Journal of Air Transport Management 69 (2018) 1–14

Contents lists available at ScienceDirect

Journal of Air Transport Management

journal homepage: www.elsevier.com/locate/jairtraman

The economic value of additional airport departure capacity

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ABSTRACT

This article presents a model for the economic value of extra capacity at an airport. The model is based on a series of functional relationships linking the benefits of extra capacity and the associated costs. It takes into account the cost of delay for airlines and its indirect consequences on the airport, through the loss or gain of aeronautical and non-aeronautical revenues. The model is highly data-driven and to this end a number of data sources have been used. In particular, special care has been used to take into account the full distribution of delay at the airports rather than its average only. The results with the simple version of the model show the existence of a unique maximum for the operating profit of the airport in terms of capacity. The position of this maximum is clearly dependent on the airport and also has an interesting behaviour with the average number of passenger per aircraft at the airport and the predictability of the flight departure times. In addition, we also show that there exists an important trade-off between an increased predictability and the punctuality at the airport. Finally, it is shown that a more complex behavioural model for passengers can introduce several local maxima in the airport profit and thus drive the airport towards suboptimal decisions.

1. Introduction

A number of major airports in Europe are already under stress due to high volumes of traffic during peak times (Gelhausen et al., 2013). Since traffic in Europe is expected to grow by 50% in the next 20 years (EUROCONTROL, 2013), it is expected that many other airports will be severely congested in the medium term, and that airports that are currently congested at peak times will have problems all day long. As a consequence, the major European public-private research partnership SESAR (Single European Sky ATM Research) has dedicated an Operational Focus Area (OFA05.01.01) to the development of the Airport Operations Center (APOC) to consider mitigation measures to avoid large delays at these airports and the associated costs.

Delays are a direct consequence of levels of congestion at airports. These impact directly on the airlines. For these, delays usually mean sub-optimal levels of operation, as well as decreased satisfaction of their customers, leading to potential decreases of market share. The value of this shortfall can be evaluated for different types of airline, aircraft, and delay duration, etc. (Cook and Tanner, 2015).

However, it is clear that expanding the capacity of an airport is costly. Depending on the nature of the bottleneck and the severity of the congestion, the airport might need to physically expand its infrastructure. This could mean, for example, increasing the number of runways, the number of terminals, or the number of gates. In all cases, the total *operating* costs for the airport will be higher after the expansion. As a result, there will be an optimal capacity for the airport which balances the level of congestion with the costs associated with the extra capacity.

This is the concept which is explored in this paper, using a simple model to capture this effect. More specifically, the model aims to provide some quantitative measures of the cost of capacity and the corresponding cost of delay in a very data-driven way. To this end, different types of data have been collected that guide the modelling process and allow for detailed calibration.

The structure of the paper is as follows. Section 2 presents the literature review, focusing on the main mechanisms that should be included in the model. The types and sources of data used are also discussed. Section 3 presents the model in detail, including the calibration process. Section 4 provides some results obtained with the model. Finally, conclusions are drawn in Section 5.

2. State of the art

2.1. Literature review

Many studies have been undertaken concerning various aspects of airport economics over the past few years and in this section a concise overview of the most relevant research is provided. In particular,

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https://doi.org/10.1016/j.jairtraman.2018.01.001
Received 21 March 2017; Received in revised form 27 December 2017; Accepted 3 January 2018
0969-6997/

consideration is given to the main mechanisms that link capacity to cost and delay, and the associated strategies adopted by airports over the years.

Since a significant part of an airport's operating costs is fixed, excess capacity will produce high overall unit costs, as the fixed costs will be spread over lower than optimal traffic levels. Whilst attempts may thus be made to use the current facilities as much as possible, to take advantage of economies of density or capacity utilisation (McCarthy, 2014), being close to capacity is likely to produce more delays. So both capacity utilisation and delays can have an impact on airport cost efficiency (Pathomsiri et al., 2008), with Alder and Liebert (2011) empirically finding that the positive impact of utilisation is greater than the negative impact of delays.

Delays have impacts for both passengers and airlines (Cook and Tanner, 2015). As passenger satisfaction may be linked to commercial spend – the money spent by passengers – at the airport (Airports Council International, 2016), delays can have a direct negative impact on an airport's performance, although this relationship is yet to be confirmed (Merkert and Assaf, 2015) due to very limited research. This in turn is due to the lack of appropriate and publicly available passenger satisfaction data. On the other hand, higher delays at the airport may have the opposite effect, since passengers have more time to use the commercial facilities (D'Alfonso et al., 2013), even though the only known empirical study in this area found no significant relationship between commercial revenues and delayed flights (Fuerst et al., 2011).

Adapting airport capacity to the expected level of traffic is a complex task and many possibilities are discussed in the literature. First, so-called ‘soft’ management approaches have been examined. These include minor modifications to management processes at the airport, without having an impact on the infrastructure itself. They are quick to implement and relatively low cost, but clearly limited in scope. They can relate to strategic planning or tactical adjustments (Barnhart et al., 2012). They can also include more local solutions, such as improvement planning (Daniel, 2002; Jorge and de Rus, 2004), changes to air traffic control (ATC) rules, price changes, and incentive schemes for airlines to use larger aircraft – given that the infrastructure for this is already in place – even if this may lead to additional congestion in the terminals (Gelhausen et al., 2013; Berster et al., 2013). In the broader sense, they include developing intermodality with high-speed trains, diverting traffic or using multi-airport systems (Martín and Voltes-Dorta, 2011), even though these typically require at least some infrastructure change.

The feasibility and effectiveness of using pricing to manage congestion has been frequently discussed in the literature, with the theoretical arguments summarised by Zhang and Czerny (2012). However, such practices have rarely been applied and tested. One of the key issues is the extent to which airlines already self-internalise congestion, on which point views vary (Brueckner, 2005). Moreover, Adler and Liebert (2011) empirically found that delays had no impact on aeronautical revenues but that this was significantly higher at congested airports. Other research has shown that it is important to take into account different passenger types when assessing the efficiency of any potential new pricing scheme. Unsurprisingly, passengers having a higher value of time – typically corresponding to business-purpose passengers – will benefit from increased charges during peak times to protect them from the congestion caused by passengers with lower values of time (Czerny and Zhang, 2011; Yuen and Zhang, 2011). Such pricing solutions are also difficult to implement because many airports are subject to economic regulation, most commonly in the form of a price-cap (Adler et al., 2015). Another alternative, but related, demand-management technique frequently studied in the literature is a type of reform of the current slot allocation process, for example by using slot auctions and secondary trading systems. This would have a major impact on airlines and passengers, but most likely a lesser impact on airport revenues (Madas and Zografos, 203-226; Verhoef, 2010).

The second possibility to cope with excess demand is to change the infrastructure itself, usually by extending the current number of terminals, runways, gates, etc.: so-called ‘hard’ management approaches. These measures are usually slow to implement and very costly, but can bring great increases in capacity in some way or another. There will be a significant lag between the potential expansion decisions and the full released capacity, during which demand and the environment may change. This introduces a complex dynamic behaviour of development and investment, which in part creates a demand for more flexible solutions (Leucci, 2016; Kwakkel et al., 2010). It also poses the problem of the risk aversion of the airport operators, and, more generally, the problem of how expectations are formed with regard to the likely investment return. Some research points out that the various uncertainties in the airport system, including the uncertainty of future demand (Xiao et al., 2013) and the unpredictability of degradation (Desart et al., 2010), increase the difficulties of airport capacity decision-making processes. Moreover, as airports are not isolated entities, airline network (delay propagation) effects can add further complexity to the validity of a capacity extension (Cook and Tanner, 2015). The decision-making process of the airport under various uncertainties is a complex subject, as noted in Sun and Schonfeld (2016) and Kincaid et al. (2016).

The literature also points out the need for more subtle definitions of capacity, in particular ensuring that there is differentiation between arrival versus departure capacity, and runway versus terminal capacity. It has been shown that there is some trade-off between the former (Gilbo, 1993), and that there exist some non-trivial relationships between the latter (Wan et al., 2015). Currently, runways typically represent the bottleneck for the traffic flow, rather than terminals (Gelhausen et al., 2013; Berster et al., 2013; Wilken et al., 2011; Butler and Poole, 2008). There is also the trade-off between operational and commercial capacities, the extent of complementarity between these two, and the associated cost allocation approaches (Zhang and Zhang, 2010; D'Alfonso et al., 2013). This is linked to the flexibility allowed within each individual airport economic regulatory system and subsequent incentives which may arise (International Transport Forum, 2013).

A common research theme concerns cost-benefit analyses examining the implications of a ‘hard’ modification. In particular, it is important to emphasize that changing infrastructure may not merely affect the volume of traffic or passengers, but also the nature of the traffic and operations at the airport. Indeed, larger airports are usually more diversified in being able to provide a greater range of commercial facilities. As a consequence, commercial spend can increase disproportionately with the size of the airport. Also, leisure passengers have been shown to spend more than business passengers (Fuerst et al., 2011; Castillo-Manzano, 2010), and low-cost carrier (LCC) passengers less (Lei et al., 2010). Traffic mix changes will also bring different associated costs related to the service expectations of the airlines, related, for example, to ensuring a fast transfer time at hub airports, or swift turnarounds for LCCs. As regards airport size, much mixed evidence exists, but generally it shows that airports experience cost economies of scale, albeit with different findings related to if, and when, these are exhausted, and whether diseconomies then occur. For UK airports some research has estimated that long-run average costs decreased up to 5 million passengers, were constant for 5–14 million passengers, and then started to increase (Bottasso and Conti, 2012), whereas another UK study (Main et al., 2003) found a steep decrease in average costs until around 4 million passengers and then very moderate, but persistent decreases in costs until at least 64 million passengers. Meanwhile, for Spain it has been concluded that cost economies are not exhausted at any level of traffic for the airports considered (Martín et al., 2011), with similar results confirmed for a worldwide sample (Martín and Voltes-Dorta, 2008). These studies considered both operating and capital (i.e. long-run) costs.

A key related issue is how aeronautical charges may change as the result of the costs of new infrastructure. However, it has been shown that aeronautical revenues are very much influenced by market-