

Predictive Modeling of Perishable Supply Chains under Infrastructure Constraints: A Comprehensive Review of Data Scarcity, Intermittent Connectivity, and Informal Distribution Integration

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Abstract

Perishable food supply chains in developing economies face severe challenges affecting global food security, with post-harvest losses reaching 40% of agricultural produce in India and one-third of agri-fresh products annually. This literature review examines predictive modeling research for supply chains operating under infrastructure constraints, focusing on data scarcity, intermittent connectivity, and informal distribution networks. The review analyzes mathematical optimization, machine learning applications, and integrated decision-support frameworks across diverse geographic contexts where infrastructure deficits create food insecurity rates up to 46.4% in remote communities. A critical finding reveals a significant gap between theoretical modeling advances and practical implementation capabilities. While sophisticated mathematical optimization and machine learning techniques show promising theoretical results, real-world application remains limited due to persistent infrastructure deficits. Inadequate cold chain facilities contribute to massive losses, including 370 million tons of fruits and vegetables deteriorating annually in China alone in 2012. Current research inadequately addresses the complex interplay between formal and informal distribution networks, despite evidence that intermediary syndicates substantially influence market dynamics through price manipulation and artificial scarcity. However, emerging integration strategies demonstrate quantifiable benefits. Documented improvements include transport cost reductions up to 29% and operational savings reaching 78 million BDT through optimized distribution center placement. Advanced hybrid distribution models show that plants can directly meet 63% of mango demand and 53% of jackfruit demand, significantly reducing intermediary reliance. However, there is lack of comprehensive frameworks simultaneously addressing infrastructure limitations, data constraints, connectivity challenges, and informal market dynamics. This review identifies critical theoretical gaps and proposes a research agenda emphasizing context-adaptive modeling approaches, empirical validation methodologies, and holistic integration strategies. The findings contribute to supply chain theory by highlighting the need for paradigm shifts in modeling approaches for resource-constrained environments and establishing priorities for sustainable food system transformation research.

Keywords: Developing Economies, Infrastructure Constraints, Perishable Supply Chains, Post-Harvest Losses, Predictive Modeling

