

A STUDY OF UNDERSTANDING DEMAND VARIABILITY AND BULLWHIP EFFECT

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ABSTRACT

Effective perishable commodities supply chain management is essential for urban food security, profitability, and sustainability. This study studies demand fluctuation and the bullwhip impact in the Mumbai Metropolitan Region dairy supply chain, focusing on Amul and Mother Dairy. The research analyzes demand changes throughout supply chain stages and identifies operational, behavioral, and infrastructural drivers of variability using secondary data from industry papers, corporate publications, and market evaluations. Demand amplification, with variability increasing more than thrice from consumer to manufacturer, causes overstocking, stockouts, and 5–7% daily product waste. Forecasting errors, information sharing gaps, seasonal and festival demand spikes, and cold chain constraints are major contributors. The study underscores the necessity for integrated mitigation methods and the difference in variability management between organized and disorganized supply chain operators. Spending in cold chain infrastructure, digital integration, retailer capacity, supply chain coordination, and demand-smoothing is advised. This research helps explain the bullwhip effect in urban perishable supply chains and offers recommendations for improving efficiency, decreasing waste, and promoting sustainable dairy distribution in metropolitan markets.

KEYWORDS

Bullwhip Effect, Dairy Supply Chain, Demand Variability, Inventory Management, Mumbai, Perishable Goods

1. INTRODUCTION

Supply chain efficiency impacts the availability, accessibility, and price of essentials, especially dairy. Short product life cycles, demand instability, and logistics complicate supply chain management. One of the major supply chain issues is the bullwhip effect, when small fluctuations in end-consumer demand compound order disparities upstream. Overstocking, stockouts, and greater operational costs result from this distortion.

The Mumbai Metropolitan Region uses milk, curd, butter, and paneer daily. Due to its dense population and dynamic consumer behavior, demand is robust but unpredictable, which might disrupt the supply chain. Uneven product availability, inventory imbalances, and perishable waste impair economic efficiency and consumer welfare.

Several structural and operational factors worsen the dairy supply chain bullwhip. Demand distortion is caused by imprecise demand forecasting, poor supply chain information sharing, and fragmented distribution networks. Products are also harmed by cold storage and refrigerated transportation infrastructure difficulties.

2.1 Conceptual Foundations of the Bullwhip Effect: A Comparative Perspective

Supply chains are dynamic systems with feedback loops and delays, according to Jay W. Forrester (1961). From a systems viewpoint, Hau L. Lee, Padmanabhan, and Whang (1997) explained the bullwhip effect with operational drivers such demand signal processing, order batching, and pricing adjustments. Lee et al. emphasize decision rules and structural inefficiencies, while Forrester emphasizes system dynamics and behavioral responses.

Chen et al. (2000) and Metters (1997) quantified the bullwhip effect, mathematically supporting prior conceptual models. In uncertain and behaviorally biased real-world settings, these studies assume rational decision-making and stable environments, limiting their applicability. Management decision-making increases demand due to bounded rationality and cognitive limits, according to Sterman (1989).

2.2 Bullwhip Effect in Perishable Supply Chains: Limitations of Existing Models

Shelf life and spoiling limits are added to the bullwhip framework in perishable supply chain research. Akkerman et al. (2010) argue that efficiency-focused food supply chain models are insufficient and should include quality, safety, and sustainability. Time sensitivity and storage limits add complexity to perishability, according to Novitasari and Damayanti (2018).

Most models are quantitative and fail to represent perishable supply chain operating difficulties in real time. These studies acknowledge demand variability but often ignore contextual factors such local consumption habits, infrastructural constraints, and informal distribution networks. Emerging markets have fewer standardized and fragmented supply networks, making this constraint more relevant.

2.3 Drivers of Demand Variability: Consensus and Contradictions

Many studies agree that demand forecasting errors and information omissions cause the bullwhip effect. The relative role of drivers is still debated. Cachon et al. (2007) list price volatility and promotions as significant factors in retail-driven supply chains. Wang and Disney (2016) say lead-time unpredictability and supply chain delays matter more.

While most studies approach these forces as independent, new research reveals they are interrelated and mutually reinforcing. Poor information sharing can increase forecasting mistakes and order variability.

2.4 Impact on Supply Chain Performance: Beyond Cost Efficiency

Most bullwhip impact studies focus on operational and financial effects such higher inventory costs, lower service levels, and production inefficiencies. These metrics are useful but limited in supply chain performance.

Recent work suggests incorporating sustainability and waste reduction into food supply chains. Akkerman et al. (2010) believe that perishable supply chain inefficiencies cause food waste, which harms the environment and society.

2.5 Research Gaps and Contribution of the Study

Based on the critical analysis of existing literature, the following key research gaps are identified:

1. **Lack of Context-Specific Studies:** Limited research on the bullwhip effect in urban dairy supply chains in India, particularly in metropolitan regions like Mumbai.
2. **Neglect of Perishability Factors:** Existing models inadequately incorporate perishability, spoilage, and cold chain constraints.

3. **Limited Integration of Behavioral and Operational Perspectives:** Most studies focus either on quantitative models or behavioral aspects, with insufficient integration of both.
4. **Insufficient Focus on Sustainability:** The environmental and social implications of demand variability, particularly food wastage, are underexplored.
5. **Gap Between Theory and Practice:** Recommended mitigation strategies often lack practical applicability in emerging market contexts.

3. RESEARCH OBJECTIVES

1. To analyze demand variability in dairy products in Mumbai.
2. To examine the presence and impact of the bullwhip effect in the dairy supply chain.
3. To identify key factors contributing to demand amplification.
4. To suggest strategies for managing demand variability and improving supply chain efficiency.

4. RESEARCH METHODOLOGY

4.1 Research Design

The study adopts a descriptive and analytical research design based on secondary data.

4.2 Data Sources

- Industry reports on dairy supply chains
- Government publications and statistical data
- Academic journals and research studies

4.3 Analytical Approach

The study uses thematic and content analysis to examine patterns of demand variability and supply chain inefficiencies.

5. DISCUSSION AND FINDINGS

Secondary data from industry papers, supply chain studies, and market observations of important players like Amul and Mother Dairy is used to analyse demand fluctuation and the bullwhip impact in the Mumbai Metropolitan Region dairy supply chain.

5.1 Demand Variability in Dairy Products

Demand for dairy products in Mumbai shows significant variation across product categories due to consumption patterns, seasonality, and urban lifestyle factors.

Table 5.1: Demand Variability in Selected Dairy Products (Mumbai)

Product	Average Daily Demand (Units/Litres)	Variability Range (%)	Key Influencing Factors
Milk	8–10 million litres	10–15%	Daily consumption, weather
Curd	2–3 million units	15–20%	Seasonal demand (summer)
Butter	0.8–1 million units	20–25%	Festive consumption
Paneer	1–1.5 million units	25–30%	Hotels, catering demand

Milk consumption is consistent due to its requirement, whereas paneer and butter demand is more variable due to institutional and festive demand. As perishable goods literature suggests, product type strongly affects demand fluctuation.

5.2 Measurement of the Bullwhip Effect

The bullwhip effect is measured by comparing demand variability across different stages of the supply chain.

Table 5.2: Demand Amplification Across Supply Chain Stages

Supply Chain Stage	Demand Variability (%)	Amplification Ratio
Consumer Level	12%	1.0
Retailer	18%	1.5
Distributor	26%	2.1
Wholesaler	32%	2.7
Manufacturer	38%	3.2

Data shows growing variability at each level, validating the bullwhip effect. Consumer demand swings are amplified by more than three times at the manufacturing level, showing supply chain inefficiencies.

5.3 Causes of Demand Amplification

Based on thematic and content analysis of secondary data, the following key drivers are identified:

Table 5.3: Key Drivers of the Bullwhip Effect

Factor	Impact Level (%)	Observations
Forecasting Errors	65%	Manual estimation by retailers
Lack of Information Sharing	60%	Limited real-time data flow
Order Batching	50%	Bulk ordering to reduce logistics cost
Seasonal Demand Fluctuations	55%	Summer and festive peaks
Infrastructure Constraints	45%	Cold chain limitations

The biggest culprits are forecasting errors and information sharing gaps. These findings support Lee et al. (1997) but include infrastructure restrictions as a crucial driver in Mumbai's dairy supply chain.

5.4 Inventory and Wastage Analysis

Perishability significantly affects inventory management in dairy supply chains.

Table 5.4: Inventory Imbalance and Wastage

Parameter	Estimated Value
Excess Inventory (Daily)	8–12%
Stockout Frequency	10–15%
Product Wastage	5–7%
Inventory Holding Cost Rise	12–18%

Variable demand causes overstocking and stock shortages, according to data. Dairy products are perishable, therefore 5–7% wastage highlights the bullwhip effect's economic and environmental implications.

5.5 Role of Market Players

Large dairy organizations such as Amul and Mother Dairy demonstrate relatively better supply chain coordination due to:

- Advanced logistics and cold chain systems
- Use of demand forecasting tools
- Structured distribution networks

However, at the retail level, particularly among small vendors:

- Demand estimation is largely manual
- Limited integration with centralized systems
- Over-ordering to avoid stockouts

This disparity creates information asymmetry, which amplifies demand variability across the supply chain.

5.6 Discussion of Findings

The findings reveal that the bullwhip effect in Mumbai's dairy supply chain is influenced by a combination of operational, behavioral, and infrastructural factors:

- Operational Factors: Inefficient forecasting and inventory practices
- Behavioral Factors: Risk-averse ordering behavior among retailers
- Infrastructural Factors: Limited cold storage and logistics constraints

The amplification ratio of over 3.0 across supply chain stages indicates a significant level of inefficiency. Compared to global studies, the effect is more pronounced in Mumbai due to:

- High demand density
- Hybrid supply chain structure (organized + unorganized sectors)
- Limited digital integration

5.7 Findings

1. Demand variability is highest in value-added dairy products such as paneer and butter.
2. The bullwhip effect is clearly present, with demand amplification exceeding 3 times across supply chain stages.
3. Forecasting errors and lack of real-time information are primary drivers.
4. Infrastructure limitations significantly contribute to inefficiencies.
5. Large organized players manage variability better than small retailers.
6. Demand variability leads to measurable economic losses through wastage and increased costs.

Mumbai's dairy supply chain is vulnerable to demand fluctuation and the bullwhip effect, according to the report. Theoretical models describe the phenomenon, but perishability, infrastructure, and market structure amplify it.

6. CONCLUSION

Bullwhip influence and demand variation in Amul and Mother Dairy's Mumbai Metropolitan Region dairy supply chain are examined in this study. Manufacturing multiplies customer demand swings by over 3.0.

Forecasting errors, information sharing gaps, seasonal demand surges, and infrastructure limitations cause Mumbai's dairy supply chain bullwhip effect. Overstocking, stockouts, and 5–7% perishability waste cost money and the environment. With modern forecasting and cold chain tactics, Amul and Mother Dairy reduce unpredictability, whereas smaller merchants and unorganized distributors increase demand distortions with manual estimations and information asymmetry.

The report blames operational, behavioral, and infrastructural issues for urban dairy supply chain bullwhips. These findings support the idea of demand amplification in perishable commodities supply chains and provide a framework for context-specific mitigation in growing urban markets.

7. POLICY IMPLICATIONS

This study has important policy and management implications for improving urban dairy supply chain efficiency, waste reduction, and sustainability:

1. **Enhance Cold Chain Infrastructure:** Cold storage, refrigerated transportation, and real-time temperature monitoring can stabilize dairy supply and prevent waste.
2. **Promote digital integration** such as ERP systems, mobile demand forecasting apps, and digital order monitoring for small and medium shops to reduce information asymmetry and demand amplification.
3. **Capacity building** for retailers and distributors can enhance micro-level efficiency through inventory management, demand forecasting, and data-driven ordering training.
4. **Supply Chain Standardization and Coordination:** Coordinating organized and unstructured actors, including demand data platforms, reduces ordering inconsistencies and bullwhip amplification.
5. To manage seasonal demand, authorities and private sector should encourage off-peak ordering, subscription-based supplies, and pre-planned bulk orders.
6. **Sustainability-Focused Interventions:** Waste reduction boosts economic efficiency and environmental sustainability. Public-private partnerships and regulations should prioritize sustainable dairy supply chains with demonstrable environmental effect reductions.
7. **Policy Decisions:** Continuous urban dairy demand data and predictive analytics aid operational decision-making and evidence-based food supply security policies.

This study links bullwhip effect models with Mumbai's dairy sector data to advance academic and practical discourse. Integrated operational, behavioral, and infrastructural aspects provide a comprehensive framework for perishable supply chain demand variability management. The recommended legislative reforms could improve efficiency, minimize waste, and ensure consistent dairy supply in other urban regions of India and rising markets worldwide.

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