Improving Air Traffic Performance Using System-Wide Coordination of Flight Speeds

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THIRTY YEARS OF SYSTEMS RESEARCH EXCELLENCE

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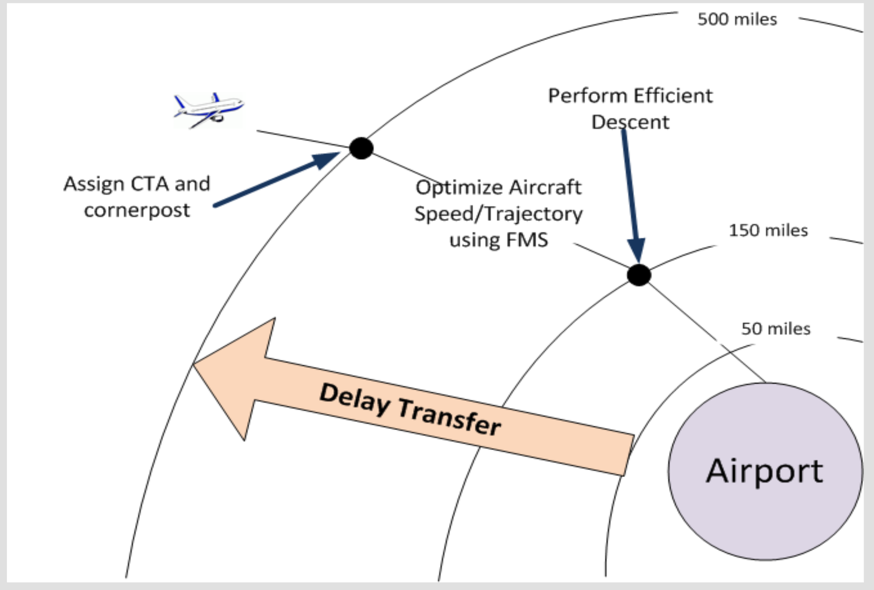
Background

In the U.S. National Airspace System today there is little coordination of the speed of individual flights, e.g. a flight might speed up or take "short cuts" only to arrive near its destination airport to be put into a hold pattern. Speeds can be set and adjusted to achieve strategic airline and system performance objectives. Coordination is required among FAA traffic managers, airline operational control centers and the flight crews.



Motivating Work

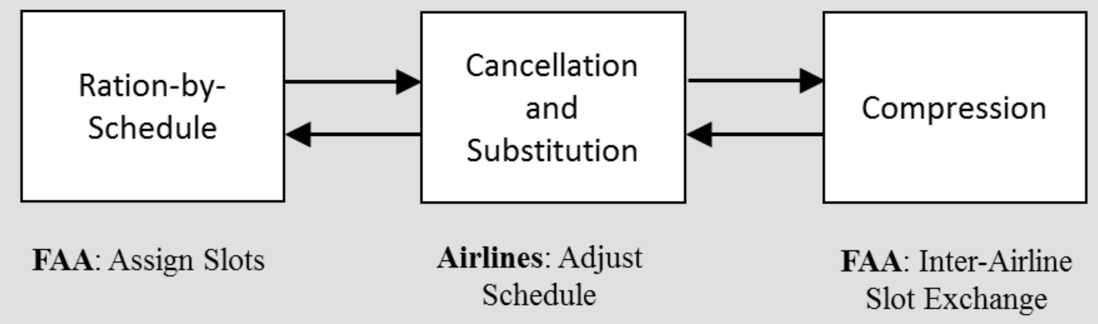
Prior work, e.g. Knorr et al 2011, has shown that substantial fuel is wasted dealing with arrival congestion in the airspace adjacent to busy airports.

- Maneuvers, such as vectoring, "tromboning" and circular holding patterns, are highly inefficient especially when performed a low altitudes.
- Operational systems and trials are addressing this challenge:
  - Attila used at Atlanta, MSP and Charlotte by Delta Airlines
  - London Heathrow: System allows airborne holding close to airport to be exchanged for reduced speed during cruise (United Airlines estimates potential to save 45 kg fuel per flight)
  - Airservices Australia (ALOFT) used speed control at Sydney saving 1 million kg of fuel in 2008
  - The Terminal Area Precision Scheduling and Spacing System (TAPSS) system
  - The Airline Based En Route Sequencing and Spacing tool (ABESS)

Concept and Background

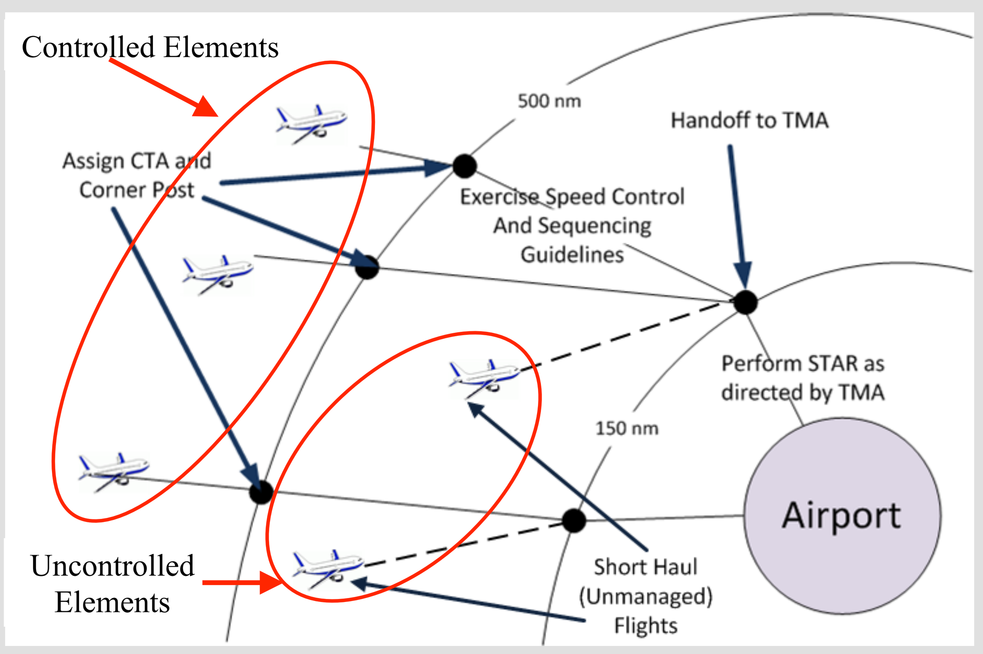
- During ground delay programs (GDPs) flights managers assign a controlled time of departure (CTD) to flights
- Assigning controlled times of arrival (CTAs) in lieu of CTDs may offer a more attractive means of delay assignment
  - Provides carriers more flexibility in planning
  - Allows for system-wide trade-offs
- Replace CTDs with CTAs in GDP planning and control
- Remove the exemptions radius
- Allow en route speed adjustments by carriers
- Allow carriers to make decisions on flight delay through substitutions and cancellations
- Propose new flight operator planning model for substitution and cancellation
  - Model matches carrier flights to assigned capacity
  - Hedges for the possibility of early clearance

GDP Planning Process



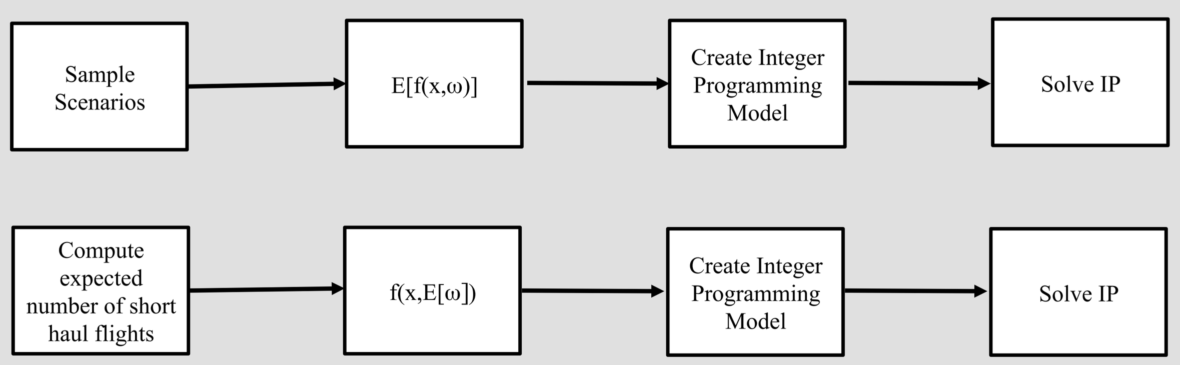
Approach maintains the same general GDP planning process but allows speed control of airborne flights

Operational Context

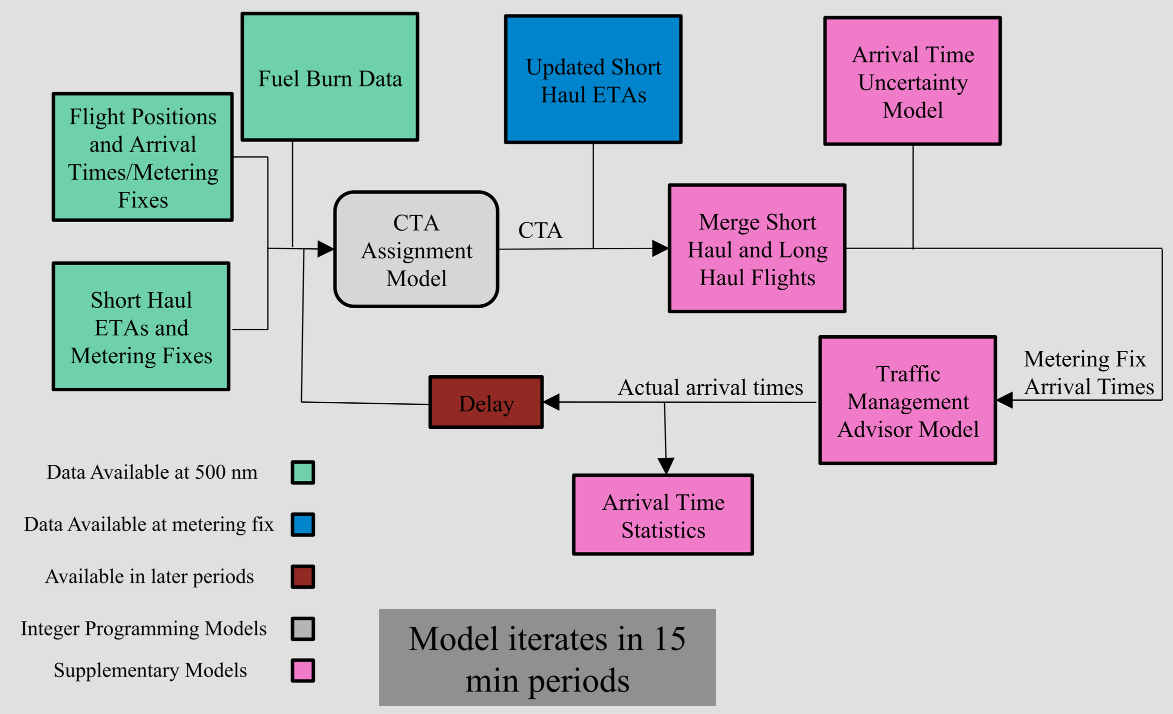


Modeling Approaches

- Adopted two approaches for estimating queuing delay
  - Scenario Based Approach
  - Functional Approximation Approach
- Can we achieve comparable performance using a functional approximation?



Simulation Framework

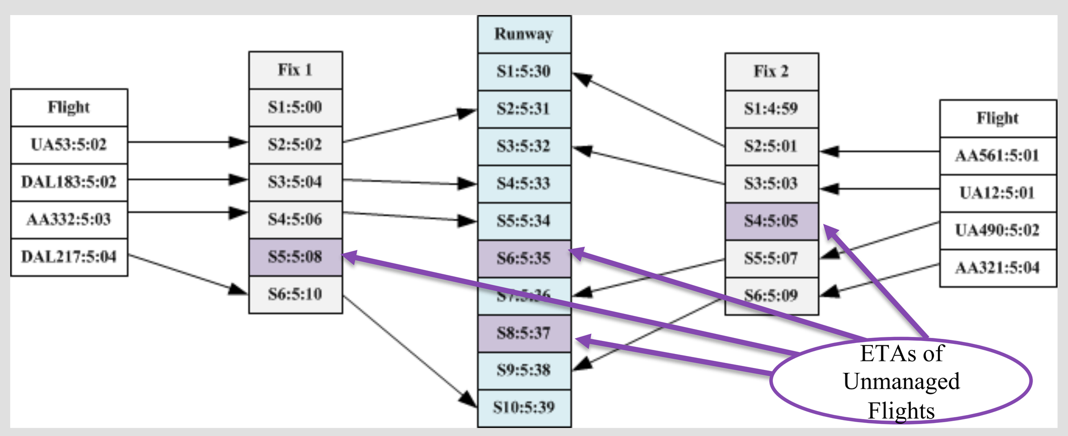


Computational Performance

- Computational Performance was evaluated in Python
  - Intel Xeon 2.66 GHz quad core processor with 12 GB of RAM
  - GUROBI solver was used
- FA model achieves comparable accuracy but runs orders of magnitude faster

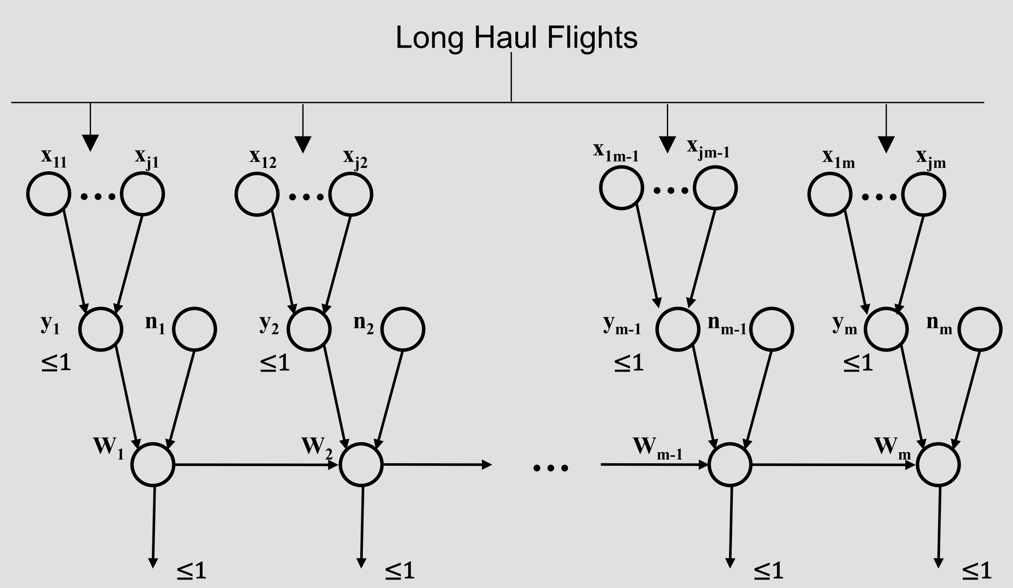
Model	Number of Variables	Number of Constraints	Percentage Delay Transfer	Solution Time (s)
Throughput	156	235	5.98	0.08
FA	173	342	24.68	0.23
Scen 100	5503	5361	9.98	1.30
Scen 500	27188	26007	16.23	7.91
Scen 1000	54188	51507	22.32	17.00
Scen 1500	81188	77007	22.46	17.96
Scen 1750	94603	89511	25.85	26.21

Illustration of Assignment Process



- Flights are given an assignment time at a fix and a runway using IP model
- Some runway and fix slots will be occupied by unmanaged flights
  - Model slots are designed with slack to accommodate these interruptions
  - The arrival times of unmanaged injections can vary causing excess queuing delay

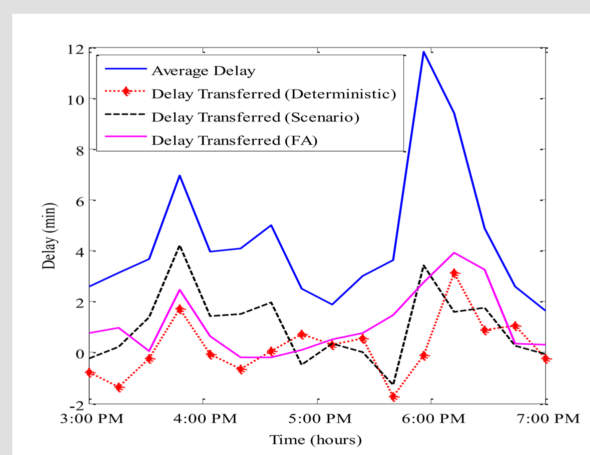
Model Illustration



x_{ji} – Decision to assign flight j to slot i (deterministic)
y_i – Number of long haul flights assigned to slot i (deterministic)
n_i – Number of short haul flights expected to arrive at slot i (stochastic)
W_i – Total number of flights arriving at slot i

Delay Transfer Performance

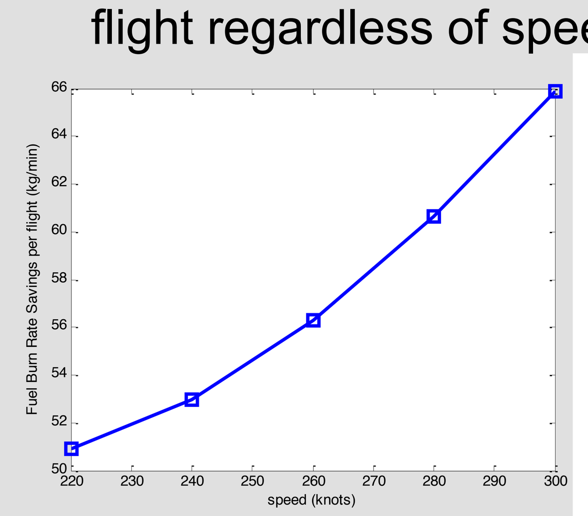
- All models transfer some amount delay near the airport to the en route phase of flight
- Scenario based model yields strong delay transfer performance
- FA model formulation performs marginally better

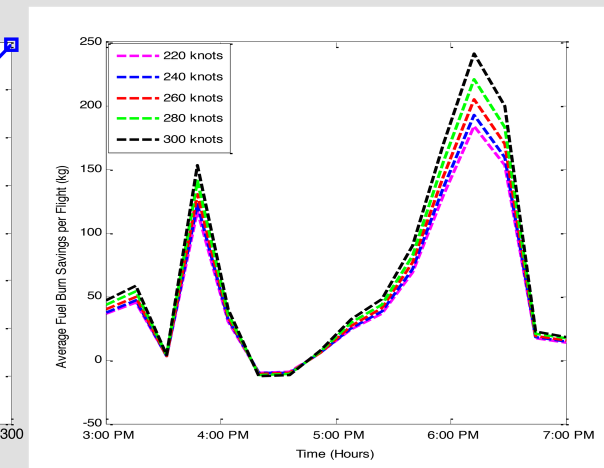


Model	Delay Transfer
Deterministic	5.98%
Functional Approximation	24.68%
Scenario (1500 scenarios)	22.46%

Average Fuel Burn Savings

- Delay transfer yields noticeable improvement in fuel burn
- Average savings exceeds 54.65 kg of fuel per flight regardless of speed





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