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The over-constrained airport gate assignment problem

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Abstract

In this paper, we study the over-constrained airport gate assignment problem where the objectives are to minimize the number of ungated flights and total walking distances or connection times. We first use a greedy algorithm to minimize ungated flights. Exchange moves are employed to facilitate the use of heuristics. Simulated annealing and a hybrid of simulated annealing and tabu search are used. Experimental results are good and exceed those previously obtained.

Keywords: Airlines; Transportation; Tabu search; Simulated annealing

1. Introduction

The primary purpose of flight-to-gate assignments in airports is to assign aircraft to gates to meet operational requirements while minimizing inconveniences to passengers. Planners seek to minimize distances passengers have to walk to departure gates, baggage belts and connecting flights since this is a key quality performance measure of any airport. For connecting flights, minimizing distances is key to smooth operations due to short connection times common in many international airports. While certain walking distances are fixed when schedules can be conformed to, others can change from time to time. For example, the distances traversed by transfer or connecting passengers from gate to gate can change due to changing gate assignments resulting from randomness in operations. Airlines, ground-handling agents and airport authorities, therefore need to assign gates to flights dynamically to minimize walking distances and consequently, connection times. A flight-to-gate assignment policy satisfying operational requirements can be derived at the start of each planning day based on published flight schedules and booked passenger loads. In the Airport Gate Assignment

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Problem (AGAP), the objective is to find feasible flight-to-gate assignments which minimizes total passenger walking distances including distances between connecting flights. In the problem, the planning horizon would typically be a time interval that includes flight peak periods since if gate assignments are done well during these periods, gate shortages are unlikely to occur outside these periods. The typical distances in airports considered are: (1) the distance from check-in to gates for embarking or originating passengers, (2) the distance from gates to baggage claim areas (check-out) for disembarking or destination passengers, and (3) the distance from gate to gate for transfer or connecting passengers. In the over-constrained case, where the number of aircraft exceeds the number of available gates, we include the distance from the apron or tarmac area to the terminal.

This paper is organized as follows. In the next section, we provide a short summary of work done on this and related problems. In Section 3, we give a model for the AGAP. In Section 4, we discuss a basic greedy algorithm that minimizes the number of flights not assigned to gates and in Section 5 we give a simulated annealing heuristic for the problem. In Section 6, we provide a tabu search method and in Section 7 develop a hybrid simulated annealing with tabu search heuristic. In Section 8, computational results and comparisons are given and in Section 9, we summarize our findings and suggest future work.

2. Previous work

Braaksma and Shortreed [1] provided one of the first attempts to use quantitative means to minimize intra-terminal travel through the design of terminals. The assignment of aircraft to gates, which minimize travel distances, is easily motivated and understood problem but difficult to solve. The total passenger walking distance is based on passenger embarkation and disembarkation volumes, transfer passenger volumes, gate-to-gate distances, check-in-to-gate distances and aircraft-to-gate assignments. The cost associated with the placing of an aircraft at a gate depends on the distances from key facilities as well as the relations between these facilities. The basic gate assignment problem is a quadratic assignment problem and was shown to be NP-hard by Obata [2]. Babic et al. [3] formulated the gate assignment problem as a 0–1 integer program and used a branch-and-bound algorithm to find solutions where transfer passengers were not considered. Mangoubi and Mathaisel [4] used an LP relaxation of an integer program formulation with greedy heuristics to solve the problem of Babic et al. with the difference that their model includes transfer passengers. Bihr [5] used a 0–1 LP to solve the minimum walking distance problem for fixed arrivals in a hub operation where a simplifying assignment formulation is employed. Wirasinghe and Bandara [6] considered, additionally, the cost of delays and used an approximation procedure in their analysis. Yan and Chang [7] proposed a network model that is formulated as a multi-commodity network flow problem. An algorithm based on the Lagrangian relaxation, with subgradient methods together with a shortest path algorithm and a Lagrangian heuristic was developed for the problem. Baron [8] used simulation to analyze the effects of passenger walking distance resulting from different gate-use strategies where both local and transfer passengers are considered. Simulation models for the problem can also be found in, for example, Cheng [9,10]. Some models have suggested ways to resolve stochastic flight delays in the planning stages. In Hassounah and Steuart [11], planned scheduled buffer times were found to improve punctuality. Yan and Chang [7] and Yan and Hou [12] added a fixed buffer time