Sourcing Strategies in Humanitarian Supply Chains: Forecasting and Optimization Models

Abstract

Natural disasters result in loss of human lives, economic damage, and disruption to living conditions. The increasing frequency and severity of natural disasters create a need for an efficient and resilient humanitarian supply chain. Effective disaster relief operations rely on the availability of the relief materials in a timely manner. This is possible by having proper sourcing strategies, which include demand estimation, optimal procurement planning, and sustainable sourcing decisions. However, humanitarian supply chains are characterized by real-time data, uncertainty, and complex operational constraints, which often hinder effective decision-making. This thesis addresses these challenges by developing an integrated framework that combines data-driven demand forecasting, optimization-based procurement planning, and sustainability-oriented supplier evaluation to enhance decision-making in humanitarian supply chains for the flood-affected regions in India.

This study develops a hybrid demand forecasting framework by combining statistical time-series models, autoregressive integrated moving average (ARIMA) models, principal component analysis (PCA), and the Random Forest method. The proposed hybrid model captures both linear and nonlinear patterns across diverse disaster-related variables, providing an accurate prediction of affected populations to estimate the relief demand at both the national and state levels in India. To predict the affected population, the time series, machine learning, and deep learning methods were explored and their performance was evaluated using error metrics. Furthermore, this study links the forecasting with operational planning in which the requirements of various items have been quantified, and the annual demand quantities are disaggregated into pre-monsoon, main-monsoon, and post-monsoon flood waves. To procure the relief items, this study formulates a bi-objective mixed-integer linear programming model for supplier selection and order allocation. It demonstrates how proactive and reactive decisions can reduce costs and improve responsiveness in the face of disaster-related uncertainty.

Due to the inherent nature, uncertainty cannot be ignored. This study extends the deterministic model by incorporating chance-constrained optimization with conformal prediction intervals for capturing the demand uncertainty. This approach allows decision-makers to meet demand with a high confidence level. Alongside uncertainty modelling, this study examines how

humanitarian organizations can achieve sustainability, ensuring productivity and performance by integrating economic, social, and environmental dimensions for sourcing. A hybrid Fermatean Fuzzy (FF)-based multi-criteria decision-making (MCDM) framework, integrating Criteria Importance Through Inter-Criteria Correlation (CRITIC) and Combined Compromise Solution (CoCoSo) method, is applied to prioritize sustainability criteria and rank suppliers. The result of the combined CRITIC-CoCoSo method indicates that the economic dimension holds the highest weightage, followed by social and environmental, reinforcing the dominance of cost-related factors in supplier selection. Additionally, key performance indicators, such as delivery efficiency, crisis responsiveness, and environmental compliance, have been proposed in post-selection, which improves the performance and resilience of humanitarian logistics.
Overall, this study presents a comprehensive decision support framework for humanitarian organizations and policymakers. By linking forecasting, optimization, uncertainty quantification, and sustainability, this study advances both the theory and practice of humanitarian logistics. It shows how data-driven analytics can support timely, efficient, and equitable disaster response, contributing to more resilient and sustainable humanitarian supply chains.

Keywords: Disaster management; Humanitarian logistics; Humanitarian supply chain; Floods; Demand forecasting; Machine learning; Supplier Selection; Conformal Prediction; Bi-Objective Optimization; Chance-Constrained; Sustainability; Fermatean Fuzzy; MCDM; Key Performance Indicator, Performance Management. India.