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IMPACT OF CONNECTION BANK REDESIGN ON AIRPORT GATE ASSIGNMENT

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ABSTRACT

Along with marketing and maintenance implications, hub optimization is an important part of the flight schedule development process. The Air Canada flight schedule at its Toronto hub is based on two-hour non-directional connection banks. The purpose of this research is to analyze an alternative to this rule consisting of directional connection banks and, more specifically, to assess how this would impact the gate assignment performance.

1 INTRODUCTION

The flight schedule development process comprises many sub-processes. These include the determination of the number of departures for a specific city-pair and their timing, the creation of flights with single or multiple legs, the assignment of an aircraft type to the flight, the determination of aircraft rotations and the assignment of a physical aircraft to each rotation. This is a sophisticated iterative process which must take into account the attractiveness of the flight schedule to prospective passengers, the aircraft range, the time needed for overnight checks at specific airports, the availability of pilot and flight attendant crews, etc. At hub airports, connection times have to be optimized for passengers and, at the same time, the peak period requirements and fluctuations of fixed resources, such as gates, must be minimized. Trietsch (1993) provides a description of the various aspects to consider when scheduling flights at hub airports.

The flight schedule is the primary input for determining the demand for gates. However, there are various types of demand. For example, transborder departure flights for a given aircraft type are not accepted at all gates and could be constrained by a lack of resources at a given period of the day. Domestic or international departures are more constrained at other times. To factor in these elements, one needs to consider the gate assignments themselves.

The gate assignment problem is particularly complex at Terminal 2 of Toronto airport. The objective is to assign all flights to gates while minimizing the number of aircraft tows, the walking distance for passengers, the taxi time for aircraft, the number of aircraft type changes at a given gate, the number of different gate assignments for a given destination and the number of foreseeable potential perturbations to the gate plan during the day-of-flight operations. Simultaneously, various constraints must be satisfied, such as aircraft type acceptance at a given gate, space restrictions for specific aircraft types at adjacent gates, mandatory tows from a service to another (e.g., an aircraft rotation involving an international arrival and a domestic departure), towing capacity in terms of number of vehicles/operators and authorized movements on the congested apron. An additional complication to be taken into consideration is that demand for gates is higher during the summer season whereas the winter schedule is more subject to inclement weather. Magoubi and Mathaisel (1985) provide a formulation of some of these elements.

For the purposes of this study, we have altered the flight schedule of a selected peak season day in order to create a directional bank scenario. We compare the resulting demand curve for gates with the initial non-directional flight schedule demand curve. Finally, we assign the flights to gates with a simulation that was previously developed to explore various facets of the gate assignment problem.

2 CONNECTION BANKS

When an airline operates hubs, schedule attractiveness to the passengers must take into account connection times. A connection is made when a passenger arrives at an airport on one plane and departs on a later flight. To attract passengers, the airline must minimize the time passengers wait between connecting flights. However, there also exists a minimum connection time which cannot be compromised. During this time, all mandatory airport procedural requirements, like customs, are satisfied. To maximize the number of possible connections while minimizing connection and wait times, the airline schedules flights in clusters throughout the day. In other words, groups of arriving flights are scheduled to arrive at the hub station prior to a number of subsequently departing flights. The interval of time between the two groups must be engineered to accommodate the minimum connection time. The natural result is a window of time, known as a connection bank, existing between the first arrival and the last departure.

In its schedule development process, Air Canada assumes two-hour non-directional time banks (7:00 AM, 9:00 AM, 11:00 AM, etc.) at its Toronto hub. There nonetheless exist different types of connections: eastbound (e.g. Vancouver to Toronto to Boston), westbound (e.g. Halifax to Toronto to Winnipeg) and southbound (e.g. Montreal to Toronto to Houston). A possible alternative to these two-hour non-directional connection banks is directional connection banks with, for example, westbound connections at 7:30 AM, 9:30 AM, 11:30 AM, etc and eastbound connections at 6:30 AM, 8:30 AM, 10:30 AM, etc.

In reality, the connection banks are only approximate. There is considerable effort to respect them, but they are subject to many different constraints such as curfews, slot availability, aircraft rotation and crew availability. These factors sometimes result in departure times outside the appropriate connection banks.

Our experiment is based on the flight schedule of 13-July-98. The directional scenario has been created by subtracting 30 minutes from eastbound aircraft rotations and adding 30 minutes to the westbound ones. Southbound aircraft rotations remain unchanged. Not all factors are considered in this initial phase of study. Marketing considerations, feasibility with respect to types of resources other than gates and the feasibility of these changes with respect to the rotations would be considered in later phases.

3 GATE ASSIGNMENTS

An important consideration of this possible change to the schedule development process is the impact on hub resources, specifically gates. Demand for gates varies considerably with respect to the time of day. It is advantageous to minimize fluctuations in resource requirements during the course of the day and consequently minimize the number of gates needed at peak periods. One objective of this research is to determine how peaks and fluctuations would differ with the use of directional connection banks. In addition, since the gate requirements depend on many constraints (service type, aircraft acceptance/restriction rules, towing, etc.), another goal is to assess the impact of the proposed change on the gate assignments.

Hassounah and Steuart (1990) propose a model for determining the total requirement of identical gates. They consider the effect of late arrivals and departures. However, their model cannot be directly applied to our problem. Our goal is not the determination of gate requirements per se but to calculate, within the existing gate structure and zone assignments, the gate assignment performance. In addition, our problem cannot be separated into various problems with identical gates because, for example, adjacent Rapidair (no customs) and Transborder (customs) gates can be dynamically reconfigured inside the terminal at need with stanchions and supervision of security people for controlling the flow of passengers.

The current gate assignment system at Air Canada could eventually have been used to run our scenario. However, it would have necessitated a major effort, longer than developing a simulation application with such tools as ARENA. In addition, simulation tools allow Monte Carlo sampling which was thought necessary for subsequent phases of our study.

Figure 1 shows a schematic of the gate assignment model used in our simulation tool. The algorithm assigns demand to the most preferred available gate unless there is no gate available within the preferred gates of the current demand line. In this case, it tries to change the assignment of an already assigned demand line to a less preferred gate in order to make room for the current demand line. It searches over all the acceptable gates for the current demand. If it cannot find one, the demand line is included in the towing list and taken care of manually. This towing list is not empty at the beginning since it contains all the mandatory tows from one service to another (e.g. international to domestic area) and, the initial and final aircraft placements. Operational gate assignment tools generally consider more factors than this for daily assignments but, at a planning stage for connection bank policy scenarios, this was considered sufficient.

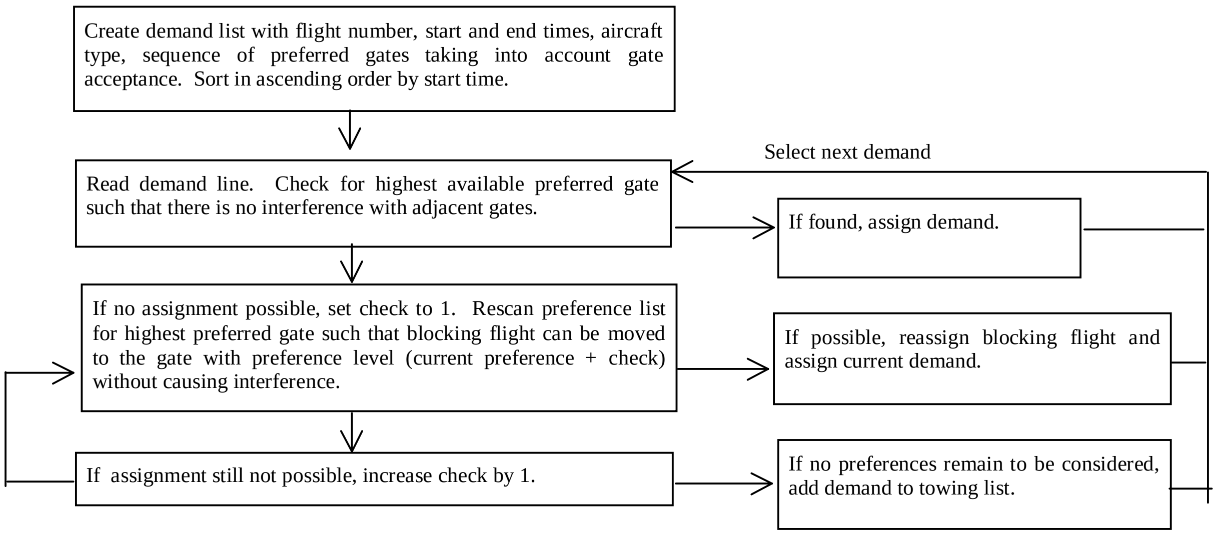

Figure 1: Gate Assignment Model

4 PRELIMINARY RESULTS

Figure 2 shows the demand curve for the base case (non-directional banks) and our scenario (directional banks). It indicates that both global peak demand and fluctuations (standard deviation) would be lower under the directional scenario. At first glance, this could seem a compelling argument in favor of directional connection banks. However, this can be too simplistic a view. Two additional aspects have to be verified: the gate assignments with respect to the demand mix and the independence of the scenario with respect to the particularities of the flight schedule considered. The latter aspect is justification for the use of a simulation tool, with the possible exception of the animation piece.

The gate assignment results are summarized in Table1. We consider only the performance measures pertinent to our model. For example, we could have calculated the number of equipment swaps at a given gate but, since our gate assignment model does not aim at minimizing them, we did not consider this measure. The relevant performance measures are the number of unassigned flights, the preference satisfaction level (e.g., if half of the demand were assigned their most preferred gate and the other half their second most preferred gate, the result would have been 1 * 50% + 2 * 50% = 1.5; consequently, a smaller value is preferrable) and the first preference satisfaction percentage which reflects the stability of the assignments (one would like, for example, all departures for Vancouver at the same gate).

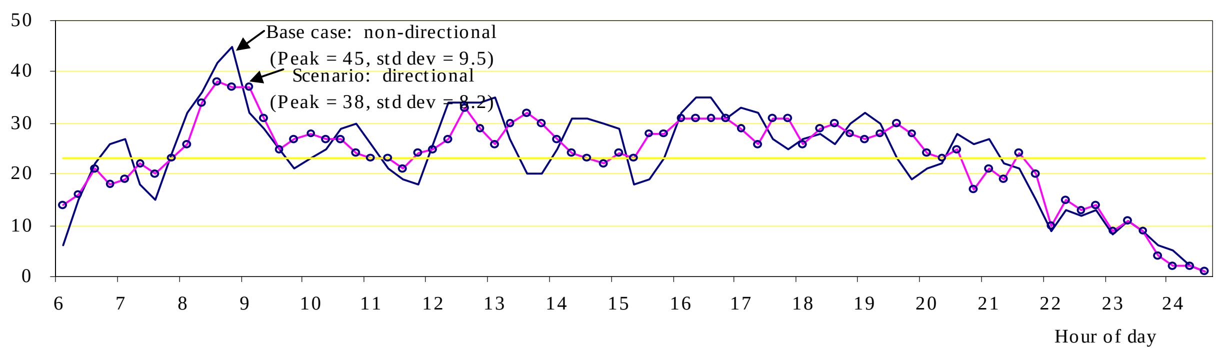

Figure 2: Demand for gates - Toronto Terminal 2 on 13-Jul-98
(average = 23)

Table 1: Gate Assignment Results

	Non-directional (base case)	**Directional (scenario)**
Unassigned demand (added to towing list)	*2 from 366*	3 from 366
Unassigned percentage	0.55%	0.82%
Preference satisfaction level	3.13	3.05
First preference satisfaction percentage	46.5%	46.6%

The gate assignment results oppose the apparently compelling difference in the global demand curves. One would have expected a lower unassigned demand under the directional scenario, but it is slightly higher. In the base case, the unassigned demand consisted of two transborder flights in the peak period while, in the directional scenario, it consisted of two different transborder flights and one domestic flight approximately one hour after the peak period. As expected, the two preference satisfaction measures are better under the directional scenario but not as much as we would have intuitively believed. This shows that we should be caution in drawing conclusions rapidly from global demand figures.

5 CONCLUSIONS

This first phase of our study shows that tools can be developed, in an effort of only a few people-months, to assess the impact of change in flight schedule development policy on resources such as gates. In this initial phase, only a deterministic model was used. The ARENA simulation was used only for animation and performance assessment purposes.

Results with the simulation showed that there is a smaller improvement in gate assignment performance under the directional scenario than one might have expected by a simple comparison of the gate demand curves. This improvement could have been caused by particularities of the flight schedule of the day considered (13-July-1998).

In a second phase, we would like to consider schedule adherence variability (arrival and departure lateness) as an additional factor. More gates are needed to cover this uncertainty. Hassounah and Steuart (1990) showed that this uncertainty can cause an increase of more than 30% in the number of gates required in a simple case when reducing the spacing between connection banks by half.

In addition, we would like to consider other elements, like those mentioned at the end of section 2: marketing, feasibility with respect to resources other than gates, feasibility of changes to rotations. Also, we would like to conduct a study that is more independent of the particularities of a given flight schedule by introducing demand uncertainty into the model. One can achieve this by testing a sufficient number of different days and/or by generating random perturbations of the demand. Each method has its advantages and disadvantages and it will be one of the first tasks of this second phase to set up a program to ensure that results are statistically significant.

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