

On the Real-time Airport Parking Position Reassignment Problem

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Abstract. In actual day to day airport operations, interference (such as the flight ahead of schedule, delay and cancellation) is a common occurrence. This article is mainly focus on how to quickly and reasonably solve the real-time parking position reassignment problem caused by interference. A real-time airport parking position assignment model solved by GUROBI optimization software is built and the objective of this model is to minimize the number of passengers assigned to apron and the number of inconsistency between the reassignment scheme and the original one. Finally, the result of a test case verifies that the proposed approach performs well.

Introduction

Interference (such as the flight ahead of schedule, delay and cancellation) is a frequent occurrence in airport daily operations, which forced the airport authority to reassign aircraft to different parking positions in real-time. Since these aircraft information may vary and is updated frequently, the reassignment process must be immediately and reasonably. And traditional methods are not appropriate for solving real-time parking position reassignment problem owing to time-consuming.

Beyond that, with the airport flight traffic is growing, fixed and limited resources such as the airport runways, taxiways and parking positions are falling short of needs while activity planning is increasingly crucial and complex. Fig. 1 illustrates the two types of possible parking positions: air-bridge parking position and remote parking position (apron). Airports and airlines usually prefer air-bridge parking positions because they connect to an airport terminal passenger gate through air-bridge and are more convenient for passengers. In our partner airport, the number of passengers allocated to apron has increased in the last years, which increases the bus transfer costs and leads to the deterioration in service quality. Consequently, under the premise of ensuring the safety of flight and landing, through the rational allocation of parking positions to improve the efficiency of the airport and the level of service to passengers, which has become the airport operators need to further study and solve the problem.

In this paper we deal with the Real-Time Parking Positions Reassignment Problem which is similar to the Airport Gate Assignment Problem (AGAP). The Parking Positions Allocation Problem refers to seeks feasible aircraft-to-parking position assignments with satisfying some constraints to minimize the number of passengers assigned to apron and the number of inconsistency between the reassignment scheme and the original one.

AGAP has already been studied by many researchers. In order to minimize the variance of idle times as the optimization objective, the corresponding models are built on the basis of branch and bound method, genetic algorithm and other methods to achieve the robustness goal of the gate assignment by Bolat A[1-2]. J Xu and G Bailey (2001) consider an airport gate assignment problem that dynamically assigns airport gates to scheduled flights based on passengers' daily origin and destination flow data. They reformulate it as a mixed 0-1 integer problem with a linear objective function and constraints. And they design a simple tabu search meta-heuristic to solve the problem [3]. Ding et al. (2004) analyses the shortcomings in the solve approach given by Xu and Bailey and then put forward a new heuristics for over-constrained flight to gate assignments [4]. S Yan and CH Tang (2007) thought stochastic flight delays that occur in actual operations also have to be taken into account. They develop a heuristic approach embedded in a framework designed to help the airport authorities make airport gate assignments that are sensitive to stochastic flight delays [5]. CH. Tang designed a gate reassignment model to deal with temporary gate shortages and stochastic

flight delays [6]. H Zhao and L Cheng proposed a mixed integer model and used colony algorithm to solve airport gate assignment problem [7].

Many scholars have made a great deal of attention to AGAP and basic models for real-time allocation of parking positions or parking position pre-assignment are also proposed. However, how to quickly and reasonably solve the real-time parking position reassignment problem caused by interference and minimize the number of inconsistencies between the reassignment scheme and the original one are rarely involved.

This article is mainly focus on how to quickly and reasonably solve the real-time parking position reassignment problem caused by interference. And this paper has been organized in several sections. In the next section, we give a formulation of the Parking Positions Allocation Problem as we model it. In Section 3, we design a two-phase computerized method to solve real-time parking position assignment. In Section 4, computational results and comparisons are presented and in Section 5, the conclusion of this paper is given.



Figure 1. Airport parking positions

Model Development

In this section, we formulated the problem as an integer programming model with some constrains and the model is devoted to minimization of the passenger assigned to apron. Some constraints are necessary to this problem and mainly include two points: each aircraft must be assigned to only one parking position and no two aircraft with overlapping parking position occupation times are assigned to the same parking position at the same time.

Besides the above-mentioned constrains, we also need to take into account some additional restrictions related to the airport facilities. First, Aircraft-parking position compatibility must be considered. For example, due to the space restrictions related to the sizes of the available parking positions and aircrafts, some parking positions are forbidden to some aircrafts of specific types. Next, the process of an aircraft parking contains three parts: disembarkation of the arrival flight, waiting, and embarkation of the departure flight. During the waiting period, airport operators may decide to tow (move) aircraft from apron to air-bridge parking position for improving the air-bridge utilization. However, note that only if the duration of the waiting period is long enough then we can move the aircraft through the towing tractor. Finally, adjacency conflicts must be taken into account. For example, two large aircraft can't be assigned to adjacent parking positions concurrently.

Mathematical Notation. The notations used are listed as followed.

Sets:

F: set of aircraft;

M: set of aircraft which was assigned to on previous run and moves are allowed for the aircraft;

N: set of aircraft which have already arrived and moves are forbidden for the aircraft;

R: set of air-bridge parking position;

A: set of remote parking position;

G: AUR

Parameters:

t_i^a : The estimated time of arrival of aircraft i , $i \in F$;

t_i^d : The estimated time of departure of aircraft i , $i \in F$;

T_{buffer} : The buffer time between two aircraft assigned to the same parking position;

N_i^p : The number of passengers of aircraft i , $i \in F$;

x'_{ik} : Binary parameter equal to 1 if aircraft i was assigned to original parking position k on previous run, $i \in M$, $k \in G$;

B_k : Binary parameter equal to 1 if parking position k belong to A, $k \in G$;

H_k^s : The idle start time of parking position k , $k \in G$;

A_{kl} : Binary parameter equal to 1 if parking position k adjacent to parking position l , $k, l \in G$;

Q_{ik} : Binary parameter equal to 1 if aircraft i is compatible with parking position k , $k \in G$, $i \in F$;

P_{ij} : Binary parameter equal to 1 if the type of aircraft i conflicts with the type of aircraft j while aircraft i, j assigned to adjacency parking positions and aircraft j belongs to R_i , $i, j \in F$;

R_i : Set of aircraft conflicted with aircraft i ;

Variables:

x_{ik} : Binary parameter equal to 1 if aircraft i is assigned to parking position k , $i \in M$, $k \in G$;

Mathematical Model. Objective of this model is to minimize the number of passengers assigned to apron and minimize the number of inconsistency value which indicates an aircraft is reassigned to a parking position different than the original one. The weights are α , β . And the mathematical model for Parking Positions Allocation Problem is now presented as follows:

$$\min f \quad \alpha \sum_{i=1}^m \sum_{k=1}^n x_{ik} \times B_k \times N_i^p + \beta \sum_{i=1}^m \sum_{k=1}^n (x_{ik} - x'_{ik})^2 \quad (1)$$

Subject to:

$$\sum_{k=1}^n x_{ik} = 1 \quad \forall i \in F, \quad \forall k \in G \quad (2)$$

$$\sum_{j \in R(i)} x_{jk} + x_{ik} \leq 1 \quad \forall i \in F, \quad \forall k \in G \quad (3)$$

$$x_{ik} P_{ij} + x_{jl} P_{ij} \leq 1 \quad \forall A_{kl} = 1, \quad \forall i, j \in F \text{ and } i \neq j, \quad \forall k, l \in G \text{ and } k \neq l \quad (4)$$

$$x_{ik} = 0 \quad \forall Q_{ik} = 0, \quad \forall i \in F, \quad \forall k \in G \quad (5)$$

$$H_k^s \leq t_i^d \quad \forall i \in F, \quad \forall k \in G \quad (6)$$

$$x_{ik} = 0 \quad \forall k \in \{k | x'_{ik} = 0 \text{ and } B_k = 0\}, \quad \forall i \in M \quad (7)$$

$$x_{ik} = 1 \quad \forall x'_{ik} = 1, \quad \forall i \in N, \quad \forall k \in G \quad (8)$$

Constraint (2) ensures that each aircraft must be allocated to only one certain parking position. Constraint (3) specifies that two aircraft's schedule can't overlap if they are arranged to the same parking positions. Constraint (4) restricts that two large aircraft can't be assigned to adjacent parking positions concurrently. Constraint (5) ensures that aircraft-parking position compatibility must be satisfied. Constraint (6) guarantees that each aircraft must be allocated to the parking position whose idle start time doesn't exceed the estimated time of departure of the aircraft. Constraint (7) ensures that only can move the aircraft from apron to air-bridge parking position through the towing tractor. Constraint (8) ensures that those arrived aircraft for which moves are forbidden can only assignment to their original parking position.

Solution Strategy

For computational purposes, we develop a two-phase computerized method which includes the pre-assignment and reassignment phases to solve real-time parking position assignment.

Phase1: Pre-assignment. Consider the following.

The first phase's execution time is the start time of the daily airport operations. The relevant elements, including aircraft information, the available parking positions and parameters are provided in the preprocessing phase. Then, obtain an optimized pre-assignment result based on relevant elements.

Phase2:Reassignment.Consider the following.

This phase is designed to automatically and quickly provide the reassignment result after preprocessing of the updated aircraft and parking position data until the end of daily operations, or until the last aircraft's parking position is fixed in daily operations. Time interval for updating data is set to be 30min.

Step1.Calculate the idle start time for each parking position according to the aircraft's arrival/departure time (The aircraft's parking position is fixed).

Step2.On the phrase of data preprocessing, we need to update the aircraft information such as whether it can be moved, whether it has arrived, arrival time, and departure time.

Step3.Obtain a new optimized reassignment result based on updated elements, using the optimization software GUROBI.

Computational Study

In order to solve the model as mentioned in the last sect effectively, the optimization software GUROBI is taken into application. And we performed computational study based on our partner airport.

The planned parking position assignment data used for computational study were based on the operating day, December 24, 2016 and included 81 aircraft and 5 aircraft types. The Partial aircraft information is shown in Table 1. There were 19 parking positions in operation, of which 10 were remote parking positions.

Table 1 Part of aircraft information

Aircraft ID	towed	Arrival time	Departure time	Aircraft type	Passenger	Actual parking position
B1	yes	12/23 22:46	12/24 7:05	B737	232	10
D2	no	12/24 8:29	12/24 9:45	A320	96	10
D75	no	12/24 10:32	12/24 11:40	B737	284	9
D35	no	12/24 11:30	12/24 12:15	A320	29	15
A60	no	12/24 13:34	12/24 18:50	A320	102	6

After data preprocessing phase, we used software to obtain an optimized pre-assignment result listed in Table 2. In pre-assignment results, aircraft A19, A27, A55, A57, B59 need to be towed from apron to air-bridge parking position by towing tractor. Compared with parking position allocation scheme in actual operations, the number of passengers in pre-assignment results with the model and program proposed in this paper is increased from 11591 to 14469, a growth of 24.82%.

Table 2 Pre-assignment results

Parking position ID	Aircrafts assigned to the parking position	Passengers assigned to air-bridge parking position
1		
2		
3	A19, A36, D21, D25, D50, D66, D67	1286
4		
5	B58, D32, D46, A20, B77, D16, C17, D26, A80, A52	1757
6		
7	B59, B45, B61, B62, B64, B8, D71 ,D51	1677
8	A57, D74, C12, D13, D47, D37, A15, D78, D65, D42	2099
9	A27, C68, A76, A54	758
10	B1, D2, A28, D29, D7, B79, D41, D10, B73	1790
11	A11, D3, D4, C5, A6, B70, A40, A81	1612
12	D24, B30	
13	A23	
14		
15	A31, B43, D33, D75, D69, B63, A38, A22, C18	1977
16	A55, B44, D34, D35, D14, A48, D49, C9, B72	1513
17	A53, B56	
18	D39	
19	A60	
Total		14469

Due to weather, traffic control and other reasons, the following aircraft's arrival/departure time are altered compared with the original flight schedule as is shown in Table 3.

Table 3 Irregular aircrafts information

Aircraft ID	state	Arrival delay	Departure delay
B1	Cancelled		
D47	Advanced	-15min	--
C9	Due	+20min	+25min
C12	Due	+40min	+45min
D35	Advanced	-10min	--
D67	Due	+70min	+70min
A20	Due	+35min	+35min
B45	Due	+25min	+18min

As described above, automatically and quickly provide the reassignment result after preprocessing of the updated irregular aircrafts information in Table 3 and parking position data. After running about 10 seconds, we can obtain the real-time reassignment result. And the total aircrafts reassigned parking position inconsistency between the reassignment scheme and the original one refers to Table 4. The reassignment results showed in Fig. 3. Due to the gap between the successive aircraft assigned to the same parking position is too small, some aircraft can't be seen clear in figure. As can be seen, when 8 of the 81 aircrafts in the model are disturbed, only 4 of the aircrafts have a real-time reassigned parking position which is different from the original parking position, and has less interference.

Table 4 Parking positions inconsistencies

Aircraft ID	Original parking position	Reassignment of parking position
B73	10	9
C17	5	16
B72	16	11
C12	8	16
D34	16	12

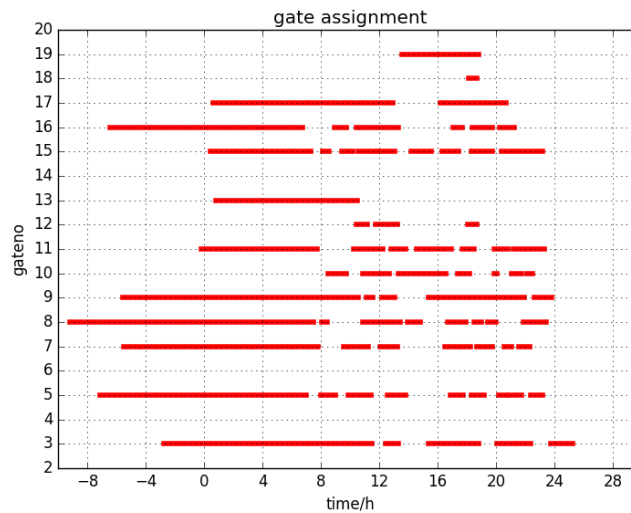


Figure 2. Figure of reassignment results

Conclusions

In this paper, we have shown a binary integer program model for the aircraft parking position reassignment problem that minimizes the number of passengers assigned to apron and the number of inconsistency between the reassignment scheme and the original one. For computational purposes, we develop a two-phase computerized method which includes the pre-assignment and reassignment phases to solve real-time parking position assignment. GUROBI and python were used to code the program which was applied to our partner airport and be illustrated to provide optimal solutions in a matter of seconds. In practice, this tool may be used by parking position managers to optimize the reassignment of aircraft to parking positions meet alterations in aircraft arrival/departure times in real-time.

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