Air Freight Logistics under Uncertainty: Integrated Tail Assignment, Flight Departure Time Adjustment, and Shipment Routing

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Air cargo operations face significant challenges due to flight time variability, which can disrupt schedules and delay shipments, especially critical for time-sensitive cargo and in the context of express delivery. In this paper, we integrate aircraft tail assignment, flight departure time adjustment, and cargo routing decisions under flight time uncertainty. We formulate the problem as a two-stage stochastic programming model: the first-stage determines the sequence of flight legs assigned to each aircraft, while the second-stage, after flight times are realized, determines the demand to be served, its routing, and flight departure times. To improve computational performance, we develop tailored algorithms for demand itinerary generation and implement a backward scenario aggregation algorithm that preserves uncertainty characteristics while reducing problem dimensionality. Scenarios are generated using three years of historical data, allowing realistic temporal and spatial dependencies to be retained. Using data inspired by the domestic network of a major Chinese express air cargo carrier, we conduct experiments across multiple seasons. The proposed approach consistently outperforms deterministic benchmarks based on average and minimum flight times, with profit improvements of up to 4.3% and 3.8%, respectively, during the Winter Monsoon season, when variability is highest. Moreover, we show that the value of stochastic planning increases significantly when the network operates under tighter connectivity conditions. Under reduced fleet availability, profit improvements rise to 7.0% and 9.7% relative to the benchmarks based on average and minimum flight times, respectively, highlighting how delay propagation in tightly coupled aircraft rotations makes deterministic plans particularly fragile. Overall, the results demonstrate that anticipating uncertainty at the tactical planning stage improves both operational robustness and revenue performance in large-scale air cargo networks.