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Anticipatory modulation of air navigation charges to balance the use of airspace network capacities

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ABSTRACT

Excess of air traffic demand over available capacity in certain segments of the European airspace network typically results in substantial delays imposed on airspace users, despite a possible parallel existence of underutilised adjacent network segments. Recent EU legislation lays down a performance scheme for air navigation services (ANS) and network functions, in an attempt to improve overall efficiency of the ANS, across the areas of safety, environment, capacity and cost-efficiency. It sets a framework for a possible introduction of incentive schemes which would drive the behaviour of involved stakeholders towards meeting the established performance objectives. In such a context, this paper examines an economic concept to incentivise a more efficient use of available network capacities. We put forward a method and develop a model for an anticipatory, time-dependent modulation of ANS charges, aiming to alleviate the demand-capacity imbalance on an airspace network, at minimal cost to airspace users. The proposed method is conceptualised as a bi-level optimisation problem, reconciling the perspectives of network manager and individual network users. The results of a medium-scale real-life case study indicate that an imposition of a revenue-neutral matrix of tolls and rebates on a congested airspace network may yield a fairly equitable route assignment, which seems capacity-wise more efficient than current administrative demand management practices.

1. Introduction

The spatial/temporal profile of air traffic demand places ample pressure on European airspace network. The excess of demand over available capacity in certain segments of the network typically results in substantial delays imposed on airspace users, despite a possible parallel or close-to-parallel existence of underutilised adjacent (in space and time) network segments.[1] Capacity expansion as a means to tackle such a problem typically exhibits long lead times (EUROCONTROL PRC, 2009) and comes at a high price (Helios, 2006). As an alternative, various actions may be taken on the demand side, ranging from inherently administrative ones, such as (centralised) allocation of take-off time windows ("slots"), to purely economic ones, e.g. congestion charging, via hybrid solutions, such as slot auctions. Such measures may yield beneficial effects in a much shorter term, by pursuing/incentivising a more efficient utilisation of available network capacity.

Drawbacks of typically applied administrative demand management (DM) measures are reflected chiefly in competition issues (Gillen, 2007). Economic-based DM measures, on the other hand, are less burdened with such concerns,[2]

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[1] Hereinafter, network segment is a four-dimensional (4D) notion, denoting a given part of the network in a given time period.

[2] However, economic-based measures have their own issues, which are mostly related to users' resistance to participate precisely because they involve paying, and, more generally, to distributional effects of such measures (Hensher and Puckett, 2007).

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forcing an allocation based on users' willingness to pay for the use of a scarce infrastructure segment. Both economic and hybrid DM measures have been extensively examined in theoretical setting, primarily in the airport congestion context (e.g. Daniel and Pahwa, 2000; Pels and Verhoef, 2004; Janic, 2005). Some of these measures have been enforced at a number of major airports, with varied success (Gillen, 2007). However, to date, only a handful of studies address the possibility of introducing economic-based measures in the European air traffic management (ATM) system as a means of relieving airspace congestion.

Recent EU legislation lays down a performance scheme for air navigation services (ANS) and network functions, in an attempt to improve overall efficiency of the ANSs, across the areas of safety, environment, capacity and cost-efficiency (European Commission, 2010a, 2013a). It sets a framework for a possible introduction of incentive schemes, consisting of financial advantages and disadvantages, which would drive the behaviour of involved stakeholders towards meeting the established performance objectives. Moreover, Regulation (EC) 1794/2006 (as amended by Regulation EU 1191/2010 and Implementing Regulation EU 391/2013) entitles Member States to modulate ANS user charges, so as to reflect efforts made by ANS users to, *inter alia*, (European Commission, 2006, 2010b, 2013b):

- optimise the use of ANS, and
- "reduce the overall costs of ANS and increase their efficiency, in particular by modulating charges according to the level of congestion of the network in a specific area or on a specific route at specific times".

In such a context, this paper examines an economic concept to incentivise a more efficient use of available network capacities, which could contribute to improved network performance in areas of capacity and, possibly, cost-efficiency. We put forward a method and develop a model for an anticipatory modulation of ANS route charges, aiming to alleviate the demand-capacity imbalance on an airspace network, at minimal cost to airspace users.

The remainder of the paper unfolds as follows. Section 2 sets the context of the research, offering an overview of relevant earlier contributions. In Section 3 the proposed method of modifying air traffic demand by introducing charging incentives is elaborated and the model presented. Section 4 describes the model application on a real-world case-study and presents the key results. In Section 5 the results are discussed, and analysis of the limitations of the method and possibilities for further improvements and extensions is presented. Finally, Section 6 sums up the findings of this research and presents concluding remarks.

2. Background

2.1. Congestion in European Airspace

European Air Traffic Management (ATM) system controlled on average about 26,300 flights per day in 2010. On busiest day traffic reached more than 32,500 flights, with over 3,000 flights simultaneously airborne in certain periods (EUROCONTROL DNM, 2011).

Nearly 9% of all flights crossing European airspace were delayed due to en-route capacity shortfalls in 2010.[3] For more than half of those the experienced en-route ATFM delay was longer than 15 min, averaging 34.4 min per flight (EUROCONTROL DNM, 2011). Such long delays are main contributors to airline delay costs, since a minute of longer delay costs more than that of a short one (Cook and Tanner, 2011). The estimated value of en-route ATFM delay costs to airlines in 2010 amounts to about EUR 1.35 billion (EUROCONTROL PRC, 2011a).

European en-route airspace is fragmented into nearly 70 Area Control Centres (ACC), each of them responsible for a defined volume of airspace. However, 17 of those ACCs generated 90% of total en-route ATFM delays in 2010, despite the fact that they controlled only 37% of total flight hours in Europe. While some of congested ACCs cause delays mainly due to staff shortages, others are located within high-density traffic areas (Ibid), and despite being relatively highly efficient, they are frequently lacking capacity to match the demand. One might argue that the latter ones are particularly appropriate candidates for an application of DM measures, whereby relatively minor shifts of demand from highest-density network segments to adjacent less loaded ones (if available) might yield considerable benefits.

However, under the present European ATM system settings there are only fairly limited DM actions undertaken by network manager prior to the day of operation. The majority of efforts in earlier stages seem to be confined to capacity management. More specifically, the rule is to "approve" all submitted flight plans (desired 4D routes) with the correct syntax, no matter if it is already obvious that the available capacity cannot accommodate such demand (Jovanović, 2011). The consequences of such practice are then corrected by administrative DM measures (slot regulation) enforced on the day of operation. As a result, significant delay costs arise, coupled with unfair effects of applied regulations (in terms of choice which flights are to be delayed), with typically no reasonable alternatives provided by the network manager.

[3] In ATM terminology those flights were affected by the so-called air traffic flow management (ATFM) en-route "slot regulations", basically consisting of imposing delays on flights on the ground to prevent capacity violations en-route.