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Combinatorial optimization and decision-focused learning for stochastic tail assignment

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Network schedule optimization is one of the main applications of OR to the air transport industry. This process involves designing aircraft schedules that are both operationally feasible and cost-optimal. Tail assignment is the process of assigning specific aircraft (tails) to planned flights, typically occurring a few days to weeks before operations. Airlines routinely solve this problem using Mixed Integer Linear Programming (MILP). However, these methods often overlook the resilience of routing solutions to delays and the associated costs of delay propagation along planned routes. While airlines commonly mitigate delay impacts by adding artificial time buffers between flights as hard constraints, this approach is frequently suboptimal and can lead to infeasible instances in practice, limiting its operational utility.

We propose a novel approach to the tail assignment problem that explicitly accounts for delay propagation in flight schedules. Our method consists of two key components. First, we develop a neural network-based delay prediction and propagation model trained on historical data, which we use to generate realistic delay scenarios and evaluate the delay costs of candidate tail assignments. Second, we implement a decision-focused learning approach that encodes an assignment policy as a deep learning pipeline combined with the tail assignment MILP as a combinatorial optimization layer. This policy is trained in a supervised manner using high-quality solutions computed offline via column generation.

Experimental results demonstrate that our approach generates tail assignment solutions that significantly reduce the total cost (operational + delay costs) compared to traditional methods, while maintaining computational efficiency comparable to deterministic tail assignment algorithms. This makes our solution practical for real-world airline operations, where both solution quality and quick decision-making are essential.

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