Abstract

Ensuring the timely and cost-effective movement of food grains across India is critical for sustaining the Public Distribution System (PDS), one of the world's largest food security programmes. The Food Corporation of India (FCI), responsible for managing national foodgrain logistics, currently relies on fragmented planning processes, informal decision-making, and limited computational tools, leading to inefficiencies, high operational costs, and vulnerability to disruptions. This thesis develops a comprehensive optimization-driven framework to strengthen FCI's interstate foodgrain movement through strategic, tactical, operational and resilience-oriented planning layers.

At the strategic level, an annual planning framework is formulated to minimize transportation expenditure, rationalize warehouse inventories, and evaluate the impact of capacity augmentation. Multiple variants, including multimodal models and integer-rake–based formulations, are developed and tested across realistic allocation and offtake scenarios. The results highlight substantial savings potential and provide insights into optimal inventory distribution, rake utilization, and multimodal routing.

For monthly and daily execution, a novel railhead-centric optimization framework is introduced, capturing operational realities such as rake type restrictions, two-point destinations, Traditional Empty Flow Direction (TEFD) concessions, and unbalanced supply–demand conditions. Dedicated execution methodologies, including a daily optimization algorithm, are designed to ensure minimal deviation from monthly plans. These models are implemented within a web-based decision support software framework currently under deployment at FCI, enabling digital indent collection, real-time freight integration, and automated movement planning. Field validation with FCI confirms significant monthly and daily cost savings, along with major improvements in transparency, operational coordination, and planning efficiency.

To address vulnerability in the supply chain, the thesis proposes a bilevel interdiction model that identifies critical railheads whose disruption would maximize system cost. A reformulated solution methodology with relaxed interdiction integrality is developed to ensure tractability on large datasets. Experiments across balanced and unbalanced scenarios reveal cost escalation patterns and resilience insights relevant for policy planning.

Overall, the research delivers an integrated, data-driven, and implementation-oriented framework spanning strategic annual planning, tactical and operational execution, and disruption resilience analysis, offering substantial managerial, financial, and policy benefits for strengthening India's foodgrain supply chain.

Keywords: Foodgrain Logistics, Mathematical Optimization, Multimodal Transportation, Interstate Transportation, Bilevel Programming, Public Distribution System (PDS), Food Corporation of India (FCI), Decision Support System, Mixed Integer Programming, Supply Chain Resilience, and Operations Research.