Advanced Arrival Slot-Trading Mechanisms
Evaluation Using Agent-Based Simulation

Research Group : Michael Ball, Robert Hoffman, Philippe Montebello, Dzung Nguyen, Thomas Vossen, Adam Wilson

The National Center of Excellence
NEXTOR
For Aviation Operations Research

Introduction

Severe weather conditions can reduce the arrival capacity at any given airport. How can the Federal Aviation Administration (FAA) deal with arrival reduction in order to manage airport congestion ?

Ground Delay Programs (GDPs)

The flights headed for this airport are delayed before departure (Ground Delay Program) in order to alleviate any further congestion at the airport.

Delayed flights
Congestioned Airport

ATLANTIC OCEAN

The arrival capacity of the airport is represented as a set of arrival slots.
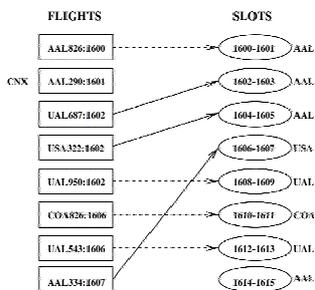
Current resource allocation process :
FAA : initial "fair" slot allocation   [Ration-By-Schedule]
Airlines : flight-slot assignments/reassignments   [Cancellations/Substitutions]
FAA : periodic reallocation to maximize slot utilization [Compression]

• Ration By Schedule (RBS)   • Compression
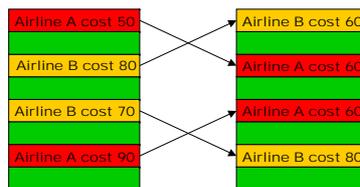
FLIGHTS   SLOTS   FLIGHTS   SLOTS
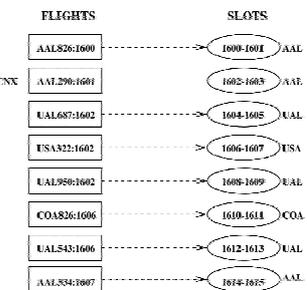
How to Improve the Procedure ?

Compression can be interpreted as 1-for-1 slot trading between different airlines. An advanced trade mechanism (2-for-2, k-for-n...) can substantially improve results...

Principle of Slot Trading

After RBS, companies own slots. They propose feasible trades to minimize the cost of the delays. The FAA chooses which trades to execute.

Airline A cost 50	Airline B cost 60
Airline B cost 80	Airline A cost 60
Airline B cost 70	Airline A cost 60
Airline A cost 90	Airline B cost 80

Reduction of the cost for A: 50+90-60-60 = 20
Reduction of the cost for B: 80+70-60-80 = 10

Simulation

2-for-2 slot trading is a more restricted version of basic k-for-n slot trading. It simplifies the structure of the slot exchange, but does it allow for a fair amount of possible exchanges ?

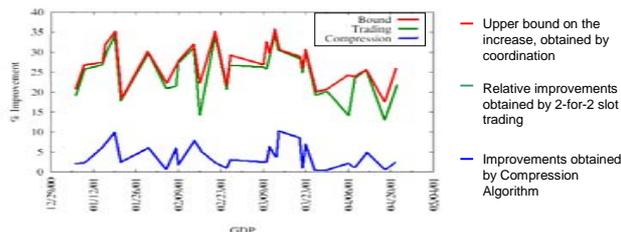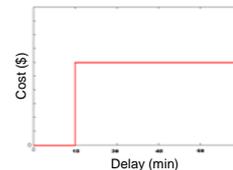This simulation is based on real data, but we remodeled the behavior of the FAA and of the airlines.

- **Cost function of the flights :** to identify which trades the airlines would propose and the "internal value" of each one.

- **Strategy of the FAA :** FAA mediation strategy and efficient method to solve the problem.

First Results

On-time performance:
▪ All the flights have the same cost function.
▪ All the airlines try to minimize the number of flights that are delayed for more than 15 minutes.

Cost ($)
Delay (min)

% Improvement
GDP

Bound
Trading
Compression

— Upper bound on the increase, obtained by coordination

— Relative improvements obtained by 2-for-2 slot trading

— Improvements obtained by Compression Algorithm

2-for-2 slot trading nearly achieves all potential benefit, no real need of k-for-n trading (principle of "diminishing returns").

On-Going Research

Motivated by the promising results of on-time performance, we are now considering more realistic objective functions and different trade mechanisms.

Simulating Flight Cost Function

Assume each cost function has the same shape (the S-curve below), parameters allow us to distinguish different flights and different airline priorities.
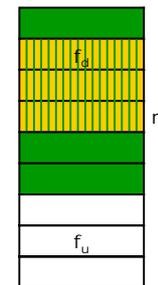
First delay time/cost
Critical time/cost
Cancellation time/cost
Cost
Delay (min)
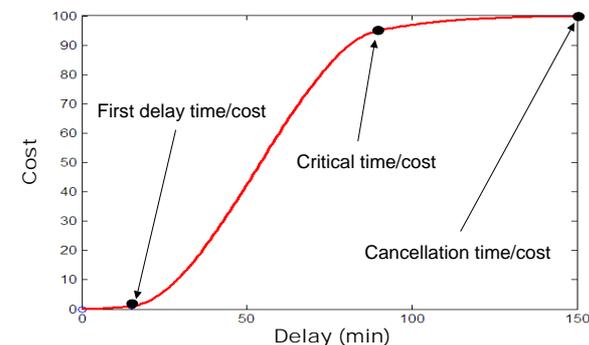
Trade Mechanism

▪ **Efficient offer representation**

2-for-2 slot trading :
Only one plausible kind of offer: move down flight f_d to a slot no later than m (yellow area) in return for moving up flight f_u to slot I or earlier (green area).
Each trade is thus characterized by a tuple (d,m,u,l)

f_d
m
l
f_u

▪ **Mediation mechanism**

The mediator (FAA) selects the trades to execute by maximizing the number of moves up with insuring the feasibility of those trades:

- each flight is assigned to one and only one slot
- trades only include offers proposed by the airlines
- a flight is moved down only if another flight is moved up
- at most one flight is moved down for any flight moved up