Predicting & Planning Airport Acceptance Rates for Improved Traffic Flow Management Decision Support

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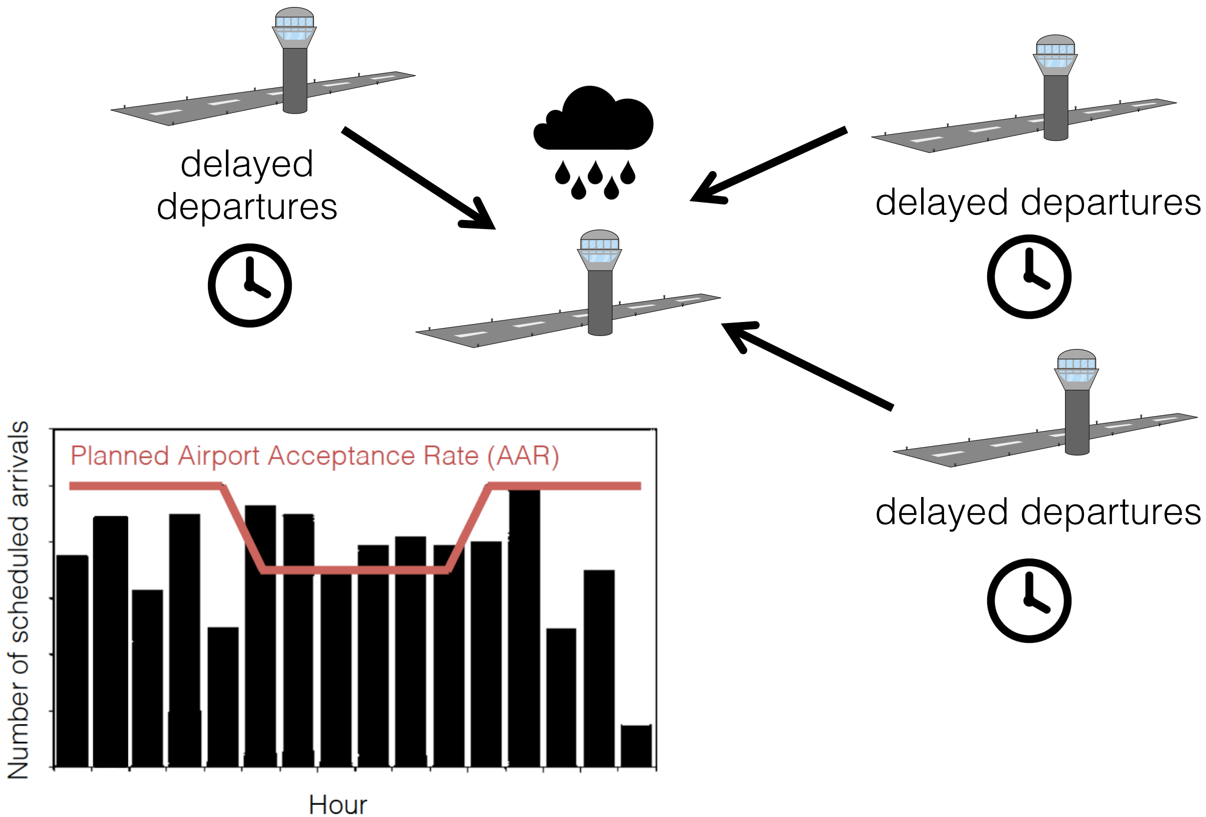
Introduction

- Traffic Flow Management (TFM) has the goal of adjusting the traffic flows to correct demand-capacity imbalances
  - Accomplished through different types of strategies at strategic/tactical time frames

Example of strategic TFM measure: Ground Delay Program



Introduction

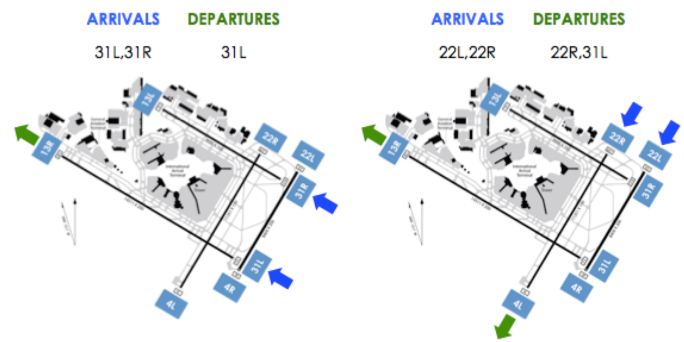
- Efficient planning of airport capacity is key for the successful accomplishment of TFM

Actual capacity > Planned capacity → Capacity sub-utilization, unnecessary ground delays → Under-delivery costs

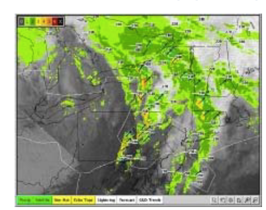
Actual capacity < Planned capacity → Tactical intervention, excessive airborne holding, diversions → Over-delivery costs

- However, precisely predicting future flow rates is a challenge
  - Airport capacity depends on a number of factors/decisions that are uncertain, especially for long time horizons
- Even more challenging for multi-airport (metroplex) systems because of existing operational interdependencies
  - Interdependent runway configurations
  - Shared terminal airspace

Runway Configuration



Weather conditions

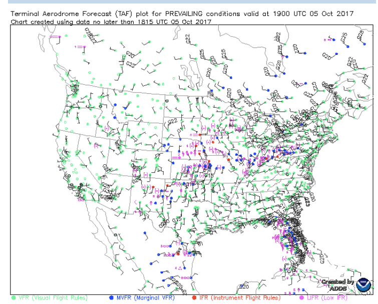


Wind speed and direction, ceiling, visibility, convection

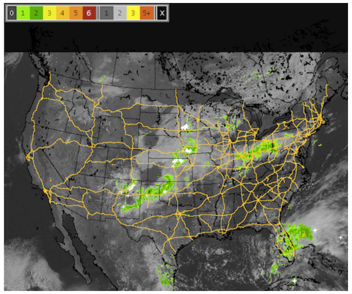
Introduction

- Currently, the planning of Airport Acceptance Rates (AAR) is done on the basis of experience
  - Many weather products
  - Few translation tools
  - Subjective evaluation

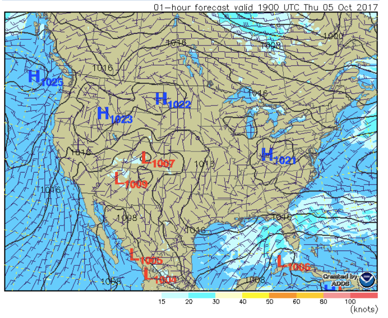
Ceiling/visibility



Convective weather



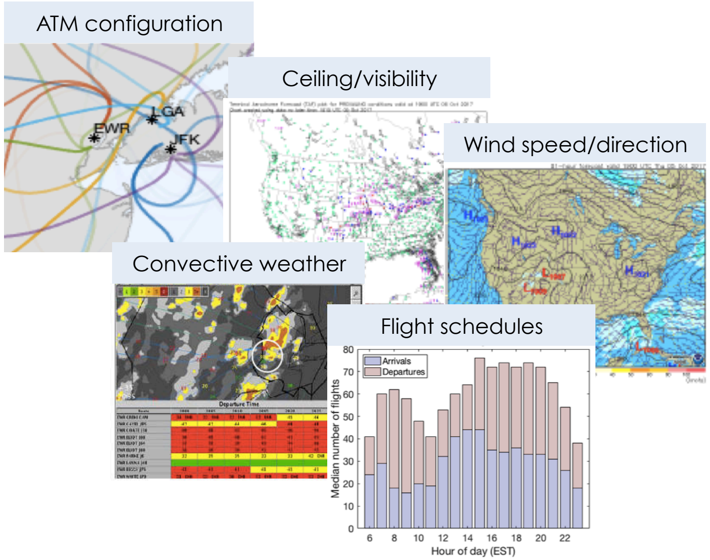
Wind speed/direction



Can we leverage currently available operational data to automatically provide capacity information and improve traffic flow management decision support?

Research Approach

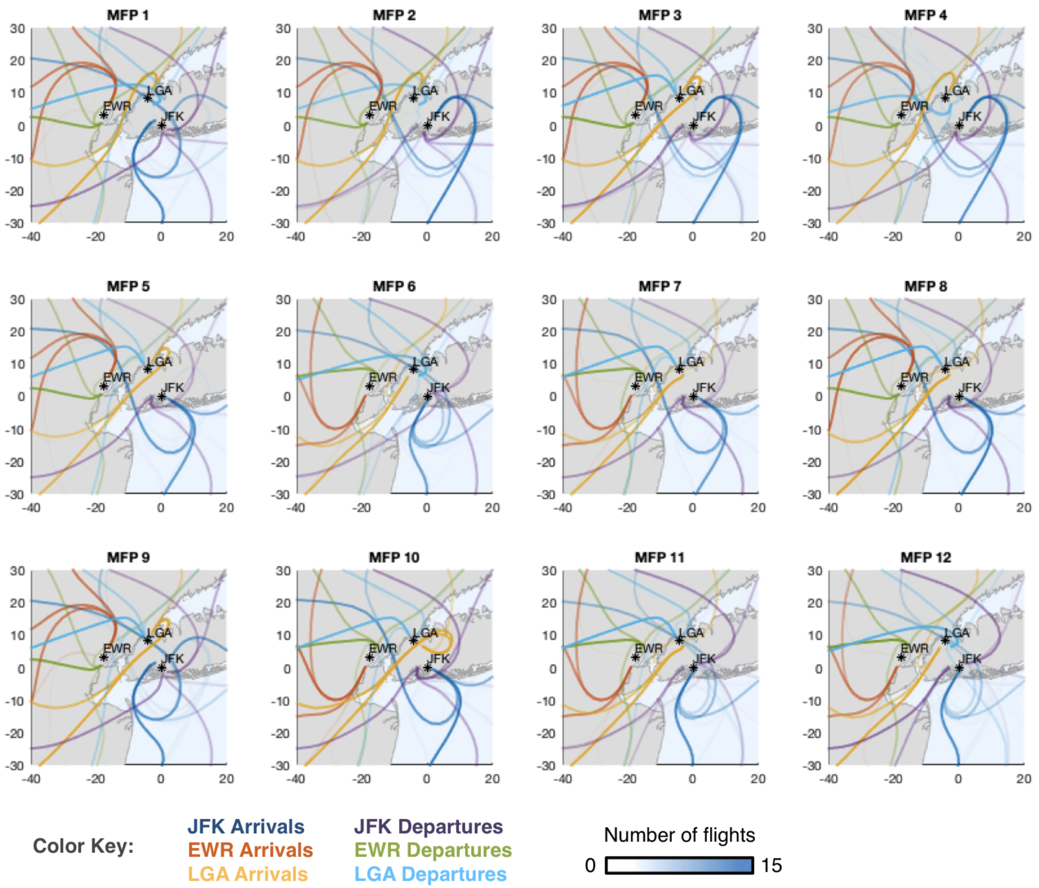
- Historical data – New York metroplex (JFK, EWR, LGA)
  - ✓ Metroplex configuration and throughput
    - ✓ Knowledge from trajectory data analytics
  - ✓ Weather forecasts
    - ✓ TAF – Terminal Aerodrome Forecasts
    - ✓ ARSI – Arrival Route Status and Impact
  - ✓ Metroplex demand
    - ✓ ASPM – Aviation System Performance Metrics

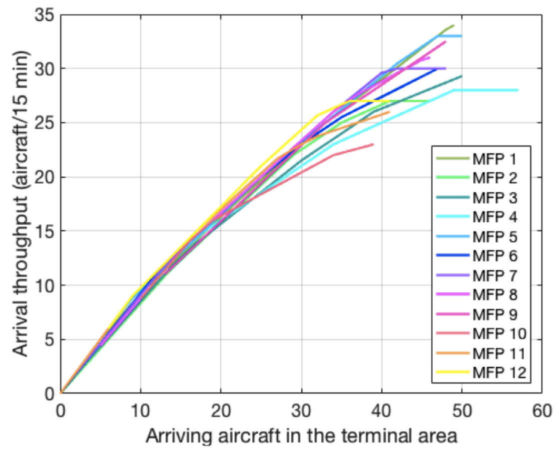


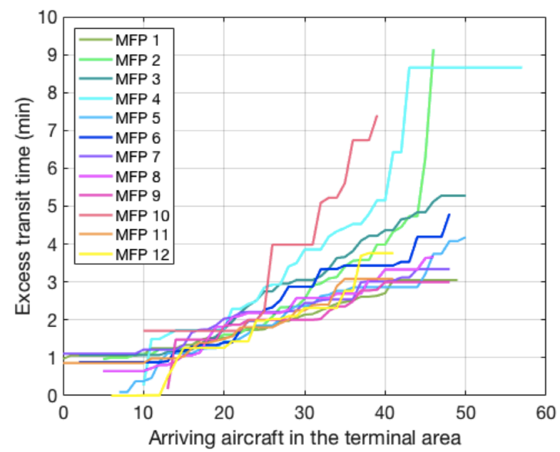
- Use of machine learning & optimization methods to develop a data-driven framework for airport capacity planning
  - Estimating capacity with proper quantification of uncertainty
  - Prescribing a target flow rate (AAR) to manage the traffic towards the capacity-constrained airport

New York Metroplex

- Very dynamic airspace use and high variability in throughput performance across different configurations
- Anticipating the behavior of the metroplex as a system is important towards predicting throughput

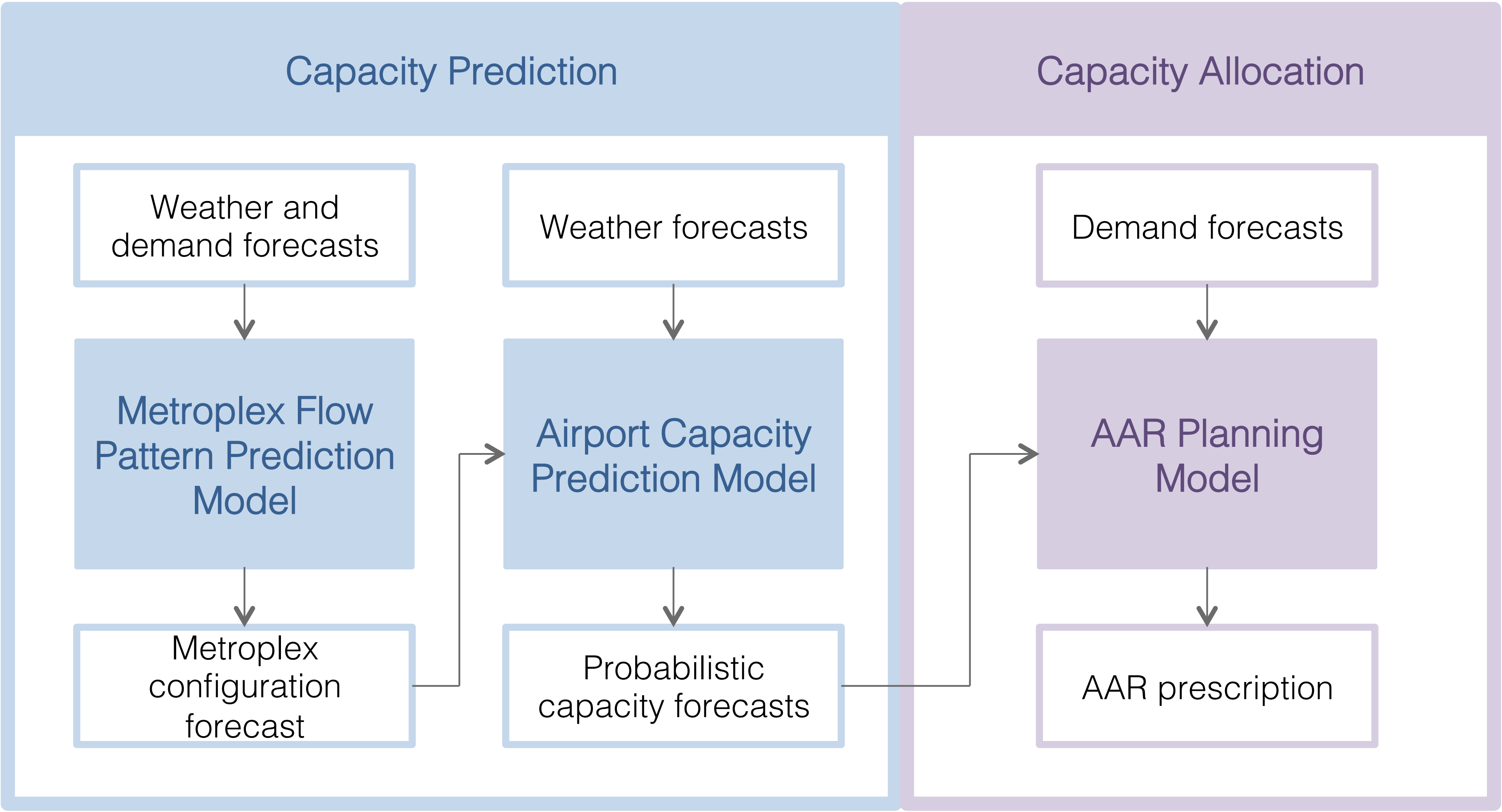






Data-Driven Airport Capacity Planning Framework

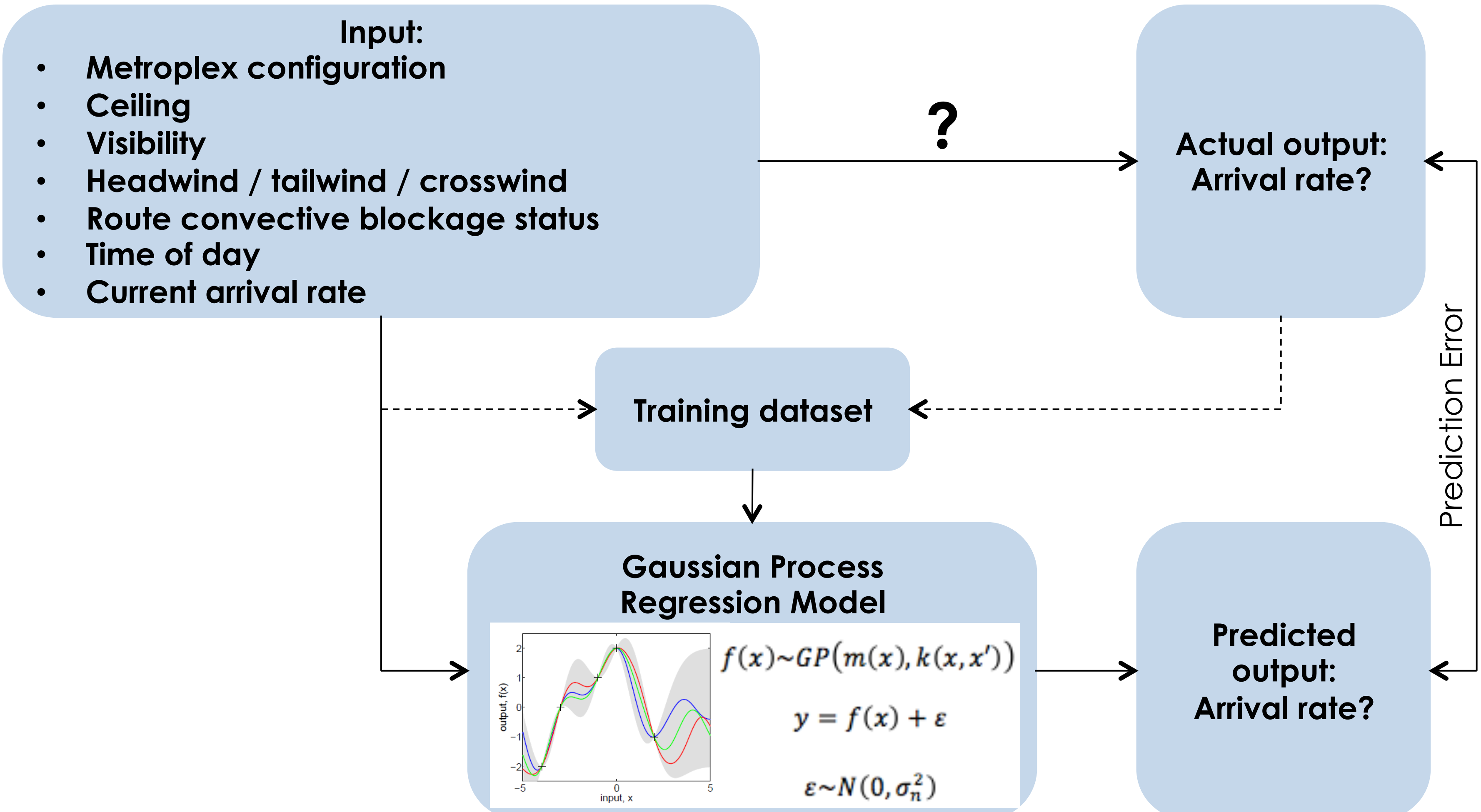
- Tackling the problems of capacity estimation and allocation using machine learning and optimization



Airport Capacity Prediction

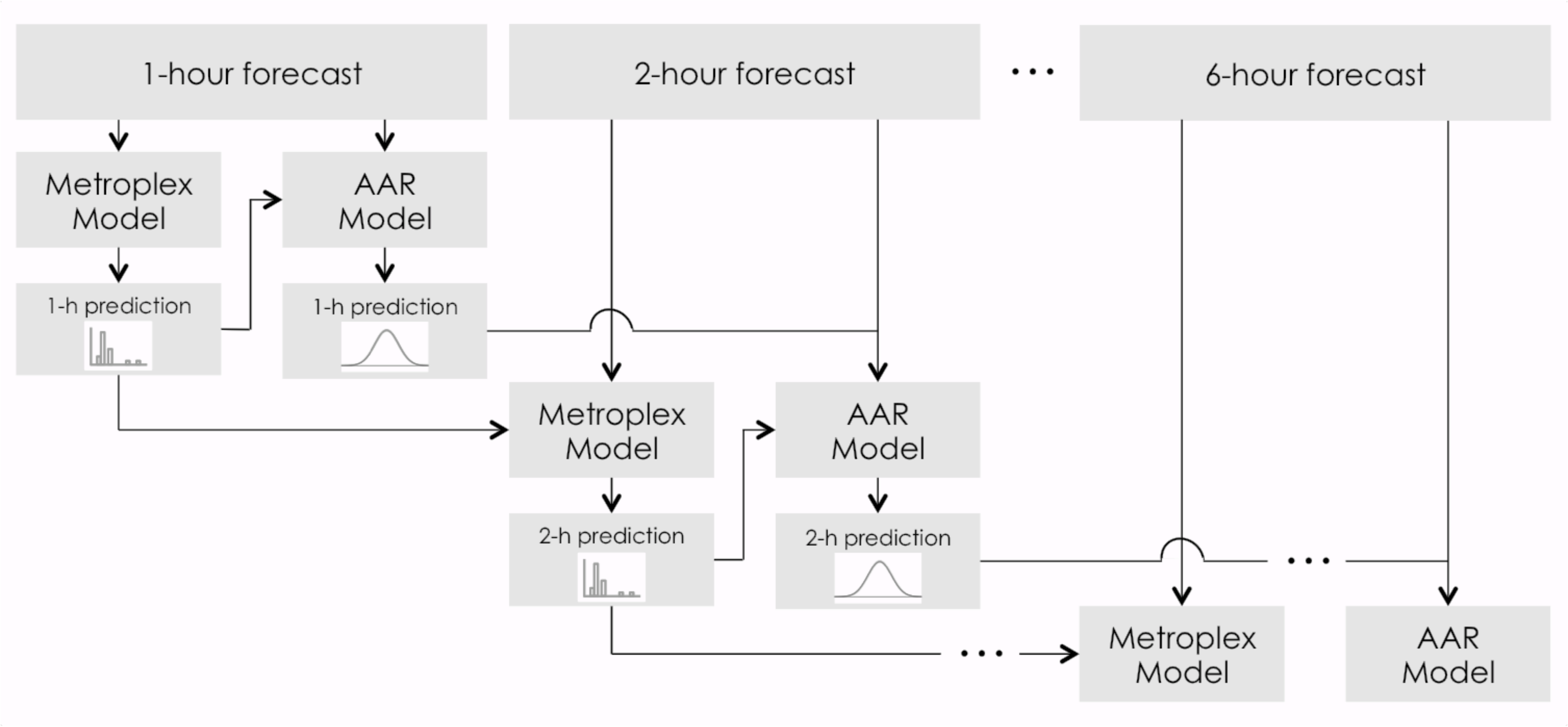
Model and Features

- Supervised learning problem – regression



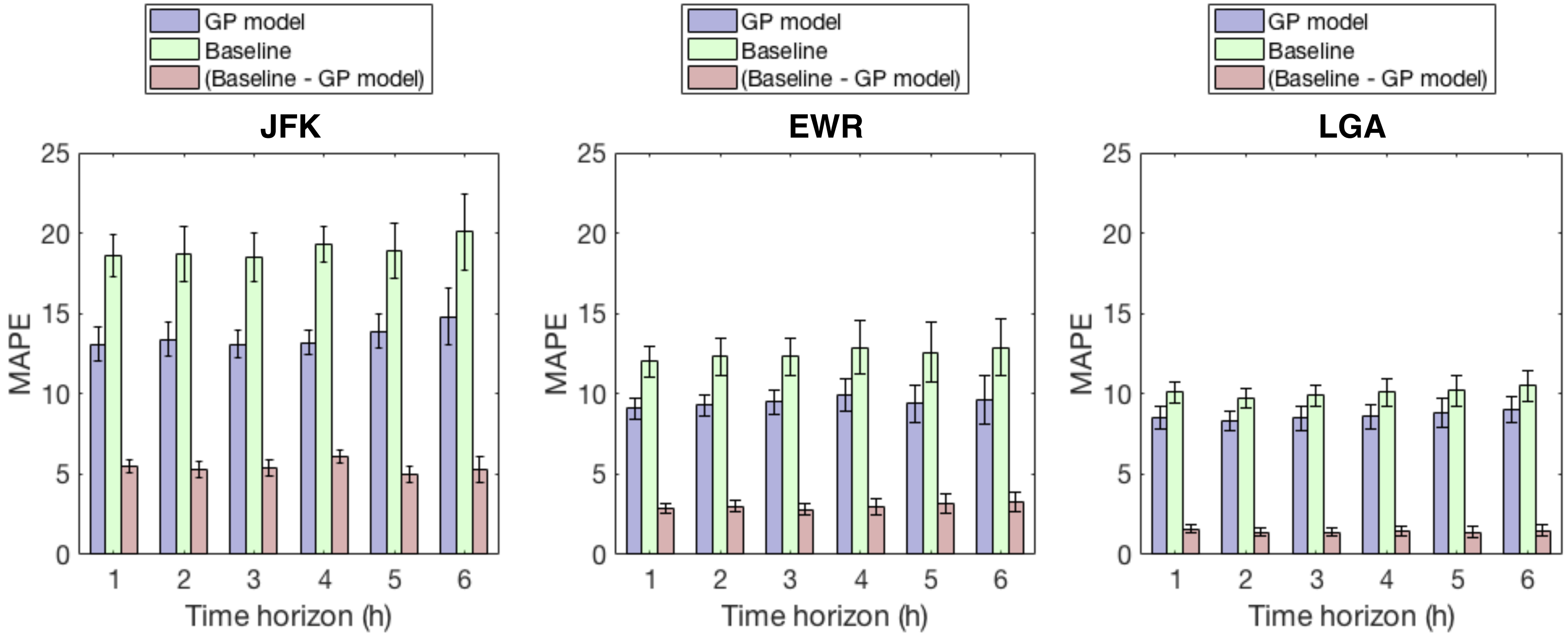
Airport Capacity Prediction
Forecasting Procedure

- Iterative procedure for obtaining the predictions for each time period throughout the planning horizon
- Monte Carlo sampling approach for uncertainty propagation



Airport Capacity Prediction
Performance Evaluation

- Data-driven capacity predictions obtained with the Gaussian Process model reduced the prediction error by 5.4% at JFK, 3.0% at EWR and 1.5% at LGA when compared with baseline capacity estimates reported by the FAA



Data-Driven Airport Capacity Planning Framework

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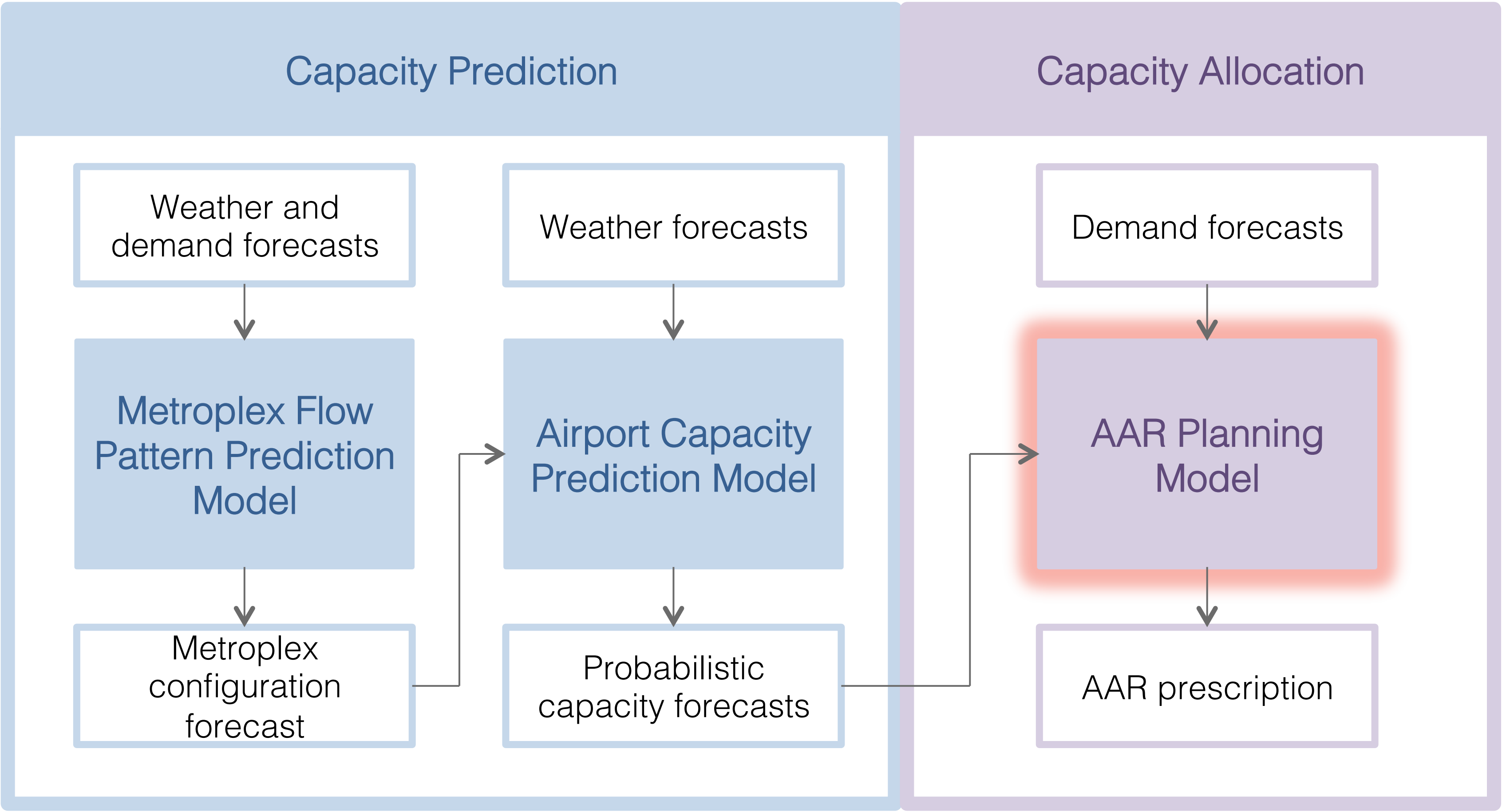
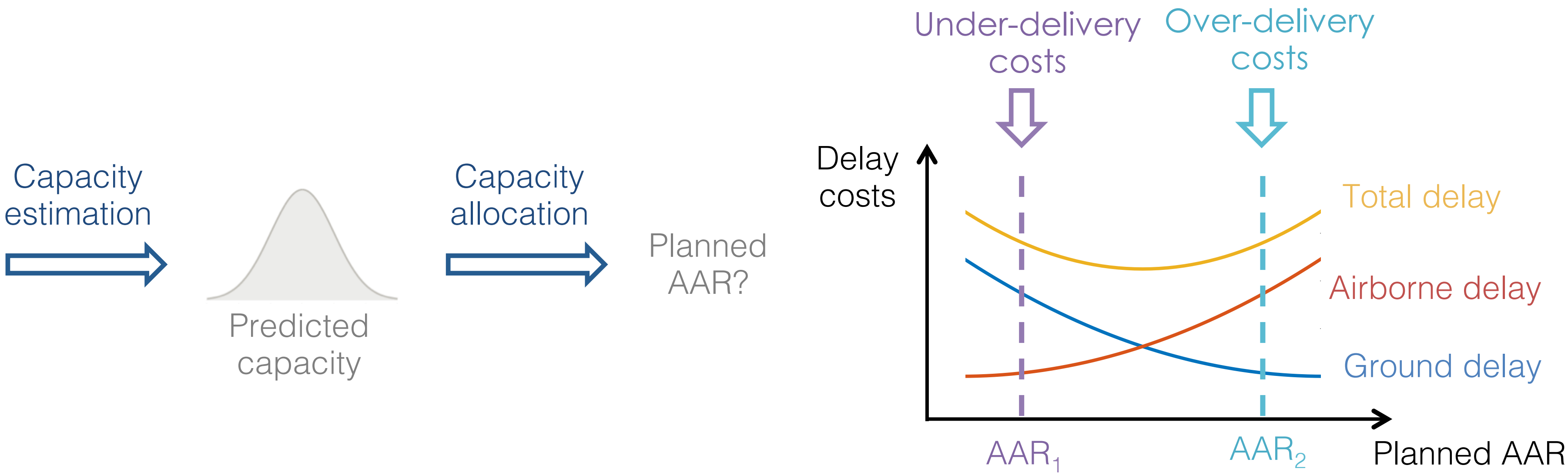


AAR Planning Model

- Goal: determine how much capacity to be allocated in order to minimize overall delay costs (ground + airborne)

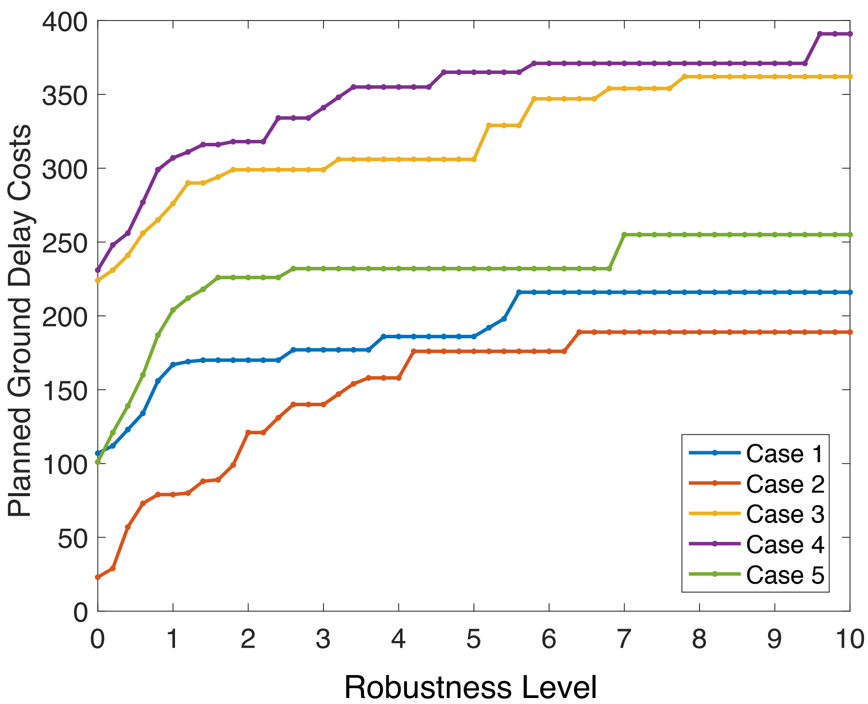


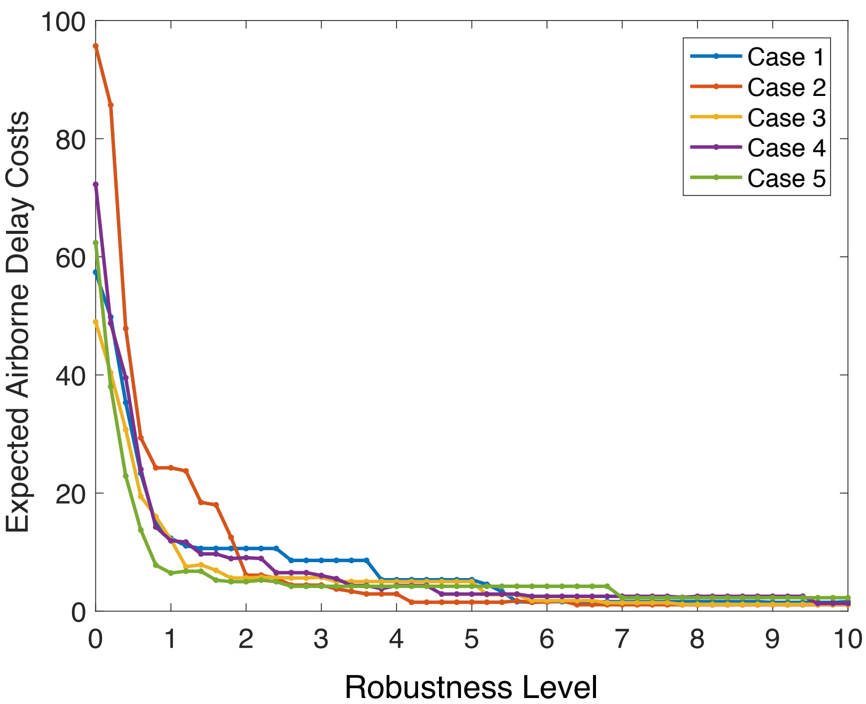
- Stochastic optimization model that incorporates robustness goals

- Impacts of AAR planning model towards TFM decision support are evaluated with the planning of Ground Delay Programs (GDP)
  - Five test cases corresponding to historical GDP events at JFK

AAR Planning Model
Robustness Effects

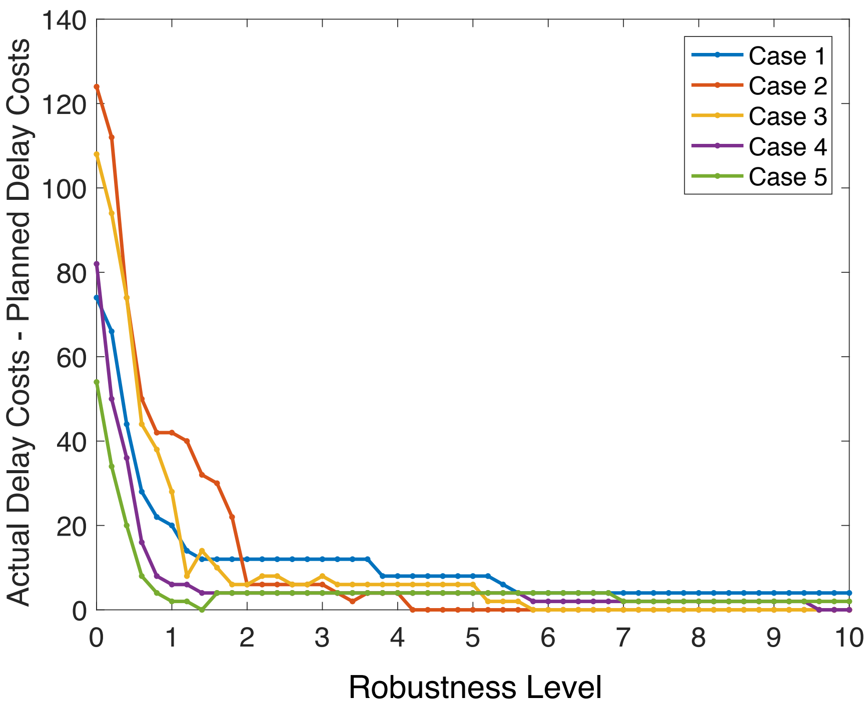
- Increasing the robustness level…
  - Decrease in expected airborne delay costs at the cost of increase in ground delays





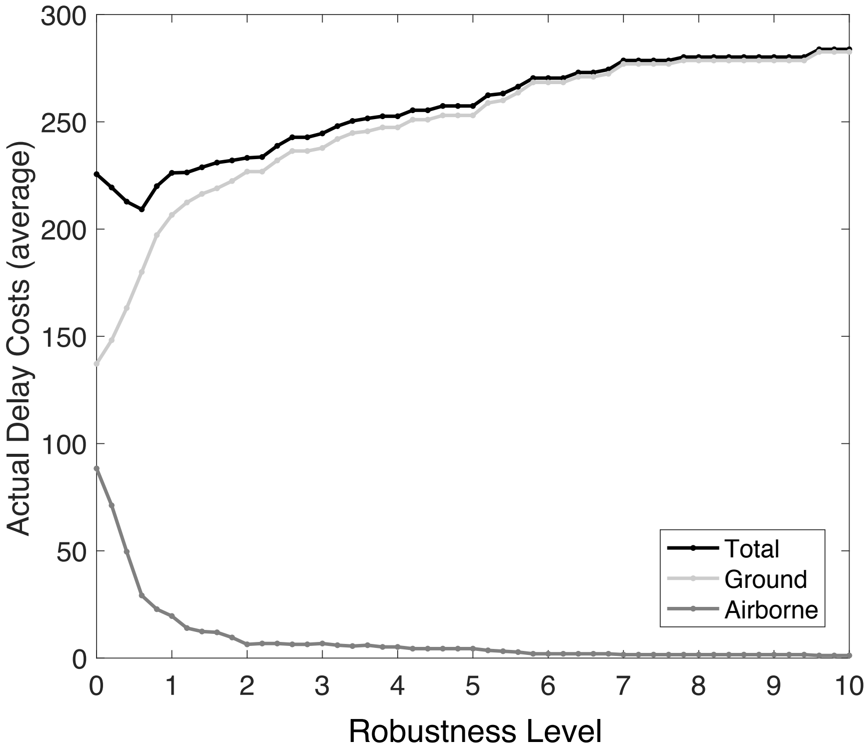
AAR Planning Model
Robustness Effects

- Increasing the robustness level…
  - Decrease in expected airborne delay costs at the cost of increase in ground delays
  - Increase in delay cost predictability



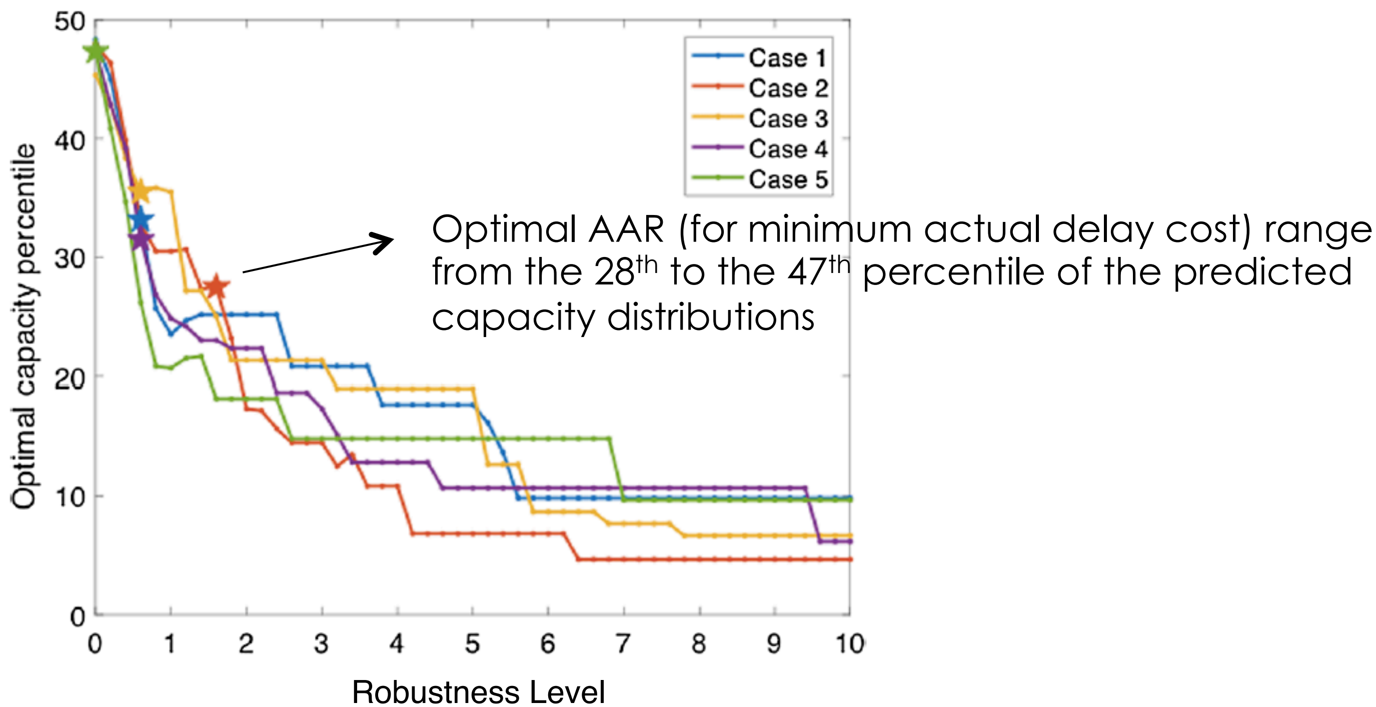
AAR Planning Model
Robustness Effects

- Increasing the robustness level…
  - Decrease in expected airborne delay costs at the cost of increase in ground delays
  - Increase in delay cost predictability
  - Increase in actual delay costs (yet, increase in efficiency observed for small levels of robustness)



AAR Planning Model
Robustness Effects

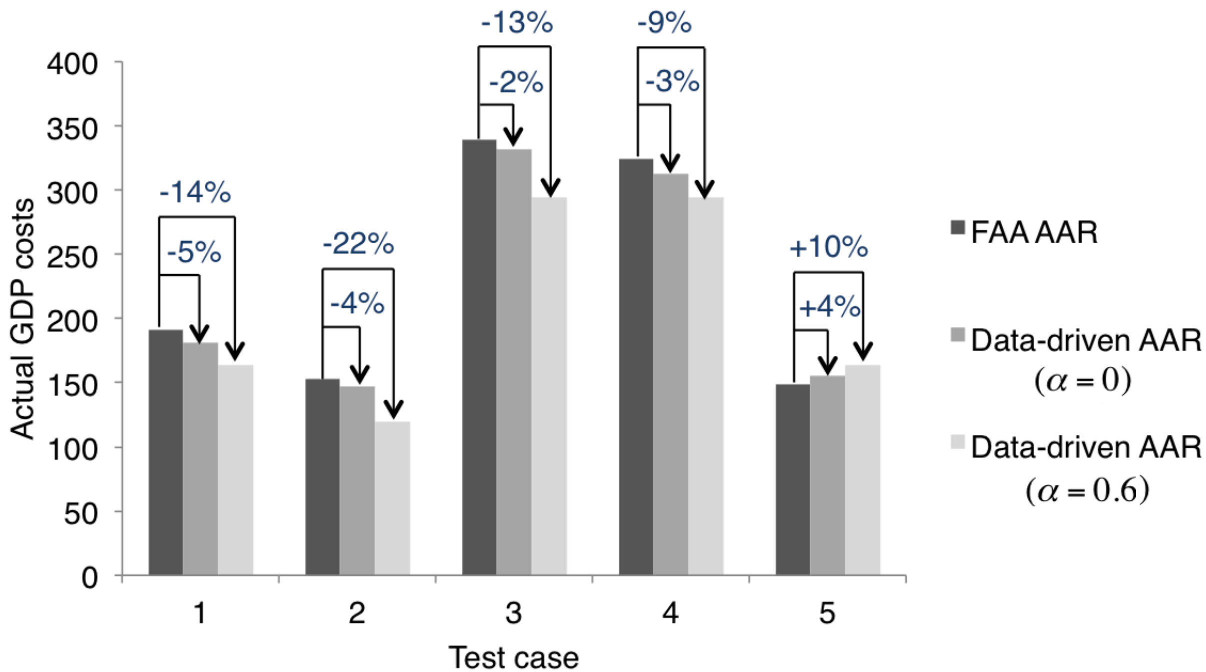
- Increasing the robustness level…
  - Decrease in expected airborne delay costs at the cost of increase in ground delays
  - Increase in delay cost predictability
  - Increase in actual delay costs (yet, increase in efficiency observed for small levels of robustness)
  - Decrease in optimized arrival rates



AAR Planning Model

Benefits Assessment

- Comparison between GDP delay costs resulting from use of data-driven AAR and baseline AAR reported by the FAA
  - Overall reduction in GDP delay costs between 2.4% and 9.7% with data-driven AAR



Summary

- Data-driven framework for predicting and planning airport acceptance rates for strategic TFM
  - Accounts for complex metroplex operations
  - Uses machine learning to map weather and metroplex configuration forecasts into probabilistic arrival capacity forecasts
  - Uses optimization to process the capacity forecasts and prescribe an optimal AAR
- For the test cases analyzed, the data-driven AAR showed potential to decrease TFM delay costs by up to 9.7%

Summary

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Predicting and planning airport acceptance rates in metroplex systems for improved traffic flow management decision support☆

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A R T I C L E I N F O

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Capacity management
Multi-airport systems
Machine learning

A B S T R A C T

Efficient planning of Airport Acceptance Rates (AARs) is key for the overall efficiency of Traffic Management Initiatives such as Ground Delay Programs (GDPs). Yet, precisely estimating future flow rates is a challenge for traffic managers during daily operations as capacity depends on a number of factors/decisions with very dynamic and uncertain profiles. This paper presents a data-driven framework for AAR prediction and planning towards improved traffic flow management decision support. A unique feature of this framework is to account for operational interdependency aspects that exist in metroplex systems and affect throughput performance. Gaussian Process regression is used to create an airport capacity prediction model capable of translating weather and metroplex configuration forecasts into probabilistic arrival capacity forecasts for strategic time horizons. To process the capacity forecasts and assist the design of traffic flow management strategies, an optimization model for capacity allocation is developed. The proposed models are found to outperform currently used methods in predicting throughput performance at the New York airports. Moreover, when used to prescribe optimal AARs in GDPs, an overall delay reduction of up to 9.7% is achieved. The results also reveal that incorporating robustness in the design of the traffic flow management plan can contribute to decrease delay costs while increasing predictability.

Questions?

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