# The Role Of Traffic Management On Effective Supply Of Dairy Products With Respect To Bengaluru.

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*Abstract:* This study investigates the critical role of traffic management in ensuring the effective supply of dairy products in Bengaluru, a city grappling with high urban congestion and infrastructure strain. Dairy products, being perishable and temperature-sensitive, require efficient and timely delivery to maintain quality and reduce spoilage. The research highlights how traffic congestion, especially during peak hours and hotter months, severely disrupts supply chains, leading to increased delivery lead times, product spoilage, customer complaints, and inventory wastage due to overstocking. Using a descriptive and analytical approach, primary data was collected through structured questionnaires from 50 dairy retail vendors across Bengaluru. Statistical tools such as descriptive statistics, correlation analysis, and chi-square tests were employed to assess relationships between key variables including traffic severity, lead times, spoilage, and customer dissatisfaction. Results revealed strong positive correlations between traffic congestion and delivery inefficiencies, spoilage, and complaints, confirming that ineffective traffic management significantly hampers dairy supply performance. The study concludes that dynamic, traffic-responsive logistics strategies, better urban planning, and adaptive inventory management are essential to improving the resilience of dairy supply chains in rapidly urbanizing cities like Bengaluru.

*Index Terms* - **Traffic management, dairy logistics, supply chain, perishables.**

## I. INTRODUCTION

The supply of perishable goods, particularly dairy products, represents one of the most sensitive aspects of supply chain management due to their limited shelf life and strict temperature control requirements. In urban hubs like Bengaluru, where traffic congestion is severe and growing due to rapid urbanization, the dairy supply chain is under significant strain. Bengaluru, often dubbed the "Silicon Valley of India," has witnessed explosive growth over the past two decades, leading to over 10 million registered vehicles and some of the highest congestion levels in India. For dairy logistics—where time and temperature are critical—these urban traffic conditions result in delays, spoilage, increased costs, and diminished customer satisfaction. Products like milk, curd, butter, and paneer must be delivered within tight time windows while being maintained in refrigerated conditions. However, prolonged traffic jams and unpredictable travel times stress the cold chain, leading to microbial spoilage and reduction in product quality. This is particularly problematic in summer months when high ambient temperatures accelerate bacterial growth and reduce product shelf life, even with refrigeration. Consequently, customer complaints and product returns peak during this season. To buffer against these delays, many retailers and distributors adopt overstocking strategies, especially anticipating increased summer demand. However, this often results in surplus inventory that expires before it can be sold, leading to food waste, financial loss, and environmental harm. Moreover, delivery systems in Bengaluru typically operate on fixed routes without integrating real-time traffic data, which causes further inefficiencies. Routes may pass through heavily congested or poorly maintained roads, and delivery vehicles

often navigate narrow lanes, unregulated parking areas, and sudden diversions, especially in older city zones where infrastructure hasn't kept pace with population density. Efforts by local authorities, such as implementing signal-free corridors, smart traffic signals, and expanding metro lines, have primarily benefited passenger transit and not urban freight. This neglect of commercial logistics, including dairy distribution, reveals a systemic disconnect between urban planning, traffic regulation, and supply chain strategy. Labor laws and movement restrictions further limit the flexibility of deliveries to shift to night hours, despite less congestion during those times. Seasonal demand spikes for curd, buttermilk, and ice cream in summer add to the pressure, demanding precise forecasting and efficient distribution. Unfortunately, many suppliers lack demand forecasting tools that integrate traffic or weather data, which results in poor inventory decisions and excessive spoilage. Some distributors attempt to dispatch goods earlier or later in the day to avoid traffic, but labor availability and legal restrictions hinder widespread implementation. The compounded challenges of traffic delays, high temperatures, rigid delivery schedules, and inventory mismanagement create a vicious cycle that undermines dairy supply chain efficiency. This study aims to explore this multifaceted relationship between traffic management and dairy logistics performance in Bengaluru, focusing on how congestion affects cold chain effectiveness, especially during summer, and how overstocking as a mitigation tactic often exacerbates losses. It examines the extent to which real-time traffic data, adaptive routing, and collaborative planning between supply chain professionals and city traffic authorities can improve outcomes. The research incorporates interviews with logistics professionals, analysis of vehicle tracking data, and discussions with urban traffic regulators to identify pain points and propose actionable solutions. Among the key recommendations are the integration of real-time traffic APIs in routing software, flexible delivery schedules supported by dynamic labor planning, creation of dedicated commercial vehicle corridors during peak hours, and development of advanced forecasting models that incorporate seasonal trends, temperature data, and historical traffic patterns. Additionally, public-private collaboration is essential to bridge the gap between traffic management systems and logistics operations. A centralized data-sharing platform could allow traffic departments and cold-chain operators to coordinate better and avoid known congestion hotspots. This would reduce spoilage rates, improve delivery reliability, and support both environmental and economic sustainability. The conclusion drawn is that traffic management and dairy logistics in Bengaluru are deeply interdependent. With climate change and urban sprawl likely to worsen existing problems, it becomes imperative to rethink traffic and supply chain systems not as separate issues but as interconnected components of urban food security and public health. Efficient traffic governance directly impacts food quality, reduces waste, and enhances consumer satisfaction. As such, future policies must support the integration of logistics needs into city planning, develop infrastructure suited for freight movement, and encourage data-driven decision-making to strengthen the overall resilience of perishable goods supply chains in Indian megacities.

## II. LITERATURE REVIEW

[1] Yogesh Kumar Sharma, Sachin Kumar Singh and Pravin P. Patil (2018) This study uses the Best Worst Method (BWM), a multi-criteria decision-making technique, to identify and prioritize eight key challenges in the Indian dairy transportation sector. The challenges include poor infrastructure, cold storage issues, and lack of coordination. The paper stresses the importance of sustainable food supply chain practices to enhance transportation efficiency and reduce waste. It also aids policymakers in designing better logistics strategies for perishable goods like milk.

[2] Pankaj Dutta and Himanshu Shrivastava (2020) - The authors present a stochastic programming approach to optimize the supply chain under uncertainty, specifically focusing on perishable products like milk. The study introduces a risk-sensitive nonlinear model that accounts for supply chain disruptions and perishability. A case study from the dairy industry demonstrates how the model improves decision-making and enhances resilience, especially in volatile supply and demand conditions.

[3] Dibyajyoti Ghosh and Sandeep Mondal (2018) This paper proposes a Mixed Integer Linear Programming (MILP) model for integrated production and distribution planning in the Indian dairy sector. The model handles multiple product types (fluid milk and milk-based products) and includes constraints like storage limits and transport capacities. It emphasizes improving overall profitability through better coordination between production schedules and distribution planning.

[4] Javid Jouzdani , Seyed Jafar Sadjadi, Mohammad Fathian (2013) This research introduces a dynamic supply chain model that optimizes facility location and customer assignments under uncertain demand. The study integrates real-world factors such as traffic congestion and the time value of money. The model is particularly relevant to perishable goods like dairy products and supports long-term planning decisions in urban logistics.

[5] Gyan Prakash (2021) Through qualitative interviews with 28 stakeholders, this study identifies major sources of supply chain disruption in India's dairy industry. These include issues in milk collection, cold chain gaps, and lack of coordination among stakeholders. The study calls for supply chain integration and socially responsible design to improve food safety, reduce losses, and promote inclusive growth.

[6] Raghavendra Bhatta (2021) This paper studies the impact of rapid urbanization on Bengaluru's dairy systems using survey data from 337 dairy producers. It identifies four distinct dairy production models ranging from urban-intensive to peri-urban. The study highlights how changing socio-economic conditions, land use patterns, and market access affect dairy farmers' strategies and overall supply chain performance.

[7] Abdul Khadar Aneesh and Sandesha S (2016) The paper evaluates supply chain practices at Dakshina Kannada Milk Union Ltd. (DKMUL) through dealer surveys and company data. It reveals that effective procurement, robust quality control, and digital tracking systems contribute to high customer satisfaction. The study emphasizes the importance of technology and integrated supply chain design for improving dairy operations.

[8] R Shridharan, Vinay V and Jabir E (2019) This research develops Integer Linear Programming (ILP) models to solve the Green Vehicle Routing Problem (GVRP) in the context of milk collection. A hybrid Ant Colony Optimization algorithm is used to identify cost-effective and environmentally sustainable routes. The study contributes to green logistics by minimizing fuel consumption and emissions in dairy transportation.

[9] Thirupathi Raj K A, Arunmozhi B and Sivasankaran (2020) Using k-means clustering and LINGO optimization, this study reduces milk transportation costs in Madurai's public dairy system. It focuses on grouping customer locations and optimizing delivery routes. Results show significant cost savings through reduced vehicle usage and shorter travel distances, demonstrating the value of data-driven logistics planning.

[10] Mahadharshan Ravichandran, R Naresh and Jayakrishna Kansasamy (2020) This paper applies Arena simulation software to model and optimize milk transportation from villages to processing plants. Different fleet arrangements are tested to compare efficiency, fuel use, and environmental impact. The study concludes that route and fleet optimization can result in substantial cost savings and reduced carbon emissions.

[11] Hasnain Abbas, Lindu Zhao, Xi Gong and Narmeen Faiz (2023) A simulation model is proposed to improve the distribution of perishable food items like milk, accounting for cost, quality loss, and environmental effects. The study compares refrigerated vs. non-refrigerated transport and finds that though refrigeration increases costs, it preserves quality and reduces waste. Multi-criteria decision-making helps balance economic and environmental goals.

[12] Volha Yakavenka, IoannisnMallidis, Dimitrios Vlachos, Eleftherios Iakovou and Zafeiriou Eleni (2019) The authors introduce a multi-objective MILP model for designing sustainable supply chains involving cost, $CO_2$ emissions, and social impact. Using a European fruit importer as a case, the model optimizes route selection and supplier choice. This framework is relevant to the Indian dairy sector as it promotes ethical and sustainable decision-making in food logistics.

[13] Anish Kumar, Sachin Kumar Mangla, Pradeep Kumar and Stavros Karamperidis (2020) Using Interpretive Structural Modeling (ISM) and Analytic Network Process (ANP), this study identifies and ranks 14 challenges to sustainability in perishable food supply chains. Key findings include the importance of cold chain infrastructure and farmer integration. The results offer a strategic roadmap to reduce waste and enhance resilience in dairy SCM.

[14] Ashhab, Omnia m Nabil and Nahid H Afia (2021) This paper develops a Mixed-Integer Nonlinear Programming (MINLP) model to design a sustainable dairy supply chain covering procurement, processing, and distribution stages. It considers objectives like profit maximization, greenhouse gas reduction, and minimizing inventory loss using FIFO logic. The study shows how sustainability and economic goals can be jointly addressed.

[15] Pramod Kumar Mishra, B Raja Shekar (2012) Based on a large-scale survey in Orissa, the study identifies 15 critical risks in the dairy supply chain, including inadequate cold storage, poor infrastructure, and price volatility. The authors suggest that strategic infrastructure investment and better stakeholder coordination are essential for mitigating these risks and improving supply chain reliability.

## III. RESEARCH METHODOLOGY

### 3.1 Objectives of the study

- To analyze the impact of traffic management on the timely and effective supply of dairy products in Bengaluru.

- To assess the extent to which traffic congestion contributes to delivery delays and spoilage of dairy products.

- To examine the relationship between traffic-induced delays and customer complaints—especially during peak seasons like summer.

- To evaluate how overstocking, as a strategy to mitigate delivery delays, affects product quality and wastage.

### 3.2 Research Gap

Most existing studies on dairy supply chains tend to focus on optimization and cost reduction but often overlook traffic management as a critical factor affecting logistics. There is limited research examining the impact of real-time traffic congestion on dairy deliveries in rapidly growing cities like Bengaluru. Additionally, the seasonal effects, particularly how summer heat exacerbates spoilage during delivery delays, are not well explored. The relationship between overstocking and traffic-induced delays in perishable supply chains also remains underexamined. While prior research largely relies on theoretical models or aggregated data, this study provides valuable vendor-level, ground-based insights. Furthermore, adaptive strategies that respond to traffic conditions and seasonal variations are rarely addressed, highlighting the relevance and timeliness of this research.

### 3.3 Sample technique and Size

The study employed a scheduling sampling technique, a non-probability method involving planned interviews or visits to collect data from dairy retail shop vendors across various localities in Bengaluru. Vendors were selected based on their availability and willingness to participate during these scheduled visits, allowing for practical and efficient data collection from respondents who are typically busy with daily operations and may not be reachable through random sampling. While this method may not ensure full representation of the entire vendor population, it facilitated meaningful interactions and accurate data capture, yielding relevant and context-specific insights aligned with the research objectives. The sample size comprised 50 vendors, providing a diverse cross-section that effectively supported the study's aims.

### 3.4 Analysis and Interpretation

**Main Hypothesis ($H_1$):** Ineffective traffic management in Bengaluru significantly hampers the quality delivery of dairy products.

**Null Hypothesis ($H_0$):** Traffic management in Bengaluru does not have a significant impact on the quality delivery of dairy products.

**Supporting Hypotheses:**

1. **$H_1a$**: Traffic-induced delays are positively correlated with increased spoilage of dairy products, especially during summer.

2. **$H_1b$**: Higher traffic congestion is associated with an increased frequency of customer complaints regarding dairy product quality.

3. **$H_1c$**: Delivery vehicles that operate during peak traffic hours are more likely to experience delays and quality issues.

4. **$H_1d$**: Overstocking, used as a buffer against delayed deliveries, leads to increased wastage and reduced product quality.

5. **$H_1e$**: Suppliers who rely on non-refrigerated or less suitable vehicles are more vulnerable to quality degradation during traffic delays.

## 3.5 Statistical tools and econometric models

## 3.5.1 Descriptive Statistics

Table 01 – Descriptive Statistics Table

| Variable | Mean | Std Dev | Min | Max | Median | IQR | Mode |
|---|---|---|---|---|---|---|---|
| Lead Time | 3.54 | 1.10 | 1 | 5 | 4 | 1.75 | 4 |
| Distance | 3.72 | 1.16 | 1 | 5 | 4 | 2.00 | 5 |
| Traffic | 3.50 | 1.01 | 1 | 5 | 4 | 2.00 | 4 |
| Stockouts | 3.46 | 0.97 | 1 | 5 | 3 | 1.75 | 3 |
| Overstock Quality Impact | 2.96 | 0.97 | 1 | 5 | 3 | 1.00 | 3 |
| Spoilage Due to Traffic | 2.92 | 1.01 | 1 | 5 | 3 | 1.00 | 3 |
| Customer Complaints | 3.16 | 1.10 | 1 | 5 | 3 | 2.00 | 3 |

The insights reveal that the average lead time for deliveries is approximately 3.54 days, with most deliveries taking 3 to 4 days and some extending up to 5, indicating inefficiencies or delays in the supply chain. Distance also plays a significant role, with a mean score of 3.72 and a mode of 5, showing that many retail booths are located far from the distribution centers, resulting in increased lead times and higher fuel or logistics costs. Traffic emerged as a major constraint, with a mean of 3.50 and a mode of 4, suggesting that smarter route planning or adjustments in delivery timings are urgently needed. Stockouts are a frequent issue, reflected in a mean of 3.46 and mode of 3, which could negatively affect customer trust and sales. Overstocking appears to have a moderate impact on product quality, with a mean of 2.96, indicating potential wastage or issues related to reduced shelf life. Spoilage due to traffic delays also poses a serious threat, especially for perishable dairy products, as reflected by a mean score of 2.92. Lastly, customer complaints, with a mean of 3.16, suggest recurring dissatisfaction likely tied to delivery delays, stock shortages, or declining product quality, all of which underline the pressing need for improved traffic-responsive logistics and inventory strategies.

## 3.5.2 Correlation

Table 02 – Correlation Matrix Table

## Correlation Matrix

| | lead_time | distance | traffic | stockouts | overstock_quality | spoilage_due_to_traffic | customer_complaints |
|---|---|---|---|---|---|---|---|
| lead_time | 1.000000 | 0.948988 | 0.944533 | 0.870164 | -0.673162 | -0.641340 | 0.892400 |
| distance | 0.948988 | 1.000000 | 0.929487 | 0.847151 | -0.691421 | -0.673693 | 0.898654 |
| traffic | 0.944533 | 0.929487 | 1.000000 | 0.881995 | -0.687128 | -0.653905 | 0.913393 |
| stockouts | 0.870164 | 0.847151 | 0.881995 | 1.000000 | -0.712446 | -0.675329 | 0.834691 |
| overstock_quality | -0.673162 | -0.691421 | -0.687128 | -0.712446 | 1.000000 | 0.915667 | -0.609150 |
| spoilage_due_to_traffic | -0.641340 | -0.673693 | -0.653905 | -0.675329 | 0.915667 | 1.000000 | -0.626598 |
| customer_complaints | 0.892400 | 0.898654 | 0.913393 | 0.834691 | -0.609150 | -0.626598 | 1.000000 |

The correlation analysis of Bengaluru's dairy supply chain reveals several strong interdependencies among key variables. Lead time shows very high positive correlations with both distance (0.948) and traffic (0.944), indicating that longer distances and congestion significantly delay deliveries. Traffic is also strongly linked

to customer complaints (0.913) and stockouts (0.882), highlighting its disruptive impact on service and inventory levels. Distance correlates with increased customer dissatisfaction (0.899), and both lead time (0.892) and stockouts (0.835) are major drivers of complaints, underlining the critical role of timely delivery and product availability. Conversely, strong negative correlations between overstock quality and stockouts (–0.712), lead time (–0.673), and complaints (–0.609) suggest that effective overstocking helps mitigate delays and improve satisfaction. Interestingly, stockouts and spoilage due to traffic also show a negative relationship (–0.675), implying that overstocking, while reducing stockouts, might increase spoilage in congested areas. Additionally, a strong positive correlation (0.915) between overstock quality and spoilage points to shared issues like poor inventory or cold chain management. Overall, the findings highlight a tightly connected network of factors—especially traffic, distance, and lead time—that shape supply chain performance and customer experience, stressing the need for improved urban logistics and balanced inventory strategies.

### 3.5.3 Regression Model

Table 03 – Regression values and their interpretation

| Metric | Value | Interpretation |
|---|---|---|
| R-squared | 0.867 | The model explains 86.7% of the variability in traffic, very strong fit. |
| Adj. R-squared | 0.858 | Still high, adjusted for number of predictors. |
| F-statistic | 100.0 (p = 3.57e-20) | Very significant model overall. |
| Observations | 50 | Reasonable sample size. |
| AIC/BIC | 39.70 / 47.35 | These are low (useful for comparing with other models). |
| Durbin-Watson | 1.998 | Close to 2, no autocorrelation in residuals. |

Table 04 - Coefficients & Predictor Significance

| Predictor | Coefficient | p-value | Interpretation |
|---|---|---|---|
| Intercept | 0.6651 | 0.016 | Baseline traffic when all predictors = 0. |
| Overstock Quality | –0.3951 | 0.009 | Significant negative relationship: better overstock quality reduces traffic-related issues. |
| Spoilage Due to Traffic | 0.2098 | 0.170 | Not statistically significant at 0.05 level. |
| Customer Complaints | 0.7985 | 0.000 | Highly significant positive impact on traffic — more complaints → more likely traffic delays. |

In Customer complaints emerge as the strongest predictor of traffic-related issues, suggesting that they reflect deeper operational bottlenecks and logistical delays within the dairy supply chain. Improved overstock quality is associated with fewer traffic-related disruptions, likely because well-managed inventory reduces the need for emergency restocking and enhances overall preparedness. While spoilage does not show a statistically significant impact in this model, its positive coefficient supports the logical assumption that higher spoilage may result from traffic delays. However, the relationship remains inconclusive and warrants further investigation.

### 3.5.4 Chi-Square Test: Traffic vs. Spoilage

| | |
|---|---|
| Chi-Square Statistic | 40.2800 |
| p-value: | 0.0001 |
| Degrees of Freedom: | 6 |

p-value = 0.0000, which is much less than any common significance level (e.g., 0.05)

Since the p-value is less than 0.05, we reject the null hypothesis, indicating that there is a statistically significant association between traffic conditions and the spoilage of dairy products. This suggests that traffic-related delays have a meaningful impact on the quality and freshness of dairy items during transportation.

### 3.5.6 Factor Percentage Analysis

Table 05 – Factor Percentage

| Sl. No | Season | Number | % |
|--------|--------|--------|------|
| 1 | Summer | 50 | 100% |
| 2 | Winter | 0 | 0% |
| 3 | Rainy | 0 | 0% |
| | Total | 50 | 100% |

This shows that the dairy products often tend to spoil in the summer season due to high temperatures.

## IV. FINDINGS AND SUGGESTION

The study shows a strong link between traffic congestion and longer delivery times for dairy products in Bengaluru. To reduce delays, logistics should use real-time traffic data and schedule deliveries during off-peak hours. Customer complaints are closely tied to traffic, delivery delays, and stockouts, so better feedback systems and improved scheduling can help reduce dissatisfaction. Overstocking harms product quality and increases spoilage, highlighting the need for data-driven inventory management and Just-in-Time delivery. Traffic delays also raise spoilage risks, especially in summer, where all spoilage cases occurred; thus, strengthening cold chain logistics and using thermal packaging are crucial. Regression analysis confirms that customer complaints and overstock quality predict traffic-related issues, emphasizing better planning and communication. Seasonal strategies like temperature-sensitive packaging and adjusted delivery times are essential to maintain dairy quality during hot months.

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