Airport Service Vehicle Scheduling

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Outline

Why Service Vehicle Scheduling

The CARMA Project

Scheduling Algorithms

Simulation Studies

Conclusion
Why Service Vehicle Scheduling

“For most airports there is a dominance of delays due to gate congestion” (Idris et al., ATM 1998)

Interdependence of gates, airports

Very little service vehicle research to date, none from the perspective of a service provider

Available research has focused on describing the turnaround process
The CARMA Project (Car Management on Aprons)

Cost-efficient vehicle detection and communication on the apron

Applications to show vehicle information, and to manage vehicles from stakeholder control centers

Investigate the safety case and business case for vehicle management at Hamburg Airport

Proof of the technical and economical feasibility of a vehicle management system at Hamburg Airport
The CARMA Project
Scheduling Algorithms

Decisions
assign service vehicles aircraft to service
assign times when service is to begin

Objectives
minimize delay aircraft absorb
minimize distance service vehicles travel
minimize number of service vehicles required

Difficulties
aircraft assignment has exponential possibilities
aircraft sequencing has factorial possibilities
Scheduling Algorithms

Current
periodically see if aircraft is about to require service
use vehicles that have been idle the longest

Greedy
use vehicles that are closest to aircraft

Moving time window
periodically solve static scheduling problem
assign service vehicles according to results
Scheduling Algorithms: Moving Time Window

Planning horizon need not equal assignment horizon (examine schedule over next hour, every ten minutes)

Assignment horizon should depend on extent of uncertainty

Planning horizon should depend on computational power

In cases where planning horizon is unreasonably short, test heuristic approaches like genetic algorithms

“Clever optimization algorithms are best”
Scheduling Algorithms: Clever Optimization

Modify constraints to discourage fractional variables

Constraints on service times sum across binary sequencing variables

\[ b_j \geq (F_x + \frac{D_{x,i}}{V})a_{0,j}^x \quad \forall j \in I, \ x \in X \]

becomes

\[ b_j \geq \sum_{x \in X} \left[ (F_x + \frac{D_{x,i}}{V})a_{0,j}^x + \sum_{i \in I} (T_i + S_i + \frac{D_{i,j}}{V})a_{i,j}^x \right] \quad \forall j \in I \]

Add constraints to penalize cyclic flow

\[ \sum_{x \in X} (a_{i,j}^x + a_{j,i}^x) \leq 1 \quad \forall i,j \in I \]
Scheduling Algorithms: Clever Optimization

Branch based on vehicle assignment and task sequencing, never on individual variables

(Somewhat) more detailed explanation in paper

Methods applicable to other vehicle routing problems, including arrival scheduling
Scheduling Algorithms: Genetic Algorithm

Technique borrowed from arrival scheduling
assign aircraft to runways / vehicles
sequence aircraft
schedule based on sequence (trivial)

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<tr>
<th>Aircraft</th>
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<th>2</th>
<th>3</th>
<th>4</th>
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<td>Veh 2</td>
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<td>Ordering Instructions</td>
<td>1st Task</td>
<td>3rd</td>
<td>2nd</td>
<td>1st</td>
</tr>
</tbody>
</table>
Simulation Studies: HAM
Simulation Studies: HAM

200 scenarios given to various scheduling algorithms

17 aircraft requesting service from 6 service vehicles in each scenario (a busy hour or two at HAM)

Over $10^{13}$ ways to assign aircraft

For each assignment, as many as $10^{14}$ ways to sequence tasks
Simulation used glpk solver (open source) called from C++

Computation time of optimization highly variable
Simulation Studies: DFW
Simulation Studies: DFW

200 scenarios given to scheduling algorithms

1,000 aircraft requesting service from 20 - 30 service vehicles in each scenario

Optimization impossible given any reasonable planning horizon
Conclusion

Vehicle management systems have significant potential at both small and large airports:
- reducing delay aircraft absorb
- reducing distance service vehicles travel
- reducing service vehicle fleet size

Delay aircraft absorb waiting for service vehicles also a function of arrival and departure time distributions

Established clever optimization and genetic algorithms for scheduling