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A systematic approach to assess the effectiveness of airport noise mitigation strategies

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ABSTRACT

Regional airports are often located very close to the urban area they serve and the increasing traffic rate that many of them have experienced in the last years has produced several impacts on the communities living close to the airport area, mainly aviation noise. If not properly managed, noise impacts produced by airport operations can cut down significantly the development of airport air traffic with direct effects on the economic and territorial systems. Aeronautical noise has greatly reduced in the last decade, due to aircraft design technological improvements and more severe regulations. However, the noise reduction during a single event does not make the issue of the airport location – and then the whole noise impact – less significant. This paper proposes an assessment process to evaluate the effects of actions adopted to reduce airport noise impacts on populated areas. Both airport-related factors – such as number of take-off; day-evening-night distributions of movements; aircraft type; flying paths – and land-use characteristics have been considered and combined in a density index that synthesizes the impacts of airport noise on the territory. The assessment process has been tested on a real case, the airport of Bologna in Northern Italy. The predicted results, compared with available real data for the test case, are significant and encourage the use of the proposed assessment process as decision support system for the airport management.

1. Introduction

Aircraft noise has been the main hurdle between air traffic expansion and welfare of local communities around airports. Although air transport affects the environment in different ways and at different spatial levels, both noise and carbon local impacts emerge as the worst (Schipper et al., 2001; Postorino and Mantecchini, 2014). These detrimental effects are linked to the activities taking place at airports and in some areas high environmental impacts, specifically high levels of aircraft noise, have even led to operational constraints (Upham et al., 2003).

The problem of airport noise has become more and more important in the US since the 50's with the introduction of jet engines. When the problem appeared in Europe too, regulators were forced to introduce methods for aircraft noise emission control during the aircraft certification procedure. These "at source" countermeasures were addressed to the development of devices designed to reduce the aircraft noise by introducing, for instance, thrusters. Further results were obtained by aerodynamics studies to identify the source of turbulent airflow that can generate additional noise. As a consequence, the past twenty-five years have seen a significant reduction in the number of persons exposed to significant noise levels of 65 dB(A) or more (Nelson, 2004). Concerning the evaluation of airport noise effects on health, there is an extensive literature on population annoyance associated with aircraft noise (Miedema and Vos, 1998; World Health Organization Burden of disease from environmental noise WHO, 2011). Several studies show a correlation among aircraft noise exposure and cardiovascular or psychological diseases; most of them measure annoyance, some others measure general health and medication use and report correlation between self-rated health conditions or self-reported health complaints and aircraft noise exposure (Smith et al., 2002). Recent studies (Franssen et al., 2004) show a statistic correlation between aircraft noise and use of medication for cardiovascular disease, increased blood pressure and sleep disturbance. As for the estimation of sleep disturbance, Wijnen and Visser

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(2003) found a relation linking the percentage of people awakened and noise levels.

Two opposing requirements should be satisfied when locating or expanding an airport. From one side, airports should be located as close to towns and cities as possible, to reduce ground access times and make them more accessible. On the other hand, airports should be located as far from towns and cities as possible, to minimize noise impacts (Ashford and Wright, 1992). One of the major issues the airline industry will face in the next future is its ability to meet the capacity expansion demand at major airports and at the same time reduce the negative impacts of increased airport operations on surrounding communities. There is a large number of studies concerning airline operation negative impacts on surrounding neighbourhoods, with a particular focus on the effects of airport noise on property values and land use planning around the airport (Uyeno et al., 1993; Espey and Lopez, 2000; Nelson, 2004; McMillen, 2004; Lu and Morrell, 2006; Cohen and Coughlin, 2008).

Despite the attempt to limit the amount of emissions associated with the single event, the continuous air traffic growth has worsened the problem because the number of operating aircraft has grown exponentially and the introduction of tougher certification rules has affected only new generation aircraft. Moreover, the effects of sound propagation do not refer to the single event, but to the amount of events that occur in a short time period and the time lag between two events. Therefore, the aircraft industry has been forced to find other forms of noise management – such as restrictions and total or partial ban to the use of some categories of aircraft (ICAO, Annex 16, 1993) – to improve the welfare of local communities exposed to these impacts.

To solve the airport noise problem – and then satisfy both communities and airport operators –technological and organizational procedures have been adopted among others. European large airports, such as London's Heathrow, Amsterdam's Schiphol, Zurich and Frankfurt, employ a wide array of noise cutback, mainly by imposing strong compulsory restrictions and adopting different approaches to mitigate noise, which depend on the various national regulations and the degree of local pressure. Laws and regulatory frameworks governing the monitoring of aviation noise and the various control strategies in EU Member States include, for example, the French Law on Urban Planning of 1985, the Belgium Environmental Law, the Italian Decrees set out by the Environment Minister in 1997 and the Netherlands Aviation Law of 1995 (for a complete critical review, see Girvin, 2009).

One of the most used aviation measures designed to reduce noise due to arriving and departing aircraft – also called Noise Abatement Procedures (NAPs) – is the thrust cutbacks realized when aircraft are at least 800 ft above the runway threshold after their take-off (FAA, 1993; ICAO, 2002). Arrival NPAs are less widely used – a well-known example is the Continuous Descent Approach, CDA (Filippone, 2014).

According to 2009 data, 490 airports worldwide have adopted NAPs (Netjasof, 2012), but most of them are not optimized for the local conditions. Particularly, they are usually set to obtain a specific noise reduction, but do not take into account the actual noise impact on the involved population (Erkelens, 2000; Hebly and Visser, 2008). In order to achieve such goal, some optimized procedures have been developed by combining thrust cutbacks with both fixed trajectories and climb ratios ensuring compatibility with the Air Traffic Control (ATC) principles.

NAP optimization reduces noise to a specific target value and allows considering some specific performance parameters. For example, the number of dwellings exposed to a prefixed cumulative level of noise or the number of times people are woken up by aircraft noise are estimated and monitored (Wijnen and Visser, 2003). The performance parameters can be used to support the identification of market-based actions for noise mitigation, for example noise charge schemes. Some measures analysed in the literature to reduce noise impacts refer to various forms of aeronautical charge modulation, addressed to compensate the disturbance caused by aircraft or penalising night and evening movements. Economic efficiency theories suggest that the polluter (in this case airlines and, indirectly, airports) should pay the full cost of environmental damages and nuisances caused by their activities (Turner et al., 1994). This charge system can be applied as an "addition" or 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). The idea to apply environmental charges in air transport came out thirty years ago in the context of OECD (Pearce, 1976). The original idea was to apply a tax proportional to the number of people suffering from airport noise. However, the critical issue was the quantification of the economic damage caused by noise. As the biological damage measure was too complex and uncertain, further studies conducted over the years focused on the quantification of the economic analysis of externalities. In particular, the hedonic price method has been developed and applied in several studies and Mayeres et al. (1996) among others showed that the hedonic price method is the most commonly used to assess noise social costs.

Following the approach of Bentes et al. (2013), the efficiency analysis of noise mitigation strategies can be performed by considering a combination of trajectory optimization, noise simulation models and Geographic Information Systems (GIS). One of the most widely used noise simulation models is the Integrated Noise Model (INM), the Federal Aviation Administration (FAA) standard tool for noise assessments (FAA, 2007). Starting from input data including airport information (localization and climatic data), flights (number and type of operations, flight profiles) and the position of the observer (based on a survey grid), noise boundaries due to airport aviation activities are depicted.

In this paper, an assessment process is proposed to identify optimal strategies addressed to reduce the noise impacts on the airport surrounding areas. Starting from airport operational characteristics – such as number of movements, aircraft type and approaching path – the noise contours identifying some predefined noise levels (usually the noise limits imposed by regulatory framework) are identified by using noise models such as the INM. Then, the noise impact on the activity system around the airport – whose main characteristics are number of living people, number of dwellings, type of buildings among other factors – is computed based on Geographic Information Systems (GIS). To synthesize the impacts of airport noise on the territory, the Noise and Territory Overlap (NTO) index is proposed, which combines airport and land use characteristics. The NTO index makes available comparisons among different scenarios – corresponding to changes in both airport and/or land use characteristics – and provides a measure of the effectiveness of potential actions. The assessment process has been applied to the airport of Bologna in Northern Italy.

The paper is organized as follows. Section 2 describes the possible noise actions used to reduce the noise impact, including discussion on some indexes suggested or imposed by current regulations. Section 3 describes the proposed approach while Section 4 refers to its application at the airport of Bologna. Finally, Section 5 draws some main findings and conclusions.

2. Regulatory and operational context

The impact of aircraft noise on communities located near an airport is closely correlated to: 1) the amplitude and frequency of the actual noise produced by aircraft during take-off and landing;