Determination and applications of environmental costs at different sized airports: aircraft noise and engine emissions

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Abstract

With the increasing trend of charging for externalities and the aim of encouraging the sustainable development of the air transport industry, there is a need to evaluate the social costs of these undesirable side effects, mainly aircraft noise and engine emissions, for different airports. The aircraft noise and engine emissions social costs are calculated in monetary terms for five different sized airports, ranging from hub airports to small regional airports. The number of residences within different levels of airport noise contours and the aircraft noise classifications are the main determinants for accessing aircraft noise social costs. Whist, based on the damages of different engine pollutants on the human health, vegetation, materials, aquatic ecosystem and climate, the aircraft engine emissions social costs vary from engine types to aircraft categories. The results indicate that the relationship appears to be curvilinear between environmental costs and the traffic volume of an airport. The results and methodology of environmental cost calculation could input for to the proposed European wide harmonised noise charges as well as the social cost benefit analysis of airports.

Keywords: environmental costs, airport operation, European Commission policy

1. INTRODUCTION

Over the years, increasing attention has been paid to the sustainable development of the aviation sector. More and more, environmental and social concerns are posing a severe limitation to the growth of the air transport industry. Although the global economic downturn and political turmoil has caused a decline in the number of flights and passengers over the past two years, these concerns remain valid.

It is now widely recognised that the costs of these externalities must be internalised and paid for by the aviation industry and its users [EC, 1999, 2001]. Two of the most important externalities generated from commercial flights are noise nuisance and aircraft engine emissions. From these two, noise nuisance has the largest impact on the community surrounding airports, while engine emissions have both local and global impacts.

Noise causes both nuisance and health effects, for instance sleep deprivation. More and more airports in the world, often forced by governments, have applied different types of noise management measures that range from noise abatement procedures to limits on the total noise allowed. Among these measures are night flight restrictions, night quotas, and noise charges and penalties. In 1999, only 10 out of the 27 enlarged European Union countries, Norway and Switzerland have some forms of noise charges [Lu, 2000]; in 2003 all 27 countries have noise related charges [Boeing, 2003].

Aircraft engine emissions have extensive impact on human health, vegetation, materials, ecosystem and the climate. Aircraft exhaust pollutants and CO_2 emissions cause damage during landing and take-off (LTO), ground stages and during cruise mode of flights. The latter is known as the only direct human-made source of pollution in the upper troposphere and lower stratosphere and results in global warming. Compared to the introduction of noise management measures, there are fewer airports applying engine emissions mitigation measures. In 1999, engine emissions charges are in place only at some Swiss and Swedish airports [Morrell and Lu, 2000]. In 2003, no other airports have introduced these charges [Boeing, 2003]. These charges are targeted only at local emissions; the International Civil Aviation Organisation (ICAO) is working on measures targeting on the emissions during cruise mode [ICAO, 1996, 1998].

This paper provides a framework in which the environmental cost of airports is assessed. The environmental cost consists of noise and emissions costs. The noise social cost depends heavily on the density of the population surrounding the airport, whilst, engine emissions vary according to the number of flights and the aircraft types used at an airport. The calculation of environmental costs can be used in various types of analyses. The methodology can serve as a common basis for the determination of unit noise charges in the noise charge calculation formula proposed by the European Commission [EC, 2001]. Furthermore, the results can be used to assess the environmental impact of airport expansion plans and traffic forecasts. The environmental costs can also be compared with the social and economic benefits of an airport in order to assess the relationship between the airport and the surrounding region, as to when growth of the airport would lead to more environmental cost than it would yield economic benefit.

This paper presents the methodology for calculating the noise and emission social costs. The empirical analysis is carried out for three British airports (London-Heathrow, London-Gatwick and London-Stansted airports) and two Dutch airports (Amsterdam Airport Schiphol and Maastricht Airport). Various applications of the environmental cost results are addressed and investigated. Conclusions are discussed in the final section.

2. NOISE SOCIAL COST ESTIMATION: METHODOLOGY AND MODEL

The hedonic price method, which is applied here for calculating the aircraft noise social cost, is based on the household equilibrium marginal willingness to pay. According to Lu and Morrell [2001] the hedonic price method is the most widely used method for the evaluation of noise social costs. It is used to extract the implicit prices of certain characteristics that determine property values. Examples are location, attributes of the neighbourhood and community, as well as environmental quality [Johansson, 1987; Nelson, 1980, 1981]. For this approach, however, it is necessary to assume that each individual has the same utility function, in order to obtain the unique price estimation for noise impacts [Pearce and Edwards, 1979].

By using the hedonic price method, the annual total noise social cost C_n is derived from the following formula:

$$C_n = \sum_i I_{NDI} P_v (N_{ai} - N_0) H_i \qquad (1)$$

Where I_{NDI} is the noise depreciation index (NDI) expressed as a percentage; P_v is the annual average house rent in the vicinity of the airport and $I_{NDI} P_v$ is the annual noise social cost per residence per A-Weighted decibel (dB(A)). The noise level above the ambient level is $N_{ai} - N_0$, where N_{ai} is the average noise for the i-th section of the noise contour; N_0 is the background noise or the ambient noise. This is finally multiplied by H_i, the number of residences within the i-th zone of the noise contour.

The NDI or the percentage reduction of house price per dB(A) above background noise, is derived from various studies using regression functions. The annual house rent P_v is converted from the average house value in the vicinity of the airport by the mortgage interest rate and the average house lifetime.

It should be noted that the noise level versus annoyance curve is in a form of non-linear relationship, the higher the level of noise, the increasingly greater annoyance [Finegold et al., 1994; Schultz, 1978]. Therefore, $I_{NDI}P_v$ in the formula (1) is adjusted by the noise versus annoyance function in order to reflect the real noise nuisance imposed on the residents surrounding the airport.

After calculating the aggregate noise social cost, the question leads to how to allocate this total external cost to individual flights. The principle of this process should be based on the real impact of noise nuisance on the residents, generated dynamically from each specific flight. The factors influencing the noise impact include aircraft types, engine types, time of a day, flight paths as well as landing and take-off procedures. According to the availability of the data during the research period, a simplified approach for deriving the marginal noise nuisance, caused by each specific engine/aircraft combination flight was developed [Lu, 2000; Swan, 1999].

3. ENGINE EMISSIONS SOCIAL COST ESTIMATION: METHODOLOGY AND MODEL

Differences in aircraft operation and engine types, emission rates and airport congestion are considered as important parameters influencing the damage level of pollutants. The air pollution at ground level resulting from the landing and take-off of flights is distinguished from the cruise level impact, the latter of which is not taken into account in the present paper.

The calculation of the engine emissions social cost is the opposite approach from calculating the noise costs. First, the social costs for individual aircraft movements with specific engine type and standard flight modes are derived, applying the unit social cost for each pollutant. Second, the annual social cost could be determined by summing across the annual aircraft movements and emissions inventory.

F_{ij}, the amount (kilograms) of the jth pollutant emitted during the ith flight mode, can be derived from the following formula:

$$F_{ij} = t_i f_i e_{ij} \tag{2}$$

Where t_i is the time spent during the ith mode (hours); f_i the fuel flow during the ith mode (kg/hr); e_{ij} the emission indices of the jth pollutant during the ith mode (kg pollutant/kg fuel). Equation (3) shows the calculation of C_{ek}, the social cost per flight for the kth engine/aircraft combination (€/flight):

$$C_{ek} = \sum_{j=1}^{6}\sum_{i=1}^{5} \alpha_i F_{ij} U_j \tag{3}$$

Where α_i is the weight for each mode (depending on the damage multiplier factor; for example 10 for cruise; 1 for the other phases of flight and ground movement, which means the same pollutant causes 10 times larger damage when emitted during cruise.); U_j is the unit social cost for the jth pollutant (€/kg). Five operational modes are calculated separately, which are take-off, climb-out, approach, taxi/idle and cruise. Finally the annual emissions social cost, C_e, is computed as follows:

$$C_e = \sum_k D_k C_{ek} \tag{4}$$

Where D_k is the total number of the annual aircraft landings for the kth engine/aircraft combination.

The unit social costs, U_j, are determined by Lu [2000] and are based on an extensive review of the literature [Levinson, et al., 1998; Eyre, et al., 1997; Perl, et al., 1997; Mayeres, et al., 1996]. In the literature, environmental costs are estimated in monetary terms; they are based on the relationship between pollution and damages on human health, vegetation, buildings, climate change and global warming. This method traces the links between air emissions and adverse consequences, considered as the best proved method for evaluating the social cost of emissions [Small and Kazimi, 1995].

Pollutants taken into account are HC, CO, NO_x, SO_2, CO_2 and N_2O. Since, except for Nox [Archer, 1993], there is no definite conclusion [IPCC, 1999; Peper, 1994] on the damage of pollutants emitted during cruises, only Nox is taken into account.

4. CASE STUDIES: DATA AND ASSUMPTIONS

Three British airports (London-Heathrow, Gatwick and Stansted airports) and two Dutch airports (Amsterdam Airport Schiphol and Maastricht Airport) are taken as the case studies for the empirical analysis. Based on the aircraft noise classification used at Heathrow Airport, aircraft types are categorised into 7 categories, with a representative aircraft type being selected for each of the categories, as shown in Table 1. The various aircraft types for different categories are listed in Appendix A.

TABLE 1 Aircraft categorisation

Category	Aircraft	Representive aircraft
1	Propeller aircraft	Jetstream 31
2	Chapter 3 jets: short haul	B737-300
3	Chapter 3 jets: wide-body twins	A310-200
4	Chapter 3 jets: 2^{nd} generation wide body multi-engines	B747-400
5	Large chapter 2/3 jets: 1st generation wide-body	B747-100F/200/300
6	2^{nd} generation twin jets: narrow body twins*	B737-200QN
7	1^{st} generation jets: narrow body multi-engines	B727

Note: including Chapter 2 and hushkitted versions.

Table 2 presents the aircraft movements by category in 2001 at these five airports. Heathrow has the highest number of aircraft movements, followed by Schiphol, Gatwick, Stansted and Maastricht.

TABLE 2 Aircraft movements by category

Aircraft category	Heathrow	Gatwick	Stansted	Schiphol	Maastricht
1	0.9%	5.4%	10.3%	3.8%	78.4%
2	69.8%	74.1%	69.7%	78.6%	16.2%
3	16.3%	13.8%	2.0%	6.2%	0.0%
4	10.1%	1.9%	1.8%	6.4%	0.0%
5	2.4%	2.9%	0.7%	4.6%	0.0%
6	0.1%	1.7%	15.2%	0.4%	2.7%
7	0.4%	0.2%	0.3%	0.0%	2.7%
Total movements	463,568	252,453	169,578	456,700	59,248

Source: UK CAA, 2002a,b,c; Schiphol Group, 2001 and Maastricht Airport, 2003.

Tables 3 and 4 show the number of residences within each noise contour zone, which is calculated using the fleet mix and number of movements in 2001. Different noise measurements are used in these two countries: Leq is used in the UK; Kosten Unit (KU) in the Netherlands. Heathrow has more than 100 thousand of residences living within 57 Leq noise contour; Schiphol also have around 122 thousand of residences live within the 20 Ku noise contour in the vicinity of the airport. The 57 Leq and the 20 Ku noise contours are the lowest noise levels measured. Although Maastricht has the least aircraft movements (Table 2), there are more residences affected by noise nuisance than those at Gatwick and Stansted (Tables 3 and 4).

TABLE 3 Residences within noise contour at Heathrow, Gatwick and Stansted airports*

Leq level (dBA)**	Heathrow	Gatwick	Stansted
>72	653	22	13
69~72	2,304	22	13
66~69	6,391	87	17
63~66	14,522	217	130
60~63	23,087	435	391
57~60	57,565	1,478	435
Total	**104,522**	**2,261**	**1,000**

Source: UK CAA, 2002a,b,c.

Note:

* The average persons per household (2.3), from the UK statistics office, are applied for converting affected population into residences.

** 51 Leq is used as the background noise level for the calculation in the next section. Note the number of residences within the noise contour 57 to 51 Leq is unknown. The inclusion of these would lead to higher noise social costs.

TABLE 4 Residences within noise contour at Schiphol and Maastricht airports

Kosten Unit (KU)*	Schiphol	Kosten Unit (KU)	Maastricht
>65	14	40~65	0
60~65	33	35~40	176
55~60	70	20~35	1,440
50~55	402	10~20	11,671
45~50	1,675		
40~45	3,358		
35~40	3,857		
30~35	13,539		

25~30	44,048		
20~25	55,634		
Total	**122,630**	**Total**	**13,287**

Source: Schiphol Group, 2002; Maastricht Airport, 2002.

Note: * 10 KU is used as the background noise level for the calculation in the next section. Note the number of residences within the noise contour 20 to 10 KU is unknown. The inclusion of these would lead to higher noise social costs.

The average NDI value concluded from a number of research papers is within 0.60-0.62% with Noise Exposure Forecast (NEF) as a noise descriptor[1]. KU used in the Netherlands ranges from 20 to 65 KU, which is 1.5 times the range compared to NEF's 20-50. Therefore, the NDI value is adjust to 0.40% for the calculation of noise social costs at Dutch airports. On the other hand, based on the narrower range of the Leq system, the NDI value is set at 1.00% for the UK airports. The average housing prices at the airport area are listed in Table 5. Table 6 presents the unit social costs for each of the pollutants from engine emissions.

TABLE 5 Housing prices in 2001

Airport	Housing price (€/residence)
Heathrow	260,394
Gatwick	230,130
Stansted	201,077
Schiphol	168,000
Maastricht	151,000

Source: UK CAA, 2002a,b,c; Schiphol Group, 2002 and Maastricht Airport, 2002.

TABLE 6 Unit social costs of pollutants from engine emissions

€/kg	HC	CO	NO_x	SO_2	CO_2	N_2O
Social cost	3.49	0.07	9.69	51.71	0.02	1.03

Source: Derived from the data listed in Lu [2001] and converted to the 2001 value.

[1] NEF (Noise Exposure Forecast), one of the cumulative noise event measures, reasonably varying between 20-50, was mostly used in the United States prior to the development of the L_{dn} index.

5. CASE STUDIES: EMPIRICAL RESULTS

The social costs calculation is based on the annual airport movements, the current fleet mix and the number of the residences annoyed, which means that the cost level varies as the endogenous or exogenous parameters are changed. For example, if airlines reduce the number of flights to an airport, or change the types of engines for some aircraft types, the annual number of movements from the airport will be lower and different levels of emissions are generated. The corresponding environmental cost is different in order to accurately and dynamically reflect the real social cost of aircraft emissions. Furthermore, if the characteristics in the vicinity of the airport changed, the cost level would vary correspondingly. For instance, the more noise insulation investment (recycling the charges collected), the less annoyance the residents would incur. In this case, even with the same number of flights, the perceived noise nuisance of the airport would be reduced.

5.1 Noise social costs

The calculation results of equation (1) for noise social costs at the current aggregate noise level are presented in Table 7. The noise social costs for different aircraft categories at Heathrow vary from €28 per landing for Jetstream to €3,007 for B747-100F/200/300/SP, with the weighted average of €774 per landing (or €387 per movement). The average noise social cost at Schiphol, although having similar aircraft movements to Heathrow, appears to be €377 per landing, less than half of that at Heathrow. On the contrary, Maastricht, with least aircraft movements, but situated in a more densely populated area, has higher noise social costs than Gatwick and Stansted.

5.2 Engine emissions social costs

The social cost of engine emissions has been calculated on the basis of assumptions on engine types and emission rates. These assumptions are necessary because of limitations in data availability and because further complexity in terms of using every actual aircraft/engine combination would not result in significantly greater accuracy. Therefore, substituting the related parameters and data in equations (2), (3) and (4) [ICAO, 1995], the average social cost per landing for each aircraft type is shown in Table 8. As the impacts of engine emissions are less airport-specific, the social costs for individual aircraft types are assumed the same for all five airports.

TABLE 7 Noise social cost by aircraft category (€/landing)

Category	Aircraft type	Heathrow	Schiphol	Gatwick	Stansted	Maastricht

1	Jetstream 31	28	14	1	1	14
2	B737-300	510	265	19	11	259
3	A310-203	831	431	31	17	422
4	B747-400	1,975	1,024	74	41	1,003
5	B747-100F/200/300	3,007	1,560	113	63	1,528
6	B737-200QN	2,035	1,056	76	43	1,034
7	B727	2,194	1,138	82	46	1,115
	Weighted average	774	377	25	16	111

TABLE 8 Engine emissions social cost by aircraft category

Category	Representative aircraft type	Engine emissions cost (€/landing)
1	Jetstream 31	43
2	B737-300	389
3	A310-203	952
4	B747-400	4,839
5	B747-100F/200/300	3,581
6	B737-200QN	448
7	B727	644

The figures in Table 8 include not only the social cost at the ground level resulting from the standard LTO procedures, including take-off, climb-out, approach and taxi-idle modes, but also the costs of the emissions from 30 minutes' cruise either prior to landing or following take-off. The engine emissions social costs rang from €43 to €4,839 depending on aircraft types.

It should be noted that NO_x is the only cruise emission included, due to the higher uncertainties of other emissions. If other pollutants were incorporated, the cost would be higher. Furthermore, the same unit social costs for each pollutant is applied to both ground level and cruise. However, it has been argued that the damage in the upper atmosphere might be 10 times higher than at ground level [INFRAS and IWW, 1995]. Therefore, the values presented in Table 8 could be considered as a conservative (lower) estimation.

5.3 Environmental costs

The environmental costs here are defined as the aggregation of both noise and engine emissions social costs. From Tables 7 and 8, the environmental costs for five airports are presented in Table 9 and Figure 1. The annual environmental social cost is calculated to be €645 million for Heathrow, followed by Schiphol (€471 million), Gatwick (€161 million), Stansted (€82 million) and Maastricht (€11 million).

TABLE 9 Average and annual environmental cost comparison

	Heathrow	Schiphol	Gatwick	Stansted	Maastricht
Average noise cost (€/landing)	774	377	25	16	111
Annual noise cost (million €)	179.5	86.0	3.1	1.3	3.3
Average emission cost (€/landing)	1,004	842	626	477	126
Annual emission cost (million €)	465.6	384.7	158.1	80.8	7.5
Average environmental cost (€/landing)	1,779	1,219	651	492	237
Annual environmental cost (million €)	645.1	470.7	161.2	82.1	10.8

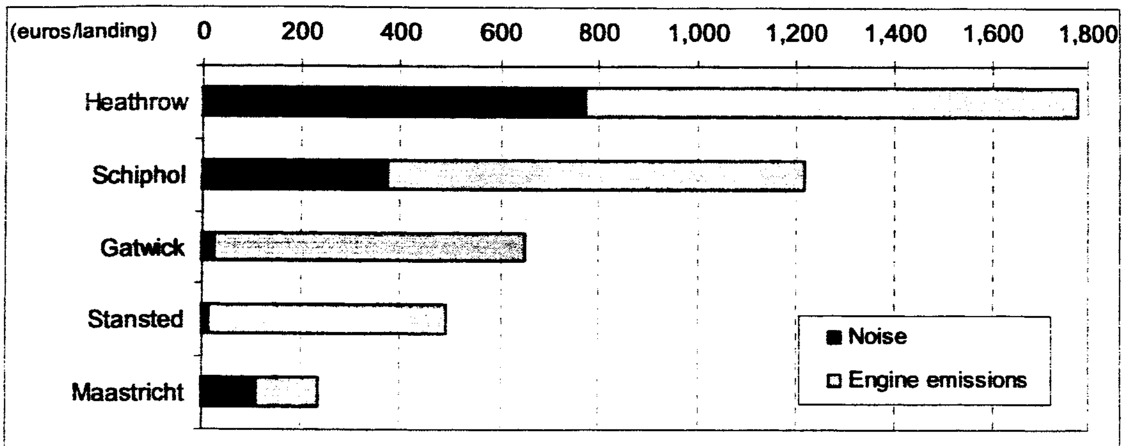


FIGURE 1 Average environmental cost comparison

Comparing the environmental cost with the traffic volume of an airport, the results for these five airports indicate that the relationship appears to be curvilinear between annual environmental costs and aircraft movements (Figure 2). This implies that the marginal environmental cost is increasing as aircraft movements increase. In other words, adding a certain amount of traffic to a hub airport would cause more environmental damages than that at a regional airport. Note that this comparison is only valid when the characteristics of airports are similar especially in terms of their surrounding neighbourhoods.

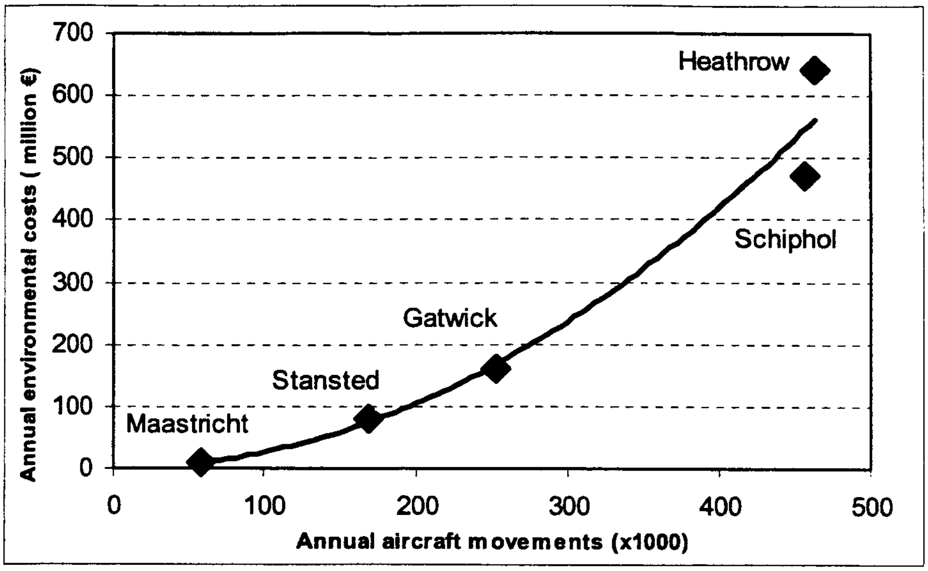


FIGURE 1 Relationship between environmental costs and aircraft movements

6. APPLICATIONS OF ENVIRONMENTAL COSTS

Next to showing the degree of the environmental impacts at various airports, several applications of this result and methodology are presented and discussed in this section. First of all, the methodology of calculating aircraft noise social costs can be used to determine the proposed European wide noise charge levels. Furthermore, the environmental costs valued in monetary terms can form the input of cost-benefit analysis of an airport or an airport system.

This section provides a brief overview of how the results can be applied. However, complete analysis of these applications is beyond the scope of this paper and requires further research. All these applications focus on the influence of an airport on the region and are to be seen from the perspective of a region.

6.1 European wide harmonised aircraft noise charges

One of the main objectives of the EU common transport policy is to promote the sustainable development of transport activities [EC, 1999]. The use of economic instruments is considered to be an efficient and effective way of improving the environmental performance of an airport [ICAO, 1996, 1998; OECD, 1998]. The EC's proposal for potential harmonised noise charges provides the possibility to modulate aircraft noise charges as a function of its environmental impact [ANCAT, 1998; EC, 2001]. This formula for calculating noise charges, C, is as follows [EC, 2001]:

$$C = C_a \cdot 10^{\frac{L_a - T_a}{10}} + C_d \cdot 10^{\frac{L_d - T_d}{10}} \qquad (5)$$

where:

- C_a and C_d are the unit noise charges at departures and arrivals for the considered airport. They reflect the relative importance of noise emissions at arrivals and departures for the impacted population.
- L_a and L_d are the certificated noise levels at approach, and flyover and lateral measurement points.
- T_a and T_d are noise thresholds at departures and arrival corresponding to categories of relatively quiet aircraft for the considered airport.

While the certificated noise levels and the noise thresholds are known, no common and transparent method has been developed for calculating the unit noise charges, namely C_a and C_d, at each of the European airports. The methodology of calculating noise social costs can be applied here by deriving the marginal noise impacts of different aircraft categories into a separate departure and arrival index.

Our method has taken into account various theoretical and practical aspects. Firstly, the calculation is based on both the certificated noise levels and the number of residences affected by noise, which is derived from the noise contours around airports. This implies that the methodology has fulfilled the condition that *'noise charges should be proportional to the incremental nuisance for human beings caused by individual aircraft separately at arrival and departure'* [EC, 2001]. In addition, the same approach could be practically applied to any airport, each with their own traffic and operational characteristics. Finally, for a preliminary analysis, the data needed to calculate the unit charges can be easily obtained for the majority of the European airports.

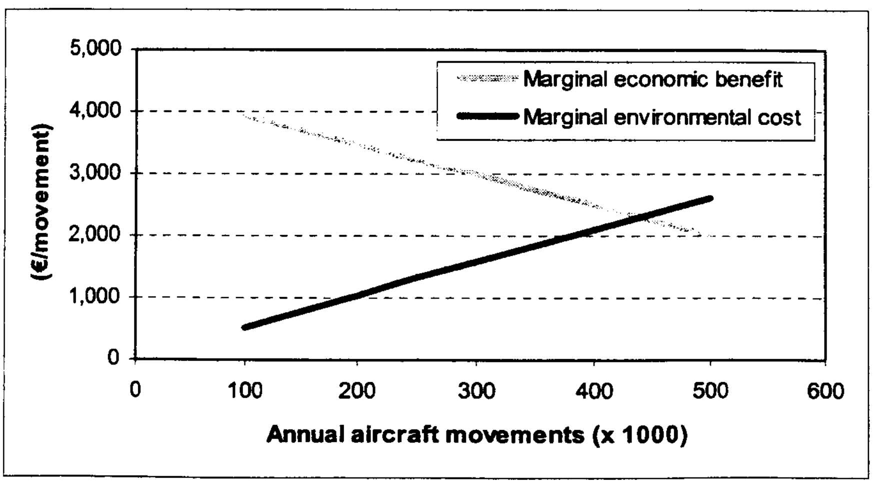
6.2 Cost-benefit analysis of an airport or an airport system

In the context of sustainability, an airport can only exist if it generates more social and economic benefits to the region or nation than its damages on human beings and the environment. Furthermore, an airport is operating most efficiently when its marginal social benefit is equal to its marginal environmental cost. Any movement beyond this threshold would result in more environmental damage than its generated benefit to the society. The same applies to an airport system. An airport system consists of a few hub and regional airports in a geographically close area[2]. If the hub airport has reached its threshold, any additional flight would be better allocated to other airports.

So far, the method has not been fully developed for quantifying the economic benefits generated from an airport for the region. However, the existing research indicates that an airport would generate approximately some 1,000 to 1,100 jobs per one million passengers [ACI, 1998]. This figure, however, does not include the social benefit of an airport (such as accessibility of the region and public obligation).

The following analysis is done by comparing the economic benefits of an airport, resulting from employment for the region, and their environmental costs for both noise and engine emissions. However, the precise added value of an airport should be evaluated by taken into account all possible influences of an airport on the local communities and the nation. Moreover, other factors, such as external safety and congestion, would also result in environmental costs.

Based on the estimation of the total economic benefits of the case study airports and their environmental costs, Figure 2 shows the marginal economic benefit and marginal environmental cost in relation to aircraft movements by using a regression analysis. This regression analysis has been done on all 5 airports, two of which are main hubs and three are other airports. It can be argued that a main hub airport and a different type of airport have significantly different characteristics, which makes a general analysis impossible. Due to the size of the sample, it is not feasible to split it and perform a separate analysis on the hubs and on the other airports. Notably, the analysis only serves as an illustration thanks to the limited sample size; no general conclusion can be drawn from here.



2 A good example is the London airport system, with five airports in the greater London area. Those are London-Heathrow, Gatwick, Stansted, Luton and City airports.

FIGURE 2 Economic benefit versus environmental cost

This figure shows that the marginal environmental cost is increasing as aircraft movements increase, while the marginal economic benefit is decreasing. The tentative results appear that the two curves intersect at approximately 450,000 movements per year. This is the level at which an airport is operating most efficiently with its marginal economic benefit equal to the marginal environmental cost. By expanding this analysis to include more airports and factors, policy makers would be able to determine the equilibrium of an airport system and to evaluate any investment or expansion of an airport.

7. CONCLUSIONS AND RECOMMENDATIONS

With the European Communities' policy of strengthening market incentives to improve environmental performance [EC, 1999], and the EC's proposal for a potential harmonised noise charges [ANCAT, 1998, EC, 2001], the assessment of the real social costs of those externalities is vital for those policies. The methodologies developed in this research paper for evaluating the social costs of both aircraft noise and engine emissions have been applied for different sized airports, each with their own traffic and operational characteristics.

Of all five airports, Heathrow Airport has the highest noise and engine emissions social cost which is the result of its large number of aircraft movements and high population affected by noise. With also high volume of aircraft movements and population, Schiphol, however, has lower noise and engine emissions social costs than Heathrow. Maastricht has higher noise costs than Gatwick and Stansted, but the least engine emissions costs. The environmental cost, aggregation of noise and engine emissions costs, is calculated to be €1,779 per landing for Heathrow, followed by Schiphol (€1,219), Gatwick (€651), Stansted (€492) and Maastricht (€237).

The calculation of environmental costs in monetary terms can be applied in a variety of analyses. The method can be used in determining the proposed European unit noise charges. The environmental costs can serve as an input for cost-benefit analysis of an airport and an airport system.

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APPENDIX A: AIRCRAFT CATEGORY

Category	Aircraft type	Category	Aircraft type
1	Small props	4	B747-400
	Large props		A340
			MD11
2	B737-300,400,500		
	B737-600,700,800	5	B747-100
	B757		B747-200 (Ch 2)
	BAe146		B747-200,300 (Ch 3)
	A319,320,321		DC10
	Business jet (ch 3)		Tristar
	CRJ Canadair Regional Jet		
	ERJ Embraer EMB 135/145	6	B737-200 (Ch2/3)
	F100		BAC-11, Tu134
	MD80		DC9
	MD90		Business Jet (Ch2)
3	B767-200	7	B707
	B767-300		B727 (Ch2/3)
	B777		DC8
	A300		Concorde
	A310		Tu154
	A330		VC10
			IL62