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Technical note

A new indicator to measure the noise impact around airports: The Real Estate Tolerance Level (RETL) – Case study around Charles de Gaulle Airport

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ABSTRACT

The Community Tolerance Level (CTL) is a new indicator which characterizes the impact of aircraft noise around local airport. It corresponds to the exposure sound level (DENL or DNL) where 50% of the population is highly annoyed. Inspired by this indicator, this paper aims at calculating the Real Estate Tolerance Level (RETL) which corresponds to the exposure sound level where a property price is 50% depreciated compared to the price of the same property which would be situated in an area whose DENL is below 50 dB(A). The use of a notarial database analyzed with the Hedonic Price Model (HPM) made it possible to calculate the percentage of property price depreciation around CDG airport, with 1-dB steps of DENL, and so far to calculate the RETL. 19,891 house transactions and 23,264 apartments have been localized with a Geographic Information Systems (GIS) and crossed with the Sound Environment Curves provided by Airport of Paris. The RETL value for single houses and for apartments around CDG is 75.8 dB. It is comparable to the mean CTL value which has been estimated to 73.3 dB from the DNL data of 43 airports over the world (about 73.9 dB from DENL data). The RETL is predictable without field survey and could characterize the impact of aircraft noise around local airports. It could be a good indicator to follow the evolution of population tolerance over the years.

1. Introduction

In a context of continuous growth of airport activities, the link between objective acoustic measurements and population noise exposure still remains an issue for public stakeholders and researchers. In the transportation field, Miedema dosage–response curves are used to quantify the exposed population to noise (percentage of annoyed or highly annoyed people) [1,2]. These curves are based on DENL or DNL, and are approximated with polynomial models which accounted for 44% of variance [3]. The relevance of these curves is discussed today because the data which has been used to build the models was collected between 1960 and 2000. It seems that nowadays, people are more annoyed by noise than the Miedema had predicted [4,5]. Moreover, these curves correspond to a best-fit model based on annoyance data collected around different airports in Europe, North America and Australia, using different methods. Consequently, there may exist a bias in comparing and mixing the data [6]. A recent idea consists in working on a local indicator which characterizes the impact of noise around each airport and which better fits to populations' local reactions. The predicted impact follows a sigmoid model. The inflection point where 50% of the population is highly annoyed corresponds to the local indicator (the Community Tolerance Level – CTL), and is specific to the community of people who lives around each airport [7]. The advantage of the CTL is that it is modestly correlated to DNL. So, when adding this local indicator to DNL in a multiple regression, the model accounts for 66% of variance. The drawback of this CTL indicator is that it is difficult to estimate *a priori*, and still needs field studies to be calculated. Fidell et al. [7] propose to investigate the use of complaint rates in order to predict CTL values in a community. In this paper, the use of property price depreciation is investigated in order to calculate a similar local indicator, which could characterize the impact of

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aircraft noise. This indicator is still not predictable *a priori* before new airport construction, but makes it possible to study local population reactions to noise, avoiding its tiredness because of repetitive field surveys about noise.

So, an indirect way of following population reactions or studying differences between communities is to examine property price depreciation in noisy areas, using the Hedonic Price Method (HPM) [8]. The hedonic price theory is based on the idea that the value of a property can be described through a list of characteristics – such as the number of rooms, the period of construction, the location, the noise level of the environment, etc. The observed price variations for different properties can be accounted for by a variation of these characteristics. Thanks to this hedonic method, it is possible to estimate the impact of each characteristic variation on price, independently from the other characteristics. For noise, the HPM makes it possible to quantify the effect of the environmental sound level on property value, which depends on the probability of being annoyed. In most studies, the load of noise is characterized with the noise exposure level (DENL or DNL) which is defined in terms of equivalent sound level L_{Aeq} with a 10-dB penalty for the night, and a 5-dB penalty for the evening.

With the recent development of Geographic Information Systems (GIS), statistical treatments of environmental quality measurements are made easier. The HPM approach allows an analysis of a huge corpus of data, including several thousands of observations, providing more reliable indications than surveys confined to a few hundreds of households [9].

A lot of HPM studies were carried out at international airports (particularly in the US and in Canada) [10,11]. All these studies, as well as these meta-analyses [12,13], show that despite the dispersion of the results, the conclusion was consistent: aircraft noise mainly has a negative and statistically significant impact on prices [14]. Few studies have been performed in France on price depreciation (see Faburel and Maleyre [15] for Orly Airport, South of Paris), although cost-benefit analyses are useful to justify public policies [16].

A new study was then performed in 2013 for Roissy Charles De Gaulle Airport (CDG, North of Paris). One of the aims of this study was to suggest a new indicator which could characterize the impact of noise and its evolution over time. Originally, the idea consisted in applying the Community Tolerance Level (CTL) approach to the real estate depreciation due to noise. The Real Estate Tolerance Level (RETL) was suggested as a new indicator which could characterize the local impact of noise around each airport.

The following section presents the key assumptions underlying the hedonic model and the statistical method. It develops the hedonic price method theory in order to calculate the price depreciation, while Section 3 focuses on the development of the empirical model applied for this particular study. Section 4 presents the results for the Val d'Oise department: the percentage of property price depreciation due to aircraft noise and the RETL calculation. The results are discussed in Section 5, considering the use of RETL as a noise indicator. The last section presents some conclusions and recommendations for further studies.

2. The hedonic price method

2.1. Hypothesis

The first hypothesis is that aircraft noise affects market prices of residential properties. As highlighted in some research [17,18], damage will be noticed only to the extent that purchasers are aware of it and are able to detect differences in noise between areas. In other words, the noise indicator which is used to communicate with the population in the HPM should correctly characterize the noise exposure and this exposure should influence home buyers or renters when they negotiate a price [19].

In France, there are several public information policies on noise exposure directed at residents or buyers around big airports, particularly through the noise exposure map (*Plan d'Exposition au Bruit* – PEB) [20]. The PEB aims at preventing current or future populations from being annoyed by noise. Thus, the act sets rules to prohibit or limit the possibility of building in areas subjected to aircraft noise. The PEB is based on DENL calculated contours. It sets four noise areas. Two areas have high noise levels ($L_{DEN} > 70$ dB and L_{DEN} between 65 and 70 dB). One is considered as a moderate area (within the contours [55–65]) and the last one is considered as a low noise area (within the contours [50–55]). Each contract of property sale (or rental agreement) around an airport has to include a clear and legible clause specifying the noise area where the property is located.

In addition, other sources of information are available around CDG airport. In 1996, the Environment and Sustainable Development Centre (*la Maison de l'Environnement et du Développement Durable – MED*) was created at CDG airport (the same as Orly airport). The aim of this specific MED is to provide information on the territorial impact of airports. Resources are available to the public, such as 3D visualization software and interactive multimedia tools. Since October 2006, air traffic controllers provide information hotlines within the MDE twice a week. They answer any questions including ones about noise around airports and flight paths. According to the staff of the CDG MDE, some prospective buyers go to the MED to learn about aircraft noise over their future property. It helps them understand the differences in noise exposure between the areas they visit; so it is likely that all the buyers and sellers are well informed about noise. Nevertheless, one might notice that the DENL indicator might not be the best one to communicate about aircraft noise around airports. Dynamic indicators which focus on flyovers could improve noise understanding [21–24].

Another hypothesis is that the shape of the house price depreciation due to noise follows the same curve as the probability of being annoyed by aircraft noise. It is then likely that a non-linear relationship between noise exposure and price depreciation is appropriate in the urban fringe around airports. Recent studies on the HPM [25] have already shown that the link between noise levels and house prices is not linear. However, the shape of the relationship still remains to be studied [10]. These recent studies also show that the level threshold under which the noise impact can be neglected has to be carefully selected in the models.

2.2. The hedonic price model

The mathematical model is based on a functional relationship between the price of a property, and its characteristics. For this study, the property price is P_i. Characteristics are generally divided into four classes: (1) structural characteristics S_i of the house such as size, number of rooms, etc.; (2) features of the socio-economic neighborhood N_i such as the quality of the school district, the crime rate of the area, the social composition of population, etc.; (3) accessibility characteristics A_i such as the proximity to city center, proximity to employment, etc.; (4) specific environmental amenities E_i such as noise, air pollution, etc. There is always a non-explained part of the price represented by ε_i, a normally distributed error term.

$$P_i = f(S_i, N_i, A_i, E_i) + \varepsilon_i \quad (1)$$

Several basic functional forms such as linear, semi-log, log–log and Box–Cox forms can be applied to the hedonic price model. Linneman [26] found that the Box–Cox transformation cannot be