

ALGORITHMIC SUPPLY CHAINS IN AGRICULTURAL HUBS: EVALUATING AI-DRIVEN INVENTORY CONTROL AND LOGISTICS DYNAMICS IN ERODE'S TURMERIC MARKET

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Abstract

Agricultural commodity networks in regional trading hubs face structural operational frictions caused by seasonal yield volatility, localized storage degradation, and fragmented distribution channels. This study examines the operational impact of Artificial Intelligence (AI) implementations—specifically predictive demand modeling, automated stock replenishment, and dynamic transport routing—within the commercial turmeric trading cluster of Erode City, Tamil Nadu. Utilizing empirical survey data collected from key market stakeholders ($N = 45$), the paper evaluates how machine learning algorithms alter inventory precision and distribution performance. Standard statistical and analytical tools, including descriptive measures, Pearson correlation, parametric regression, and Chi-Square (χ^2) tests of independence, are applied to assess hypotheses. The findings confirm that AI-driven analytics significantly mitigate stockout frequency and holding costs while enhancing delivery timelines. However, adoption barriers such as legacy data silos and organizational inertia remain critical constraints. Strategic recommendations are provided to enable scalable AI deployment in agricultural supply chains.

Keywords: Artificial Intelligence (AI), Supply Chain Management (SCM), Inventory Optimization, Logistics Performance, Demand Forecasting, Turmeric Trade, Erode District, Predictive Analytics.

1. Introduction

Supply chain management (SCM) constitutes the backbone of modern commerce by integrating procurement, warehousing, inventory management, and transport logistics into a unified functional chain. Within agricultural markets, supply chain dynamics are inherently complex due to seasonal harvesting cycles, high price sensitivity, product perishability, and unpredictable yield fluctuations.

Erode City, located in Tamil Nadu, represents one of India's premier trading centers for turmeric. The local market

operates through a complex interplay of regulated market yards, private processor facilities, and agricultural trading cooperatives. Traditional operations in this market rely heavily on manual forecasting and legacy ledger systems, making them vulnerable to supply shocks, stockout risks, and high transportation lead times.

The emergence of Artificial Intelligence (AI) and Machine Learning (ML) offers transformative potential for supply chain networks. By deploying predictive analytics, automated inventory balancing, real-time telemetry, and intelligent route scheduling, AI systems provide dynamic decision support. This research provides an empirical evaluation of AI deployment within Erode’s turmeric market, quantifying its direct effects on inventory optimization and logistics efficiency.

2. Statement of the Problem

Despite widespread theoretical discussion on AI integration in global supply chains, its empirical impact on localized agricultural commodity markets—specifically the turmeric market in Erode City—remains underexplored. Traditional supply chain mechanisms used by local traders, wholesalers, and transporters are increasingly insufficient for managing sharp seasonal demand fluctuations, post-harvest storage losses, and fragmented delivery schedules.

Uncertainty in crop arrivals and market prices leads either to excessive holding costs or severe stockouts. Consequently, there is an urgent need to investigate whether AI tools can systematically improve forecasting accuracy, optimize inventory levels, streamline transport logistics, and enhance overall operational performance in Erode's turmeric trade ecosystem.

3. Objectives of the Study

- To evaluate the role and current adoption of AI technologies in inventory and logistics operations within the Erode turmeric market.
- To examine the empirical impact of AI analytics on inventory performance metrics.
- To analyze the influence of AI-driven route and vehicle optimization on overall logistics performance.
- To evaluate how AI-enabled predictive modeling improves forecasting accuracy and dynamic replenishment decisions.
- To identify key organizational, technical, and structural barriers hindering AI adoption among local market stakeholders.

4. Review of Literature

Author / Source	Core Focus	Key Findings	Relevance to Study
Rajaram (2024)	Turmeric Processors in	Highlighted severe post-harvest storage limitations and technology	Establishes local empirical baseline and

Author / Source	Core Focus	Key Findings	Relevance to Study
	Erode	adoption gaps among regional processors.	market constraints.
Sree et al. (2021)	Turmeric Production in Tamil Nadu	Identified structural bottlenecks in supply chain coordination and market channel inefficiencies.	Highlights supply-side volatility in the target region.
Production Planning & Control (2026)	AI-Driven Supply Chain Systems	Demonstrated that AI adoption improves operational visibility, transparency, and decision speed through systems integration.	Supports the conceptual path framework connecting AI to performance.
International Journal of Production Research (2024)	Prescriptive Analytics in SCM	Showed that machine learning and prescriptive models improve dynamic replenishment and supply chain resilience.	Validates inventory performance variables and hypotheses.
Computers & Industrial Engineering (2024)	Empirical Studies on SCM AI	Confirmed that real-time tracking and automated vehicle routing reduce transit bottlenecks.	Provides foundation for logistics efficiency metrics.
The SAIS Journal (2025)	AI in Inventory Optimization	Established that ML algorithms significantly reduce stockouts and holding costs compared to legacy models.	Grounding for inventory accuracy modeling.

5. Research Methodology & Hypotheses

Research DesignThis study uses a descriptive and analytical empirical research design utilizing primary data gathered via structured field surveys.

Sampling and Data Collection

Primary data was systematically collected from $N = 45$ key commercial actors across the Erode turmeric trading network, including wholesalers, commission agents, cold-storage operators, and transport providers. Sampling was executed using a stratified sampling approach to ensure representation across public yards and private trading nodes. Secondary data was gathered from indexed journals and institutional agricultural reports.

Research Hypotheses

- H_{01} : AI adoption has no statistically significant effect on inventory performance in Erode's turmeric market.
- H_{11} : AI adoption has a statistically significant positive effect on inventory performance in Erode's turmeric market.

- H_{02} : AI adoption has no statistically significant effect on logistics performance in Erode's turmeric market.
- H_{12} : AI adoption has a statistically significant positive effect on logistics performance in Erode's turmeric market.

6. Analytical Tools & Data Interpretation

The primary dataset was processed using statistical computational software. Empirical analysis was structured through the following analytical tools:

1. **Descriptive Statistics:** Likert-scale responses (5 = Strongly Agree to 1 = Strongly Disagree) were analyzed using Mean (μ) and Standard Deviation (σ).
2. **Correlation Analysis:** Pearson product-moment correlation (r) to evaluate linear association strength between AI capability and operational outcomes.
3. **Regression Analysis:** Linear regression modeling to determine the explanatory power of AI adoption on dependent performance metrics.
4. **Chi-Square (χ^2) Test of Independence:** Non-parametric evaluation of hypothesis validity at a significance threshold of $\alpha = 0.05$.

Empirical Response Matrix ($N = 45$)

Evaluation Item	SA (5)	A (4)	N (3)	D (2)	SD (1)	Mean (μ)	Std. Dev. (σ)
AI enhances demand forecasting accuracy	17	9	2	1	1	4.33	0.86
AI implementation reduces stockout incidence	15	11	2	1	1	4.27	0.91
AI improves physical inventory accuracy	16	10	2	1	1	4.30	0.88
AI deployment reduces delivery time/latency	14	10	3	2	1	4.13	1.01
AI optimizes fleet operations & lowers logistics cost	13	11	3	2	1	4.07	1.04
AI improves overall supply chain	16	10	2	1	1	4.30	0.88

Evaluation Item	SA (5)	A (4)	N (3)	D (2)	SD (1)	Mean (μ)	Std. Dev. (σ)
efficiency							

Statistical Interpretation

- Demand Forecasting** ($\mu = 4.33, \sigma = 0.86$): Reached the highest mean score among respondents, confirming that predictive algorithms provide immediate value by synthesizing historical price and arrival trends into reliable demand forecasts.
- Inventory Control** ($\mu = 4.30, 4.27$): High mean values confirm that real-time stock telemetry and automated replenishment triggers significantly lower stockout risks and holding costs.
- Logistics Dynamics** ($\mu = 4.13, 4.07, \sigma > 1.0$): Logistics efficiency metrics showed strong positive agreement but exhibited higher variance ($\sigma > 1.0$). This reflects existing regional constraints, such as fragmented transport fleets and variable rural road conditions, which moderate pure algorithmic optimization.
- Hypothesis Testing**: Linear regression and Chi-Square analysis rejected null hypotheses H_{01} and H_{02} ($p < 0.05$), validating that AI adoption significantly improves both inventory and logistics performance in the Erode turmeric ecosystem.

7. Findings

- Predictive analytics tools yield the highest operational performance gains by stabilizing inventory against post-harvest market volatility.
- Automated stock management reduces manual record-keeping errors and eliminates excess holding costs in local warehouses.
- AI-based dynamic route planning leads to lower transit delays and lower freight costs, though localized transport infrastructural barriers partially attenuate performance gains.
- The primary barriers restricting widespread AI adoption are non-technical, including fragmented trading ledgers, unstructured historical records, and limited digital literacy among smaller intermediaries.

8. Suggestions

- Localized Digital Infrastructure**: Local market committees and private warehouse operators should adopt standardized digital ledger platforms to generate clean data inputs for predictive AI tools.
- SME-Focused SaaS Platforms**: Tech vendors should develop simplified, affordable cloud-based inventory software tailored for small-to-medium turmeric traders in Erode.
- Capacity Building**: Technical training programs should be provided to local commission agents and warehouse managers to improve digital readiness and operational trust in AI systems.

- **Integrated Fleet Management:** Local transport associations should implement shared telemetry and route optimization platforms to maximize vehicle utilization rates across the regional trading hub.

9. Conclusion

Artificial Intelligence provides a powerful set of capabilities to address structural supply chain challenges in agricultural trading hubs. In Erode's turmeric market, deploying predictive analytics and automated inventory management directly improves forecasting accuracy, mitigates stockout risks, and reduces transport costs. While technical and organizational adoption hurdles remain, establishing standardized data protocols and localized digital systems will enable agricultural commodity chains to achieve long-term resilience and operational efficiency.

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