Airline Scheduling Problems
Introduction

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Can we manage airlines manually?

(Source: NASA)
Can we manage airlines manually?

Huge number of valid period duties

- e.g., 297 flights $\Rightarrow$ millions valid period duties

(Source: Vietnam Airlines)
Can we manage airlines manually?

Huge number of valid period duties
e.g., 297 flights ⇒ millions valid period duties

(Source: NASA)

Operations Research has been applied for airline industry for a long time

(Source: Vietnam Airlines)
Challenges - Economic view

Total cost allocation 2003
Major/national US passenger carriers
(Source: E. Ben-Yosef)
Challenges - Economic view

- Economic deregulation
  Fuel, demand, crisis,…

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Challenges - Economic view

- Economic deregulation
  - Fuel, demand, crisis, ...
- Noise and safety regulation
  - Higher standard applied

Total cost allocation 2003
Major/national US passenger carriers

(Source: E. Ben-Yosef)
Challenges - Economic view

- Economic deregulation
  Fuel, demand, crisis,...
- Noise and safety regulation
  higher standard applied
- Competition
  Low-cost, dynamic pricing,...(yield management)

Total cost allocation 2003
Major/national US passenger carriers
(Source: E. Ben-Yosef)
Challenges - Technical view

(Source: NASA)
Challenges - Technical view

▶ Dynamic/uncertain
  ▶ Fuel cost
  ▶ Travel demand
  ▶ Weather disruption
  ▶ ...

(Source: NASA)
Challenges - Technical view

- **Dynamic/uncertain**
  - Fuel cost
  - Travel demand
  - Weather disruption
  - …

- **Complex**
  - Aviation rules
  - Union/contractual agreements
  - Activity relationship (trade-off)
  - …

(Source: NASA)
Overview
Motivating examples
Course description

Challenges - Technical view

- Dynamic/uncertain
  - Fuel cost
  - Travel demand
  - Weather disruption
  - ...

- Complex
  - Aviation rules
  - Union/contractual agreements
  - Activity relationship (trade-off)
  - ...

- Large-scale
  - Exponential combination

(Source: NASA)
Business process of a carrier (1)

(Source: C. Barnhart)
Business process of a carrier (2)

(Source: D. Klabjan)
Every airlines has its own processes, but most follow the similar process and terminology.
Schedule planning process

Schedule Design

Fleet Assignment

Aircraft Routing

Crew Scheduling

Select optimal set of *flight legs* in a schedule

A flight specifies origin, destination, and departure time

Contribution = Revenue - Costs

Assign crew (pilots and/or flight attendants) to flight legs

(Source: C. Barnhart)
Schedule planning process - different view

(Source: Google)
Flight scheduling

- Given aircraft availability per type, determine the schedule of flights to operate over a given session in order to maximize anticipated profits.
- Cyclic weekly problem with exceptions for holidays
- Starts usually from the previous year schedule
- Requires a passenger flow model to evaluate revenues
  - Estimated passenger demand per day and OD
  - Passenger preferences (departure time, number of legs, etc.)
  - Seating capacity per flight
  - Output: number of passengers per itinerary
Fleet assignment

- Given a weekly flight schedule, aircraft availability per type, estimated profits for each flight and aircraft type, find the aircraft type to assign to each flight so as to maximize total estimated profits while ensuring aircraft ow conservation in the network.
- Cyclic weekly problem with exceptions for holidays.
- Profits per flight and type are approximated via a passenger ow model (iterative process).
Aircraft routing

- Given a flight schedule for an aircraft type and aircraft availability for this type, determine aircraft routes that satisfy short-term maintenance requirements.
- One maintenance (inspection lasting about 4 hours) at most at every three or four days.
- Cyclic weekly problem or dated monthly problem.
- In general, feasibility problem or through value maximization problem.
Crew scheduling

- Given a monthly flight schedule for an aircraft type, determine the schedules of the crew members.
- Typically divided into two steps: crew pairing and crew assignment (crew rostering, crew rotation).
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Remarks

- Given a monthly flight schedule for an aircraft type, determine the schedules of the crew members.
- For small- and medium-sized airlines, certain steps can be integrated.
Crew scheduling (IWR, Heidelberg, 2005)

- Set of complicated operational rules
- Complex network of airports, large set of flights

Data set of Vietnam Airlines (2004) solvable to optimality in **10 minutes** on 32 processors
(4 hours of sequential computation)
Crew scheduling (IWR, Heidelberg, 2005)

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Experiments for Jetstar Pacific crew scheduling (2008)
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Possible rule violation, 61 duty/ground out-base nights
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Possible rule violation, 61 duty/ground out-base nights

No rule violation, 35 duty/ground out-base nights
Topics (tentative)
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- Operations Research in Airline Industry [1+2=3 periods]
  - Introduction [1 periods]
  - Airline planning and scheduling problems [2 periods]
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- Mathematical programming [3+3+2+1=9 periods]
  - LP and IP models - their solvers [3 periods]
  - Mathematical programming for transportation [3 periods]
  - Set partitioning/Multicommodity network flow models [2 periods]
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- Aircraft scheduling [1+3+3=7 periods]
  - Flight planning [1 period]
  - Fleet assignment [3 periods]
  - Aircraft maintenance routing [3 periods]
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  - Flight planning [1 period]
  - Fleet assignment [3 periods]
  - Aircraft maintenance routing [3 periods]
- Crew scheduling [3+3=6 periods]
  - Crew pairing [3 periods]
  - Monthly crew assignment (Crew rostering) [3 periods]
Topics (tentative)

- Operations Research in Airline Industry \(1 + 2 = 3\) periods
  - Introduction \([1\) periods\]
  - Airline planning and scheduling problems \([2\) periods\]

- Mathematical programming \(3 + 3 + 2 + 1 = 9\) periods
  - LP and IP models - their solvers \([3\) periods\]
  - Mathematical programming for transportation \([3\) periods\]
  - Set partitioning/Multicommodity network flow models \([2\) periods\]

- Introduction to scheduling algorithms \([2\) periods\]

- Aircraft scheduling \(1 + 3 + 3 = 7\) periods
  - Flight planning \([1\) period\]
  - Fleet assignment \([3\) periods\]
  - Aircraft maintenance routing \([3\) periods\]

- Crew scheduling \(3 + 3 = 6\) periods
  - Crew pairing \([3\) periods\]
  - Monthly crew assignment (Crew rostering) \([3\) periods\]

- Student seminar \([3\) periods\]
References

- Airline journals and the Internet
## Course evaluation (tentative)

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<tr>
<th>Part</th>
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| **Assignment 1**              | 30%   | 1 month  
Vietname airlines problems  |                                 |
|                               |       | Problem description  
quantitative solutions survey (report, presentation)                  |
| **Assignment 2**              | 30%   | 1 month  
Solving an airlines problems  |                                 |
|                               |       | GNU C/C++  
C/C++ programming (source code, report)                                |
| **Final examination**         | 40%   | 45-60 minutes  
Multiple choice, open                                                      |
| **All**                       |       |                                                                      |
Enjoy your study :-}