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AIRPORT NOISE CHARGES AND LOCAL COMMUNITIES: APPLICATION TO REGIONAL AIRPORTS

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Abstract

There have always been conflicts among airports and local communities due to the aeronautical noise generated by airport operations. In fact, this is a factor that - if not properly managed - could severely cut down the growth of air traffic in an airport with direct effects on the economic and territorial system. Beside this, in the last decade the critical issues related to the impact of aeronautical noise on airport operations have greatly reduced, thanks to technological improvements in aircraft design. Nevertheless, the reduction of noise emissions during a single aircraft operation does not make the issue of the airports' location less important. This is the case of regional airports in EU, which have recently experimented a large traffic increase due to the development of low-cost traffic. It is now clear that the problem cannot be reduced to its mere technological aspect, but it ought to be dealt with the involvement of the various stakeholders in order to mitigate the emissions and adequately compensate the impacts to local communities. Typically, there are two possible countermeasures to mitigate the effects of aircraft noise: operational measures, based on the application of technological and organizational devices and market-based measures. The application of noise taxes, aiming at compensating the negative externalities generated by airport operations is becoming increasingly widespread in EU. In this paper, a methodology for the application of noise taxes based on the actual noise of aircraft operating into an airport is discussed and implemented in a test case.

Keywords: Environmental impact, Airport, Aircraft noise, Noise charges.

1. Introduction

Historically, aircraft noise has been the main hurdle between the development of air traffic and local communities living around airports. Indeed, despite the fact that air transport impacts the environment in different ways and at different spatial levels [1-7], namely locally and globally, the local impacts result the most

Nomenclatures

A_i	Share of each aircraft type in a given fleet mix
C	Airport environmental cost
c_i	Environmental tax for a given aircraft type and movement
dB	Decibel
EPNdB	Aircraft certification noise level (effective perceived noise)
N_i	Number of movements of each aircraft type
P	Average price of estates
H_i	Number of estates in each area bounded by noise contours

Abbreviations

ANEF	Aircraft Noise Equivalent Factor
ANL	Approach Noise Level
DNL	Departure Noise Level
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
NDI	Noise Depreciation Index
OECD	Organization for Economic Cooperation and Development
RAL	Reference Aircraft Level

severe. These, in most cases, are linked to the activities taking place at airports; in particular the aircraft noise in certain areas of airports has even led to operational constraints. The problem of airport noise had begun to spread in the US since the 50's with the introduction of jet engines. When the problem appeared in Europe, regulators were forced to introduce methods for aircraft noise emission control during the phase of certification of an aircraft. These countermeasures “at source” consisted in the development of devices to reduce aircraft noise by introducing, for instance, thrusters to mitigate the noise. Further contributions were achieved through the study of aerodynamics to identify the source of turbulent air flow that can generate additional noise, Fig. 1.

Despite the attempt to limit the amount of emissions associated with the single event, the dramatic growth in air traffic exacerbated the problem because the number of operating aircraft grew exponentially and the introduction of tougher certification rules impacted only on the aircrafts of new generation [8-10]. The effects of sound propagation, moreover, are investigated not only regarding a single event, but also especially considering the amount of events that occur in a time period and the time shift between two events. Therefore, the aircraft industry was forced to find other forms of noise management aiming at improving the welfare of local communities exposed to these impacts. Among these forms of management there were restrictions and total or partial ban to the use of certain categories of aircraft [11].

Another widely used measure is the adoption of "noise abatement procedures", i.e. flight procedures aiming at minimizing the overflight of residential areas during take-offs or landings. A common characteristic of these procedures is that they are not optimized for the local conditions and, although they are developed to obtain a specific noise reduction, they do not take into account the perceived noise impact, as this is mainly dependent on the distribution of dwellings and population in the territory [12,13].

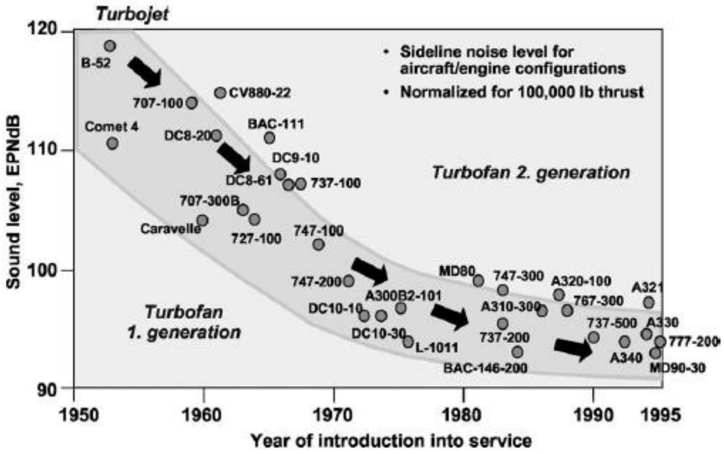

Fig. 1. Reduction of aircraft noise with to respect the year of entry into service [12].

Finally, again from an operational point of view, the extreme resource is represented by the use of caps on the number of movements at a given airport. The latter solution is obviously very critical, as it puts a brake on the growth of an airport and therefore limits both the active and passive accessibility of the region with direct and indirect consequences that can result. Another measure that has proven to be highly effective is inherent to the various forms of modulation of aeronautical charges, as to reflect the greater disturbance caused by aircraft or aiming at penalising night and evening movements. Matter of fact, this taxation system can be applied or as an "addition" or as a "deduction" with respect to the normal amount of taxes paid by the carriers (noise charges or surcharges), or as a real "environmental tax" (noise tax). Environmental taxation is a market-based measure and is independent from the airlines' or airports' operations.

The use of these strategies has led to a reduction of airport noise, estimated at about 20 dB over the last thirty years, thus resulting in a reduction of perceived noise by about 75% [14]. At EU Community level, there is a strong segmentation of methodologies for the management of airport noise: even if these measures appear to be quite similar, they are applied in a highly heterogeneous way. For instance, noise charges or taxes are used in almost all EU countries, but they are applied with very different methodologies and philosophies. Sometimes, in fact, the amount of the tax derives from the basis of a noise value recorded during the overflight, while in other cases it is determined on the basis of the noise certification values of the target (predefined) aircraft. Moreover, the criteria for the modulation are very different: to give an example, certain methods determine the amount of taxes from a database of aircraft ranked in classes with a similar level of acoustic emission, whereas others calculate this amount on the basis of the actual noise level measured. Besides, some airports or EU countries are not involved in the application of these instruments. Considering the strong intra-European competition in the aviation sector, noise taxation is a factor that can unbalance the market in favour of those countries or airports that have lower environmental taxation. If we consider a carrier which is up to decide on the starting-up of a new route from a target airport to a bunch of possible destinations that apply each a different kind of environmental taxation, it is clear that the airline is going to prefer the destination with a "softer" taxation.

2. Modulation of environmental taxes at airport

The proposal to apply environmental charges in air transport came out originally thirty years ago in the earlier works of OECD. The original idea was to apply a tax whose amount was proportional to the number of people exposed to airport noise. The critical issue was how to quantify the economic damage caused by noise: as the quantification of the biological damage was too complex and uncertain, further studies conducted over the years, progressively focused on the quantification of the economic analysis of externalities [15]. In particular, the hedonic pricing method has been developed and applied in numerous studies: Mayeres et al. [16] showed that the hedonic price method is the most commonly used for assessing the social costs of noise. They used the value of real property located in areas affected by aeronautical noise, obtaining the so-called noise depreciation index (NDI), which represents the amount of reduction in the value of property per unit of noise, expressed in dB [17]. Over the years there have been a lot of studies aiming at determining the NDI for different territorial realities [18,19]: average estimated values range from 0.6% to 0.83% depreciation per dB of cumulative noise that affects the estate (Table 1).

Table 1. Noise depreciation index: values obtained in different studies.

Source	Airport	Period	NDI (% per dB)
FAA	Los Angeles	1991	1,26
Kaufman	Reno	1995	0,28
Levesque	Winnipeg	1986	1,30
O'Byrne	Atlanta	1985	0,64
Tarassoff	Montreal	1990	0,65
Uyeno	Vancouver	1993	0,90
Schipper	30 UK airports	1998	0,83
Gautrin	Heathrow	1975	0,50
Lu and Morrell	Various EU	1990-2006	0,60 – 0,62
Dekkers and van der Straaten	Schipol	1999-2003	0,77

For instance, dividing the territory affected by the noise in "*i*" zones, the total economic damage *C* produced by noise is given by:

$$C = \sum_i NDI \cdot dB_i \cdot P \cdot H_i \quad (1)$$

where *P* is the average price of the estates and H_i is the number of estates in each area. The next section addresses the issue of the definition of the amount of taxes for a target airline operating in a target airport on the basis of the noise produced.

3. Evaluation of aircraft noise performance

The determination of the acoustic performance of aircraft is the most important issue for the detection and calibration of methodologies aimed at the assignment of environmental taxes. In particular, in the scientific literature there are two groups of methods for assessing the acoustic performance in aviation services [8]. On the one hand those related to the single event, which are used to assess the performance of a single aircraft, and on the other hand the cumulative ones, which are used to evaluate the acoustic performance within an aggregate time period. The latter method is normally used for assessing the noise level of an airport in terms of average noise produced in the territory while the former allows ranking the aircrafts according to the noise performance based on the values of the resulting noise certification scheme provided for by the ICAO (International Civil Aviation Organization). Notwithstanding, in some areas actual acoustic values recorded at particular points in the area during flyovers are used for the determination of environmental taxes. The aggregate performances allow estimating the impact of airports in the area adding the noise recorded in a given period with the use of weights, which are different in each country, to impose for instance greater importance on more annoying events, those taking place during sensitive periods or evening and night.

3.1. Aircraft noise equivalent factor (ANEF)

Most of the methods to determine environmental taxes and the methodologies proposed for the modulation of aeronautical charges on the basis of the internalization of the cost of noise were based on the absolute performance of individual aircraft. Mostly they rely on the use of the certification values of each aircraft, but the way in which these values are aggregated varies greatly. Finally, apart from England, there are no Europe-wide structured systems for the management of airport noise that provide an unified method to determine the noise performance of an aircraft, the amount of environmental taxes and to decide whether or not imposing operating restrictions

An analysis of the critical issues and the best practices adopted at Community level and in other countries like the US has led towards a methodology that combines the contextualization of the performance evaluation of aircraft noise with the use of noise management tools, such as the modulation of noise taxes and the imposition of operating restrictions. The purposes of this methodology are: developing a tool to assess the performance of the single event in relative terms, namely enabling the assessment of performances with reference to a sound level chosen by the analyst, for example the sound level of the Best Available Technology (*BAT*); identifying a suitable methodology based on the performance values of certain aircraft, to fix noise management tools; relating the actual noise disturbance generated by the single movement to the criterion for the evaluation of environmental taxes.

On these bases the so-called *ANEF* methodology (acronym for Aircraft Noise Equivalent Factor) has been developed. The premise of this methodology is to determine the acoustic performance in absolute terms, therefore the values used for the determination of the acoustic performance are those certified by the ICAO. For each certified aircraft there are three noise levels (*EPNdB*). The first one,

$EPNdB_{\text{approach}}$ is used for the assessment of landing noise, while the values $EPNdB_{\text{sideline}}$ and $EPNdB_{\text{flyover}}$ are used for the assessment of take-off noise and along the overflight path.

Since these values are recorded at different distances, the UK Civil Aviation Authority has derived a correction of 9 *EPNdB* during landings in order to make these values comparable with those measured during takeoffs, defining the approach noise level (*ANL*):

$$ANL = EPNdB_{approach} - 9dB \tag{2}$$

where $EPNdB_{approach}$ is the noise certification level in approach. The noise level at takeoff is the mean of the levels provided for take-off, as shown in the following formula, where *DNL* is the Departure Noise Level.

$$DNL = \frac{EPNdB_{flyover} + EPNdB_{sideline}}{2} \tag{3}$$

Once these values have been identified, they are put in comparison with the acoustic reference values typical of the aircraft chosen as a reference of a particular level of technology, or with a certain noise level chosen by the analyst. This value is the *RAL* shown in the formula below, where *RAL* is the acronym for Reference Aircraft Level. Every aircraft *j* for a given movement (takeoff or landing) has his specific value of *ANEF*.

$$ANEF_{D,j} = \frac{DNL_j}{RAL} \tag{4}$$

$$ANEF_{A,j} = \frac{ANL_j}{RAL} \tag{5}$$

ANEF is the ratio between two items in logarithmic scale: therefore, noise levels should be transformed into numerical equivalents. Given a target fleet mix and chosen a specific RAL, it is therefore possible to derive the noise levels of the whole fleet or to determine the aggregate performance of a single aircraft simply adding the two contributions. Summarizing, the ANEF method allows evaluating the acoustic performance of a single aircraft in relative terms or with reference to a specific noise level. It provides a value that is directly proportional to the perceived noise and therefore to the environmental costs. For example, a 3 dB difference in the noise level means that the first aircraft will have twice the amount of ANEF than the second. A possible way to apply this result to the modulation of environmental taxes consists in deriving the tax amount from the actual noise generated by each movement.

The ANEF methodology can be used for evaluating the aggregate performance of an airport or a fleet mix (set of planes landing or taking off in an airport in a predefined period of time) by weighting the ANEF values of the classes that make up the fleet mix with the share of each class in the fleet mix (%), labelled Ai in the formula below.

$$ANEF_{Airport} = \sum_{i=1}^{n} ANEF_i \cdot A_i \tag{6}$$

3.2. ANEF as a tool to set environmental taxes

The first aspect to be considered is the annual assessment of the environmental cost of an airport (C). This value includes the cost of mitigation measures, the expenditure incurred for the management of noise impact and the social cost of noise, calculated for example according to the theory of hedonic price.

The value of the environmental tax c_i for a given aircraft type "i" is determined by the use of the following expression:

$$c_i = \frac{C \cdot ANEF_i \cdot A_i}{N_i} = \frac{\sum_i NDI \cdot P \cdot H_i \cdot ANEF_i \cdot A_i}{N_i} \tag{7}$$

where N_i is the number of movements (take-offs or landings) of aircraft of type "i" in the fleet mix and A_i is the share (%) of this aircraft class in the fleet mix. In this way, given the environmental cost, it is possible to allocate the environmental mitigation costs (noise charge) of a given fleet mix according to the actual noise produced by each type of aircraft, with reference to a target aircraft which has the lowest level or taxes or no taxes at all (the so call best available technology level).

4. Application to a real case

The airport object of the study is the Guglielmo Marconi International Airport (IATA: BLQ, ICAO: LIPE). According to ICAO Annex 14, the aerodrome reference code is 4C. It is located approximately 6 km North West of the centre of Bologna, in the central region of Emilia-Romagna, and it is the seventh busiest airport in Italy.

The traffic is mostly a combination of normal carriers (ex flag carriers), such as Alitalia, British Airways, KLM, Air France and Lufthansa among others, and low-cost carriers (Ryanair, Easyjet, Wizzair, Vueling, Germanwings) that link the Bologna airport to a number of destinations in Europe. The percentage of charter flights is a small part of the total air traffic, connecting the airport to long haul destinations. The fleet mix is dominated by mid size aircraft, such as Airbus series A-319 and A-320, and the Boeing 737 and the MD-80 series aircraft. In 2012, there were 67,257 movements and 6 million passengers. and the main aircraft in the fleet mix, according to airport data, is shown in Table 2.

Table 2. Fleet mix operating at Bologna airport during 2012.

Aircraft type	%
Boeing 737	30
Airbus 319-320	25,1
Embraer 190-195	22,9
CRJ 900-1000	7,7
Fokker 100	3,7
MD 80-82	3,3
Avro RJ100	2
Wide Body (A330, B747)	1,4
BAE 146	1
Other	2,9

The number of dwellings located within the noise contours corresponding to different noise levels have been obtained from airport sustainability report (Table 3). In Fig. 2 are shown the noise contours, simulated using INM – Integrated Noise Model, corresponding to the three peak weeks of traffic, according to the national regulatory framework.

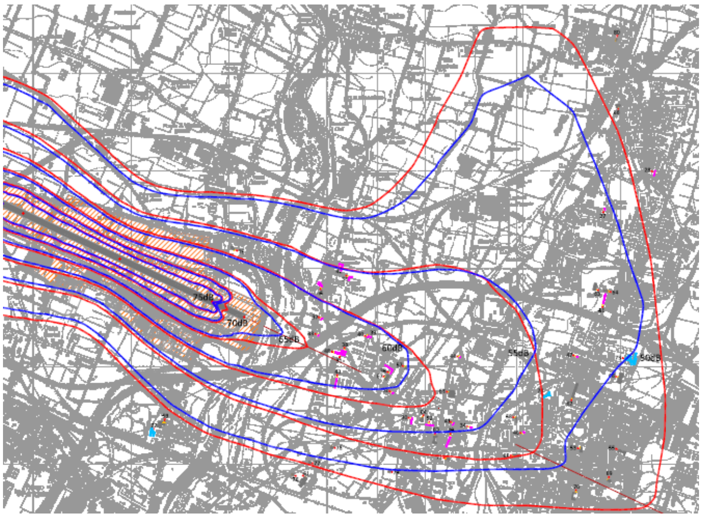

Fig. 2. Example of noise contours (source: Bologna airport).

The average price of dwellings located within airport noise contours was obtained from local Chamber of Commerce database and the value has been inflated at current value by applying the Euro area inflation rates, obtaining the following price: 203.400 €/residence.

Table 3. Number of dwellings located within specified noise contours.

Noise level (dB)	Avg. Noise level (dB)	No. of residences
55-60	57,5	531
60-65	62,5	349
65-70	67,5	7
>70		0
Total		887

The noise total cost can be estimated by (1), considering an average value of noise depreciation index (*NDI* = 0,6% per *dB* of noise) as in Table 1:

$$C = \sum_i NDI \cdot dB_i \cdot P \cdot H_i = € 64.458.477$$

and the noise tax for each aircraft type "*i*" can be evaluated considering the (7). The value of ANEF have been calculated by the author, as reported in [8]. The results are shown in Table 4 and, as expected, the higher the higher the noise produced by each single aircraft and the higher the single movement tax. It is important to remember that each value of ANEF is representative non only of the single noise level of a given class of aircraft, but considers furthermore the comparative relation with a predefined noise level.

Table 4. Noise tax for a single movement of each aircraft type.

Aircraft	%	Movements	ANEF	c_i(€)
Boeing 737	30	18.510	0,089	**94**
Airbus 319-320	25,1	16.228	0,069	**73**
Embraer 190-195	22,9	14.871	0,018	**19**
CRJ 900-1000	7,7	4.719	0,017	**18**
Fokker 100	3,7	2.252	0,021	**22**
MD 80-82	3,3	1.922	0,190	**201**
Avro RJ100	2	1.076	0,018	**19**
Wide Body (A330, B747)	1,4	754	0,230	**243**
BAE 146	1	557	0,019	**20**

5. Conclusions

Airport noise has historically been the main source of conflict among airports and local communities and is even now a factor that can significantly influences air transport market conditions. This situation stems from the heterogeneity in the regulatory provisions among different EU countries. In addition, although the noise is a factor that strikes the logic of sustainable development of the aviation sector, there are still no objective methods to evaluate the cumulative acoustic performances of airports and airlines. In this paper, a dimensionless indicator of aircraft noise, based on the noise certification values, has been described and applied to set noise taxes. This, together with other indicators usually adopted for the assessment of the noise impact generated by airport operations, allows to evaluate the acoustic performance of a fleet mix of aircrafts (operated by a given company or at a certain airport) in a concise and objective way. Finally, the methodology for assessing the efficiency of an acoustic fleet mix of aircraft described in this work represents a tool for assessing the sustainability of the noise level at an airport or with reference to an airline, and can be effectively applied in combination with other indicators and other methods already used in both the scientific literature and legal doctrine in order to support planners, airport operators, company managers and Regulators.

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