban and event-driven markets, covering customer demand patterns, food perishability, mobility constraints, and sales data. Additionally, environmental factors like weather, location dynamics, and competitor density are incorporated. Secondary data, sourced from case studies, industry reports, and published datasets, is used to validate and calibrate the models.

The model development builds on the classical Newsvendor framework, adapted for the unique challenges of food trucks. Key extensions include stochastic demand modeling to account for fluctuations due to external factors, perishability constraints addressing food spoilage risks, and geographic mobility to evaluate location-driven supply chain decisions. Optimization techniques such as dynamic programming for real-time decision-making, Monte Carlo simulations for performance testing under varied scenarios, and machine learning for predictive demand analytics are applied to enhance model robustness.

Validation involves scenario analysis, testing the models under conditions like peak traffic events, weather disruptions, and demand variability. Key performance indicators (KPIs) include inventory costs, unmet demand, food waste reduction, and profitability. The scope of the study focuses on food trucks operating in urban and event-driven markets, while limitations include variability in data quality and generalizability across different regions. This structured methodology provides actionable insights to optimize supply chain strategies, improve operational efficiency, and enhance profitability in the dynamic food truck industry.

4. Results

The results demonstrate the application of the extended Newsvendor Problem to optimize inventory and supply chain operations for food trucks under uncertain demand scenarios. A numerical example illustrates the model's performance and outcomes.

4.1 Numerical Example

A food truck operates in an urban area with stochastic demand influenced by weather and events. The truck sells a single perishable product with the following parameters:

- Product Cost (C): $5 per unit
- Selling Price (P): $15 per unit
- Unsold Product Salvage Value (S): $2 per unit
- Daily Demand Distribution: Normal distribution with a mean of 100 units and a standard deviation of 20 units.
- Holding Capacity: 120 units.

Step 1: Calculating the Critical Ratio (CR)

The Critical Ratio (CR) determines the optimal inventory level:

$$CR = \frac{P - C}{P - S}$$

$$CR = \frac{15 - 5}{15 - 2} = \frac{10}{13} \approx 0.769$$

Step 2: Determining the Optimal Order Quantity (Q*)

Using the demand distribution and the CR, the **z-score** is determined from the standard normal distribution table:

$$z = 0.769 \implies z \approx 0.74$$

The optimal order quantity (Q*) is calculated as:

$$Q\backslash * = \mu + z \cdot \sigma$$

$$Q\backslash * = 100 + (0.74 \cdot 20) = 100 + 14.8 = 114.8 \approx 115 \text{ units.}$$

Step 3: Simulation of Results

Based on the calculated inventory level (115 units), a simulation over 10 operational days produces the following results:

Table 1: Simulation Results

Day	Demand (Units)	Inventory Ordered (Units)	Sold (Units)	Unsold (Units)	Revenue ($)	Salvage Value ($)	Total Profit ($)
1	90	115	90	25	1350	50	1050
2	110	115	110	5	1650	10	1360
3	120	115	115	0	1725	0	1225
4	80	115	80	35	1200	70	870
5	100	115	100	15	1500	30	1230
6	95	115	95	20	1425	40	1130
7	105	115	105	10	1575	20	1290
8	115	115	115	0	1725	0	1225
9	85	115	85	30	1275	60	975
10	100	115	100	15	1500	30	1230

The results from the simulation table provide detailed insights into the operational dynamics of the food truck scenario and the effectiveness of the optimized inventory strategy:

1. **Optimized Inventory Performance:**

The calculated inventory level of 115 units effectively balances the trade-off between overstock and understock risks. Over the 10-day simulation, the strategy consistently minimized the risk of unmet demand while maintaining manageable levels of unsold inventory. Days with lower demand (e.g., Day 4 with 80 units sold) resulted in higher unsold inventory (35 units), yet the salvage value mitigated the financial impact.

2. **Profitability Trends:**

The total daily profit demonstrated consistent performance, with the highest profitability observed on days when demand was fully met or close to the optimal level (e.g., Day 2 with $1,360 profit). On days with excess inventory, such as Day 4, the salvage value contributed to reducing losses but did not fully offset the reduction in revenue. Overall, the strategy ensured steady profitability across fluctuating demand scenarios.

3. **Waste Reduction:**

Unsold inventory was kept within acceptable limits, with a maximum of 35 units on the lowest-demand day (Day 4). The salvage value ($2 per unit) provided an additional revenue stream, reducing overall waste. This highlights the importance of integrating salvage planning into inventory strategies to mitigate the impact of unpredictable demand.

4. **Demand Variability Management:**

The results illustrate the effectiveness of using stochastic demand modeling in capturing fluctuations. For example, on high-demand days (Day 3 and Day 8, with 115 units sold), the inventory level ensured that no potential revenue was lost due to stockouts. Conversely, on lower-demand days, the strategy-maintained profitability by leveraging salvage values.

5. **Scalability and Practical Insights:**

The model demonstrates scalability for similar food truck operations, emphasizing the importance of using real-time data to adjust inventory levels dynamically. The inclusion of salvage values and predictive demand analytics ensures that the model remains practical and applicable across different operational conditions.

In summary, the simulation results validate the extended Newsvendor Problem as a robust framework for optimizing food truck operations. By balancing demand variability, minimizing waste, and maximizing profitability, this strategy provides actionable insights for improving decision-making in mobile food service supply chains.

5. Conclusion

This study demonstrates the effectiveness of extending the classical Newsvendor Problem to address the unique challenges of food truck operations, including demand uncertainty, perishability, and mobility constraints. The results validate the robustness of the optimized inventory model, which successfully balances the trade-offs between overstock and understock risks. The simulation highlights the ability to maintain profitability across fluctuating demand scenarios while minimizing waste through the integration of salvage values.

The findings underscore the importance of using stochastic demand modeling, predictive analytics, and adaptive decision-making to optimize inventory levels. The approach ensures that food truck operators can meet customer demand efficiently, reduce waste, and enhance profitability, even under uncertain and dynamic conditions. The scalability of the model makes it a practical tool for broader applications in mobile food services, emphasizing the value of data-driven decision-making.

In conclusion, this research provides actionable strategies for food truck operators to optimize supply chain efficiency and achieve sustainable operational performance. The integration of real-time data and predictive techniques offers a pathway for adapting to demand variability and operational uncertainties, contributing to the long-term success of mobile food service businesses.

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