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Author(s):
Fröhlich, Philipp; Wittmer, Andreas; Weinert, Robert; Axhausen, Kay W.

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SUSTAINABILITY AND AIR TRANSPORT: ZURICH AIRPORT CASE STUDY

Philipp FROEHLICH, Verkehrsconsulting Fröhlich, Seestrasse 53, CH-8806 Bäch SZ, Switzerland, (froehlich@ig-modus.ch)

Andreas WITTMER, Center for Aviation Competence, c/o Institute for Public Services and Tourism, University of St. Gallen, Dufourstrasse 40a, CH-9000 St. Gallen, Switzerland, (andreas.wittmer@unisg.ch)

Robert WEINERT, Center for Aviation Competence, c/o Institute for Public Services and Tourism, University of St. Gallen, Dufourstrasse 40a, CH-9000 St. Gallen, Switzerland, (robert.weinert@unisg.ch)

Kay AXHAUSEN, Institute for Transport Planning and Systems (IVT), Swiss Federal Institute of Technology (ETHZ), Wolfgang-Pauli-Strasse 15, CH-8093 Zürich, Switzerland, (axhausen@ivt.baug.ethz.ch)

ABSTRACT

The research goal was to evaluate the environmental sustainability of Zurich Airport. The method used was to compare the environmental costs to the economic and social benefits generated by the airport. The analysis was completed on both the regional and global levels. The results show that Zurich Airport air transport generates more economic value than environmental and social costs.

Keywords: airports; air transport system; sustainability; case study; cost benefits study

INTRODUCTION

Mobility is a key driving force in the world economy. Almost all activities, from production and consumption to leisure and recreation, require transport – and increasingly air transport. The benefits of transport are manifold, and the interdependence between the economy, environment, society and transport is complex. Therefore, European transport policy (European Commission 2006) attaches great importance to transportation services and infrastructure.

In addition to its positive effects transport also has negative impacts. For example, air pollution and noise are negative impacts generating costs that must be borne by the economy and society. From the economic point of view, these negative impacts lead to direct costs such as costs of emissions control systems. From society's point of view, air pollution and noise are disruptive and cause health problems. From the ecological point of view, these impacts place a burden on the environment not the least of which is global climate change.

The existence of air transport benefits and impacts leads to the conclusion that there is a level of service where it is possible to balance the economic, social and ecological benefits and costs. From the perspective of sustainable development, the additional environmental costs resulting from the transport activity must be lower than the additional economic and social benefits gained from the transport activity. The focus of this article is to assess the sustainability of air transport in the Zurich region by comparing the economic benefits of air transport to its environmental impacts (e.g. air and noise pollution).

Several studies have examined Zurich Airport's regional economic importance. These show that the airport contributes significantly to the region's attractiveness as a prime business location in Switzerland, and that the airport has substantial spin-off benefits for the surrounding area (Infras 2006, Infras und Ecoplan 2008). This is consistent with other studies showing that airport proximity is a positive location factor and contributes to the prosperity of the region; these are especially true in small national economies (like Switzerland) that can profit from an international division of labor (Schips, Mosimann 2005). Often a country's economic center lies in the city near that country's largest airport – as is the case in Zurich.

An economic analysis of air transport in Switzerland can be based on a supply or demand perspective. Key variables for both perspectives include the airport's maximum airside (airspace and airport infrastructure) and landside (ground access) capacity. This article is based on the assumption that these capacity thresholds have not been reached at Zurich Airport. The maximum capacity of Zurich Airport lies in the range of 330,000 to 340,000 flight movements per year. The year with the highest number of movements was 2001 with 325,000.

The research is based on comparing the economic, environmental, and social marginal benefits and costs of three scenarios in order to evaluate the question of how changes in the number of flight movements would effect sustainable development of air transport in the Zurich region. The following three scenarios were examined:

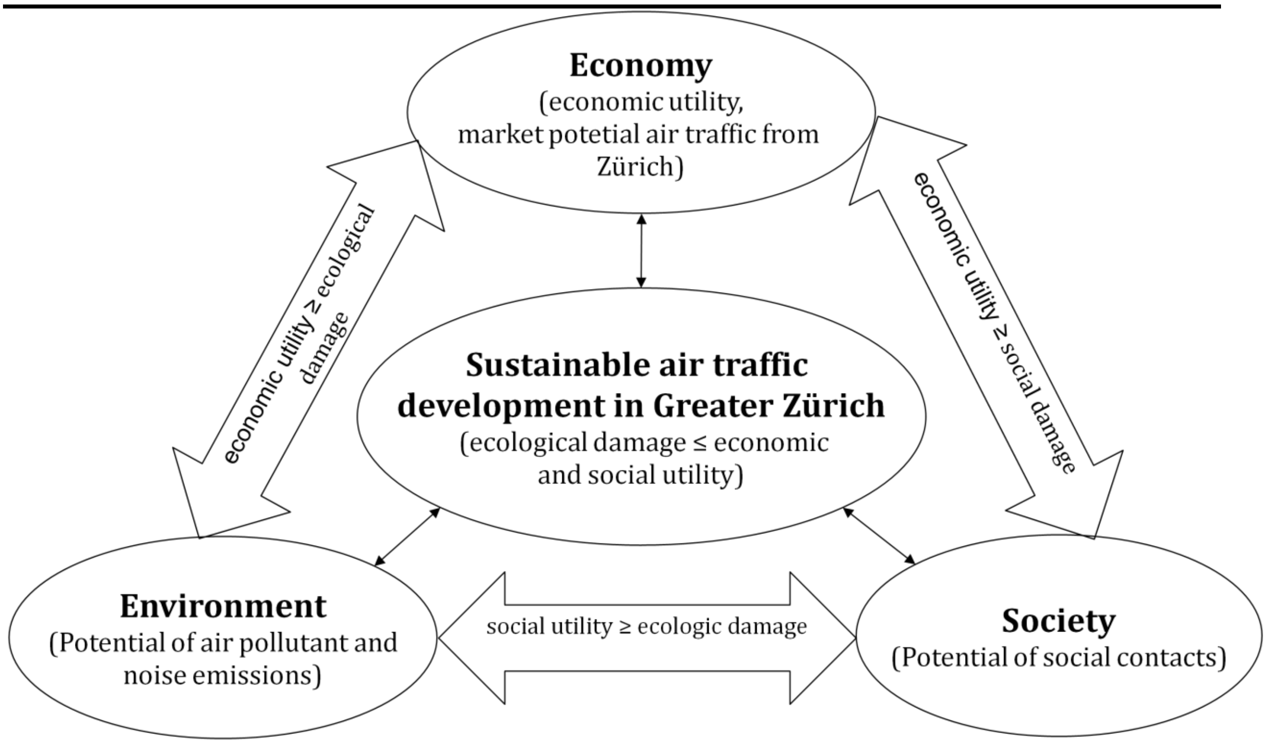
- **Status Quo Scenario:** This scenario is based on existing flight movement data (approximately 275,000 movements per year).
- **Growth Scenario:** This scenario assumes strong economic growth and increasing globalization leading to an increase in flight movements by +15% (to 320,000 per year).
- **Reduction Scenario:** This scenario assumes reduced economic growth and/or regulatory changes to reduce flights at Zurich Airport leading to a decrease in flight movements by -10% (to 250,000 per year). This scenario was the reality at the beginning of the year 2002 after the air transport crisis (e.g. SwissAir bankruptcy).

The next section of this paper describes the analytical framework used to evaluate the marginal costs and benefits of air transport service, the third section describes the data and analysis, and the final section presents results and conclusions.

ANALYTICAL FRAMEWORK FOR EVALUATING AIR TRANSPORT SUSTAINABILITY

Transport services are provided in complex interdependent system combining many different economic, environmental and social factors. The interdependence among these different factors has either positive or negative effects on sustainable development. Figure 1 illustrates in simplified form how these factors apply to the case of air transportation. The figure is based on the St. Gallen Management Model (Rüegg-Stürm 2004).

Figure 1: Impact of economic, environmental and social factors on air transport sustainability



Source: Wittmer, Fröhlich, Weinert, and Axhausen 2008

As illustrated in Figure 1, sustainable air transport is achieved when the different factors are well-balanced and one factor is not impacted too heavily by another. More precisely the question becomes: do the long-run social and economic benefits of air transport outweigh the social, economic and environmental costs?

A key element in assessing sustainability is defining the system: the physical area in which impacts and benefits will be evaluated. This is important because different weights will be assigned to different factors depending on the territorial level where the factors are being assessed (BAZL 2008). There are three standard assessment areas used in this type of analysis: local, national and global.

A local analysis considers the area around the specific airport as a catchment area for workplaces and as a residential area. A national analysis focuses on economical contributions and the internalization of external costs. A global analysis focuses on the international perspective and is concerned with the primary conflict between international competitiveness and global climate impact (BAZL 2008).

This research considered the local perspective, defined as the area within the Zurich Airport landing and take off (LTO) cycle, and also the global perspective. For the global perspective analysis all the emissions generated by the aircraft is assigned to the origin airport. An important point to consider in defining the system is the fact that airport decision-makers generally focus on local level benefits and costs when analyzing airport sustainability because it has a direct influence on the political process. This is particularly true in countries such as Switzerland with well developed systems of direct democracy.

The dominant marginal costs for air transport are air pollution and noise (Laesser 1996, Wittmer et al. 2008) while the dominant benefit is the external marginal utility for people living and working in the airport catchment area. The next section describes these costs and benefits in more detail and presents data for the Zurich Airport area.

MARGINAL UTILITY AND MARGINAL COSTS

Economic Utility of Transport

This research evaluates the economic marginal utility of increased and decreased aircraft movements at Zurich Airport by calculating the travel time changes compared to those based on the 2007 level of aircraft movements. The travel time changes for passengers, weighted according to demand, can then be described monetarily. Next, this monetary value can be compared to the environmental costs. Finally, it should be noted that the social benefits (social utility) of air transport were considered in connection with the travel time savings.

This section begins with a background description of accessibility and then presents the details on how the marginal utility of travel time changes was estimated in this research.

Accessibility

Accessibility on the one side concerns the generalized costs, i.e. the weighted sum of the individual characteristics of the connections, and on the other side the quantity and quality of the possible destinations.
Accessibility is thus understood as the sum of the weighted opportunities that can be reached from a defined origin (for example a city). Since Lill (1889) it is known that the attractiveness of a destination declines exponentially as the generalized costs of a connection or route increases. This implies an exponential weighting function. As a rule, economics implies that the first or second unit of a good has a greater value for the user than the thousandth or millionth unit. Therefore economic theory proposes to scale the amount of such goods with the natural logarithm. Accessibility is therefore a welfare-theoretical clean measure of the utility of all destinations in a region for a given capacity of the transport networks. There is, however, no universally valid process for converting these accessibility values to monetary values that could be used to compare benefits and costs. Therefore, as described in the following section, this research used the concept of travel time changes with a value for travel time savings to estimate economic utility of air transport.

Changes in Travel Time and Value of Travel Time Savings

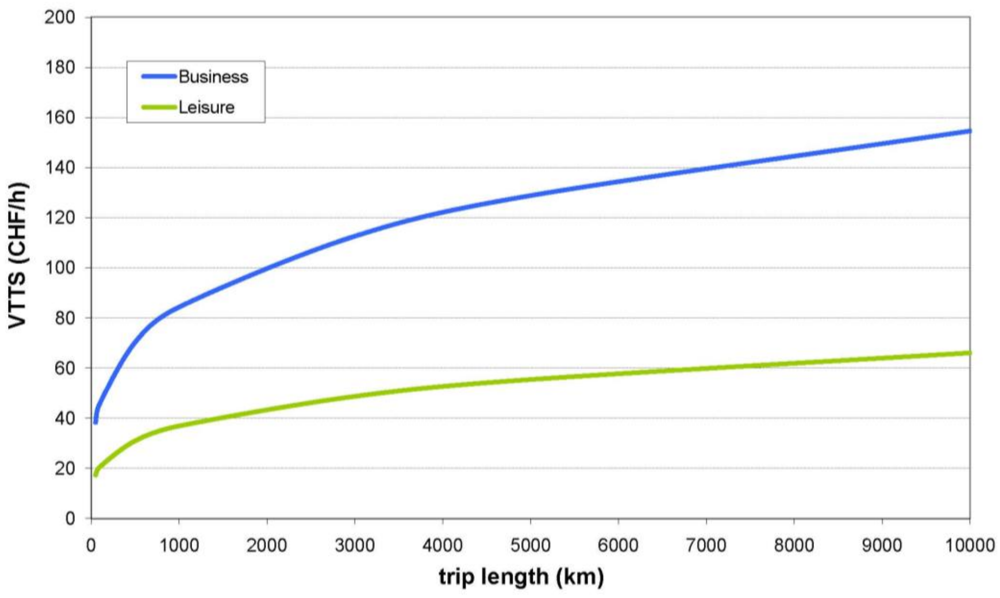
Contrary to the case of accessibility, a direct relationship to consumer demand can be established by using the value of travel time changes. This approach has been used to evaluate the economic utility of many different transport projects for decades (SN 671 810, 2006; Heatco 2006). The method is based on calculating the travel time difference between scenarios (the simplest being with or without the project). This travel time difference is then multiplied by the demand. The conversion of travel time to monetary values is then estimated using data on the value of travel time savings. These monetary values are then used in the benefit part of the cost-benefit analysis.

The term "Value of Travel Time Savings (VTTS)" is used as an indicator for participants' willingness to pay (Hensher, Rose and Greene 2005). VTTS is understood as the amount of money an individual is willing to pay in order to save one unit (usually one hour) of travel time. To calculate the value of travel time savings, the trade-off of individuals between travel time and cost must be determined, and then weighted according to the population in the sample. The value of travel time savings represents the basic value of the substitution between travel time and cost.

Only few value of travel time savings studies have been completed in the field of air transport (Hess, Adler, and Polak 2007, van Eggermond 2007) – and none has ever been conducted on the Zurich Airport. Many of the studies that have been done focus on a specific customer segment and many identify a very high willingness to pay for travel time savings.

Given the lack of specific data for Zurich Airport, distance-related time values were determined based on the Swiss value of travel time savings study by Hess, Erath, and Axhausen (2008). Two different trip purposes were considered separately: business and leisure travel. As shown in Figure 2, it is clear that people place a higher value on travel time savings for business trips than they do for leisure trips, and that values for both types of passenger increase as the trip length increases.

Figure 2: VTTS for trip purposes business and leisure

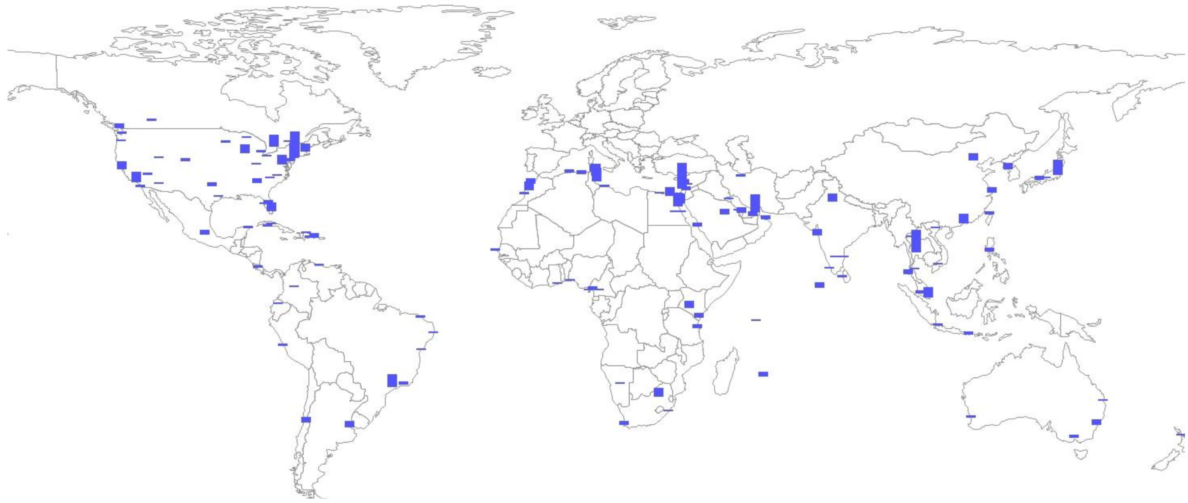


Source: author's calculations based on data from Hess, Erath, and Axhausen, 2008

An empirical study (Laesser, Wittmer 2006) gives the distribution of trip purposes for air traffic at Zurich Airport of 40% business and 60% leisure. The demand-weighted average flight time according to the air transport model is 4.2 hours. Assuming that the average speed is 700 km/h, an average flight distance of approximately 3,000 km can be calculated. Thus the mean VTTS for Swiss air demand can be estimated to be CHF 74.30/hour. This represents a conservative (i.e. low) value of travel time savings compared to the general studies referred to above.

The local air passenger demand departing from Zurich for the year 2007 was used as demand data (BFS 2008) for the evaluation. In Figure 3 the local passenger demand from all Swiss airports in the year 2007 for destinations outside Europe is illustrated. In addition, opportunities regarding transfer by public transport to the alternative airports of Basel and Geneva were considered in the analysis.

Figure 3: Local Passenger from Swiss Airport to destination outside Europe in 2007



Note: Maximum demand: New York-JFK 142'000 Pax per year

Source: Data from BFS 2008, own illustration

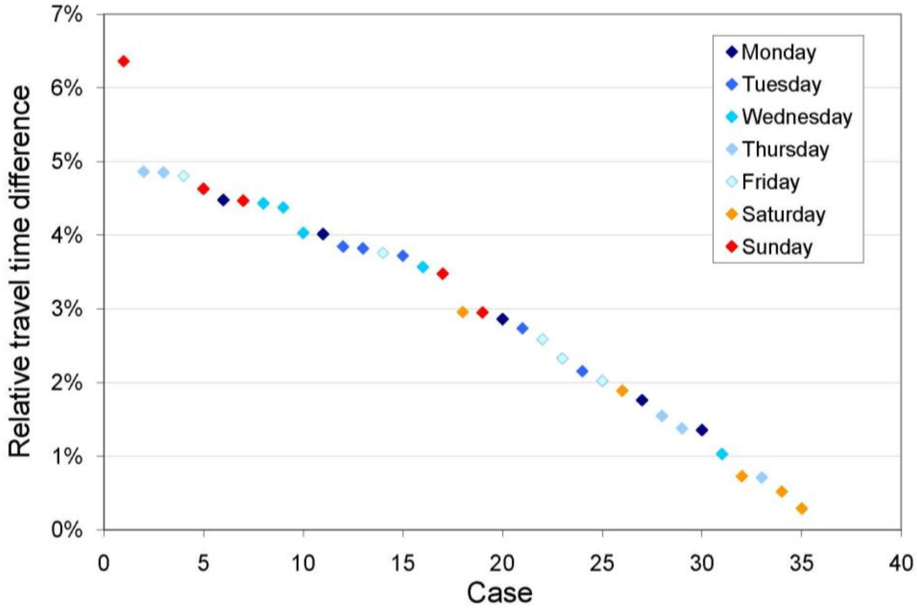
Travel time is composed of flight time in the aircraft (pure flight time), transfer waiting time, and the so-called origin waiting time, which indicates the time interval between two reasonable connections. Model calculations can thus not only consider pure flight time, but also the coordination of flight schedules and the time wise availability of the flights.

In order to calculate the difference in travel times a smaller version of the worldwide air transport model (Froehlich 2007), was constructed using the VISUM software (PTV 2007). It was necessary to use a smaller version of the original model to keep the computing time reasonable. The model considers 222 European airports and 162 major airports in the rest of the world for a whole week in November 2006. The flights were generated from OAG data

(Official Airline Guide, London) and also included the OAG's assumptions about minimum transfer times at airports.

The calculation of demand weighted travel time changes was accomplished by randomly adding 15% (for the Growth Scenario) or subtracting 10% (for the Reduction Scenario) to flights from Zurich in the flight timetable of November 2006. This approach was chosen because we lack the knowledge of the airline company network planers regarding which flights would be added or subtracted. For both scenarios, five simulations with different random numbers for each weekday were computed for a full week. The evaluation performed 35 simulation runs per scenario to calculate the average travel time changes. Figure 4 illustrates the variation in travel time changes in the different simulation runs.

Figure 4: Variation in travel time changes due to randomly subtracting 10% of flights



Negative impacts of transport

According to economic literature, the most significant negative impacts of transport are impacts on the environment and society. Many of these impacts are externalities. Externalities are economic costs that are not considered (i.e. explicitly paid) by those upon whom they are imposed. An externality is said to exist, if an actor's economic utility function (Y) includes real variables that are directly determined by other actors (X) – independent of the effect on the actor concerned (Y) (Schipper et al. 2001, Myles 1995, Baumol, and Oates 1988, Mishan 1971). In order to fully consider the negative externalities generated by any activity, the full costs of that activity must be quantified, and adequate instruments must be developed, through which an internalization of these costs can be achieved.

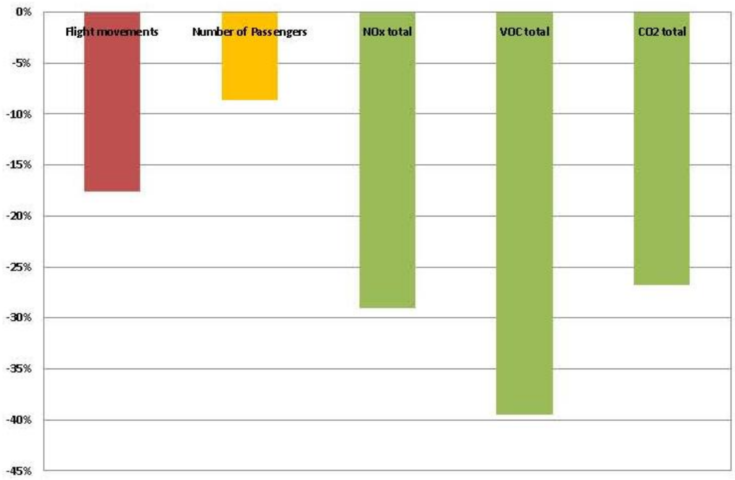
A key question when considering environmental externalities is the economic cost of ecological damage. In order to estimate these economic costs researchers attempt to sum the costs for all the impacts caused by the activity, examples include: higher hospital costs, decreasing productivity of employees, costs for reducing pollution (e.g. pollution control equipment), costs for containment, etc. This quantification can be made for the total costs or network costs (Dings et al. 2002; Schmid et al. 2003). Network costs in the context of air transport may be understood to be the additional costs that arise in connection with a specific additional flight movement of a specific aircraft type within a particular airport region (LTO cycle). These costs are technology-specific and differ from the average costs particularly in terms of noise. Both the airplane technology and the flight path are important factors in this evaluation (Schmid et al. 2003).

Air Pollution and Greenhouse Gases

The main air pollution generated by air transport are carbon dioxide (CO2), nitric oxides (NOx), and volatile organic compounds (VOC) generated by burning fuel to power the airplane (BAZL 2008, CE Delft 2007). On the average, CO2 stays in the atmosphere for 60 years before it is absorbed or broken down (IPCC 2007). A very small amount of NOx and VOC (compared to CO2) is generated in air transport, but these compounds are also considered in this analysis. Two other pollutants generated by air transport are the condensation trails and cirrus clouds caused by water vapor and particles released during combustion. They remain in the atmosphere for several weeks. These pollutants were not included in the analysis since a lack of relevant data.

An analysis of flight movements, number of passengers, and emissions for the period from 2000 – 2007 at Zurich Airport shows (Figure 5) that the number of flight movements has declined, but that the seat load factors and therefore the weight of the planes have increased. The impact of this change on emissions must be carefully evaluated since reducing the number of operations would, certibus partibus, generate fewer emissions while the increase in weight would generate more emissions.

Figure 5: Development of flight movements, number of passengers and emissions 2000 – 2007



Source: Data from Unique Airport Zurich (2007)

In order to analyze the emissions in detail the research focused on estimating the emissions per passenger or ton of freight. Generally, transport units (commonly referred to as: work load units - WLU) are used for calculation in this context, whereby one passenger or 100 kg freight represents one transport unit (1 WLU = 1 passenger or 100 kg freight). In order to calculate the environmental costs of air transport, the emissions per transport unit was calculated and then used in the analysis. In 2007, the average number of transport units per flight movement was 92.1. The mean value of this co-efficient in the period between 2000 – 2007 was 85.4. In the analysis performed for this research the emission cost was calculated for both 85 and 92 transport units.

The emission values per transport unit differ from year to year for the different substances. For all three emission gases, the value is at its lowest in 2007. The mean value for the respective emissions from 2000 – 2007 reflects the average emissions per transport unit for the period. A third value is the highest emission value per transport unit in this period.

In the literature, emission costs are calculated with different approaches, and depending on the source, the differences in the results can be very high, e.g. for CO2 the emissions costs range between 27€ per ton (Boiteux and Baumstark 2001), and 140€ per ton (Infras and IWW 2004). Furthermore, the actual prices in the emissions trading market vary, so that prices may differ significantly due to economic developments. This research applied the highest values for the three emission gases and therefore costs are estimated rather highly.
The emissions costs used in this research were: for CO2, the value of € 140 per ton (Infras 2004, converted to CHF at exchange rate: € 1 = CHF 1.6367); for NOx, the estimated future trading price of € 3,600 (www.cleanerandgreener.org, converted to CHF at exchange rate: € 1 = CHF 1.6367); for VOC Swiss federal guidelines were applied: CHF 3,000 per ton (Federal Regulation on the steering tax on volatile organic compounds (VOCV)).

Noise Impacts

Noise is a subjective and psychological concept defined as audible sound that disrupts the activity or balance of human or animal life (Maibach, et al. 2007, Pompl 2007). Aircraft noise is primarily caused by running engines and, to a lesser degree by aerodynamic noise (Pompl 2007). Noise impacts are thus limited mainly to the vicinity of airports and approach or outbound routes. Noise is measured in units called decibels (dB) with various different measurement approaches.

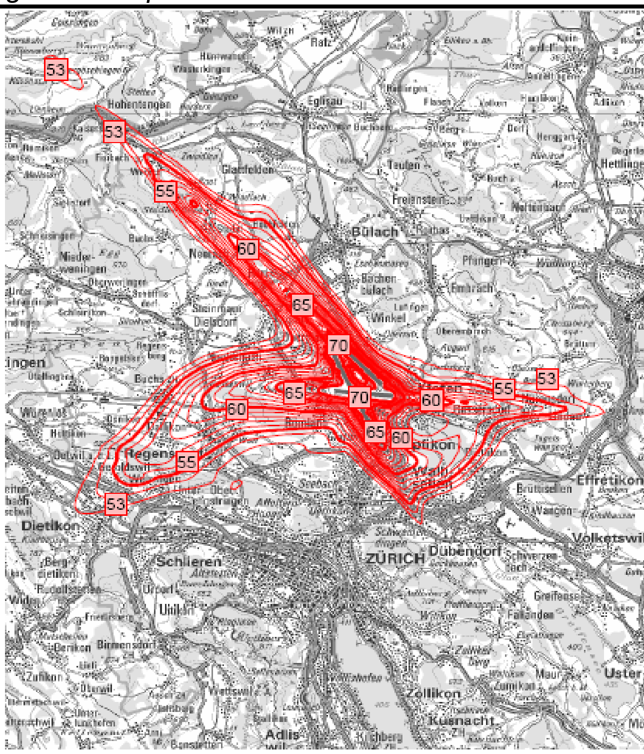
Several different studies have estimated the economic cost of noise at Zurich Airport (Amt für Verkehr Zurich 2008, BAZL 2008, EMPA 2006 and 2008, INFRAS and IWW 2004, Wirth 2004). The data and methods from these studies could be used in this research, but it was necessary to determine which would yield the most accurate results.

For purposes of this research a dB and movement orientated approach was used to estimate noise costs. This approach uses the number of flight movements in the three scenarios to estimate a dB factor that comes into effect in the case of growth or reduction of the movements. For the estimation of the noise costs on the basis of the dB and movement orientated approach, the following assumptions were made:

- The conversion of the flight movement increase or decrease to dB is carried out according to EMPA 2003.
- For simplification, the calculations are made for the daytime only (6-22 h), even though legislation has determined differentiated marginal values for noise generated during the daytime and night time periods.
- The flight paths, fleet mix, and allocation of planes to the flight paths are constant in all three scenarios.
- The most recent noise calculations of Zurich Airport (2007) are the basis for the calculations. The difference between flight movements in the Status quo Scenario (275,000 ATM) and the actual flight movements in 2007 (268,501 ATM) is disregarded.
- The analysis of individuals (based on resident population hectare grid data from the year 2000 population census) with the respective noise (equal-loudness contour) was conducted using a geographical information system. Since equal-loudness contours are only available in 1-dB steps, the calculation was proportional. In the case of an increase in the noise level due to 15% more movements, for example, it is assumed that 61% of individuals within the 55-dB perimeter are affected by noise over 55 dB.

The number of individuals affected by noise pollution and the degree to which they were impacted (in dB) were calculated based on the equal-loudness contours prepared by EMPA (based on the 2007 data) for all three scenarios evaluated in this research. The EMPA contours for 2007 are illustrated in Figure 6.

Figure 6: Map of Aircraft Noise Pollution Zurich 2007



Source: EMPA 2007

Many studies have estimated the monetary value of noise emissions. Most existing studies arrive at similar prices, but on different bases (per passenger, per 1000 passenger kilometers, etc.). Schmid et al. (2003) calculates the value in terms of Euro per dB per person and year; they estimate an amount of EUR 18 during the daytime (6-22 h) and EUR 27 for the nighttime. This research converted that study's daytime value to Swiss Francs to obtain the monetary value of 30 CHF. The adjusted number of individuals within the 55 dB noise curve is thus multiplied by CHF 30 and 55 dB to calculate the noise costs per year.

A second approach to estimating the monetary value of noise is to use the planned noise avoidance costs for Zurich Airport (Zurich Airport Annual Report, 2007, pp 61-62). This calculation is done on the basis of the noise emissions limit value, which is 60dB for residential zones and 65dB for mixed-use zones during the daytime. Noise costs are calculated on the basis of the planned noise compensation and the change in the noise impacted population due to changes in the number of aircraft movements between the different scenarios.

RESULTS AND CONCLUSIONS

The research goal was to evaluate the environmental sustainability of Zurich Airport. The method used was to compare the environmental costs to the economic and social benefits generated by the airport. The analysis was completed on both the regional and global levels. The evaluation consisted of comparing a reduction scenario (-10% flight movements) and growth scenario (+15% flight movements) to a status quo scenario (approximately equal to 2007 flight movements).

Table 1 presents the evaluation results for both the global and regional perspectives. For the global approach it is assumed that the whole emissions produced by an airliner belongs to the origin airport. In all cases the highest (i.e. least favourable) calculations were used to evaluate air pollution and noise impacts.

Table 1: Comparison of costs and benefits for the scenarios Growth and Reduction

Scenario	Regional approach		Global approach	
	Growth (+15%)	Reduction (-10%)	Growth (+15%)	Reduction (-10%)
In million CHF				
Marginal travel time	190.6	-193.3	190.6	-193.3
Marginal gas-emission	-18.1	10.0	-74.7	49.8
Marginal noise	-39.5	25.0	-39.5	25.0
Total benefit/cost	**133.0**	**-158.3**	**76.4**	**-118.5**

The primary results are:

- The marginal value of travel time savings or losses has approximately the same magnitude in absolute terms for both the reduction and growth scenarios. Since adding 15% more flights has approximately the same absolute benefit as reducing flights by 10% this shows the decreasing marginal utility for service expansion.

- For the regional approach, the value of the travel time loss (CHF 193 million) for the reduction scenario is greater than the monetary benefits of reduced gas emissions (CHF 10 million) and noise reductions (CHF 25 million). The total additional costs for the reduction scenario are estimated at CHF 158.3 million.

- For the regional approach, the travel time savings benefits in the growth scenario result in a value of CHF 191 million. The additional costs generated in this scenarios are estimated at CHF 18 million for additional gas emissions and CHF 40 million for noise impacts. The total additional benefits for the growth scenario are therefore estimated at CHF 133 million.

- The results for the global approach, where the gas-emission costs of the entire flight is taken into account, reveal slightly lower total benefits/cost values, but the main conclusion of the regional approach (i.e. that an increase in flight movements would be beneficial) is still valid.

The results show that Zurich Airport air transport generates more economic value than environmental and social costs. Therefore, using the sustainability criteria defined in this research, Zurich Airport can be considered to be operating in a sustainable manner. Furthermore, the analysis shows that Zurich Airport would remain sustainable even with a 15% growth in flight movements. Importantly, this conclusion remains valid when gas emissions for the entire flight are included in the analysis (global approach). The local approach has the advantage to link cost and benefits of an airport as well as the relevant political process at a well defined level.

Acknowledgements

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