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MODELING APPROACH FOR MANAGING THE DEMAND IN CONGESTED AIRPORT NETWORKS: THE CASE OF MEXICO CITY AIRPORT

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ABSTRACT

We introduce a discrete event simulation approach to assess flight demand when airport congestion is observed. One of the consequences of airport congestion are flight delays which in turn decrease costumer's satisfaction. The model includes flight information, airline on-time performance and flight duration and turnaround time uncertainty. When airport congestion occurs at the arrival airport, an air traffic flow management initiative is triggered as a tool for alleviating the congestion problems, particularly in the most congested slots of the airport. Analysis of selected model scenarios allows to select the parameters of the initiative where airport congestion can be minimized.

The model is set up for Mexico City airport, which is Mexico's busiest airport and highly congested. This case study describes how to model the airport network for analysing the effectiveness of specific traffic flow management initiatives in Mexico City. The use of the simulation approach will enable the decision makers to analyse the effectiveness of the present traffic flow policy as well as to evaluate different policies for coping with the increasing demand in the Mexican network of airports. The flexibility of the model makes it easy to adapt to congested airport networks in other regions of the world.

1 INTRODUCTION

Airport congestion can result in the situation where the use of an airport by a specific aircraft delays or prevents the use of it by another aircraft in the same time interval. Due to the constant growth of air transportation, congestion problems and flight delays are becoming more acute in many airports. They cause constriction of growth, possible flight cancellations, frustration in passengers, environmental problems due to increased emissions, unnecessary costs due to increased fuel consumption and bad reputations for carriers and airports (Guest, 2007; Ball et al., 2010).

In airports with important capacity constraints, such as JFK and LGA in New York, FRA in Frankfurt, LHR and LGW in London, there is virtually no idle capacity available for growth and/or unscheduled flights. To diminish airport congestion, the study of the spread of flight delays becomes especially important for trips with stopovers on one hand, and in terminals with capacity problems on the other hand. The specific case of Mexico City presents both problems, since on the one hand it is an aeronautical hub for the so-called flag airline Aeromexico and on the other it is one of the main gateways to the country with flights from United States, Europe and Latin America.

Considering both domestic and international passengers, Mexico City International Airport (IATA Code: MEX) has a market share of approximately 32% of the total of transported passengers in Mexico, which makes it the busiest airport in the country (Wellens and Mujica Mota, 2017). Since its important position in terms of the number of operations as well as its functionality of the hub operations of certain carriers, MEX reveals as an important node whose operation affects the complete national network of airports. Therefore the understanding of efficient ways of managing the airport will affect not only the airport itself and the stakeholders that participate in it but also the complete national airport network. As a consequence of its high congestion level, Mexico City International Airport was declared saturated in 2013, observing that operations in the Mexican air space exceeded the maximum number that can be attended per hour (SEGOB, 2014).

Traffic flow management initiatives can be used to absorb a percentage of air traffic, to control air traffic demand and to mitigate demand-capacity imbalances (Agustin et al, 2010). The presence of alterations due to delay implies that the coordination of activities at the airport will be affected; identifying its effect in advance will allow airport management to be more efficient, allowing the continuous operation of the flight program and avoiding the export of the delay to other airports, resulting in a cascade effect.

An important aspect of delays is the stochasticity of flight duration and turnaround times. The uncertainty associated with inclement weather, airline inefficiency, passenger delays, mechanical problems, operational inefficiencies, lack of schedule robustness, safety issues, etc. has a direct influence on delay frequency and duration and thus on airport congestion.

2 METHODOLOGICAL APPROACH

The simulation model used for managing the demand in congested airport networks was developed using the SIMIO software system. SIMIO uses a process-object oriented approach which suits perfectly for the type of operations performed by the aviation industry where everything happens at scheduled times and the control of uncertainty is one of the main goals of the operation (Alomar et al., 2017; Pegden, 2007). The model involves aircraft moving between airports in a network of nodes connected by paths of a length proportional to the flight's travelling time. At the moment, only one hub is considered, together with all corresponding arriving and outgoing connections. Flight information is provided from daily, weekly or monthly information tables for flights arriving at the selected hub; aircraft, airline and airport information is linked to separate data tables.

The events in the simulation model are triggered by the information specified in the provided flight schedule, including origin airport, flight operator, aircraft type, departure time, arrival time and flight duration. Flights are generated in the model at the time of departure; the flight time is determined from the scheduled arrival time. Other data used by the model includes aircraft specific (for instance maximum take-of weight and wake category), airline specific (for instance on time performance, average arrival delay, type of operator) and airport specific (for example country of origin) information. Aircraft and airport specific data is used to be more accurate in the model logic, while airline data is used to be able to take into consideration the stochastic character of flight duration and delay. Response values include hourly number of arrivals, departures, air transport movements and used gates, as well as percentages of delayed flights at the hub airport.

At present, the model is set up for Mexico City Airport, considering 96 contact positions for air operations, 98 departure airports, 26 carriers and 22 equipment codes. Most of the data processing was done using the R software environment. Flight information was retrieved from OAG, corresponding to the first week of 2013. Current slot use, flight time distributions, on-time performance data and turnaround times were estimated with publically available data and included in the model.

To account for the stochasticity of current flight data, flight time distributions were determined from flight information published for 2 weeks in June 2017 for airlines flying to Mexico City Airport. Mexican low cost and full service carriers were analyzed individually, while other carriers were grouped by continent, as they showed a similar behavior. On time distributions could be adjusted mainly to gamma and Weibull distributions; late distributions followed a Weibull distribution in all cases. Daily scheduled flights for the period from January 1 to January 8, 2013, were adjusted with realistic flight times obtained in the previous step and the total increase of 17% in the number of flights observed from January 2013 to

2017 was taken into account generating random flights with the same origin, carriers, equipment and frequency distribution as registered flights.

In a first stage, the simulation model was used to evaluate a ground delay program in MEX; this is a specific traffic flow management initiative where a ground delay in the departure airport is imposed for a reduced number of flights when the capacity in the arrival airport is being exceeded. The objective pursued was to identify the sensibility of the system to the modification of the threshold value where the ground delay program is triggered. The model was also used to analyze the effect of flight duration and turnaround time variability on overall on-time performance and airport congestion, as well as on the effectivity of the imposed ground delay program.

3 CONCLUSIONS AND FUTURE WORK

We present a discrete-event-based simulation model that we use for analyzing the effectiveness of the ground delay program currently imposed by Mexican airport authorities as a measure to address capacity imbalances. Stochasticity of the flight duration, on-time performance and turnaround times are included in the model to analyze how the effectiveness of the ground delay program is influenced by its parameters.

Simulation runs over several scenarios suggest that, in the specific case of Mexico City airport, activating the ground delay program with 34 arrivals per hour, combined with a decision rule on which aircraft to include in the program, is the preferred option for acute congestion problems. Under conditions of severe and chronic congestion, long distance flights continue to arrive despite the ground delay program, which can increase total delay unacceptably for affected flights. In this case, cancellation of flights in combination with the studied management initiative could be an option. A number of 200 to 300 aircraft are affected per week when the program is activated at 34 arrivals per hour, and total delay time decreases to an average of 30 minutes per affected flight, decreasing also the amount of bad will from passengers.

The study showed that the stochasticity of the problem influences the system's response highly. At present, although flight time, delay and turnaround distributions were obtained, the limited amount of real data available did not allow for the analysis of the causes of delay or lengthy turnaround times, or for distinguishing differences between the distributions for all aircraft, origin, destination, hub and airline types. In a future study, the stochastic nature of delays and turnaround times will be addressed more deeply, and different types of delay affecting MEX airport congestion will be included in the study. The model can be easily adapted to hub airports and/or airport networks in other regions in the world.

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