Airport Gate Scheduling for Passengers, Aircraft, and Operations

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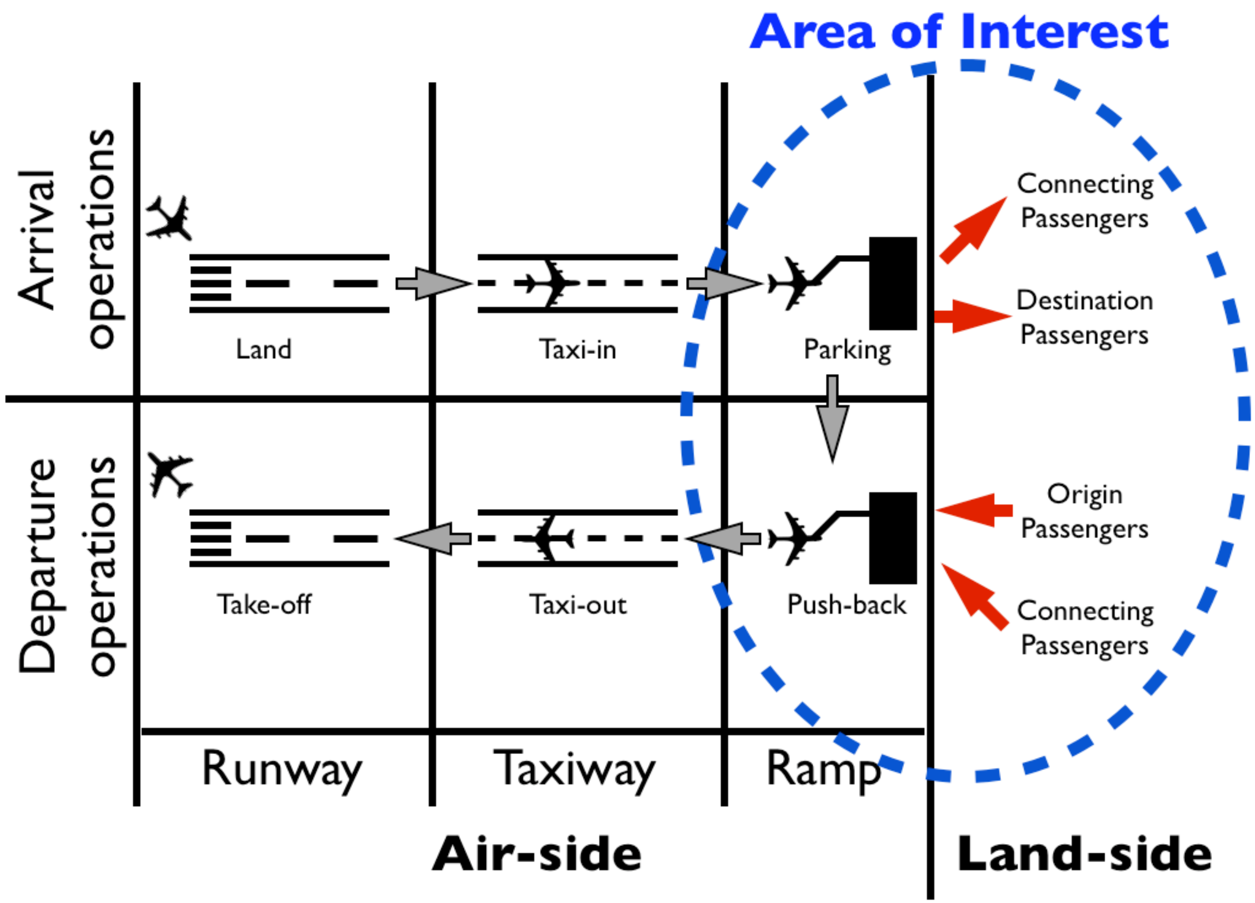
Metrics to Measure Passengers' Experience

- 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



Objective

- Improve passenger experience while ensuring robust air-side 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)

1997	1999	2002	2000	2005	2006	2007	2008	2010	2013
DMAN concept (US)	DMAN cost/benefit (US)	DMAN cost/benefit (EU)	Airport CDM concept (EU)	DMAN implementation (EU)	Airport CDM manual (EU)	Airport CDM implementation (EU)	DFlex cost/ben (US)	CDM implementation (US)	DFlex Implementation
Feron *et al*	Pujet/ Feron/ Atkins	Bohme *et al*	Lagios	Bohme	EU	Munich	Burgain Clarke, Feron	Balakrishnan Brinton Yoon	CDG

Landside: Gate Assignment Optimization an airline "classic"

1985	1998	2000	2005	2011	2011	2012
Gate Opimization concept	Gate Optimization concept	Robust Gate Assignment	Robust Gate Assignment	Gate assignment + DMAN cost/ben	Passenger motion in terminals	Passenger Metrics
Mangoubi *et al.*	Hagani & Chen	Bolat	Lim/Wang	Kim/Feron	Schultz Fricke	Cook and Tanner

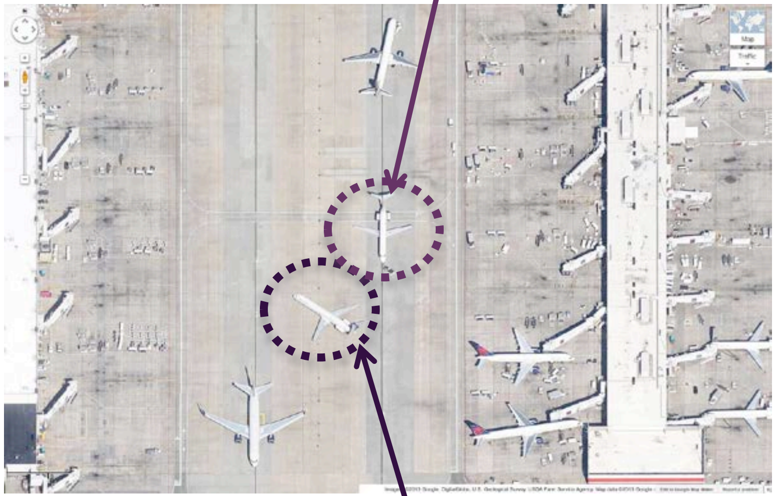
Metric 1: Passenger Transit Time

- 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.
- $Metric_{transit}$: Average transit time per passenger = total passenger transit time / total number of passengers.

Metric 2: Aircraft Taxi Time on Ramps

- Total taxi time = Σ (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

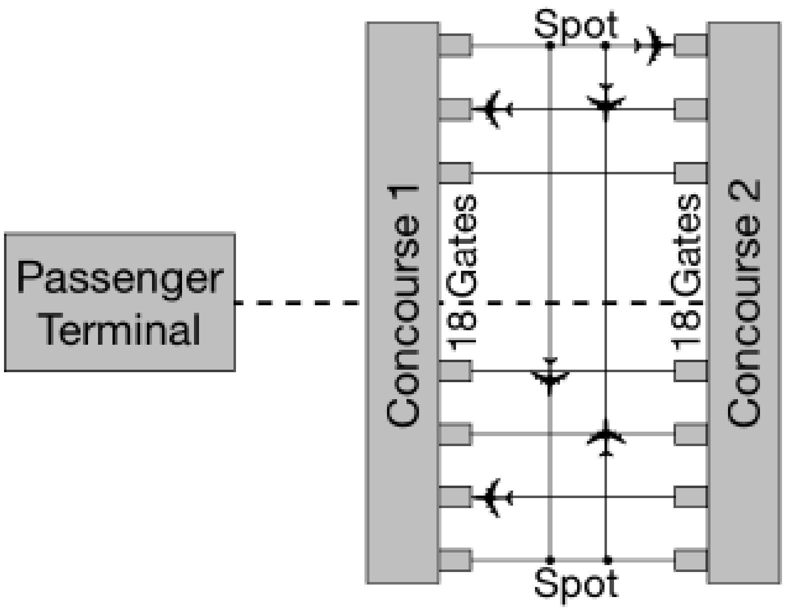


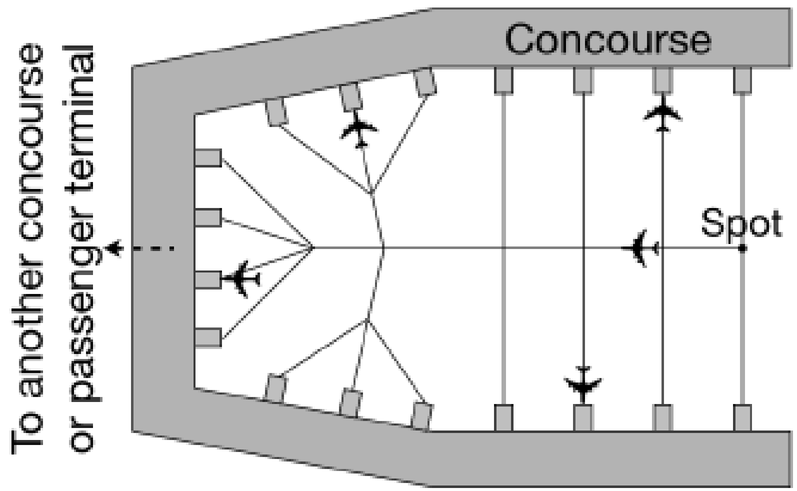
Taxiing from a taxi lane to another in order to avoid the A/C pushback
→ A taxi delay happens.

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.

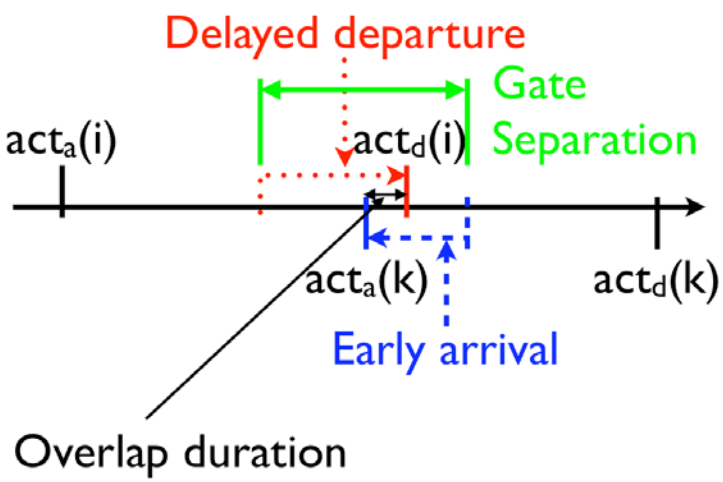




Linear terms to capture aircraft-infrastructure interactions during taxi
Quadratic terms to capture aircraft-aircraft interactions during taxi

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.
- *Metric*$_{robust}$: Average gate conflict duration = Σ (gate conflict duration*number of arrival passengers) / total number of arrival passengers.



Gate conflict model

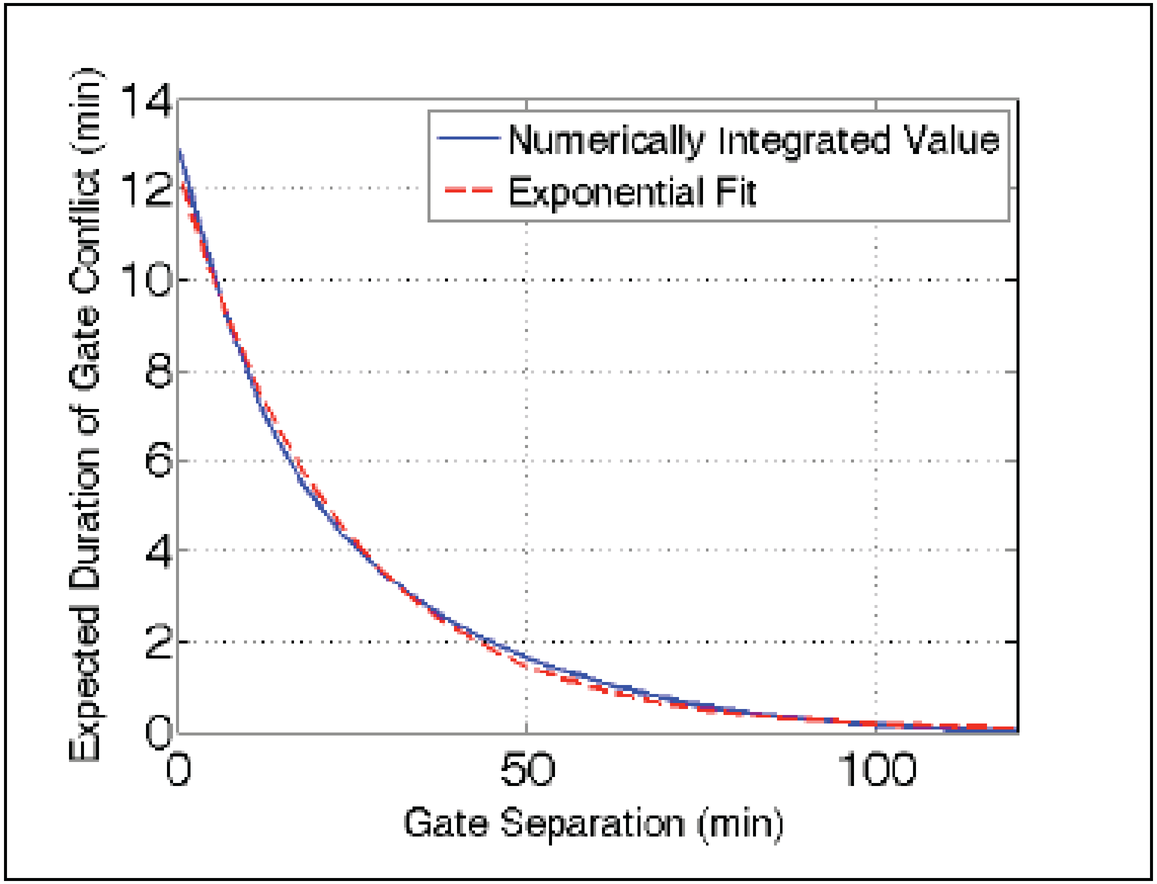


Figure 3. Expected duration of gate conflict as a function of planned separation between consecutive occupancies, together with the exponential fit $12.4*0.96^{sep(i,k)}$.

Optimization Problem

Minimize *Obj*

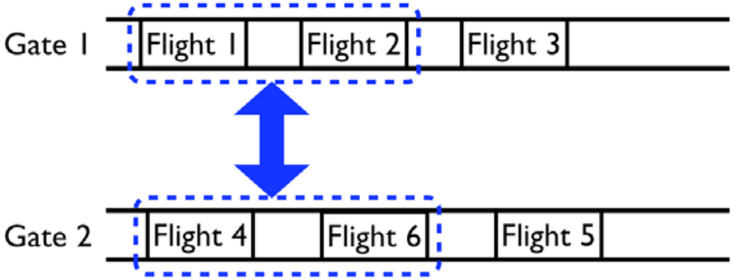
subject to

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.

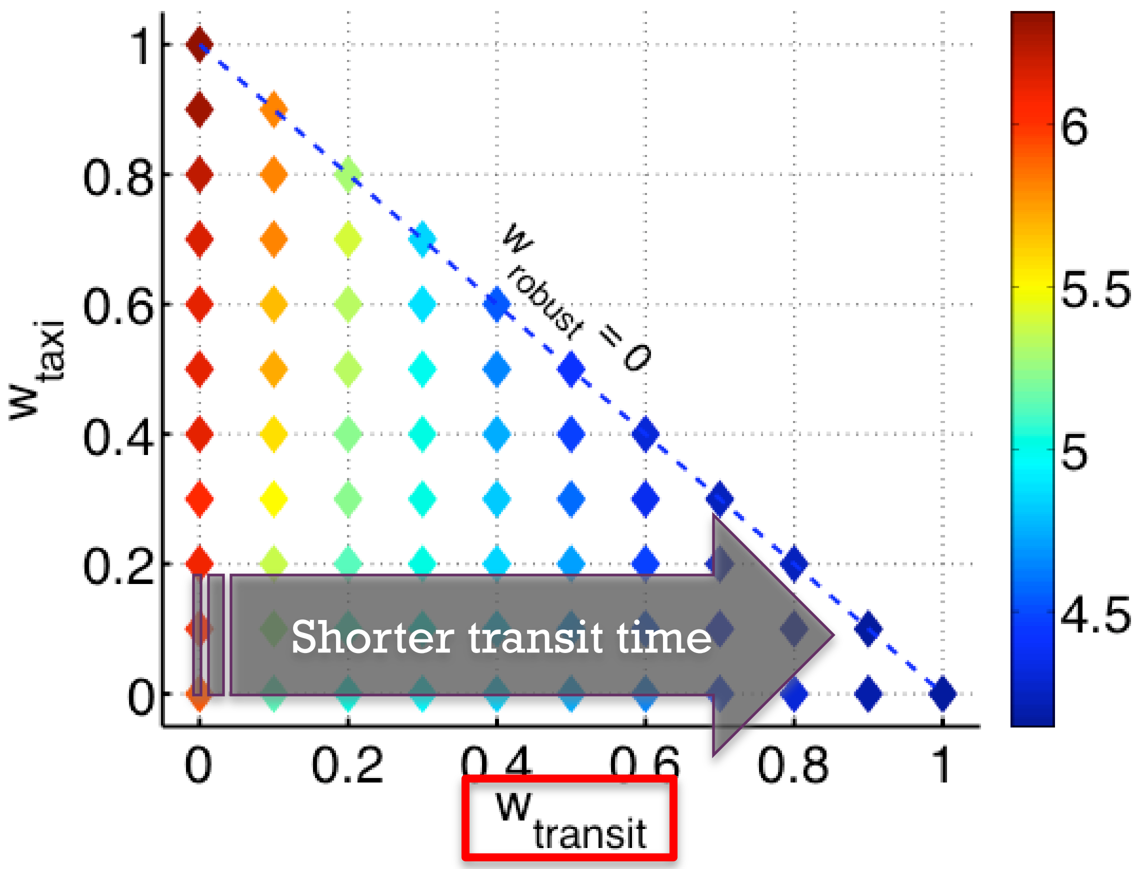


- Interval exchange move (below): Swap two groups of assignments if the corresponding two gates are able to serve the equipment types of the groups.

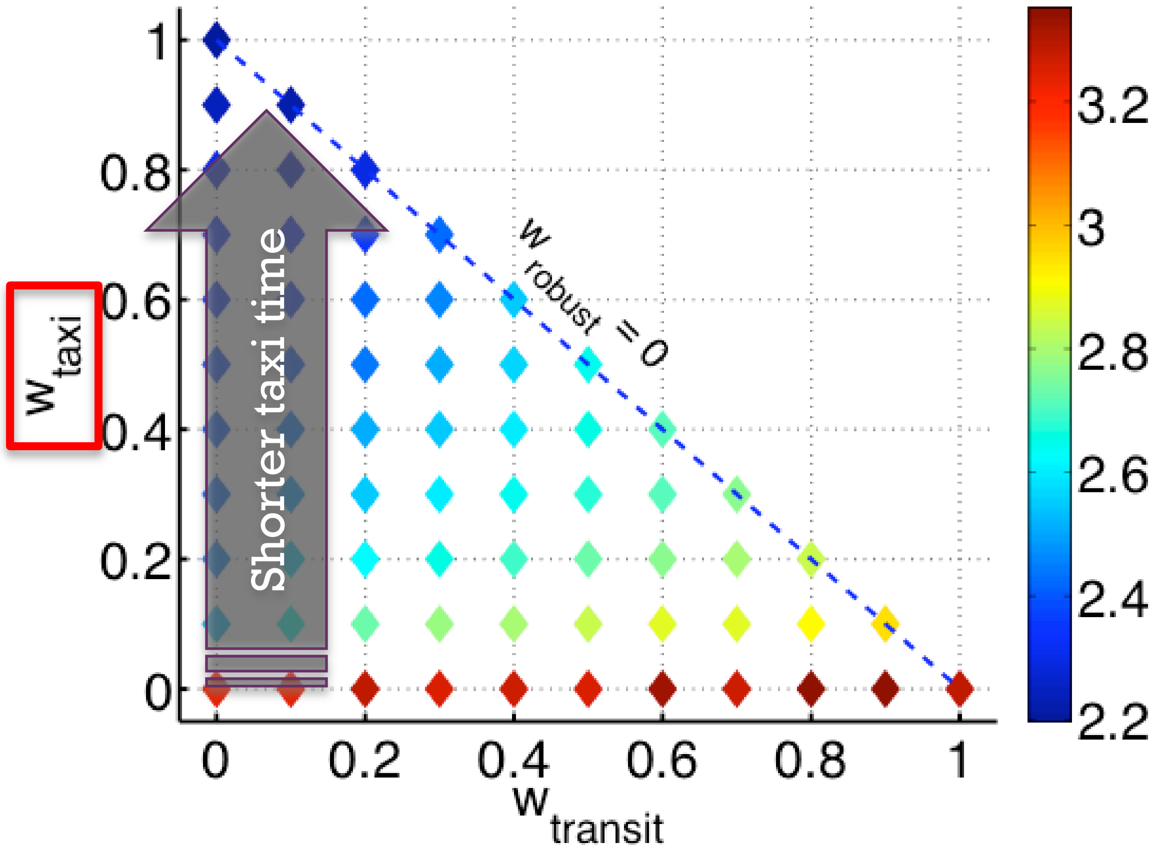
Data Source

- 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 airportfor 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.

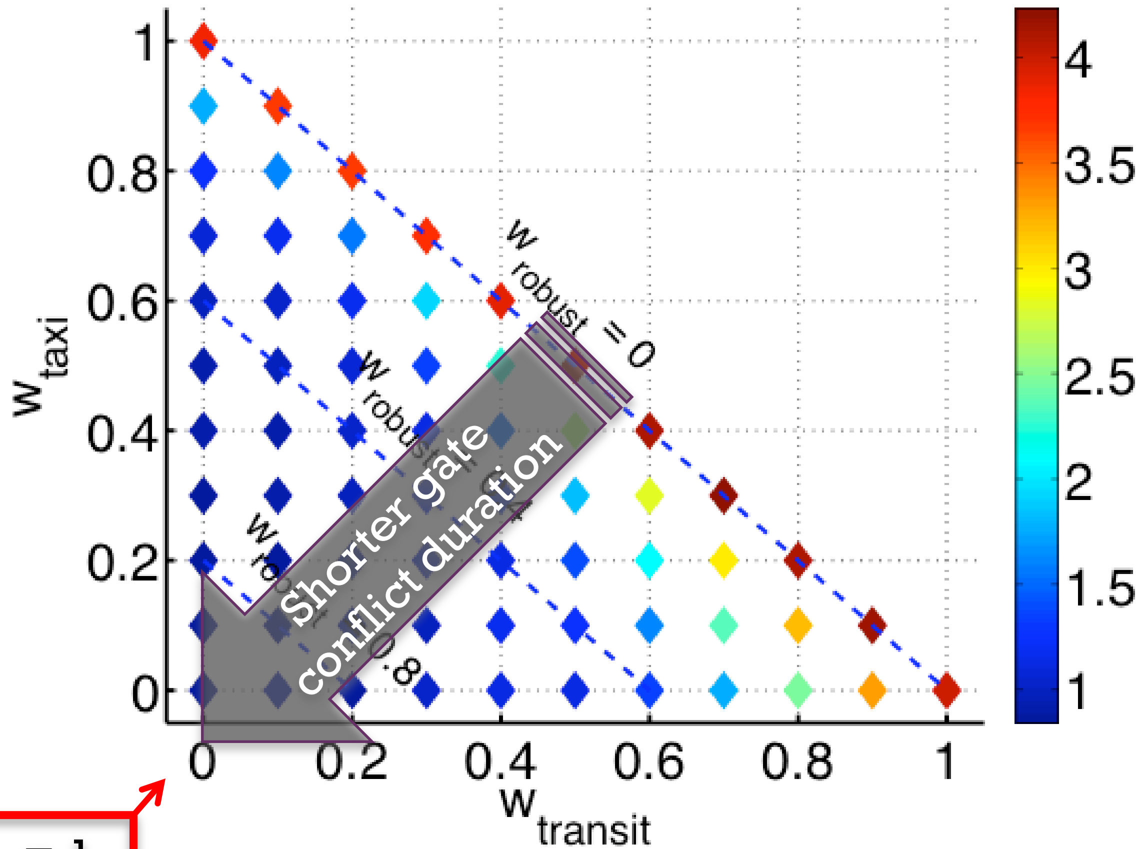
Average Transit Time in Minute per Passenger for 66 Values of ($w_{transit}$, w_{taxi}, w_{robust})



Average Taxi Time in Minute per Passenger for 66 Values of ($w_{transit}$, w_{taxi}, w_{robust})

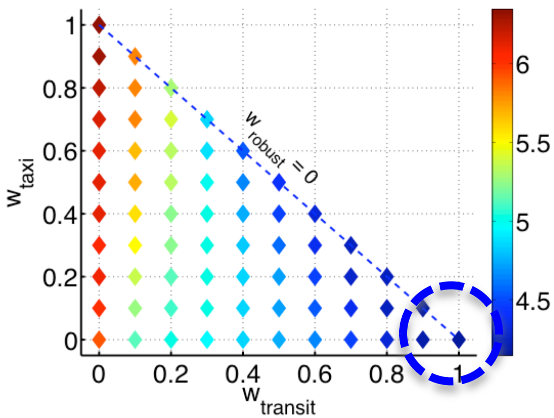


Average Duration of Gate Conflict in Minute per Passenger for 66 Values of ($w_{transit}$, w_{taxi}, w_{robust})

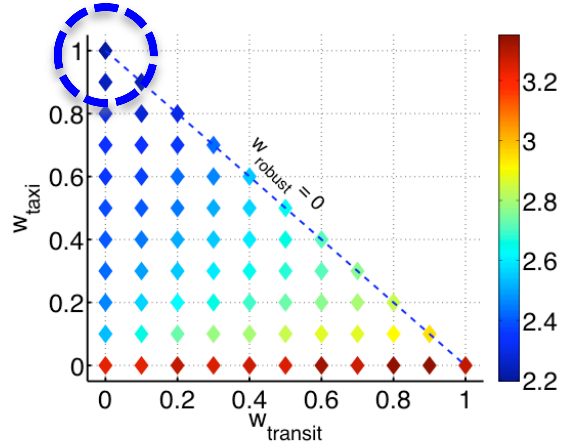


$W_{robust} = 1$

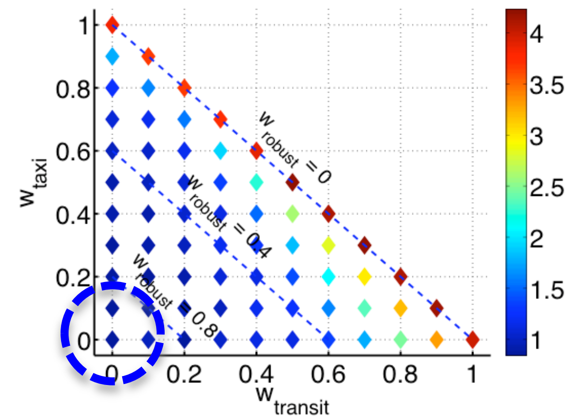
Trade-offs among metrics



Shortest transit time



Shortest taxi time



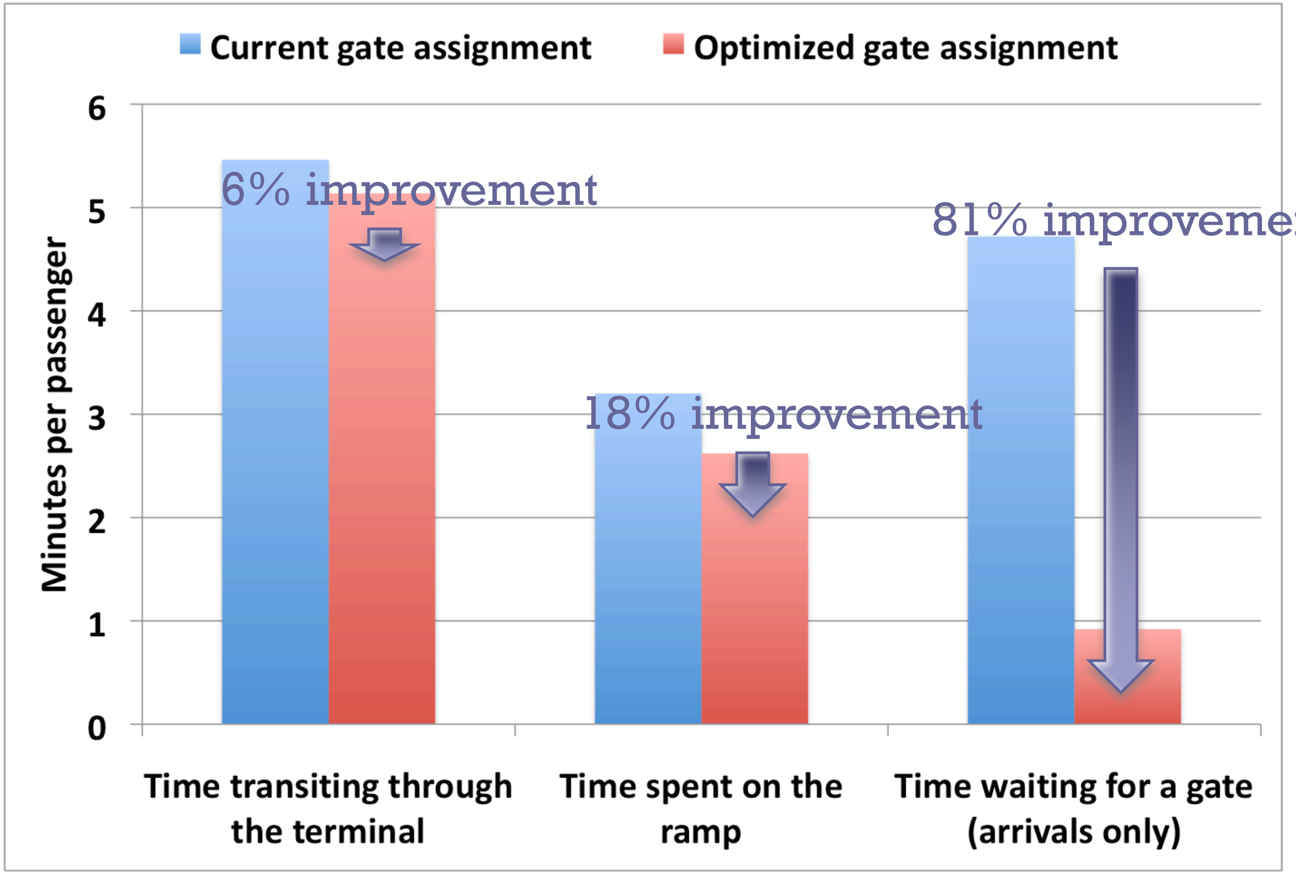
Shortest gate conflict duration

It is impossible to minimize all the metrics at the same time: trade-offs among metrics.

The optimized gate assignment is selected with $(w_{transit}, w_{taxi}, w_{robust}) = (0.2, 0.2, 0.6)$, 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



$$(w_{transit}, w_{taxi}, w_{robust}) = (0.2, 0.2, 0.6).$$

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.