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Health Impacts of Noise Pollution Around Airports: Economic Valuation and Transferability

Michael Getzner and Denise Zak
Vienna University of Technology, Centre of Public Finance and Infrastructure Policy, Austria

1. Introduction

Air transportation generates numerous economic and social welfare benefits. Airports and their expansions are associated with direct, indirect, induced effects as well as catalytic impacts on regional and national economies (Arndt et al., 2009; Braun et al., 2010). Mobility and accessibility are important factors determining competitiveness of (regional and national) economies in an increasingly globalised world. On the other hand there are numerous environmental and health impacts related to the growing demand for air transport. Since the projected annual growth rates of numbers of passengers are about 5% in the next 20 to 25 years (Mahashabde et al., 2011), the continuing growth of the aviation sector has raised questions of appropriate valuation and treatment of external costs (e.g. human and environmental health). In the context of transport markets, a distinction of externalities into positive (external benefits) and negative (external costs) is appropriate. Large infrastructure projects like airports cause various external effects, associated especially with the provision of transport services and facilities, the need of constructing transport infrastructure as well as related production of vehicles or raw materials (Schipper et al. 2001). Air traffic and associated ground side traffic contribute to local and global noise and air pollution.

Despite a large body of research on the economic effects the demand for more information about the economic effects of pollution and noise exposure is increasing. Effects on human and environmental health as well as on property values, land use planning constraints and spatial and social polarization are issues of importance, requiring further scientific work (Eurocontrol, 2007). Noise pollution is a negative externality, which is defined as an unwanted by-product of production as well as consumption processes that have adverse effects on third-part individuals and communities. Since there is no explicit market for environmental goods like quiet, the economic valuation of noise damages is not simple or straightforward (Nelson, 2008). As an example, monetary values for all relevant external effects, more precisely environmental impacts, global warming and accidents are aimed to be covered by the ExternE methodology, whereas health impacts constitute the largest part of the estimated damage costs (Bickel & Friedrich, 2005). Generating values is necessary at least for three purposes; finding a basis of a possible internalization of external costs, inclusion as an input in cost-benefit appraisals, and defining mitigation or regulation measures in terms of cost-effectiveness (Eurocontrol, 2003).

Noise affects communities around airports; causing nuisance and health effects like sleep deprivation (Lu & P. Morrell, 2006). The World Health Organization recognizes community noise (also referred to as environmental, domestic or residential noise) as a public health problem and published guidelines to combat excessive noise pollution in 1999 (Berglund et al., 1999). In an extension the World Health Organization focuses on the health effects of night-time noise exposure for Europe (World Health Organization [WHO], 2009). Auditory and non-auditory effects on human health are related to noise exposure, with the latter effects being less well established (Clark & Stansfeld, 2007). These adverse effects on human health cause costs that are of relevant concern for the affected individuals and the entire economic system. Especially treatment costs of diseases and health problems (stationary and ambulant hospital treatments, medication and consultations), productivity losses in occupational settings (sickness absence, lost output, non-productive time and invalidity) and immaterial costs due to losses in quality of life are pivotal. Effects on housing prices and rents are also important economic dimensions. Residences in noise polluted areas are subject to value decreases and occasionally cost-intensive adjustments for noise insulation facilities (Sommer, 2002).

The linkage of clinical health effects and noise is complex. A direct relation between noise exposure and certain clinical symptoms is difficult to determine because of a range of interdependencies and influencing factors (European Commission [EC], 2005).

Based on this background, the research question for our paper is twofold: First, we want to examine the recent methodological developments on the valuation of airport-related external noise costs. Special attention is paid to benefit/cost transfer and the method's implications. Second, we discuss empirical results and possible transferability of our results, and draw conclusions. The structure of the paper is the following: Section 2 provides a short review of valuation techniques with the focus on the valuation of property values and willingness-to-pay methods to reduce health-related noise pollution of air transport. Section 3 provides a comprehensive discussion of the scientific literature on valuation results and the relation of health problems to noise pollution around airports. Section 4 summarizes the empirical results in the light of transferability from the study sites to potential policy sites. Finally, section 5 discusses the summaries and concludes.

2. Environmental valuation techniques: Overview on methodology

From the viewpoint of methodology there are many potential techniques assessing the economic values of externalities and environmental impacts. As will be shown in detail, valuing the environment and – in an extended perspective – (statistical) life and health is a challenging task to undertake. One option is to examine households' preferences for certain environmental amenities via the housing market, assuming that the status of environmental quality is revealed through residential choices and decisions.

Lancaster (1966) employed a new model of consumer theory, assuming that goods are not the direct objects of utility as it was common in traditional approaches. Consumers' utility derives on the basis of the inherent characteristics or properties of the good instead.

Housing is commonly treated as a heterogeneous and composite good. This good is not only defined by its attributes like size, house type or number of rooms, but also by location characteristics, summarizing accessibility, neighborhood, environmental quality, traffic effects and local public goods (Cheshire & Sheppard, 1995). While the vicinity of public transportation, roads and airports can be experienced as amenity in terms of mobility it is also related to negative externalities (Boyle, 2001).

For the economic valuation of health effects and environmental impacts of noise exposure at airports two methods are especially widely used: hedonic pricing and contingent valuation. The essential part of these techniques is the determination of the (marginal) willingness to pay (WTP) for an avoidance or reduction of these effects (den Boer & Schroten, 2007).

2.1 Hedonic pricing and contingent valuation

Valuation of environmental amenities cannot be realized through markets (alone) due to their public good character. Accordingly, an indirect method for valuing is necessary to assume and utilize a link of a certain amenity (or disamenity) and residential property values (McMillan et al., 1980). Rosen (1974) developed theories of consumer behavior and proposed the hedonic method as a useful tool for economic valuation (Lipscomb, 2003) on the hedonic assumption that individuals value the characteristics of different goods on grounds of their attributed utility. Rosen considered a model for using hedonic prices to assess the values of attributes for differentiated goods in terms of demand and supply perspective. Hedonic prices were defined as implicit prices, which are revealed by economic agents through market behavior (Rosen, 1974; Freeman, 1979). In theory, housing prices can be understood among others as a reflection of the money value of environmental quality to the individual or home owner. Assuming that the individual's utility function is weakly separable, the marginal rate of substitution between two goods is not dependent on the quantity of all other goods. Therefore the estimation of a demand curve for environmental quality without considering the prices of other goods is feasible within the hedonic pricing method (Freeman, 1981). Another important assumption is weak complementarity (Hanley & Spash, 1993).

Estimations of the effects of amenities and disamenities on housing values have been derived from hedonic models (Nelson, 2004). In the case of airport noise it is assumed that properties exposed to noise nuisance – ceteris paribus – sell at lower prices, reflecting preferences for quieter residences (Day, 2001). Despite the wide application of this method various problems exist and there is an ongoing critical debate. On a theoretical level Ekeland et al. (2002) question the using of market data for the demand function in the sense of Rosen (1974). In the hedonic price equation as well as in the demand curve the decision on independent variables and omitted variables is crucial. Multi-collinearity of included variables is also problematic. Segmentation of housing markets also has to be taken into account (Hanley & Spash, 1993). McMillan et al. (1980) point out that the property value measure does not necessarily reflect the true willingness to pay of households, when different household classes exist. This is due to the fact that house characteristics are inflexible, and that households are limited in their mobility (e.g. relocation costs), and that households have incomplete information on health effects of noise pollution.

The welfare implications of changes in goods that are not traded on markets can theoretically be implied by this model of market equilibrium. Further developments and extensions of the hedonic property value approach like the accounting for spatial effects have been established (Kuminoff et al., 2010) as well as including geographical attributes (Collins & A. Evans, 1994).

Contingent valuation relies on the stated preferences approach (Hanley & Barbier, 2009). Placing a monetary value on noise pollution and the consequences of environmental damages in a direct way is difficult. The lack of markets results from the non-rival or non-excludable nature of these damages. Market prices therefore cannot reflect social costs (benefits) appropriately. Preferences are therefore not fully captured by market transactions, if externalities exist (Hanemann, 1994). Economic values for non-market resources are estimated based on the information collected in survey questions (Smith, 2009). Consumers are directly asked for their (marginal) willingness to pay (WTP) or willingness to accept (WTA) (Hanley & Spash, 1993). The WTA or WTP measures captured within contingent valuation surveys are understood to reflect respondent's preferences monetarily, corresponding to welfare measures in the sense of the Hicksian consumers' surplus. The choice between WTA or WTP measures for a given context remains controversial (Atkinson & Mourato, 2008). Contingent valuation is widely used in cost-benefit analysis and environmental impact assessment, although it has been the target of a broad range of criticism towards validity and reliability (Venkatachalam, 2004).

There are inherent weaknesses and strengths in both approaches. In the context of health effects of noise pollution around airports, the main advantage of the hedonic pricing method (HPM) is that actual behavior of consumers in the housing market is observed, whereas the contingent valuation (CV) method is based on statements on the willingness to pay for of a chosen sample. A critique on CV is that the hypothetical WTP might be higher than the real WTP. A weakness of HPM is that the price of noise has to be calculated at an expense of modeling assumptions (Bjørner et al. 2003). Imperfect information is another problem within HPM studies (Delucchi et al. 2002). Furthermore hedonic pricing usually values environmental impacts on humans (noise, air pollution) but basically leaves out non-use values such as existence values of environmental amenities.

2.2 Benefit transfer

In many planning efforts, it is not feasible to conduct primary valuation studies due to budgetary constraints. Benefit transfer might therefore seem to be an economical alternative. The general idea of benefit transfer is that parameters or results of valuations obtained at study sites can be transferred to policy sites (Nellthorp et al., 2007).1 Environmental value transfer is mainly transposition of estimated values on one study site, valued by market-based and non-market based economic valuation method, to another. Considerations on cost-effectiveness are the most important reason for the further use of previous research results. Using already existing calculated results is therefore an attractive alternative due to time and resource consuming original research (Brouwer, 2000).

The application of environmental value transfer ranges from water quality improvements (Barton, 2002; Bliem et al., 2011), air quality (Rozan, 2004), and health-risk reductions (Brouwer & Bateman, 2005) to airport noise nuisance case studies (Johnson & Button, 1997).

[1] For overviews of benefit transfer see e.g. Wilson and Hoehn, 2006; Lindhjem and Navrud, 2008.

Basically, there are two approaches, namely unit value transfer and function transfer. The former can be subdivided into simple unit transfer and unit transfer with income adjustments, the latter into benefit function transfer and meta-analysis. Simple unit transfer is the easiest form, assuming that the same utility (and disutility) can be experienced on study and policy sites so that directly transferring the mean benefit estimate is possible. This approach is not feasible for transfer between countries, which differ in income levels, standard of living, and regulatory and economic frameworks. Consequently, unit transfer with income adjustments (e.g. purchase power parity) as an alternative has been established. By transferring entire benefit functions, more information is transferred effectively. Problems occur due to the limitations of observations from only one study or a small number of sites, especially in the exclusion of variables and in the demand as well as in the bid function (Navrud, 2002). A way of assessing different outcomes of different studies is meta-analysis, a statistical analysis of empirical findings. Based on average or global data, meta-analysis generates a value function (Brouwer, 2000). However, in most studies of benefit transfer, even with very similar conditions at the study and policy sites, substantial differences in values still remain unexplained.

Various problems arise in transferring benefits from study to policy sites. Benefit transfers can be applied within and between regions, as well as between countries. Generally, when conducting benefit transfer, it is more likely that the valued good and the population affected will be similar, the closer the study site is to the policy site in terms of geography and socio-political context. In transferring values internationally, especially issues regarding currency conversion, the variation in measurable characteristics (e.g. income) and the complex quantification of differences in culture and shared experiences are relevant (Ready & Navrud, 2006). Rosenberger and Stanley (2006) differentiate between three potential sources of error within benefit transfer. (1) Measurement error results from judgements and assumptions of the underlying primary studies. (2) Generalization error is inversely related to correspondence between study and policy sites. (3) Publication selection bias eventually refers to selection criteria for research results and that the chosen empirical literature cannot represent an unbiased sample of evidence.

Monetarization of aircraft and airport related noise nuisance has gained high interest and stimulated a continuing debate in the scientific community. Case-specific studies, deploying revealed and stated preference methods have produced several insights and results. However, broad use of diverse approaches and techniques implies many difficulties for benefit transfers. On the one hand different theoretical assumptions of stated and revealed preference methods aggravate possible benefit transfers, which are reflected in inherent limitations in terms of general applicability. The disparity of values resulting from the use of the two methodological groups per se as well as within the methods is more problematic (Johnson & Button, 1997).

3. Empirical evidence: Economic values for air traffic noise pollution

Aircraft noise is supposed to produce a variety of economic and psychosocial effects (see in detail the section 2.4 below on health effects). Exposure to noise may affect quality of life and environmental amenity, performance and property values (S. Morrell et al., 1997). The analysis of the relationship of this environmental impact on housing prices is a common methodology and can be examined in different ways.

Noise can be defined as unwanted or undesirable sound and is perceived as an environmental stressor (Stansfeld & Matheson, 2003; Haralabidis et al., 2008). Noise is typically measured by decibels (dB), a measure of the intensity of sound pressure levels. This logarithmic scale is weighted by the frequency sensitivities of the human ear referred to as A-weighting. The scale ranges from 0, the human audibility threshold, up to 130, the pain threshold. Noise exposure levels above 40 dB(A) have an influence on individual's well-being and levels above 60 dB(A) are associated with health problems. On this scale everyday noise ranges from 45 dB(A) to 115 dB(A). Road traffic causes noise levels of over 55 dB(A), and 32% of the European Union population is permanently exposed to this kind of noise pollution. Airport and air-traffic noise exceeding 55 dB(A) affects three million people in the European Union. Airport noise is therefore the second most important source of noise nuisance (Barreiro et al., 2005).

In order to study economic impacts and the perception of noise definition and measurement techniques are required. A variety of measures for aircraft noise can be distinguished. The "noise exposure forecast", the "noise and number index" (NNI) and "annual energy mean sound level" (Ldn) have been three standard measures (McMillen, 2004). Data on noise exposure has been difficult to compare because of different national noise indices and noise standards (Nijland & van Wee, 2005). In Europe the NNI measuring the amount of noise incidents and their maximum levels throughout a day and aggregating it into a statistic, has been substituted by the Leq (Boes & Nüesch, 2011). "Leq" means "level of equivalent sound" and measures the summation of energy or number of noise events, the levels of exposure to and the time average of sound over a certain period (Bell, 2001). The day-night level (DNL or Ldn) describes the equivalent sound levels over a 24 hour period. Nighttime noise levels are increased by an adjustment factor of 10 dB (A), reflecting the higher disturbance compared to day-time noise exposure. Similarly to Ldn a day-evening-night level Lden is used with a different adjustment factor of 5 dB (A) for evening noise (Passchier-Vermeer & Passchier, 2000). While the valuation methods have remained almost unchanged over the last two decades the development of methodologies concerning noise measurement as well as the linkage of noise and annoyance has proceeded (Rich & Nielsen, 2004). According to the hedonic pricing method, findings of these studies are often presented in terms of the "Noise Depreciation Index" (NDI), which is also known as "Noise Depreciation Sensitivity Index" (NDSI). This measure defines the average house value decrease, when it comes to a 1 dB increase in aircraft noise (Dekkers & van der Straaten, 2008). In the monetary valuation of airport noise the choice of a certain threshold value, other noise sources and the accessibility to the airport need to be taken into consideration (Lijesen et al., 2010).

3.1 Hedonic pricing

In a recent study Dekkers and van der Straaten (2008) include aircraft, railway and road traffic noise in their hedonic study on housing prices around Amsterdam Airport Schiphol (for a summary of empirical studies see Table 1). A threshold value of 45 dB (A) is chosen due to the assumption that aircraft noise nuisance is perceived more disturbing than other noise sources. Data on house prices and date of sales (period 1999-2003) as well as structural housing characteristics are collected. Aircraft noise is computed by modeled flight paths, covering an area of 70 by 55 kilometers for the 2002-2004 period and of 55 by 55 kilometers for the 1999-2001 period. As a result aircraft noise has the largest effect on house prices with a stated NDI of 0.77, which means that a 1 dB (A) increase in aircraft noise leads to a decrease in average house values of 0.77%. In this analysis aircraft noise is assumed to be a continuous variable. Therefore the marginal benefit curve is a continuous function and easier comparable with the marginal cost curve. The marginal and total benefits of aircraft noise reduction are determined. Based on regression results the marginal benefit of 1 dB noise reduction amounts to €1,459 per house. Using an interest rate of 7% (comprised of 4% basic interest and 3% risk compensation) a marginal benefit of noise pollution reduction of €102/dB/house/year is calculated. This brings about an annual total benefit of 1 dB noise reduction of €574 million around the airport examined. In addition the authors emphasize the dependence of the marginal WTP for noise reduction on income, other household characteristics and preferences for environmental quality.

Ahlfeldt and Maenning (2007) also analyze land values in Berlin based on a hedonic model. The empirical results show that areas within the Tempelhof air corridor sell at approximately 9% discount due to noise pollution, while no significantly negative impacts are ascertained for Tegel Airport.

Cohen and Coughlin (2008) use a hedonic price approach including spatial effects to identify the impacts of noise on residential housing prices near Hartsfield-Jackson Atlanta International airport, often referred to as the world's busiest passenger airport. For the analysis two data sources are combined. The noise contour map for the airport's surroundings and sale price data of single-family dwellings including detailed housing characteristics, both for the year 2003, are used. The dwellings are located in and near the noise boundaries. Houses in areas exposed to a day-night sound noise levels of 70-75 dB sell for 20.8% less than houses in areas with a noise level below 65 dB. However, no statistically significant relationships between the effects of noise at this airport on the property values of the small city of College Park can be found, as Lipscomb (2003) shows.

In a case study of Winnipeg International Airport, covering sales data of 1,635 single detached houses an NDI estimate of 1.3 for 1985/1986 is detected (Levesque, 1994). Uyeno et al. (1993) distinguish between detached family houses, condominiums and vacant land in their hedonic analysis for Vancouver International Airport in 1987. The computed NDSI is 0.65 for detached houses and 0.9 for condominiums. For vacant land they find a statistically significant difference, implying an even higher impact compared to the other categories.

In contrast to other study results Pennington et al. (1990) cannot find a statistically significant noise impact from Manchester International Airport in the period 1985-1986, taking relevant neighborhood and house characteristics into account. Pommerehne (1988) compares the application of the hedonic technique and contingent valuation method to assess aircraft and road noise impacts for the city of Basle. A sample of 223 dwellings are analysed, including single and multi family houses, sole residential houses and houses with commercial and residential use. In the case of aircraft noise a mean WTP of 22.3 SFr per household/month for the hedonic analysis is found to reduce noise.

The impact of noise and air pollution on rents in Geneva is analyzed by Baranzini and Ramirez (2005). Three different databases are included in the analysis; a geographical information system, statistical data on the Geneva rental market and environmental data stemming from the "Geneva cantonal office for the protection against noise". Their results cover values for numerous sources of noise with separate results for airport noise, distinguishing between public and private sector tenants, and day (Ld measure) and day-evening-night noise levels (Lden measure). In the private rental sector the property price impact in terms of Ld per additional 10 dB(A) is 6.6%, while rents in the public sector are about 8% lower. Considering Lden for the airport area an impact of approximately 12% per additional 10 dB(A) is observed. Summarizing the results, with an impact on rents of about 1% per additional dB(A) the effect of airport noise is slightly higher than the impact of other noise sources of 0.7%.

Hedonic pricing and spatial econometrics are combined by Salvi's (2008) study on property values for Zurich Airport area. A data set is used, which includes the average aircraft noise emissions measured by different Leq metric variants. The choice of a threshold of 50 dB(A) for the noise contour zone and a second data set of 3737 single-family homes (included in the final sample) sold between 1995-2005 in the Canton of Zurich lead to a NDI of 0.97.

The research of Espey and Lopez (2000) also takes the impact of proximity to the airport on property values into account. A random sample of 1,417 single-family, owner-occupied houses of different census tracts near the airport is drawn and structural and environmental characteristics of these homes are collected. Data on noise is provided by annual noise exposure maps, which include the noise contours for the 65, 70 and 75 Ldn noise areas. Their hedonic analysis indicates that houses in areas with noise levels of 65 dB and above sell for approximately 2.4% less than homes located below this threshold. Contrary to earlier empirical findings, proximity to the Reno-Sparks airport can be treated as a disamenity with a value difference of 2.6% for equivalent houses one versus two miles apart from the airport. McMillen (2004) observes house transactions for single-family houses and assessment data in 1997 for Chicago O'Hare Airport, focusing on an area covering a 2 mile band of the defined noise contour line. The values of houses near the airport subject to noise levels from 65 dB are about 9% lower than comparable houses in less noise polluted areas.

A broader approach is used by van Praag and Baarsma (2005) who try to value noise pollution and value depreciation around Amsterdam Airport by means of an extended hedonic method, integrating subjective questions about well-being and happiness into their model.2 An equation is estimated, defining happiness as a function of household income, age, family size, noise perception and presence of noise insulation. Income and percentage change in noise levels are determining factors of the shadow price. Moreover this work has stimulated the discussion about adequate monetary compensation schemes for aircraft noise nuisance. Lijesen et al. (2010) transfer the results of the above-mentioned study from the Dutch noise index Ku (Kosten Unit) into dB values. The monthly WTA of an increase in noise exposure from 53 dB to 55 dB of a household with a net income of €1,500 per month equals 2.24%, a further rise in noise from 55 dB to 58 dB is 1.58% of household income.

In their survey on noise nuisance around Amsterdam Schiphol Airport the results of Lijesen et al. (2010) indicate that aircraft noise has the largest impact on housing prices, followed by rail and road traffic noise. Data on housing sales (1999-2003) and characteristics, variables on

[2] Recently the use of these happiness surveys has become more important in welfare economics, since happiness indicators can reflect (personal) welfare more accurately than income (cf. e.g. Layard, 2006; Bruni, 2007; Frey, 2008).

the housing environment (for example population density, distance to the next railway station) as well as transport noise sources are included. The calculated NDI is 0.8, i.e. a 1 dB decrease of noise leads to an increase of house values of 0.8% corresponding to an average value increase of €1,880 per household. Projected for the entire region of the analysis, a reduction of noise by 1 db (A) means a total benefit of €574 million.

Lu (2011) evaluated employment effects and the social costs of noise and aircraft engine emissions at the Taiwanese Taoyuan International Airport. For the estimation of annual noise costs an average NDI of 0.6 is assumed, accounting for the number of residences in each noise zone of the noise contour and the annual average house rents. These aggregate costs are allocated to individual flights on the basis of the marginal noise nuisance of the incremental effect of an extra flight on the day-night sound level. Total annual noise costs of approximately €12 million are estimated for the year 2008.

Jud and Winkler (2006) combine hedonic and event study models to assess the announcement effect of a new airport hub at Greensboro airport in North Carolina on housing prices. Noise is correlated with several property market aspects like traffic congestion and air pollution. Separating noise from other determinants of property values is considered problematic by the authors. They emphasize that the ex post perspective of most studies – in other words after the property market has adjusted to the increased noise exposure level – has to be seen critically. The announcement effect of an increase in noise intensity and frequency due to airport expansions is therefore focused. While no actual noise changes can be observed using this combination of methodologies, the announcement of significant change in airport traffic is assumed to be related to airport proximity and affects surrounding properties. The sample is drawn from housing sales occurring from 1997-2004, focusing on the change in property values prior and post the announcement, but before the construction or operation of the new airport facility. Within a 2.5 mile band around Greensboro airport the noise discount was 0.2% before the announcement, compared to a decrease of housing prices of 9.4% afterwards. Thus, a 9.2% increase in the discount is made out following the announcement. The difference in values of properties located more distant (within a 2.5- 4 mile band) to the airport decreases by 5.7%, comparing the noise discount of 2.7% before and 8.4% after the announcement.

Another event study (Pope 2008) focuses on the impact of a noise disclosure in the housing market surrounding Raleigh–Durham International Airport in North Carolina, highlighting the problem of information asymmetry between sellers and potential buyers. The airport authority sent a notification letter and a noise contour map to all homeowners living in 55 to 70 dB noise zones around the airport as well as to real estate agents. The primary data used are single-family house transactions between 1992 and 2000 in Waker County North Carolina. Only the sales of house within the defined noise zones requiring disclosure and within a one mile buffer zone around this area, serving as a kind of natural control group, are included in the analysis. Controlling for spatial and temporal confounders, a further decrease in residential property values of 2.9% in the zone of severe noise exposure (65-70 Ldn) is made out, while no effect of the noise disclosure on house prices in low noise areas can be observed. This study demonstrates that the availability of information for buyers has a potential impact on the implicit price of airport noise. One possible explanation is that there was a lack of information prior to the disclosure and that the estimated marginal value of airport noise is affected by the information status.

Study	Location	Date of Price Observation	Valuation technique	Empirical findings
Lu (2011)	Taiwan Taoyuan International Airport	2008	hedonic pricing	average NDI 0.6
Lijeson et al. (2010)	Amsterdam	1999-2003	hedonic pricing	NDI 0.8
Dekkers/ van der Straaten (2008)	Amsterdam Schiphol	1999-2003	hedonic pricing	NDI 0.77
Cohen&Coughlin (2008)	Atlanta	2003	hedonic pricing	noise discount of 20.8%
Salvi (2008)	Zurich	1995-2005	hedonic pricing/ spatial econometrics	NDI 0.97
Pope (2008)	Raleigh–Durham International Airport	1992-2000	hedonic pricing/ event study	price discount of 2.9%
Ahlfeldt& Maenning (2007)	Berlin Tegel/ Berlin Tempelhof	2005	hedonic pricing	noise discount of 9%
Jud& Winkler (2006)	Greensboro Airport	1997-2004	hedonic pricing/ event study models	noise discount of 9.2% noise discount of 5.7%
Baranzini& Ramirez (2005)	Geneva	2003	hedonic pricing	discount on rents of 1% per dB(A)
Nelson (2004)	US/ Canadian Airports		meta-analysis of 20 hedonic pricing studies	NDI 0.51-0.67 NDI 0.8-0.9
Schipper (2004)/ Schipper et al. (1998)	US/Canada/ UK/ Australia		meta-analysis of 19 hedonic pricing studies	mean NDI 0.48
McMillen (2004)	Chicago O`Hare	1997	hedonic pricing	noise discount of 9%
Lipscomb (2003)	Atlanta	1997-2000	hedonic pricing	statistically insignificant
Espey&Lopez (2000)	Reno-Sparks Airport	1991-1995	hedonic pricing	noise discount of 2.4%
Levesque (1994)	Winnipeg	1985/ 1986	hedonic pricing	NDI 1.3
Uyeno et al. (1993)	Vancouver	1987	hedonic pricing	NDI 0.65 for detached houses, NDI 0.9 for condominiums
Pennington et al. (1990)	Manchester	1985/ 1986	hedonic pricing	statistically insignificant
Pommerehne (1988)	Basle	1983/ 1984	hedonic pricing	mean WTP 22.3 SFr

Table 1. Summary of hedonic pricing studies

Nelson (2004) considered the relationship between airport noise and property values in terms of NDI estimates. The author conducts a meta-analysis of 20 hedonic property value studies for 23 US and Canadian Airports, covering 33 NDI estimates. The effect of airport noise on US housing prices is 0.51-0.67% per additional decibel, while the noise discount amounts to 0.8-0.9% for Canadian property values. Another meta-analysis by Schipper et al. (1998) surveys 19 published and unpublished hedonic studies, providing 30 NDI estimates and finds a mean NDI of 0.48 for published works that include other price influencing factors (Schipper, 2004).

Table 1 summarizes the most relevant hedonic price studies; the NDI which may be transferred to other contexts than the ones of the respective studies since it is dimensionless seem to range from 0.48 to 1.3, with a broad average around 0.8 to 0.9.

3.2 Contingent valuation

Few stated preference studies on aircraft noise have been conducted (Navrud, 2004). Pommerehne (1988) uses both techniques for the valuation of noise impacts for Basle to validate the contingent valuation method and test the compatibility of the methods. Thus 223 households were not directly asked for their willingness-to-pay for a noise reduction by a half, but were told to be part of a large survey on environmental problems guided by the University of Basle. Information then followed, describing households about the possibilities of relocation to identical dwellings, located in areas where traffic noise is reduced by half and takeover of the associated moving costs by a special fund. Actual net rents and maximum tolerable increase in rents for the new dwelling were questioned, preventing strategic behavior and enhancing realistic decision-making by the households. The results indicate a mean WTP of SFr 32.3 per household and month in the case of aircraft noise.

Caplen (2000) uses a contingent valuation framework to examine the maximum willingness to pay (WTP) to prevent and minimum willingness to accept to allow an increase (by 10%) in the frequency of aircraft flights for Southampton International Airport. Focusing on the southern end of the runway, the study was completed in 1998. The sample consisted of 150 questionnaires and 116 were returned. For an increase in daytime-flights the author finds a mean WTP of £3.35 and a mean WTP of £9.11 for an increase in night-flights.

Marmolejo Duarte (2008) tries to identify the marginal value of quiet by evaluating the acoustical impact of Barcelona’s airport expansion. 309 respondents of this contingent valuation survey stated an averaged WTP of €8.95 per person and month. Feitelson et al. (1996) discuss the impact of aircraft noise succeeding airport expansions on the WTP for residences. Home owners and tenants near a major hub airport are asked in a telephone survey for their WTP for residences without aircraft noise disturbance and then questioned for their WTP, when the same residence is exposed to various noise levels, measured in Ldn. In comparison to residences without any noise exposure the difference of valuation for those properties subject to severe and frequent noise is 2.4-4.1% of the housing prices per Ldn and for tenants this noise premium is 1.8-3.0% of the rent per Ldn. Noise can be seen as multi-attribute-externality and the results reveal that the WTP structures of households are kinked, which means that at a certain threshold of noise nuisance the households are unwilling to pay anything for the residence. The following Table 2 summarizes and provides an overview of the existing recent empirical works.

Study	Location	Valuation technique	Empirical findings
Marmolejo Duarte (2008)	Barcelona	contingent valuation	averaged WTP of 8.95€/ person/month
Caplen (2000)	Southhampton	contingent valuation	mean WTP £3.35/ month day-time flights mean WTP £9.11/ month night-time flights
Feitelson et al. (1996)	major hub airport	contingent valuation	noise discount of 2.4-4.1% of housing price per Ldn; 1.8-3% of rent per Ldn
Pommerehne (1988)	Basle	contingent valuation	mean WTP 32.3 SFr

Table 2. Summary of contingent valuation studies

3.3 Epidemiological studies: Health impacts and long-term health effects of chronic aircraft noise exposure

Noise related health effects can be distinguished into auditory and non-auditory, with the latter being further subdivided into socio-psychological and physical effects. There are sleep disturbance, disturbance in performance and daily activities, annoyance and mental health problems (fear, depression, frustration) and stress-related physical phenomena (Health Council of the Netherlands [HCN], 1999). Noise exposure directly causes physiological responses such as increased blood pressure and heart rate. Chronic noise nuisance may aggravate these reactions and foster long-term and subsequent illnesses or symptoms. Noise provokes annoyance, if the exposed individual feels disturbed. The stated physical responses may be induced by annoyance reactions (Clark & Stansfeld, 2007). Annoyance is a central psychological factor within noise effect research (Quehl & Basner, 2006). Within this chapter, we focus on the non-auditory impacts of airport noise exposure.

Kaltenbach et al. (2008) conducted a selective literature review of epidemiological studies (period of 2000-2007) focusing on illnesses, learning disorders and annoyance resulting from aircraft noise. In residential areas an outdoor day-time noise equivalent noise levels of 60 dB (A) and night time exposure of 45 dB (A) are associated with an increase in incidence of hypertension. A level of above 45 dB (A) leads to a higher prescription frequency of blood pressure-lowering medication and so a dose-dependent connection to aircraft noise can be assumed. School children are affected particularly, because daytime outdoor noise exposure levels above 50 dB (A) result in relevant learning difficulties and disorders. Annoyance of affected population is also a pivotal factor. According to a study for Frankfurt airport, 25% of local residents feel highly annoyed at day-time continuous sound levels of 53 dB(A).

Jarup et al. (2008) assessed the relation of aircraft and road traffic noise respectively and hypertension by analyzing blood pressure measurements, health and lifestyle data of 4,861 residents near six European airports.3 Results indicate that the risk of hypertension is related to long term noise exposure, particularly for night-time aircraft noise exposure. A similar association is found for daily average road traffic noise produced in the airport surroundings.

[3] This work is part of the HYENA study (hypertension and exposure to noise near airports), a four year key action project on environment and health (2002-2006). For more information see: http://www.hyena.eu.com/

In a longitudinal study, Eriksson et al. (2007) analyze the relation of the incidence of hypertension and aircraft noise around Stockholm Arlanda Airport. Between 1992-1994 and 2002-2004 a cohort of 2,754 men was surveyed. Residential aircraft noise exposure was measured in terms of Leq and divided into categories with levels above a threshold of 50 dB (A). 2,027 men completed a follow-up examination and had no former treatment of hypertension and a blood pressure below 140/90 mm Hg at enrollment. Restricted to this sample, analyses result in the association of the risk of hypertension and long-term noise exposure. Accounting for confounders, the incidence of hypertension in middle-aged Swedish men in particular is associated with aircraft noise exposure. The impact of aircraft noise on general health status and use of medication for residents near Amsterdam Schiphol is analyzed by Franssen et al. (2004). A postal questionnaire was completed by 11,812 residents in 1996/1997, comprising questions about respiratory complaints, sleep disturbance, annoyance, general health status, medication use, residential satisfaction and perceived risk, covering an area of 25 km around the airport with noise exposure levels from Lden 50 dB (A). Late evening noise exposure is associated with the intake of non-prescribed sleep medication and sedatives. For vitality related health complaints, e.g. headaches or tiredness, an association is found. Results suggest that the general health status may be poorer and the risk for cardiovascular diseases is higher at aircraft noise exposure levels above 50 dB (A).

An association of prescription prevalence of cardiovascular and antihypertensive drugs and night-time noise exposure is determined, linking prescription data of 809,379 insured persons and noise data (threshold 40 dB (A)) in the vicinity of Cologne-Bonn Airport. Aircraft noise increases the prevalence rate of the stated medication, particularly in cases where a conjunction with anxiolytic medication is given (Greiser et al., 2007).

Knipschild (1977a) links the data of 6,000 participants of a community cardiovascular survey and aircraft noise exposure of Amsterdam Airport Schiphol. Respondents are divided into two subgroups, with the first group of residents exposed to an NNI (noise and number index) exceeding 37 and the second exposed to NNI in a range of 20-30. Comparing the residents of both noise zone subgroups, in areas exposed to higher noise levels the share of residents suffering from cardiovascular impairment is 50% higher. People living in areas with higher noise levels are more often in medical treatment for hypertension and heart trouble. The author finds that the prevalence of cardiovascular disease is higher in high noise areas. Therefore evidence suggests that cardiovascular disease and aircraft noise are related causally.

The frequency of consultation of general practitioners in high noise areas surrounding Schiphol airport indicates another association: 19 practitioners provided the data (diagnosis, drug use, age, sex, address) of all their patients of one week and it is shown that in areas exceeding NNI levels of 33 the total contact rate is higher (2-3 times higher than in areas with NNI below 20). Accounting for confounders (gender, age, socioeconomics), results indicate that aircraft noise leads to an increase in the contact rate with general practitioners for psychological and diverse psychosomatic problems (Knipschild, 1977b).

The association of medication use and aircraft noise is studied by Knipschild and Oudshoorn (1977). Two villages near Schiphol airport, one not exposed to noise and the other one exposed to differing noise levels (basically no noise exposure, from 1969 exposure levels above an NNI of 35 and in a last timeframe at 1973 only exposed to daytime noise exposure) by analyzing purchase data of pharmacies in the period of 1967-1974. While the drug consumption remained unchanged in the control village, the use of antacids on prescription and cardiovascular medication increased in the six year period to almost twice its initial amount in the noise exposed area. Due to a similar increase in the use of antihypertensive drugs it is concluded that aircraft noise is a risk factor for hypertension. The consumption of sedatives and hypnotics increased in the period of high noise exposure (1969-1972) and decreased when the government regulated night-time flights. Aircraft noise can be a causal factor for sleep disturbance and mental disorders.

For the analysis of the frequency of various illnesses and medication use respectively, data of questionnaires filled in by doctors and patients is evaluated by Vallet et al. (1999). In a comparison of 275 exposed and 374 non-exposed residents in the proximity of Roissy Airport, defined by national noise contours (French measure indice psophique), associations between the level of noise exposure and use of neuro-psychiatric, sedative, anti-ulcerous and anti-acid medication are identified after adjustments for socioeconomic criteria. Aircraft noise is therefore associated with anxiety as well as annoyance. In the noisier areas a significant increase in sick leaves can be observed. No significant correlation is found for an increase in blood pressure.

Another study examines the relationship of hypertension and community exposure to aircraft noise in the vicinity of Arlanda Airport, comprising two random samples of 266 residents in noise exposed areas in the airport's surroundings and another 2693 living in other parts of Stockholm. Individual characteristics are considered in a questionnaire, also accounting for history of hypertension. After adjusting for confounders (age, gender, smoking, education) the prevalence odds ratio for hypertension is 1.6 for residents exposed to energy averaged noise levels above 55 dB (A) and 1.8 for those with noise levels exceeding 72 dB (A). Aircraft noise may increase the risk of hypertension and therefore might be a risk factor for cardiovascular disease (Rosenlund et al., 2001).

Mental and physical effects on residents near Futenma and Kadena military airfields exposed to a range of Ldn levels of 55 to above 70 are surveyed by a self-reported questionnaire (7095 valid answers). Significant dose-response relationships are found for nervousness, depressiveness and vague complaints as well as in terms of respiratory, digestive and mental instability. With increasing noise levels these responses elevate (Miyakita et al., 2002). A recent Italian study tries to assess the impact on psychiatric disorders, comparing personnel interview data of 71 participants (aged 18-75) in the immediate vicinity of Elma's airport and of 284 subjects of a matched non-exposed control group. Noise is measured in distance to the airport terms and therefore statements about intensity of the exposure or noise-sensitivity are not feasible. However, higher lifetime prevalence rates for "generalized anxiety disorder" and "anxiety disorder not otherwise specified" are reported for the exposed residents, indicating a higher risk for anxietal syndromes (Hardoy et al., 2005).

The association between road and air traffic noise exposure (occupational and community) and blood pressure as well as ischemic heart disease has also been subject to a meta-analysis. Van Kempen et al. (2002) analyze 43 epidemiologic studies published in the period of 1970-1999, finding that aircraft noise is positively associated with cardiovascular medication, the consultation of general practitioners and angina pectoris.

Children are supposed to be vulnerable to environmental impacts like noise pollution particularly. The RANCH project aims to examine exposure-effect relations between chronic noise exposure and children's health and cognition. It is the largest study funded by the European Commission focusing on aircraft and road traffic noise, covering three European countries.4 Influences of air and road traffic on children's cognition and health status as well as on mental health are assessed within this framework. In a cross-national and cross-sectional survey 2,844 school children (aged 9-10) in the vicinity of three major airports of the Netherlands, Spain and the UK were surveyed. Data of noise contour zones and on-site measurements were also used. Questionnaires and standardized test were conducted in the classrooms, and additional information was collected from parents. For analysis, data was pooled and exposure-effect relationships were developed for the whole sample. Linear associations between aircraft noise exposure and impaired performance in reading comprehension and recognition memory were detected, while a non-linear association in terms of annoyance was identified. For the analysis of mental health status a "Strength and Difficulties Questionnaire" was utilized. Aircraft noise levels were classified in ranges from 30-77 dB (A). After full adjustment no association on children's overall mental health status in terms of conduct and emotional problems or prosocial behaviour were measured, but an association of aircraft noise and hyperactivity was identified (Stansfeld et al., 2005; Stansfeld et al., 2009).

The effects of noise exposure on school children living adjacent to London Heathrow Airport with respect to cognitive performance, stress responses and mental health were studied by Haines et al. (2001a). The comparison of the health status as well as cognitive performance of 340 children (aged 8-11) at four schools located in high noise exposure areas (defined by Leq exceeding 66 dB (A)) and four control schools in less exposed areas (Leq below 57 dB (A)), including questionnaires of 21 teachers and 284 parents, revealed several associations. Chronic exposure to high levels of aircraft noise was consistently and strongly associated with higher annoyance levels. The association of poorer performances in reading comprehension as well as long-term memory recognition may be an indication of possible cognitive function impairments related to aircraft noise. In terms of reading comprehension, the association could not be attributed to socio-demographic factors, noise annoyance or noise interference. With respect to mental health, no associations between noise exposure and depression, anxiety, hyperactivity and conduct problems could be established.

Haines et al. (2001b) analyze data of 451 school children (aged 8-11) attending 10 schools in West London areas with noise levels above Leq 63 and compared them to data of 10 control schools exposed to Leq levels below 57 dB (A)). They found associations regarding annoyance levels and impaired reading performance. Psychological morbidity and hyperactivity were weakly associated with aircraft noise, while no associations were confirmed in the spheres of memory, stress responses or attention.

Elevated psychophysical stress (expressed in rest blood pressure and concentrations of epinephrine and norepinephrine) as well as lower quality of life was determined for 9-11 year old children, comparing data of 217 children before and after the operation of a new Munich airport over a two year period. Children in quieter areas (Leq 55 after and Leq 53

[4] For more information on this project and further publications see http://www.wolfson.qmul.ac.uk/RANCH_Project/

prior to opening) were matched to those living in noisier surroundings (Leq 62 after and Leq 53 prior to the opening), using socioeconomic data. Quality of life was measured by KINDL index, including psychological, physical, social and functional daily life (G.W. Evans et al., 1998).

Van Kempen's (2010) conducted a cross-sectional study around Schiphol Airport on the association of transportation noise and neurobehavioral effects, 553 primary school children (aged 9-11) completed tests on reading comprehension, perceptual skills, attention, memory as well as motor system (in terms of paper-and-pencil tests and "Neurobehavioral Evaluation System" test) to assess cognitive performance. In addition a questionnaire on health and behavioural indicators and socioeconomic status was answered by the caregivers. In the case of aircraft noise, higher noise levels in the school and residential environment lead to a significant elevation of errors in more difficult tasks within the tests. Therefore it can be concluded that performance of less complex tasks is not susceptible to the impacts of noise.

A meta-analysis of 13 epidemiological studies on noise and blood pressure of children in urban environments published in the last 30 years focuses on methodological issues. Drawing general conclusions was impeded due to differences in study design, blood pressure and noise measurement as well as accounting for socioeconomic confounders. However, a tendency that aircraft noise is positively associated with children's blood pressure was indicated (Paunović et al., 2011).

Babisch and van Kamp (2009) carried out a meta-analysis, covering 20 studies referring to aircraft noise on the basis of commercial and 8 of military activity, whilst differentiating between effects on children and adults. In conclusion, no empirically supportable, generalized exposure-response relationship due to methodological and noise data difficulties could be ascertained, although there was sufficient evidence that an association between aircraft noise and the use of cardiovascular medication and blood pressure is existent

4. Implications for transferability of values and results

The current paper has reviewed and summarized the existing (empirical) literature on the economic effects of noise pollution around airports. Transferring these diverse results is not straightforward, but the review shows that there is a broad common ground on which conclusions for new policy sites can be drawn. Regarding property values, hedonic pricing studies as well as contingent valuation surveys are commonly used for the association of airport noise related impacts on housing values. Generalization and transferability are limited due to methodological differences between the studies. Especially the differing use of noise measures, noise contours and the individual national noise standards has impeded comparability of results. The choice of a certain noise threshold, referring to the complexity and of the definition of noise exposure, is crucial and aggravates comparability and transferability.

Another difference is the consideration of spatial confounders and variables on housing characteristics. Hedonic as well as contingent valuation studies have shown decreases in residential property values. There are only a few contingent valuation studies, so their general applicability might be limited. Nevertheless, results of both methodological approaches are dependent on theoretical assumptions, subjects, and areas, and there are also studies that cannot find statistically significant results.

Taking all arguments together, it is safe to assume an average NDI of around 0.8 to 0.9 with a range of 0.5 to 1.3. This means that property values decrease by 0.8 to 0.9% with a 1 dB(A) increase in noise levels, above a certain threshold of 45 dB(A). Socioeconomic factors, however, should be taken into account, bearing in mind that often residents of lower socioeconomic status live in noise polluted areas in the vicinity of airports.

We find that the NDI – even in the light of the manifold differences between the study sites – delivers measures robust enough to value properties around airports even without employing original (primary) research. Merely all studies find significant negative impacts of air traffic noise pollution on property values, in a comparable way. Conducting cost-benefit analysis for extensions or new construction of airports, together with science based noise maps, thus allows at least for computing a reasonable and robust range of total costs of noise pollution. The WTP studies reviewed support the hedonic pricing results, but are seemingly more context-dependent (i.e. influences by the study design and the survey technique).

Health effects by themselves are reported by epidemiologic studies, focusing on incidence, prevalence and risk of symptoms and certain illnesses. Evidence is available for effects on adults and children. Empirical findings differ in terms of study design, samples, methodological assumption, noise measures and adjustments of outcomes. Various associations on health related noise effects have been identified. Hypertension risk and incidence are associated with aircraft noise (Jarup et al., 2008; Eriksson et al., 2007; Knipschild & Oudshoorn, 1977). Risk for cardiovascular diseases increases with noise levels (Rosenlund et al., 2001; Knipschild, 1977a), in particular for night-time noise exposure (Greiser et al., 2007). There is also a link of the intake of sedatives and noise nuisance at night, which may be associated with negative effects on sleep quality (Franssen et al., 2004). In terms of mental health, associations between aircraft noise disturbance and the risk of long-term syndromal anxietal states are found (Hardoy et al., 2005; Vallet et al., 1999). Annoyance is related to airport noise, both for adults and children (Vallet et al., 1999; Kaltenbach et al., 2008; Haines, 2001b). Effects on children's health are primarily cognitive, as there are associations regarding reading comprehension and memory (Stansfeld et al., 2005; Stansfeld et al., 2009; Haines, 2001a). Stress and quality of life are affected similarly and there are also weak associations for hyperactivity as well as psychological morbidity (Haines, 2001b; G.W. Evans et al., 1998). Dose-response relations that explicitly link the dose or input variable (noise) and a specific response or outcome (health problem, symptom, illness) in a population are needed (Berry & Flindell, 2009), but significant dose-response functions are still not available for most health impacts.

Despite the bulk of evidence for adverse impacts on human health, there are also ambiguous findings. For example, van Kempen et al. (2006) investigated heart rate and blood pressure of school children within a cross-national RANCH framework and found an association between noise exposure at school and at home and blood pressure for the Dutch sample , but not for the British sample. Night-time aircraft noise changes do not have disturbing effects on sleep necessarily due to the adaption of residents to noise intrusions (Fidell et al., 2000).

Several studies are also considered with the association of perinatal influences of aircraft noise in terms of low birth weight and premature birth (e.g. Knipschild et al., 1981; Matsui et al., 2003; Rehm & Jansen, 1978). Due to methodological limitations and a lack of adjustments for possible confounders, conclusions cannot be drawn (S. Morrell et al., 1997; Amt für Gesundheit, 2008).

With respect to mental health, no direct association can be established due to operationalization difficulties basically, notwithstanding existing evidence for an apparent increased prevalence of anxiety and depression among residents living in airport surroundings (van Kamp & Davies, 2008). Most of the empirical works reviewed adjust their findings for socioeconomic and other health determinants, so this could be classified as an attempt to foster robustness of results.

Regarding the transferability of health effects, the studies exhibit significant negative health effects of air traffic noise pollution. For "policy sites" without original (primary) data, it is safe to assume similar health effects. For valuing these, however, it is important to assess the number of residents affects by certain noise levels, and value these, for instance, by treatment costs, or costs of the specific diseases. Usually, national frameworks for conducting cost-benefit analysis in the transport sector are well equipped with money values for these health effects. The current paper has to leave out a detailed discussion regarding adequate money values for these noise-related health effects. Under the assumption of fully informed households, discounted property values measured, e.g., by means of hedonic pricing may reflect the individual's assessment of health risks. Therefore, property values include the valuation of some of the health impacts around airports.

However, as many scientific studies have only recently established the linkages between noise and several health problems, it cannot readily be assumed that individuals indeed hold all relevant information to assign money values to health effects, and then incorporate these into property values. Thus, hedonic prices only reflect parts of the health effects, presumably rather nuisance than more serious problems such as reading difficulties of children, or high blood pressure. It has to be left open in the current paper which share of total health costs are reflected in hedonic prices.

5. Conclusion

The present chapter attempts to assess the economic impacts of various health impacts caused by noise pollution. International scientific literature and empirical findings are reviewed in order to assess evidence for potential health impacts of noise pollution in airport's surroundings and to analyze transferability of results.

Hedonic pricing studies reporting NDI estimates and noise discounts for residential property values, rents, vacant land and condominiums demonstrate decreasing prices in zones located in airport's vicinity. Resident's willingness to pay and willingness to accept changing flight times, frequencies and various levels of noise exposure reflect people's perception of noise as an environmental disamenity.

Demand for robust and statistically reliable correlations on the likelihood of health effects occurring under environmental noise levels is increasing, especially in terms of an adequate basis of decision-making for policy authorities. For the quantification and derivation of economic costs policy makers could use dose-response relationships (Berry & Flindell, 2009), which attribute environmental inputs like noise to a specified health related output variable.

In the light of expanding expenditures and further expected pressure for national health care systems, health effects fostered by increasing demand in the air transportation sector can be substantial.

Aircraft and airport activity related noise remains a concern in terms of public health. Further research is required to capture the complex correlation of airport related noise exposure and the effects on human health appropriately. Summing up, the detrimental effect of air traffic noise pollution on property values – reflecting only parts of economic values of health problems – is about 0.8 to 0.9% per dB(A) as the most relevant noise index. Negative health effects are well proven, however, the valuation of these much more depends on the regional, legal and socio-economic context of the concrete airport subject to economic studies.

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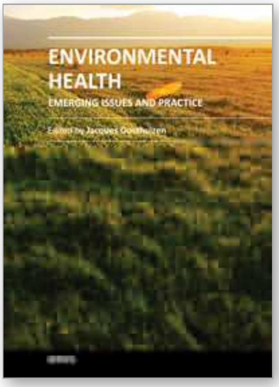

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Environmental health practitioners worldwide are frequently presented with issues that require further investigating and acting upon so that exposed populations can be protected from ill-health consequences. These environmental factors can be broadly classified according to their relation to air, water or food contamination. However, there are also work-related, occupational health exposures that need to be considered as a subset of this dynamic academic field. This book presents a review of the current practice and emerging research in the three broadly defined domains, but also provides reference for new emerging technologies, health effects associated with particular exposures and environmental justice issues. The contributing authors themselves display a range of backgrounds and they present a developing as well as a developed world perspective. This book will assist environmental health professionals to develop best practice protocols for monitoring a range of environmental exposure scenarios.