Resilient Transportation Network Design for A Major Air Carrier Against Hurricane Disruptions

Yusuf Seçerdin, PhD Student (Dissertation Advisor: Dr. Murat Erkoc)
Department of Industrial Engineering, University of Miami

Objectives

For feeder service network of a major air-carrier we aim:
• to produce optimal schedules in terms of total operating cost (service network design problem w/ asset management);
• to determine location(s) of local hub(s) within service network design problem simultaneously (hub network design and routing/scheduling);
• to maximize survivability of the service network against disruptions due to hurricanes within hub and service network design problem (resilient transportation network design);
• to develop a decision support system tool in which all proposed solution procedures for the problem above are integrated and automated.

Introduction

In this study, we consider the routing and scheduling of air fleet of a major express cargo service provider in the Caribbean. The problem is formulated as a service network design problem (SNDP) on a hierarchical hub-and-spoke network. The transportation of an express package as well as feeder service network of a major air-carrier are shown in Figure 1. This study is composed of two main parts, service network design under normal conditions and resilient service network design under the risk of disruptions caused by hurricanes.

Part I: Network Design under Normal Conditions

In this part, we propose a multistep solution procedure which first executes an initial data processing that involves feasible

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Decision Support System Tool

The solution procedure depicted in Figure 2 is integrated and fully automated in a decision support system tool (DSS) in which the basic steps of the procedure—data acquisition, route generation and elimination, optimization, and reporting—are coded as independent modules. Besides, few supplementary modules are also coded for data processing steps—input processing, pre-processing, and post-processing—in the tool. The DSS will be implemented by the company as soon as the integration between the company database and the tool is completed.

Important Result

Under normal conditions, we achieve to save up to 13.45% daily in total operating cost through eliminating unnecessary flight time and feeders, and maximizing utilization as well as optimizing routes on the network.

Comp. Experiment & Results

We compare two routing approaches in terms of operational costs, flight hours, and fleet sizing. Under the several scenarios based on fleet mix, we achieved significant cost savings for the carrier. From case to case, our procedure can save up to three aircrafts, amount of flight time from 36 minutes to 9.5 hours, and cost from 0.91% to 13.45% in total operating cost daily. A summary of the results is listed in Table 1. The current schedule of the carrier is determined as the benchmark instance for the computational experiment.

Part II: Network Design under Disruptions

The Caribbean feeder service network of the carrier can be partially or fully disrupted due to hurricanes. When a hurricane occurs other facilities-related or flight-related failures can be observed. The failure classification is shown in Figure 4.

Conclusion

Contributions of this study can be summarized as follows:
• The aircraft routing and scheduling problem is formulated as a service network design problem on a hierarchical hub-and-spoke network,
• An integrated multi-step solution procedure is proposed for the studied problem,
• The proposed solution procedure is integrated and automated within a decision support system tool.

In ongoing research, we will be focusing on developing an integrated solution procedure for resilient transportation network design problem.

Strategic vs. Operational Planning

We aim to develop a solution procedure which is able to design transportation networks at both strategic and tactical-operational levels, thus obtained network becomes reliable and resilient against disruptions due to hurricanes. Levels of planning in resilient transportation network design can be explained as follows:

• Strategic:
  • Propose a framework to get ready for a contingency plan in advance,
  • Identify temporary hub locations and capacity investment levels for major disruptions,

• Operational:
  • State-based decision-making for pre and post hurricane period,
  • Robust optimization and alternative routing and scheduling based on updated info about a hurricane.