Finding a robust assignment of flights to gates at Amsterdam Airport Schiphol

G. Diepen, J.M. van den Akker, J.A. Hoogeveen, J.W. Smeltink

December 9, 2013

Outline

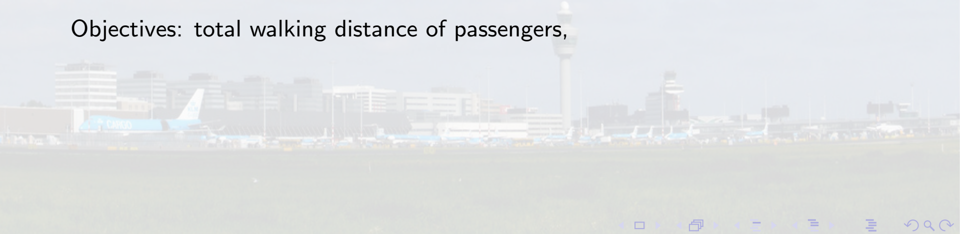
- Introduction and Literature Review
- Problem Description
- Solution Approach
- Computational Experiments
- Conclusion and Further Research

Introduction and Literature Review

”Assign a given set of flights to a (smaller) set of gates while making sure that certain criteria are met.”

- Gates can handle only flights operated by aircraft of certain sizes.
- Gates can handle only flights for certain origins/destinations (e.g. because of safety regulations)
- Two adjacent gates cannot be assigned flights operated by big aircraft at the same time.
- Two adjacent gates should not be assigned flights with equal departure times.

Objectives: total walking distance of passengers,



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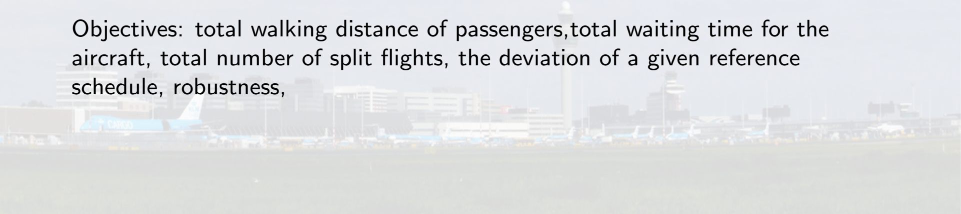

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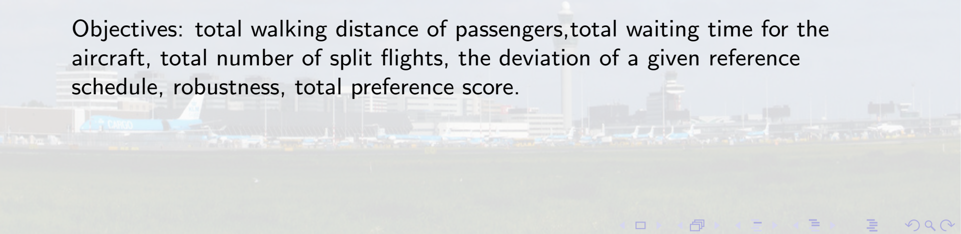

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- Nikulin and Drexl consider UnF, TWD and TPS (2008)
- dial-a-flight is considered by Espinoza et al. (2008a, 2008b)

Introduction and Literature Review

Current system in AAS:

- Based on a greedy algorithm which considers preference score points.
- Long stay flights are split into Arrival Part, Intermediate Part, Departure Part.
- Heavy burden of re-planning
- Downstream effects on the ground handler, the security personnel, the passengers etc.

There is a need for a robust schedule in the sense that *the schedule is able to cope with small perturbations.*

Problem Description

The flight schedule of a particular day is known. In addition, for each flight the known properties are:

- The region of the origin
- The region of the destination
- The size category of the corresponding aircraft
- The ground handler

For each gate, which regions and which size categories can be served and by which ground handler it is operated are known.
For each pair of flights, a convenience multiplier, $conv(v, w)$ is known.

Problem Description

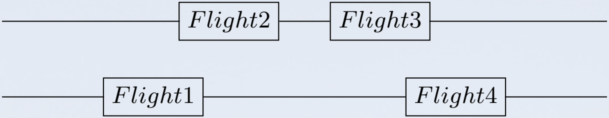

Figure : Example of a non-robust schedule

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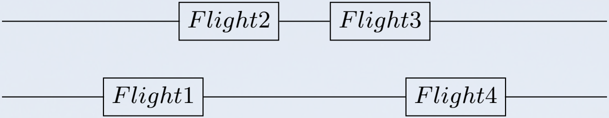
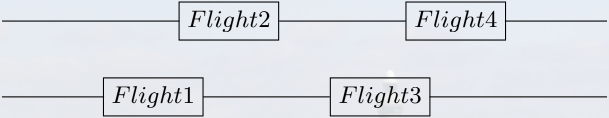


$Flight2$ $Flight3$

$Flight1$ $Flight4$

Figure : Example of a non-robust schedule



$Flight2$ $Flight4$

$Flight1$ $Flight3$

Figure : Example of a robust schedule

Solution Approach: Phase I / Model

Gate type: ”The gates in a type have same origin/destination area, ground handler and size category”
Gate plan: ”A series of flights that are to be assigned to the same gate of a certain gate type”

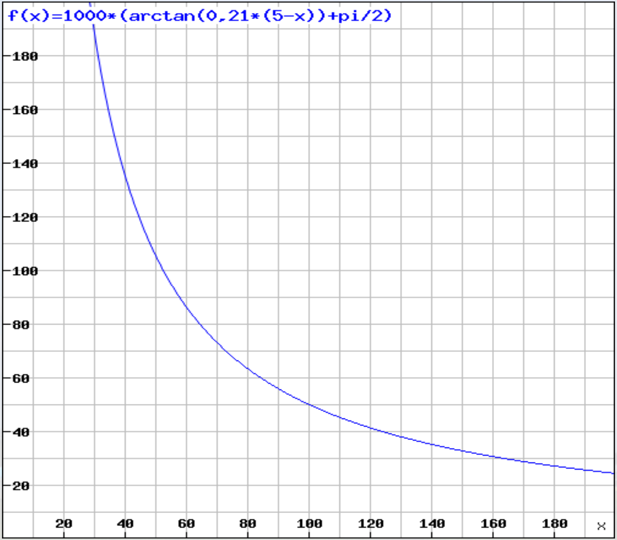
Solution Approach: Phase I / Model

Gate type: "The gates in a type have same origin/destination area, ground handler and size category"
Gate plan: "A series of flights that are to be assigned to the same gate of a certain gate type"
Each gate plan has a cost c_i ($|c_i|$: Number of flights in gate plan c_i)

$$c_i = \sum_{k=1}^{|c_i|-1} conv(k, k+1) c(Idle_{k,k+1})$$

$$c(t) = \begin{cases} 1000(arctan(0.21(5-t)) + \frac{\pi}{2}) & \text{if } t \geq 20 \\ \infty & \text{ow.} \end{cases}$$

Solution Approach: Phase I / Model



Solution Approach: Phase I / Model

V: The number of flights
A: The number of gate types
S_a: The number of gates of type a
N: The number of gate plans

$$g_{vi} = \begin{cases} 1 & \text{if flight v is in gate plan i} \\ 0 & \text{ow.} \end{cases} \qquad e_{ia} = \begin{cases} 1 & \text{if gate plan i is of type a} \\ 0 & \text{ow.} \end{cases}$$

Solution Approach: Phase I / Model

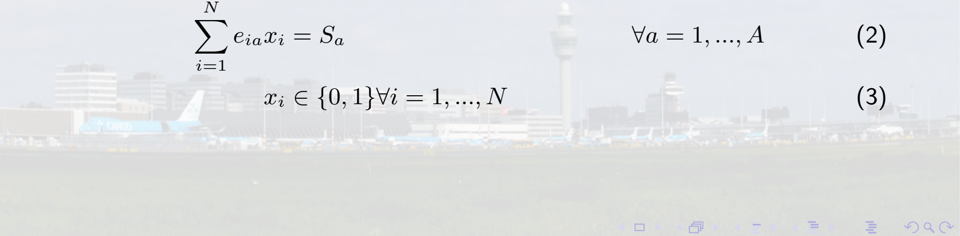
$$x_i = \begin{cases} 1 & \text{if gate plan i is selected} \\ 0 & \text{ow.} \end{cases}$$

$$min \sum_{i=1}^{N} c_i x_i$$

$$\sum_{i=1}^{N} g_{vi} x_i = 1 \qquad \forall v = 1, ..., V \qquad (1)$$

$$\sum_{i=1}^{N} e_{ia} x_i = S_a \qquad \forall a = 1, ..., A \qquad (2)$$

$$x_i \in \{0,1\} \forall i = 1, ..., N \qquad (3)$$



Solution Approach: Phase I / Model

Extension: Preference issue

$$p_{vak} = \begin{cases} 1 & \text{if flight v has preference for gate type a in preference k} \\ 0 & \text{ow} \end{cases}$$

$$\sum_{i=1}^{N}\sum_{v=1}^{V}\sum_{a=1}^{A} p_{vak} e_{ia} g_{vi} x_i \geq P_k \ \forall k = 1, ..., K \tag{4}$$

Solution Approach: Phase I / Model

Extension: Flight not being assigned
UAF_v: The extra variable for flight v to determine not being assigned.
Q_v: The cost coefficient in the objective function which is incurred due to UAF_v

$$\begin{aligned} \sum_{i=1}^{N} g_{vi} x_i + UAF_v = 1 \ \forall v = 1, ..., V \\ UAF_v \geq 0 \ \forall v = 1, ..., V \end{aligned} \tag{5}$$

Solution Approach: Phase I / Model

Extension: Long stay, flight split
For each long stay flight v, two split flights v_A and v_B are introduced.

$$\sum_{i=1}^{N} (g_{vi} + g_{v_A i}) x_i + UAF_{v_A} = 1$$

$$\sum_{i=1}^{N} (g_{vi} + g_{v_B i}) x_i + UAF_{v_B} = 1$$

$$p_{vak} = \begin{cases} 1 & \text{if flight v has preference on gate type a in pref. k} \\ 0.5 & \text{if the split version of flight v has pref. on gate type a in pref. k} \\ 0 & \text{ow.} \end{cases}$$

Solution Approach: Phase I / Solution

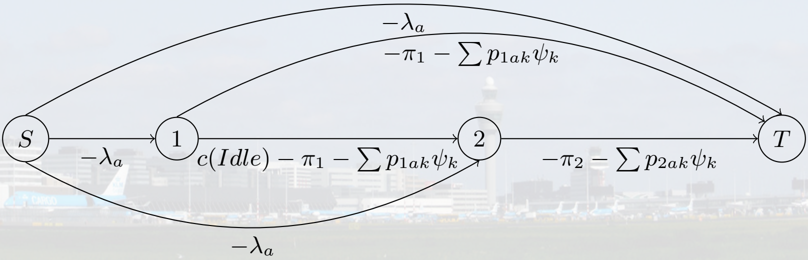
Idea: In order to reduce the size of the problem, only a set of gate plans are considered, called as presumably useful gate plans. This set of useful gate plans are identified during column generation steps of LP-relaxation.

Solution Approach: Phase I / Solution

The reduced cots of each gate plan is

$$c_i - \sum_{a=1}^{A} e_{ia}\lambda_a - \sum_{v=1}^{V}\left(g_{vi}\pi_v + \sum_{k=1}^{K}\sum_{a=1}^{A} g_{vi}e_{ia}p_{vak}\psi_k\right)$$

In order to check, each reduced cost is zero or negative, they solve shortest path problems for each gate type separately in which a path corresponds to a gate plan and the length of a path gives the reduced cost.



Solution Approach: Phase II

The information gathered from Phase I gives which gate plans are going to be performed in which gate type. The rest is manually handled by gate planners of AAS.

Computational Experiments

Instance	Flights	Gate Types	Total Gates
HS-1-GG	699	40	128
HS-2-GG	680	40	128
HS-3-GG	688	40	128
LS-1-GG	602	40	128
LS-2-GG	608	40	128
LS-3-GG	593	40	128
HS-1-SG	699	94	128
HS-2-SG	680	94	128
HS-3-SG	688	94	128
LS-1-SG	602	94	128
LS-2-SG	608	94	128
LS-3-SG	593	94	128

Computational Experiments

Instance	Take out freq 40			Take out freq 80			No take out		
	sec.	Iters.	cols.	sec.	Iters.	cols.	sec.	Iters.	cols.
HS-1-GG	139	693	14157	139	634	12892	195	557	12236
HS-2-GG	126	625	13622	128	580	12627	165	582	11971
HS-3-GG	110	642	13629	118	59	5 12628	158	537	12287
LS-1-GG	*	*	*	61	685	9910	82	640	9198
LS-2-GG	62	681	10861	67	599	9944	89	562	9640
LS-3-GG	62	693	10881	67	651	10124	82	597	9783
HS-1-SG	331	765	33004	310	652	29976	447	572	29116
HS-2-SG	300	631	31628	257	582	28410	505	589	28958
HS-3-SG	257	641	31796	236	631	28163	385	573	28423
LS-1-SG	470	1238	27975	160	700	20895	169	641	19968
LS-2-SG	137	673	24041	146	625	21960	161	562	22169
LS-3-SG	127	668	23650	122	621	22119	137	590	22276

Computational Experiments

Instance	ILP default (s)	ILP enhanced (s)
HS-1-GG	7	6
HS-2-GG	18	9
HS-3-GG	9	8
LS-1-GG	118*	52*
LS-2-GG	101	24
LS-3-GG	58	24
HS-1-SG	21	19
HS-2-SG	48	24
HS-3-SG	26	15
LS-1-SG	168	120
LS-2-SG	73**	126
LS-3-SG	94	113

Computational Experiments

Instance	LP(s)	Convert(s)	ILP(s)	Total(s)	Iters.	Columns	Poolsize	Gap (%)
HS-1-GG	139	13	6	160	634	12892	85225	0.00
HS-2-GG	128	12	6	148	580	12627	82558	0.00
HS-3-GG	118	13	5	138	595	12628	84036	0.00
LS-1-GG	61	8	21	91	685	9910	58374	0.19
LS-2-GG	67	8	23	100	599	9944	59527	0.21
LS-3-GG	67	8	5	81	651	10124	59099	0.09
HS-1-SG	310	30	12	355	652	29976	185970	0.00
HS-2-SG	257	28	13	300	582	28410	173453	0.00
HS-3-SG	236	28	13	279	631	28163	172979	0.00
LS-1-SG	160	16	161	340	700	20895	113413	0.18
LS-2-SG	146	18	21	187	625	21960	122092	0.21
LS-3-SG	122	17	196	339	621	22119	118663	0.09

Conclusion and Further Research

- Two phase solution method for the gate assignment problem at AAS
- Test of robustness by simulation
- Re-planning during the day of operation

About the author: Guido Diepen

- MS. Computer Science at Utrecht University in 2003 Thesis: The gate planning problem at Amsterdam Airport Schiphol
- PhD Computer Science at Utrecht University in 2008 Thesis: Column Generation Algorithms for Machine Scheduling and Integrated Airport Planning
- Now working at Paragon Decision Technology, which is the creator of the modeling software AIMMS

Questions