Pricing techniques for the European airspace

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Abstract—**The present work lays down the roadmap for a Ph.D. research on methods for redistributing traffic demand through pricing policies in European airspace. First, the authors introduce a classification framework for pricing schemes in network industries. The framework is then applied for identifying relevant characteristics that a pricing scheme for European airspace should have. Finally, some guidelines are drawn on which pricing approaches in other industries may be suitable for each of the delineated configurations.**

Keywords-congestion pricing; demand management; European airspace; SESAR; classification.

I. INTRODUCTION

At the current rate of growth, EUROCONTROL estimates that air traffic in Europe is likely to increase by 50% in the next 20 years [1]. Today, demand-capacity imbalances are already an issue for several airports and Area Control Centres (ACCs); in fact airspace congestion and the associated imposed Air Traffic Control (ATC) delays represent a significant cost for the whole industry. Optimising the usage of resources that are already available represents a less costly alternative to infrastructure capacity expansion, while still being effective for mitigating demand-capacity imbalances. Market-based demand management (i.e., pricing) approaches have been successfully applied in other network industries for redistributing traffic and reducing congestion. However, research on alternative pricing models for European airspace has been very limited so far (with the notable exception of [2] and [3]).

Purpose of the present work, which summarises the early stage of a Ph.D. research, is to identify pricing methods from other network industries that merit further investigation of their applicability to European airspace. Future work will build upon this analysis to further develop suitable approaches for pricing mechanisms in European airspace.

This study is a part of the SESAR WP-E project denominated SATURN (Strategic Allocation of Traffic Using Redistribution in the Network). In Section II an overview of relevant pricing theory is given; in Section III a framework for classifying pricing methods is introduced; in Section IV the framework is applied for describing the current and two (plausible) future environments for European airspace. In section V and VI two different scenarios are explained and methods of pricing are discussed. Finally, in Section VII a roadmap of future work is laid down.

II. OVERVIEW OF RELEVANT THEORY OF PRICING

The market in network industries is generally composed of several actors, namely an infrastructure manager/owner, who may also act as a regulator, one or more service providers and consumers. This structure is, in general, similar to the theoretic model of a monopolistic market.

Congestion occurs whenever a link, a node or the entire network is carrying more flow than its capacity is able to accommodate. As a consequence, the quality of service deteriorates, leading to various disadvantages for the users (delay, increase in transport costs and, ultimately, denial of service).

Since users are willing to minimise their cost for using the network (in terms of time and monetary), and congestion generates externalities, *marginal cost pricing* is generally regarded as the way to internalise the cost of congestion. A negative externality (generally referred to as *user externality*), results from the difference between marginal social cost and marginal private cost. In network industries, the *first-best pricing* principle states that a toll equal to the user's externality (a *Pigovian tax*) should be charged on each link in order to obtain the optimal network traffic flow configuration [4].

Estimating marginal costs for actual implementation is, in general, difficult. Required information includes customers' demand elasticity and cross demand. Customers are usually very reluctant to reveal their willingness to pay, as it is subject to strategic behaviour. Moreover, if marginal costs are considered only in short term, they don't cover the costs of upgrading the infrastructure, potentially affecting the development of the industry. As a consequence, marginal-cost pricing schemes are rarely implementable in reality and *second-best pricing* regimes are generally preferred for pricing in real networks.

One relevant example is *Ramsey pricing* (RP), the aim of which is to maximise social welfare under the constraint of deficit coverage. RP relies on the fact that the service can be differentiated according to area of the network, time and customers' needs. RP tries to find a mark-up for these different products to cover the economic deficit that results from marginal cost pricing. This mark-up, generally a percentage on the marginal costs, is inversely proportional to the price elasticity of the demand of the customers at zero profit (*inverse elasticity rule*). RP is in general hard to implement: since it builds upon marginal costs, and therefore faces the same information restraints.

Peak load pricing, commonly applied in utilities and public transports, is a simplified case of RP. Here users are charged for marginal and capacity costs in an environment where demand peaks (and therefore capacity shortages) are easy to predict. The resulting pricing scheme is usually divided in fixed time periods priced differently, namely off-peak, peak time and (eventually) shoulder periods.

It is generally argued that congestion charges tend to penalise users with lower incomes. Hence, several *non-monetary pricing* schemes have been proposed in order to grant equal rights to all users. These schemes generally charge a certain amount of freely distributed credits or travel permits for travelling during peak times. The equity issue is then transferred to the initial endowment of credits or permits among users. An overview of non-monetary pricing schemes for road transport can be found in [5].

III. CLASSIFICATION FRAMEWORK FOR PRICING STRATEGIES

We used the classifications proposed in [6] and [7] to build a simplified set of criteria for categorising pricing techniques across network industries, specifically data transmission networks, electricity generation, distribution and retail, road, air and rail transport. Approximately 10 pricing methods per industry (some implemented in reality, some others in theory only) were analysed and classified according to these criteria in order to discuss their applicability to European airspace.
Table I illustrates the classification criteria. Criteria 1 and 2 are market related and can thus be discussed on an industry-wide scope; criteria 3 to 8 are specific to each pricing technique. All options per criterion are mutually exclusive with the exception of criterion 8.

IV. EUROPEAN AIR TRANSPORT ENVIRONMENT

In the current configuration, European airspace has one Network Manager (EUROCONTROL) who is responsible for collecting en-route charges and redistributing them to national Air Navigation Services Providers (ANSPs). Charges are set by national ANSPs with the aim of recovering operational costs of providing Air Navigation Services (ANS) to the airlines. EU regulation No 391/2013 of 3 May 2013 – Article 16 allows Unit Rate modulation on the ANSP's side for congestion reduction purposes. From the economic point of view, the current environment is a monopolistic competition, where competitors (ANSPs) are differentiated on a location basis (country boundaries) and competitors' pricing policies are not taken into account.

The current pricing scheme of European airspace, here referred to as Scenario 0, is conceptually similar to *distance-based pricing* (road transport) [4] and *simple charges* (rail transport) [9]. *Edge pricing* in telecommunications [8] also shares similar concepts, with the notable difference of being location independent.

TABLE I. CLASSIFICATION CRITERIA FOR PRICING STRATEGIES

<table>
<tr><th colspan="4">Environment-related</th></tr>
<tr><td colspan="4">1. Control</td></tr>
<tr><td colspan="2">a. Fully centralised</td><td>b. Fully market-based</td><td>c. Market-based with a regulator</td></tr>
<tr><td colspan="4">2. Pricing strategy objective</td></tr>
<tr><td colspan="2">a. Revenue/cost oriented</td><td>b. Resource consumption oriented</td><td>c. Both 2.a and 2.b</td></tr>
<tr><th colspan="4">Pricing-related</th></tr>
<tr><td rowspan="4">3. Type of tariff</td><td colspan="3">a. Flat: a fixed fee gives unrestricted access to the network</td></tr>
<tr><td colspan="3">b. First-best: based on exact marginal costs i.e., users pay proportionally to the load they impose to the network</td></tr>
<tr><td colspan="3">c. Second-best: not based on exact marginal costs, i.e., average tariff for all users</td></tr>
<tr><td colspan="3">d. Multi-part: any combination of the previous</td></tr>
<tr><td rowspan="4">4. Modulat. of the tariff</td><td colspan="3">a. Time/space invariant: the network is tariffed in the same way all the time</td></tr>
<tr><td colspan="3">b. Time-dependent, space invariant: prices can vary according to time</td></tr>
<tr><td colspan="3">c. Time-invariant, space dependent: prices can vary according to location in the network</td></tr>
<tr><td colspan="3">d. Time/space dependent: the network is tariffed according to location and time</td></tr>
<tr><td rowspan="2">5. Users classification</td><td colspan="3">a. No differentiation: all users are equal</td></tr>
<tr><td colspan="3">b. Users are differentiated: e.g., in classes</td></tr>
<tr><td rowspan="3">6. Price setting strategy</td><td colspan="3">a. Customer-perceived value: willingness to pay determines the price</td></tr>
<tr><td colspan="3">b. Resource-estimated value</td></tr>
<tr><td colspan="3">c. Both 6.a and 6.b</td></tr>
<tr><td rowspan="3">7. Payment</td><td colspan="3">a. Monetary</td></tr>
<tr><td colspan="3">b. Non-monetary: e.g., credits or permits</td></tr>
<tr><td colspan="3">c. Hybrid monetary/non-monetary</td></tr>
<tr><td rowspan="3">8. Quality of Service (QoS)</td><td>a.i. Best effort</td><td>a.ii. Guaranteed service</td><td>c.iii. Variable</td></tr>
<tr><td colspan="3">b. Capped service: e.g., capacity-constrained</td></tr>
<tr><td colspan="3">c. Compensation for denial of service</td></tr>
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Scenario 0 (today):

Environment has:

1.b. Decentralised control: unit rates are set by ANSPs and collected by EUROCONTROL;

2.a. Objective of cost recovery: en-route charges are collected to recover operational costs of national ANSP for ANS services.

Pricing is:

3.c. Consumption-proportional: yearly adjusted unit rates;

4.c. Space dependent and time independent: unit rates vary by country (although EU reg. 391/2013 art. 16 allows national unit rate modulation and alignment among countries belonging to the same Functional Area Block);

5.a. No differentiation among customers: all airlines are equal;

6.b. Prices are set according to resource value: cost of ANS services;

7.a. Monetary payment;

8.a. and b. Guaranteed service, capped by ATC sector capacity by imposing ATC delay (but this is applied on Day of Operation).

Let us now illustrate two plausible scenarios that allow implementation of different pricing mechanisms for en-route charges.

V. Mapping pricing options to Scenario 1

Scenario 1 represents an environment where prices are set and controlled by a central authority whose objectives are cost recovery of ANS expenses and reduction of network congestion. This scenario represents a monopolistic environment having a Network Manager, ANSPs as operators and airlines as customers; this configuration is similar to rail transport in most European countries.

Scenario 1:

Environment has:

1.a. Centralised control: tariffs are set and collected by the Network Manager;

2.c. Objective of cost recovery & congestion reduction.

Pricing can be:

3.b. or c. Proportional to travelled distance, sector forecast capacity or both; either an exact marginal costs or a second-best charging scheme is plausible;

4.c. or d. Always space dependent, could be either time dependent or invariant;

5.a. Equity is a priority; hence, user classes among airlines would not be welcomed;

6.b. Prices are set according to resource value: cost of ANS services; a combination of resource and user-perceived value is also acceptable;

7.a. or c. Payment could be either monetary or hybrid;

8.a. and b. Guaranteed service, capped by ATC sector capacity (this could be applied before the Day of Operation).

Let us now consider pricing techniques developed within other network industries that are compatible with the characteristics delineated for Scenario 1 and let us evaluate their applicability to European airspace.

Flat pricing and user-class based options should be excluded *a priori*: the former because it does not incentive sustainable traffic distribution, the latter because it clashes with the requirement of equity among airlines stated by EU Reg. 391/2013 art. 16: *"Member States, [...] may, at national or functional airspace block level and on a non-discriminatory and transparent basis, modulate air navigation charges"*. Since pricing is considered at a strategic level, *real-time pricing* should also be excluded.

The pricing rule proposed in [2] defines demand and frequency of flights as functions of customers' utility; optimal tariffs are identified by equalling marginal utility to marginal costs. In the bilevel scheme proposed in [3] traffic is first distributed according to a *System Optimum* assignment to minimise overall network costs; then the network is priced in order to obtain also a *User Equilibrium* (i.e., minimisation of users' travel costs) with the same traffic distribution. Both [2] and [3], being *first-best* approaches, suffer from the implementation difficulties pointed out in Section II. Calculating actual values of marginal costs poses a severe challenge, as airlines are unlikely to reveal strategic data and estimates may not lead to reliable results.

Time dependent usage pricing (telecommunications) [8] and *Time of Usage* (electricity) [10] are of the peak-load pricing type. Users are charged proportionally to resource consumption and the tariff varies according to the time at which the service is provided. Tariffs are set according to congestion level forecasts obtained from historical data and are adjusted periodically (e.g., once a month). There are no remarkable issues in making such a pricing scheme also location dependent, as proved by other transport modes that use time-and-place dependent peak load pricing, so it is a viable option for European airspace as well.

Ramsey pricing based mechanisms, such as *responsive pricing* for telecommunications [8], and *simple charges* for rail transport [9] set the congestion charge, or the congestion dependent component of the tariff, as inversely proportional to demand elasticity of the users. *Critical peak pricing* for electricity retail [10] is conceptually similar but maximum price for peak times is generally capped. It is legitimate to assume that demand elasticity varies among users also in the air transport industry. For example an airline operating on a hub-and-spoke paradigm is likely to have a less elastic demand than one operating on a point-to-point basis due to the constraints imposed by connecting flights.

Bid-price and auction-based mechanisms, such as *smart-market pricing* for telecommunications [8] and *pay-as-bid pricing* for electricity wholesale [11] may give rise to equity issues, since they favour economically sounder airlines that are likely to pay more. However, should the auctioning process be carried out without the use of real money, but rather with freely distributed non-monetary credit, it would be acceptable and still effective for reducing congestion. Such a system could be combined with the current distance-based en-route charges so that it would also guarantee ANS operational costs recovery. A more detailed evaluation of applicability of existing non-monetary pricing schemes to an environment compatible with Scenario 1 can be found in [12].

VI. Mapping pricing options to Scenario 2

In Scenario 2 each ANSP is handed control for setting its own *en-route* charge and for modulating it to recover operational costs and reduce congestion within its own airspace. This scenario presents some features typical of a monopolistic competitive environment, similar to Scenario 0. The difference here is that ANSPs cannot ignore pricing strategies applied by neighbouring countries any more, as this would probably lead to a worsening of congestion and consequent delay. Neighbour countries become both competitors and collaborators. Also, in this scenario, congestion is controlled locally, rather than globally.

Scenario 2:

Environment has:

1.c. Market-based control with a regulator: each ANSP is responsible for setting its own tariffs, the regulator for granting cooperation among ANSPs.

2.c. Objective of cost recovery & congestion reduction: each ANSP is responsible for its own airspace.

Pricing can be:

3.b. or c. Proportional to travelled distance, sector forecast capacity or both; either an exact marginal or a second-best charging scheme is plausible;

4. Any of a., b., c., d. All combinations of time and space, dependent and invariant are suitable;

5.a. Equity is a priority; hence, user classes among airlines are not welcome;

6.c. Prices are set according to resource value and user-perceived value: cost of ANS services in competition with surrounding ANSPs;

7.a. or c. Payment could be either monetary or hybrid;

8.a. and b. Guaranteed service, capped by ATC sector capacity (this could be applied in advance of Day of Operation).

All pricing principles described in section V are still valid under this market configuration with the exception of the two first-best schemes that require a centralised, network wide optimisation.

Peak-load pricing schemes can be easily applied on a local scale. National ANSPs could either apply a peak-load scheme at a nation-wide level or on congested areas only.

More general Ramsey pricing schemes are also valid: some airlines have no viable routing alternative for certain origin-destination couples because of timing or fuel costs. The example of inelastic demand of a hub-and-spoke airline holds true here as well: the cost for rescheduling connecting flights may leave no alternative but to go through the preferred route even at a higher cost.

We believe however, that some issues may arise with non-monetary schemes. These are still applicable to this scenario but some intervention and control efforts are needed from the regulator. In the case of freely distributed credits, unless credit charges are harmonised (at least in terms of order of magnitude) it would be very difficult to determine how many credits should be issued and how they should be distributed. The case of travel permits for congested times or areas (issued in a quantity equal to the expected capacity), on the contrary, would be as easy to manage as in the centralised scenario.

VII. FUTURE WORK

The present work illustrates the early stages and motivations of our research. Our starting point is defining a framework for classifying pricing schemes and applying it for identifying approaches that may be adapted to European airspace. From several tens of schemes available in scientific literature and implemented in reality we narrowed our focus to just a few. Future work will focus on developing pricing schemes that embed the approaches identified in this preliminary analysis. Functioning and effectiveness of such pricing schemes will finally be simulated on real airspace demand and traffic data.

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