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A simulation framework for evaluating airport gate assignments

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Abstract

There are many factors that affect gate assignments in an airport's operations. These factors include static gate assignments, stochastic flight delays and real-time gate assignments. Most research on gate assignments in the past has laid stress on improving the performance of static gate assignments. None has analyzed the interrelationship between static gate assignments and real-time gate assignments as affected by the stochastic flight delays that occur in real operations. In addition, none has designed flexible buffer times for static gate assignments to effectively absorb stochastic delays in real-time gate assignments. This research proposes a simulation framework, that is not only able to analyze the effects of stochastic flight delays on static gate assignments, but can also evaluate flexible buffer times and real-time gate assignment rules. Finally, a simulation based on Chiang Kai-Shek airport operations is performed to evaluate the simulation framework.

Keywords: Static gate assignment; Stochastic delay; Real-time gate assignment; Buffer time; Simulation

1. Introduction

The main purpose of flight-to-gate assignments is to assign each aircraft to a suitable gate so that passengers can most conveniently board/deplane the aircraft. Flight-to-gate assignments not only affect an airport's operating efficiency but also its level of service. In particular, the efficient assignment of flights to gates is an important short-term solution that will alleviate the airport congestion currently faced by many airports around the world.

A number of analytical models have been developed that help airport authorities more effectively assign daily flights to gates. For example, Braaksma (1977), Babic et al. (1984), Mangoubi

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and Mathaisel (1985), Vanderstraetan and Bergeron (1988), Bihr (1990), Zhang et al. (1994), Cheng (1997), Yan and Chang (1998), Haghani and Chen (1998), Bolat (1999, 2000), and Yan and Huo (2001). These models are formulated as zero–one integer (linear or quadratic) programs, mixed integer programs or network flow problems. The objective functions are usually to minimize the total passenger walking distance, the number of off-gate events, the range of unutilized time periods for gates, the variance of idle times at the gates, or a multiple of the above.

Two classes of constraints are commonly required in the modeling: (1) every flight must be assigned to one and only one gate, and (2) no two aircraft may be assigned to the same gate concurrently. Some special constraints may also be introduced (Vanderstraetan and Bergeron, 1988; Haghani and Chen, 1998; Bolat, 1999, 2000). These models were solved using exact solution methods or heuristics, such as the simplex method, the primal-dual simplex algorithm, the branch-and-bound technique, the Lagrangian relaxation-based algorithm, the column generation-based algorithm and other heuristics.

Although the above analytical models were shown to be good in the planning stage, their "optimally planned" results did not evaluate incorporated stochastic flight delays that usually occurred in real-time operations. Consequently, the actual performance of the planned results in real-time operations was unknown. In fact, there are many factors that will affect gate assignments during real operations, including the planning of gate assignment as has been done in past analytic models (for convenience, let us call them "static" gate assignments), stochastic flight delays (including early or late arrivals and late departures), and real-time gate assignments (called reassignments). Unfortunately, most research on gate assignments in the past has laid stress on improving the performance of static gate assignments. None has analyzed the interrelationship between static gate assignments and real-time gate assignments as affected by the stochastic flight delays that occur in real operations. In addition, none has designed flexible buffer times for static gate assignments to effectively absorb stochastic delays in real-time gate assignments.

Some models have suggested ways to help resolve stochastic flight delays in the planning stages. For example, Hassounah and Steuart (1993) showed that planned scheduled buffer times could improve schedule punctuality in flight operations. Yan and Chang (1998) and Yan and Huo (2001) added a fixed buffer time between two continuous flights assigned to the same gate, in their static gate assignment models, to help absorb the stochastic flight delays that often occur during real-time operations. However, their fixed buffer time length was the same for all connected flight pairs, which does not reflect the flow conditions, i.e. peaks and off-peaks, at an airport, and could possibly result in inferior operating performance.

Some optimization models have been introduced that reassign flights to alternate gates during real-time operations when there are stochastic flight delays. For example, Gu and Chung (1999) have developed a genetic algorithm approach to solving the gate reassignment problem. Since such reassignments are typically time constrained for real operations (for example, for at the CKS airport), it is usually difficult to apply an optimal but time-consuming model to solve for real-time gate assignments. Hence, effective and efficient real-time assignment rules, other than the traditional manual practices, should help an airport staff reassign flights to gates in real-time operations, as well as to retain the planned system performance.

In this research we propose a simulation framework that will help airport authorities to analyze the effects of stochastic flight delays on static gate assignments, and to evaluate flexible buffer times and real-time gate assignment rules. In practice, the airport authority can use current or