Airport Gate Scheduling for Passengers, Aircraft, and Operations

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Metrics to Measure Passengers’ Experience

- Flight delays do not accurately reflect the delays imposed upon passengers’ full itineraries.

- Passengers’ experience is becoming a key metric to evaluate the air transportation system’s performance.

- Air travelers experience
  - Being tired of walking long distances in an airport to catch a flight.
  - Waiting on board aircraft while it is delayed by the movement of another aircraft.
  - Waiting for a gate after landing.

- Many such situations can be resolved or reduced by proper gate scheduling or assignment.
# Airport Operations

<table>
<thead>
<tr>
<th>Arrival operations</th>
<th>Departure operations</th>
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<tr>
<td>Runway</td>
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<td>Take-off</td>
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<td>Land</td>
<td>Parking</td>
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## Area of Interest
- Connecting Passengers
- Destination Passengers
- Origin Passengers
- Connecting Passengers
Objective

- Improve passenger experience while ensuring robust airside operations (minimization of conflicts).

- Three metrics are presented:
  - How long does it take for a passenger to transit to his/her destination (i.e., a gate, baggage claim, etc.)?
  - How much time does a passenger spend taxiing in the ramp area?
  - How long does it take for an aircraft to wait for an available gate?

- Intuition: passenger landside transit time (packed gate assignments) competes against airline airside delays (sparse gate assignments)
## A bit of history

### Airside: ATM has always done DMAN, seat-of-pants style (CDG controllers)

<table>
<thead>
<tr>
<th>Year</th>
<th>DMAN Concept (US)</th>
<th>DMAN Cost/Benefit (US)</th>
<th>Airport CDM Concept (EU)</th>
<th>DMAN Concept (EU)</th>
<th>Airport CDM Implementation (EU)</th>
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<th>DFlex Cost/Benefit (US)</th>
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<td>Pujet/Feron/Atkins</td>
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### Landside: Gate Assignment Optimization an airline "classic"

<table>
<thead>
<tr>
<th>Year</th>
<th>Gate Optimization Concept</th>
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<th>Robust Gate Assignment</th>
<th>Robust Gate Assignment + DMAN Cost/Benefit</th>
<th>Gate Assignment + DMAN Cost/Benefit</th>
<th>Passenger Motion in Terminals</th>
<th>Passenger Metrics</th>
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<tr>
<td>1985</td>
<td>Mangoubi et al.</td>
<td>Hagani &amp; Chen</td>
<td>Bolat</td>
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Metric 1: Passenger Transit Time

- Origin passenger transit time: from security checkpoint to a gate.
- Destination passenger transit time: from a gate to baggage claim.
- Transfer passenger transit time: from gate to gate.

$\text{Metric}_{\text{transit}}$: Average transit time per passenger = total passenger transit time / total number of passengers.
Metric 2: Aircraft Taxi Time on Ramps

- Total taxi time = \( \Sigma \) (unimpeded taxi time*number of passengers on board + taxi delay*number of passengers on board).

- Unimpeded taxi time: sum of the nominal taxi time from a spot to a gate (arrival) and from a gate to a spot (departure).

- Spot: boundary point of ramp.

- Taxi delay is caused by the interference between aircraft’s movements.

A/C Ppush-back

Taxiing from a taxi lane to another in order to avoid the A/C pushback
\( \rightarrow \) A taxi delay happens.
A Video Clip Showing Ramp Congestion
Calibrating Ramp Operations Congestion

$Metric_{taxi}$: Average taxi time per passenger = total taxi time / total number of passengers on board.

Linear terms to capture aircraft-infrastructure interactions during taxi

Quadratic terms to capture aircraft-aircraft interactions during taxi
Metric 3: Robustness of Gate Assignments

- Robust: resistant against uncertain flight delays.
- Robustness is measured by the duration of gate conflicts shown in the figure.
- The arrival should wait until the gate is released or would be reassigned to another gate.
- $\text{Metric}^{\text{robust}}$: Average gate conflict duration $= \sum (\text{gate conflict duration} \times \text{number of arrival passengers}) / \text{total number of arrival passengers}$. 
Gate conflict model

Figure 3. Expected duration of gate conflict as a function of planned separation between consecutive occupancies, together with the exponential fit $12.4 \times 0.96^{separation}$.
Optimization Problem

Minimize \( \text{Obj} \)

subject to

1. Every flight is assigned to a single gate.

2. The time gap between two successive gate schedules must be longer than the minimum requirement (buffer time).
Optimization Method: Tabu Search

- The Tabu Search (TS) is a meta-heuristic algorithm known to efficiently deal with combinatorial optimization problems such as the gate assignment problem.

- Insert move (above): Change a flight's assignment from one gate to another that is also able to serve the equipment type of the flight.

- Interval exchange move (below): Swap two groups of assignments if the corresponding two gates are able to serve the equipment types of the groups.
Data Source

- Prior studies on gate assignment rely on fictitious passenger data (e.g., number of transfer passengers).
- A major U.S. carrier provided flight schedules and the actual number of transfer passengers at a major hub airport for one day.
- All the flights are assumed to be full.
- Passengers other than those transferring within the carrier’s flights are considered to be origin and destination (O&D) passengers.
Average Transit Time in Minute per Passenger for 66 Values of \((w_{\text{transit}}, w_{\text{taxi}}, w_{\text{robust}})\)
Average Taxi Time in Minute per Passenger for 66 Values of ($w_{\text{transit}}, w_{\text{taxi}}, w_{\text{robust}}$)
Average Duration of Gate Conflict in Minute per Passenger for 66 Values of \((w_{\text{transit}}, w_{\text{taxi}}, w_{\text{robust}})\)

\[ w_{\text{robust}} = 1 \]
Trade-offs among metrics

It is impossible to minimize all the metrics at the same time: trade-offs among metrics. The optimized gate assignment is selected with \((w_{\text{transit}}, w_{\text{taxi}}, w_{\text{robust}}) = (0.2, 0.2, 0.6)\), but the choice of the weighting factors can depend on the policy of airport gate managers and airlines.
Comparison of the Current Gate Assignment and the Optimized Gate Assignment.

**Total saving = 4.7 min per passenger**

\[(w_{\text{transit}}, w_{\text{taxi}}, w_{\text{robust}}) = (0.2, 0.2, 0.6).\]
Conclusion

- This study presents three of the metrics that most affect passenger experience at congested airport:
  - transit time of passengers in passenger terminals
  - aircraft taxi time on ramps
  - the duration of gate conflicts

- These metrics compete against each other → a balancing objective function is proposed.

- The balanced objective can improve the efficiency of traffic flow in passenger terminals and on ramps, as well as the robustness of gate operations

- The gate assignment of the airport offers the potential to improve the efficiency of traffic flow in passenger terminals and on ramps, as well as the robustness of gate operations.

- Future work will account for gate-holding strategies generated by Airport CDM.