Optimization in Airline Scheduling: Successes, Challenges, and New Directions

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Airline Operations Research

- Airlines have been a hotbed of OR
- Planning process over time
  - Schedule and complex development
  - Fleet assignment and routing
  - Yield management and passenger flow
  - Crew pairing and bid lines
  - Operations and recovery
- Computational issues
  - All require solving large-scale optimization problems
Airline OR Successes

- Excess crew costs in the planning process has been driven to 0-3%
  - AA was 8-10% 15 yrs ago: now 0-2%
  - Each 1% is worth about $10 million/yr
    - 1997 had 9,000 pilots costing $1.2 billion
  - Larger schedules and complex rules

- Fleet assignment has increased profit by $tens of millions/yr

- Yield management maintains revenue despite low fares
Implementation of Airline OR

- Cost reductions were initially embraced, e.g. crew scheduling
- All airlines will say that they are unique, have a different culture, etc.
- US pilots have strange pay structure
  - Asian and European pilots are simply (high) salaried employees
  - US pilots get paid for what they fly + minimum guarantees + conflicts
Compartmentalization into Silos

- Making sequential plans is common
  - Schedule -> FAM & Routing -> Crew
  - Pricing -> YM -> promotions & sales
- Has led to optimization within silo
- Too little feedback
- What is needed is integrated planning over function and over time
  - Operations experience does not feed back into the planning process
Compartmentalization into Silos

- Each group thinks they are the most important planning group
  - Pricing and marketing define the airline
  - YM is needed to keep the pricing guys from giving away the airline
  - Schedules and complexes are product
  - Crews think the airline ends in cockpit
- Strategic planning and global optimization are impossible in this environment
How Has Airline OR Succeeded

- Very optimized in certain silos
  - Crew Scheduling
  - Fleet assignment
  - Yield management

- Savings and increased revenue has been very real

- Fleet assignment has as objective revenue - cost of operating airplanes

- YM is much needed and big success
Where to Find the Next Success?

- Decision tools in operations and recovery from disruptions
  - Begins to integrate over time and can feed back into robust planning
- Schedule development
  - Is driven by markets and strategy
- Integrate YM and FAM over time
  - Initiated at Sabre to better model revenue but is not being done over time
- Look at entire crew process
Operations and Recovery

- Integrated recovery must consider aircraft, airports, crews, passengers
- Environment is dynamic and uncertainties abound
- What about robust planning?
  - Integration over time
  - In reality is a huge stochastic program
    - Requires model for integrated recovery
- SimAir is a tool to study operations, recovery, and robust planning
Schedule Development

- Is driven by markets and strategy
- Was considered too important to turn over to a mere model
- Tremendously important and complicated problem involving:
  - Market presence
  - Structure of complexes
  - Fleets and crews
Integrate YM and FAM

- Has been initiated at Sabre to better model revenue
- One way of doing it over time is $D^3$
  - It means demand driven dispatch
  - Involves reassigning crew compatible sub-fleets so as to better match capacity to high revenue demand
  - Is a close to departure FAM
- Ira Gershkof conceived JIT
  - Industry was not ready for it
Manpower planning, conflicts, overtime flying, and reserves

In US airlines as high as 30% of the pilots may be on reserve bid lines

• Actual flying is about 50% of usual
• Of that flying, more than half is to cover conflicts and as little as 1/3 to flying to cover disruptions

The “sleeper” issue: fatigue and circadian rhythm
Crew: The Rest of The Story

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Crew Planning Overview

1 - 5 years
Long Range Planning

3 - 9 mos.

1 - 1.5 mos.
Pre-month Planning

Daily Operations

Daily

Long Range Crew Manpower Planning

Airline Business Process - Time Line

- Network Development
- Flight Profitability
- Market Analysis

- Aircraft Rotation
- Slot Management

- Vacation Assignment
- Vacancy Bidding and Awards

- Block Time Forecasting
- Schedule Generation
- Fleet Assignment

- Initial Training Scheduling
- Vacation Scheduling

- Recurrent Training Scheduling
- Flight Instructor Scheduling

- Crew Pairing Optimization
- Bidline Generation
- Bidding and Line Awards

- Involuntary and Voluntary Flying
- Crew Recovery during IROPs

- Aircraft Recovery
- Passenger Recovery

Daily Operations

Pre-month Planning

Long Range Planning
Integrated Crew Planning

Crew Manpower Planning and Crew Staffing

- Crew Pairing
- Bidline Generation
- Bidding

Vacation Scheduling

Expected Utilization

Operational Plans

Daily Operational Utilization

CONFLICTS

- Training Scheduling
- Sim Utilization
- New Hires

Feed Back to Long Range Planning
Crew Pre-Month Planning

- Crew Pairing Optimization
- Regular/Reserve Bidline Generation
- Bidding and Conflict Resolution
- Supplemental Regular Lines
- Vacation Scheduling
- Initial Training Scheduling
- Recurrent Training Scheduling
- Flight Instructor Scheduling

Month of Operation
Reserve Demand

Net Reserve Demand

Pre-Month Planning ↔ Irregular Operations

(1) Vacation Conflict
(2) Initial Training Conflict
(3) Transition Conflict
(4) Recurrent Training Conflict

Open Time Trips

Could be up to 25% total trips built

Voluntary Flying

Premium Flying

Reserves

Could cover 10% of the open trip flying

(1) Weather Disruptions
(2) Aircraft Maintenance
(3) Sick Leave

Higher Reserve Availability Desired
Integrated Planning - Function & Time

- Integrated planning breaks down silos
- Integrated planning over time horizon?
  - Current crew planning ends with bid lines
    - leaves it and goes on to the next month
- Is feedback on operations built in?
- Isn’t planning a multi-stage problem?
  - Shouldn’t the plan at any stage depend on options and scenarios at the next stage?
    - What is value of making decisions later?
Overview – Crew Schedule Process

- Manpower planning 2-3 years out
- Pairings and bidlines for monthly plan
- Swaps, conflicts, and transition
  - Pairings fall out and must be reassigned
- Operations involves rescheduling disrupted pairings
  - Voluntary overtime flying and reserves
Manpower Planning

- Manpower planning 2-3 years out
- Pilots and positions by fleet and base
  - Involves transitions – who requests move
  - Includes new hires
  - Sensitive to changes in fleet plan
- Vacation plan and recurrent training
- Reserve staffing level included
Pairings and Bidlines

- Pairings and bidlines during month
- Pairings are in fleet and for crew base
- Swaps take place
- Vacations, recurrent training, and transition conflicts cause pairings to drop out of the bidline
- In operations, pairings may be disrupted or dropped out
Conflicts: vacation, training, transition

Uncovered pairings go to reserves

- Reserve crew bidlines already assigned
- Reserves used in this way will be unavailable in operations

Recurrent training may be assigned by the airline after bidlines are assigned

- Pairings that drop out are thus controlled
Operations and Recovery

- Operations involves rescheduling for disruptions
- Reserves cover parts of pairings (usually ends) and whole pairings typically from unprotected bidlines
- However, voluntary overtime takes precedence
- Premium overtime may be only option
Reserve Crew Planning

- Spans the planning timeline
- Manpower planning allows for reserves ~25%
- Reserve bidlines assigned before conflicts and need to cover conflicts and disrupted pairings
  - Reserves needed less if recovery protects future trips
Scheduling Recurrent Training

- Between planning and operations
- Determines conflicts
  - Schedule reserves to cover pairings
  - Schedule deadheads, classes, and simulators for continuing qualification
- Mainly feasibility constraints but costs
  - Trips that fall out
  - Instructors to fill in on simulators
Crew Scheduling Issues

- Modeling and optimization have been successfully applied to:
  - Pairing optimization
  - Bidlines and rostering

- The rest of the story
  - Manpower planning and training
  - Reserve crew bidlines and utilization
  - Operations and recovery
More of the Rest of the Story

- Numbers of pilots for future fleets and schedules
- Quality of life issues
- Fatigue: circadian rhythm in planning and recovery
  - Weekly patterns of days off
- “Overtime” flying and reserve crews
- Crew compatibility, cabin crew, weekly
Fatigue

- Research shows shortening the 24-hour clock causes fatigue, slower reactions, and insomnia
  - Even for domestic fleets due to red-eyes
    - Also tendency for short duty + short rest
  - Jet lag is a familiar but serious problem
    - Even international business travelers suffer insomnia

- Maintaining sleep window in planning
  - E.g. 9pm - 4 am in pairing and bid lines

- Operations can lead to longer duties
Robust Scheduling

- Crew-compatible fleet assignment
  - Pure city at small spokes
    - Helps with crew, maintenance, plane swaps
  - Critical presence and mid-day breakouts

- Crew bases
  - Pure city gives more swaps
    - Mainly for overnighting crews

- Critical presence of crew-compatible fleets at complexes
  - Plane swaps for D3 and crew swaps
Solving These Problems

- Many, many column LPs and IPs
- Station decomposition for FAM
- Non-negative least squares methods
  - Primal-dual subproblem methods
  - Dual-primal and d-p subproblem
  - Combined objective function methods
  - Network flow specialized method
- Use of parallel cluster
  - MARS code for stochastic problems
  - Parallel SimAir (so far just a dream)
SimAir Purpose

- Allows running different schedules and different recovery algorithms and checking performance
- Allows testing different planning models with different recovery
- Improvement from better recovery
  - Initial recovery was pushback
  - Cancel short cycles, reroute planes
Temasek Project in Air Logistics and Transport

- Air logistics business process and IT
- Air cargo terminals - efficient operation
- Multi-commodity flow and cargo flow
- Crew scheduling in A-P long-haul environment
- Air cargo YM, booking, and tracking
- SimAir including passenger and cargo rerouting