Handling uncertainty in humanitarian logistic

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11 septembre 2026

The increasing frequency and unpredictability of hurricanes pose significant challenges to humanitarian logistics, where critical decisions on facility location, inventory pre-positioning, and relief distribution must be made under deep uncertainty. This paper examines the application of robust optimization models to address these challenges, with particular emphasis on distributionally robust optimization (DRO) as an advanced framework for handling uncertainty in hurricane relief operations. Unlike traditional stochastic programming, which requires precise probabilistic information often unavailable in disaster contexts, or classical robust optimization, which tends to yield overly conservative solutions, DRO offers a flexible middle ground by optimizing against the worst-case distribution within an ambiguity set constructed from limited data. Recent developments employ Wasserstein metric-based ambiguity sets to capture uncertainties in post-disaster demand, supply survivability, and road network disruptions, enabling data-driven decision-making with probabilistic guarantees. Risk-averse measures such as worst-case mean-Conditional Value-at-Risk (WMCVaR) are integrated to guard against extreme shortage scenarios while balancing cost-efficiency and service reliability. Case studies focusing on hurricane threats in the Gulf of Mexico region demonstrate that these robust optimization approaches consistently outperform conventional two-stage stochastic programming and sample average approximation benchmarks, achieving favorable trade-offs between out-of-sample reliability, operational costs, and humanitarian service quality. The findings provide actionable insights for humanitarian decision-makers seeking resilient pre-positioning and response strategies under the inherent unpredictability of hurricane disasters.