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Airport demand management: The operations research and economics perspectives and potential synergies

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ABSTRACT

Airport demand management aims to mitigate air traffic congestion by limiting the imbalances between demand and capacity at busy airports through administrative measures (e.g., slot controls) or economic incentives (e.g., congestion pricing, slot auctions). This paper provides an integrated synthesis of the contributions of the fields of operations research/management science (OR/MS) and economics on the subject matter. From an operating standpoint, assessing the benefits of demand management requires estimates of airport capacity and models of airport on-time performance. From a managerial standpoint, the design of demand management mechanisms can be supported by decision-making models of flight scheduling. From an economic standpoint, the welfare impact of congestion pricing, slot controls and slot auctions depends on the market structure at the airport. This paper proposes an integrated framework that underscores the interdependencies between these operating, managerial and economic aspects to foster cross-disciplinary approaches toward more effective demand management policies at busy airports worldwide.

1. Introduction

The growth of the air transportation sector has led to significant air traffic congestion worldwide. Flight delays, cancellations, and passenger misconnections impose significant costs, estimated at over $36 billion in the United States alone for the year 2007. Of these costs, approximately 25% ($8.3 billion) were direct costs to the airlines, 50% ($16.7 billion) were borne by passengers and 25% ($7.9 billion) represented other welfare losses (Ball et al., 2010). In comparison, the total annual profits of the U.S. airline industry have exceeded $5 billion in only four years since 2000 (Airlines for America, 2015). As a result, congestion mitigation has become one of the top priorities of Civil Aviation Authorities and Air Navigation Service Providers.

At airports where no significant capacity increase is foreseeable, the mitigation of air traffic delays may require the practice of *demand management*. Demand management mechanisms aim to control the demand for airport access to limit the imbalances between demand and capacity. Their design, implementation and assessment require consideration of several operational, managerial and economic trade-offs, and have thus attracted the attention of different research communities. As we will discuss, the relevant literatures have mostly evolved in isolation, and no single best practice has been accepted in the industry.

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This paper provides an original perspective on airport demand management that attempts to compare and combine ideas and contributions from the fields of operations research/management science (OR/MS) and of economics. Following a brief background discussion, we describe in Section 2 the major trade-offs associated with the design of demand management policies in the context of the global airline industry. We then identify the OR/MS and economics approaches to solving these trade-offs and synthesize the insights provided by each discipline (Sections 3 and 4).[1] We then propose an integrated framework for developing airport demand management strategies that underscores the interdependencies between their operational, managerial and economic aspects (Section 5). From an academic standpoint, we identify potential synergies between OR/MS and economics for future research. From a policy standpoint, we present a roadmap toward more effective demand management for airport congestion mitigation worldwide.

1.1. Airport congestion mitigation

The costs of air traffic delays motivate airport congestion mitigation interventions that fall into three categories: capacity expansion, operational enhancements, and demand management. The expansion of airport capacity takes place primarily through infrastructure expansion. This may involve brownfield expansion (e.g., the construction of new runways or the expansion of terminal buildings at existing airports) or the development of greenfield airports to replace older ones or divert traffic from the busiest among them. Recent examples include the ongoing construction of the Al Maktoum International Airport (DWV) in Dubai and of a new airport in Istanbul, the recent addition of new runways at Charlotte (CLT), Frankfurt (FRA) airports and several Asian airports, and the ongoing efforts to add a new runway and more capacity at London Heathrow (LHR) or London Gatwick (LGW) and at Hong Kong Airport (HKG). Whereas infrastructure expansion enables significant capacity increases, it is investment-intensive and often spans decades from conception to completion. Most important, it might be unfeasible in the most densely populated areas because of environmental, socioeconomic and political constraints.

Operational enhancements fall within the realm of Air Traffic Control (ATC) and Air Traffic Flow Management (ATFM). These interventions aim to optimize airport and airspace operations to minimize the magnitude and/or the costs of flight delays. Typical procedures include: (i) the ground holding of aircraft through the initiation of Ground Delay Programs (Odoni, 1987; Vranas et al., 1994; Barnhart et al., 2012a); (ii) the re-routing, speed control and airborne holding of en-route aircraft (Bertsimas and Stock Patterson, 1998; Bertsimas et al., 2011b); (iii) the selection and sequencing of active runway configurations at airports and the balancing of the number of arrivals and departures operated on each runway (Bertsimas et al., 2011a; Jacquillat et al., 2016); and (iv) the sequencing and spacing of landing and departing aircraft (Balakrishnan and Chandran, 2010; Solveling et al., 2011). These initiatives have led to significant global or local improvements in operating efficiency. However, they are insufficient for preventing high levels of congestion from occurring at airports where the number of flights scheduled at peak hours exceeds capacity by any significant margin.

The inability of many airport systems to scale up to meet increasing demand through the two aforementioned mechanisms motivates the use of demand management to limit the extent of overscheduling at busy airports. Demand management refers to administrative (e.g., slot control) or economic (e.g., congestion pricing, slot auctions) measures aimed at reducing overall airport demand or modifying the temporal characteristics of such demand. Striking differences exist in this respect between practices at U.S. airports and those elsewhere. The overwhelming majority of the busiest airports outside the U.S. are subject to *schedule coordination*, i.e., they operate with slot limits that are strictly enforced by state-appointed schedule coordinators. Slot allocation takes place through a bi-annual administrative procedure conducted under the aegis of the International Air Transport Association (IATA).[2] In contrast, the use of demand management at U.S. airports is limited. Only the three commercial airports in the New York area—John F. Kennedy (JFK), LaGuardia (LGA) and Newark Liberty (EWR)—currently operate with any scheduling limits,[3] despite the fact that several other U.S. airports are among the most delay-prone in the world. Moreover, these limits are only loosely enforced, and much less restrictive than they would likely be were the airports located in any other jurisdiction (Office of Inspector General, 2010).[4]

These regulatory differences have significant impacts on airport scheduling and on-time performance. Schedule-coordinated airports experience moderate delays. But schedule coordination practices may also lead to underuse of available airport capacity (Morisset and Odoni, 2011), to inefficient allocation of slots and to barriers to competition (NERA, 2004; Czerny et al., 2008). In contrast, the unrestricted approach to airport access in place at most U.S. airports provides additional flexibility for airline network and schedule planning and intensive utilization of available capacity, but may also lead to unsustainable levels of delay and thus to reduced levels of service. This suggests the presence of several trade-offs in demand management.

1.2. Motivation

The design of demand management mechanisms must address several operational, managerial and economic challenges. From an operational standpoint, it requires the estimation of airport capacity at a fine level of detail and the quantification of

[1] Due to the vast scope of the subject area, the presentation that follows necessarily contains some generalizations.
[2] 165 airports (including many secondary ones) were schedule-coordinated as of 2015.
[3] Strictly speaking, Washington's Reagan National Airport (DCA) also operates with scheduling limits, but current demand falls well below these limits.
[4] For an excellent review of the history of demand management (and more) in the U.S., see (Levine, 2008).