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Demonstration of reduced airport congestion through pushback rate control

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A B S T R A C T

Airport surface congestion results in significant increases in taxi times, fuel burn and emissions at major airports. This paper describes the field tests of a congestion control strategy at Boston Logan International Airport. The approach determines a suggested rate to meter pushbacks from the gate, in order to prevent the airport surface from entering congested states and to reduce the time that flights spend with engines on while taxiing to the runway. The field trials demonstrated that significant benefits were achievable through such a strategy: during eight four-hour tests conducted during August and September 2010, fuel use was reduced by an estimated 12,250–14,500 kg (4000–4700 US gallons), while aircraft gate pushback times were increased by an average of only 4.4 min for the 247 flights that were held at the gate.

1. Introduction

Aircraft taxiing on the surface contribute significantly to the fuel burn and emissions at airports. The quantities of fuel burned, as well as different pollutants such as Carbon Dioxide, Hydrocarbons, Nitrogen Oxides, Sulfur Oxides and Particulate Matter, are proportional to the taxi times of aircraft, as well as other factors such as the thrust settings, number of engines that are powered, and pilot and airline decisions regarding engine shutdowns during delays.

Airport surface congestion at major airports in the United States is responsible for increased taxi-out times, fuel burn and emissions (Simaiakis and Balakrishnan, 2010). Similar trends have been noted in Europe, where it is estimated that aircraft spend 10–30% of their flight time taxiing, and that a short/medium range A320 expends as much as 5–10% of its fuel on the ground (Cros and Frings, 2008). Domestic flights in the United States annually emit about 6 million metric tons of carbon dioxide (CO_2) taxiing out for takeoff; almost half of these emissions are at the 20 most congested airports in the country. Recent studies have also shown that low-thrust taxi emissions have significant impacts on the local air quality near major airports (Yu et al., 2004; Carslaw et al., 2006; Miracolo et al., 2011). The purpose of the pushback rate control demonstration at Boston Logan International Airport (BOS) was to show that a significant portion of these impacts could be reduced through measures to limit surface congestion.

1.1. Related work

While there has been a significant amount of prior research on the climate impacts of transportation, including aviation (Vespermann and Wald, 2011; Schwanen et al., 2011), there has been less focus on the impact of airport operations. Airport

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congestion management research has typically focused more on administrative policies such as congestion pricing and slot restrictions, and less on congestion control strategies (Hamzawi, 1992; Madas and Zografos, 2008; Mehndiratta and Kiefer, 2003).

A simple airport congestion control strategy would be a state-dependent pushback policy aimed at reducing congestion on the ground. The *N-control* strategy is one such approach, and was first considered in the Departure Planner project (Feron et al., 1997); several variants of it have been studied since (Pujet et al., 1999; Carr, 2001; Burgain et al., 2009; Burgain, 2010). This policy is effectively a simple threshold heuristic: if the total number of departing aircraft on the ground exceeds a certain threshold, further pushbacks are stopped until the number of aircraft on the ground drops below the threshold. By contrast, the *pushback rate control (PRC)* strategy presented in this paper does not stop pushbacks once the surface is in a congested state, instead it regulates the rate at which aircraft push back from their gates during high departure demand periods so that the airport does not reach undesirable, highly congested states. The main reason to adopt a rate control strategy over a threshold, or on–off, strategy is that of practical feasibility: After conversations with air traffic controllers at Boston, it became apparent that a recommended pushback rate valid over a period of time (such as 15 min) was much preferred to an on–off strategy, which would require more constant intervention.

There have been other recent surface traffic optimization efforts, such as the metering of departures at New York JFK airport by PASSUR Aerospace, Inc. (Nakahara et al., 2011), the field evaluation of the Collaborative Departure Queue Management concept at Memphis (MEM) airport (Brinton et al., 2011), and the human-in-the-loop simulations of the Spot and Runway Departure Advisor (SARDA) concept which focused on Dallas Fort Worth (DFW) airport (Jung et al., 2011). In contrast to these approaches, the pushback rate control strategy is an aggregate, centralized approach, focused on metering pushbacks from the gates rather than from the spots (the boundaries between the ramp area and the taxiways), and on the Airport Traffic Control Tower (ATCT) rather than the airline operations centers. It regulates the rate at which aircraft pushback from the gates and maintains the current first-come-first-served pushback sequences, rather than rationing traffic volume or slots at the spots to airlines based on the scheduled demand. The pushback rate control strategy was intended to be an easy-to-implement congestion management mechanism that requires few technological or procedural modifications.

This paper presents, for the first time, the design, field testing, and post-test evaluation of a surface congestion control strategy through both simulations, and the analysis of quantitative surface surveillance data and qualitative tower observations.

1.2. Motivation: departure throughput analysis

The main motivation for our proposed approach to reduce taxi times is an observation regarding the behavior of the departure performance of airports. As more aircraft pushback from their gates onto the taxiway system, the take-off rate of the airport initially increases because more aircraft are available to depart. However, as this number, denoted by N, exceeds a threshold, the departure runway capacity becomes the limiting factor, and there is no additional increase in throughput. We denote this threshold by N^*. This behavior can be further parameterized by the number of arrivals, reflecting the tradeoff between arrival and departure throughput, known as the capacity envelope (Gilbo, 1993). The dependence of the departure throughput on the number of aircraft taxiing out and the arrival rate is illustrated for a particular runway configuration in Fig. 1 using 2007 data from FAA's Aviation System Performance Metrics (ASPM) database. Beyond the threshold N^*, any additional aircraft that pushback simply increase their taxi-out times without any increase in the departure throughput (Simaiakis and Balakrishnan, 2009).

The value of N^* depends on the airport, arrival demand, runway configuration, and meteorological conditions. During periods of high demand, the pushback rate control protocol regulates pushbacks from the gates so that the number of aircraft taxiing out stays close to a specified value, N_{ctrl}, where $N_{ctrl} > N^*$, thereby ensuring that the airport is saturated and maintains runway utilization, but at the same time, the airport does not reach highly-congested states. While the choice of N_{ctrl} must be

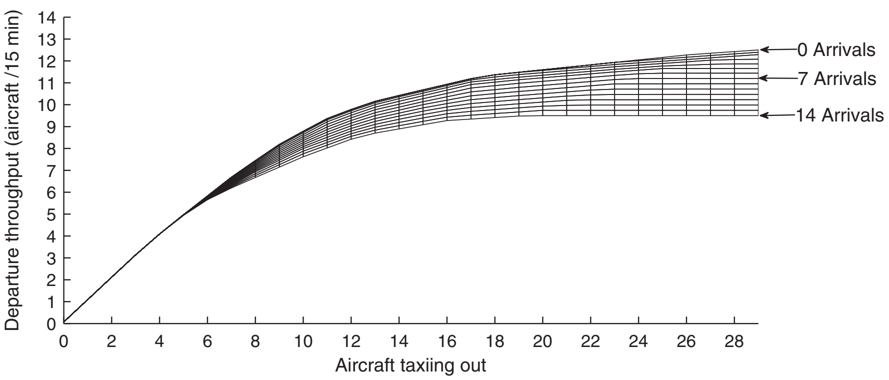

Fig. 1. Regression of the departure throughput as a function of the number of aircraft taxiing out, parameterized by the arrival rate for the 22L, 27 | 22L, 22R configuration, under Visual Meteorological Conditions (Simaiakis and Balakrishnan, 2011).