ENVIRONMENTAL TRADEOFFS ASSESSMENT AROUND AIRPORTS

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Abstract

Recently, due to the increased rate of growth of air transport and increased environmental concerns, environmental impact of aviation threatens the development of the air transport. Even though there are technological and CNS/ATM improvements to reduce the environmental effect, the increase of flights is much higher than the achieved benefits. In particular aircraft noise is perceived as one of the most important constraints to growth. In fact, ICAO's Committee on Aviation Environmental Protection (CAEP) recommended new noise abatement procedures to reduce the impact on the areas of surrounding airports [1].

While implementing new noise abatement procedures, as the main focus is reducing the noise impact, generally other environmental issues are discarded such as global emissions and local air quality. Research and harmonised tools to understand better the relationship between noise and emissions is needed in order to ensure sustainable and cost-efficient operational decisions.

This study highlights the importance to carry out trade-off assessments to understand the interrelation of different environmental impacts of proposed operational decisions and to determine the economic effects of each decision. The trade-off approach consists of:

- Specification of operational scenarios
- Quantification of environmental effects
- Evaluation by converting the quantified values into monetary terms.

One illustrative example is developed to assess the feasibility of the trade-off assessment approach.

Preferred emissions route (PER) and preferred noise route (PNR) scenarios are used to demonstrate the study feasibility. One of the important aspects of the study is to demonstrate that the combined use of airspace simulation, environmental and economic tools, makes trade-off assessment feasible for any kind of scenarios, and adds value to operational project evaluation.

1   Introduction

1.1   Background

Over the recent years, decision making related to transport infrastructure projects, operational procedure implementations, and legislation enforcements, did gradually include increasing proportion of "sustainability" dimensions in order to illustrate, defend, or even justify their relevance towards private and public interests.

However, it is widely recognized that the optimal balance between each dimension of sustainability is vague, and open to individual opinions and preference scales.

The management of environmental policy, with regard to Air Traffic Management operational procedure selection, and constraints setting in the vicinity of airports, does not escape difficulties in correctly defining sustainable development pathways, which might lead to non optimal decision making. Therefore, as far as environmental assessment of ATM related measures for an airport is concerned, there is a need to adopt a systematic evaluation process which includes the tradeoffs aspects underlying each measure and scenario.

Once the tradeoffs assessments are finalised and the implementation is achieved, as a complementary

step, an overall performance analysis can be done in combination to following the social reactions and acceptance of the procedures.

1.2   Noise and emissions

Environmental tradeoffs assessment is a relevant exercise in the evaluation of noise management effectiveness versus aviation emissions management, and vice versa. For example, preferred noise routes could lead aircraft to fly significantly longer at altitudes where the noise impact on population could be marginal. As a result, airlines might burn additional fuel (which is an additional cost for them), and the local and global pollution resulting from the air transport activity might be increasing. At the society level, it is not obvious that noise reductions gains are higher than the environmental losses. There is no simple answer to this issue, where the local terrain configuration, land utilization, type and volume of the fleet in operation do all influence the shape of the "optimal solution".
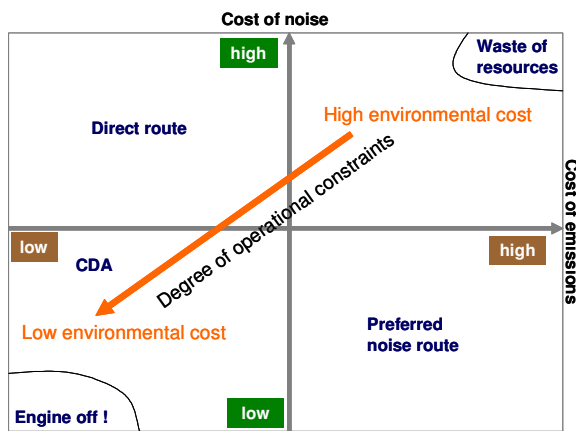

Figure 1: Noise and emissions tradeoffs

1.3   Temporal aspects

In addition to optimise the balance between different environmental effects at a given time, tradeoffs assessment should be used as an opportunity to include the dynamic aspects of the air transport system into the loop of policy setting and operational programme evaluations. As a matter of fact, the selection of an "optimal solution" is most likely to be an "optimal solution pathway" where:

- Procedures should be adapted in function of land use evolution (and vice versa)
- The cost of fuel and the traffic growth rates should regularly be used to update a

continuous evaluation process of tradeoffs assessment.
- Preferred management options with regard to noise and emissions should be based on their respective costs and benefits at different time stage, and should evolve accordingly.

Last but not least, bringing tradeoffs assessment methodologies and tools at the heart of environmental decision making, is completely relevant to, and compliant with the ICAO "Balanced Approach" which recommends that noise policy should not target single solutions but make use of any combination of solutions (i.e. Reduction of Noise at Source, Land-use Planning and Management, Noise Abatement Operational Procedures, Operating Restrictions, Noise Charges) which is the most appropriate to solve the causes of identified problems.

2   Methodology

2.1   General approach

The tradeoffs assessment methodology presented in this paper relies on a three steps approach (see Figure 2) where the airport traffic characteristic and operational organisation is considered first, followed by quantification and evaluation stages.
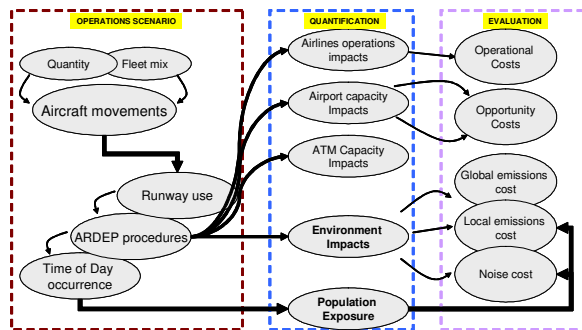

Figure 2: Overview of tradeoffs assessment framework

Operational scenario

Once the operational scenario to be assessed is specified (assumptions on future traffic mix and volume, assumptions on runway configuration frequency of utilisation, specifications of procedure attributes), each feature of the scenario having an impact on airport stakeholders[1] should then be

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[1] Airport stakeholders refer to the company running the airport itself, the airlines operating at the airport, the ATC

identified before moving to the quantification and evaluation stages.

Quantification

The quantification stage consists in evaluating the most likely impacts on airlines costs (mainly fuel cost), on airport ATC and runway capacity, on population exposure to noise, and on the quantity of emissions released to the atmosphere. It is possible that a single feature affects several stakeholders, or that a given stakeholder is impacted by several aspects of the scenarios, in which case the effects could either cumulate or compensate each others. Arrows shown in Figure 2 are illustrative and do not pretend to be exhaustive. They should be considered as a baseline to initiate the tradeoffs assessment process, and should then be adapted to local specificities.

Environmental effects can be calculated by using EEC environmental tools, TBEC for emissions and ENHANCE and INM for noise estimations.

Evaluation

The evaluation stage, shown on the right-hand side of Figure 2 proposes to translate into monetary terms the quantified results for all aspects of the previous stage. Three sorts of costs have to be evaluated.

Direct operating costs are mainly supported by aircraft operators subject to ATC regulations and directives in force at the time of operation (preferred runway use or specific climb profile to be followed at a given airport for evening or night movements). The scope of change in direct operating costs is obviously linked to the aircraft flap and engine thrust settings required to satisfy the ATC procedures, but also to the variability of production input prices. For example, the final operating cost of an extra kilogram of fuel consumed in order to follow a preferred noise route is a direct function of oil price. Thus, the world geo-political context, and state of equilibrium on the oil market do significantly influence the amount of operating costs and their evolution.

Opportunity costs refer to 'hidden' costs (i.e. not directly paid at a given time by any economic agent) which mainly occur in the airport and ATM system capacity. Opportunity costs represent the financial amount that could be gained (but will not occur) in absence of a given constraint, or scenario attribute. For example, night bans imposed by the presence of residence areas under flight paths, does

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service providers, and the population living in the surrounding area.

not cost as such to airport and airlines. However, they both could increase their profit in absence of night bans, by:

- Attracting more traffic and related income to the airport,
- Avoiding re-route flight for late arrival, being obliged to operate from airports which are farther from the final destination wished by clients, or paying airport surcharges when having to infringe the night ban.

By definition, *External costs* are not subject to financial transfers. They reflect the fact that some production, or consumption, by certain economic agents does impact the welfare of others without any market relations between these agents. In the case of air transport, external costs refer to the following items (in parenthesis, the share of each item in the total external cost arising from air transport in Europe [2] is given): Accidents (1%), Noise (8%), Air pollution (2%), Climate change (75%), Nature and landscape (4%), Urban effects (< 1%), Upstream process (10%). Considering these average European values, it is expected that the proportion of noise cost and pollution might locally be reasonably close enough to include both of them into an integrated tradeoffs assessment. When focussing on airport activities only, it is expected that the shares of noise and local air quality will be much higher than at the global level, where the climate change issue is predominant.

For evaluation of the scenarios, SOPHOS external cost database is used to estimate cost values of environmental effects.

2.2 Operational attributes

The first step for environmental tradeoffs assessment in airport/ATM related projects is to identify and specify the characteristics of scenarios to be evaluated, and the time at which they are the most probable to occur. The most common operational practices observed with regard to environmental management options are the following:

- *Preferred noise route / runway use* which may reduce the number of people exposed to noise but increase airline fuel consumption and increase local air pollution.
- *Continuous descent approach*, which may reduce both noise and emissions but might create operational challenges in terms of controller workload and thus airport throughput.

- *Concentration versus dispersion* of trajectories which may be almost neutral concerning emission but challenge individual perceptions regarding noise annoyance in function of intensity and frequency.
- *Single Taxiing and APU restrictions* which might decrease the ground noise and also decrease emissions.
- *Derated Take-off which* might reduce the noise close to the airports but having longer climb-out profiles the propagation might be longer, while there is a reduction on fuel burn and emissions for takeoff phase.
- *Arrival Management* might reduce the noise under the approach path and also the emissions, however the noise reduction is limited compared with departures.
- *Steep approaches* procedures allow an aircraft to approach an airport at more than 3 degrees. By flying higher for longer on approach, the noise impact can be reduced, however, it can have some implications for air traffic control and airspace design.

For each procedure it is necessary to quantify the aircraft categories for which flight paths and required configuration are realistically applicable, to assess the share of movement it represents and how this share may evolve in the future.

Then, for each procedure – aircraft category pair, the operational requirements need to be identified. By comparing to a base case, or a reference scenario, differences in flight length, speed, climb and descent rates and duration, steps in vertical evolutions, time of landing gear in/out, flap setting, thrust setting, etc. should be identified. In case of change, the probability of implementation occurrence should be quantified (%), as illustrated in Table 1.

Table 1: Operational impact Matrix

	Δ in climb duration	Δ in time with landing gear out	Etc.
Procedure – A/C cat pair 1	Yes (%)	Yes (%)	Yes (%)
Procedure – A/C cat pair 2	No	Yes (%)	No
Etc.	Yes (%)	No	No

Then, for each cell of the impact table, the operational cost sources, the airport and ATM capacity impacts as well as the environmental consequences, should be evaluated and finally regrouped per stakeholder.
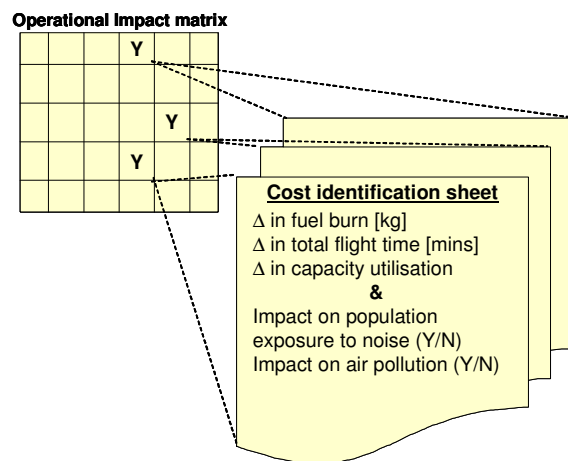

Figure 3: Link between operational impacts, operating costs, and identification of environmental impacts.

The general approach to identify the source and magnitude of changes due to operational drivers can rely on several methodologies: making use of past experience and expert judgment; setting analytical models when enough data exists; or ideally performing fast-time or real time simulations and trials.

Airport ATM capacity impacts, as well as airline operating costs can be assed via fast time simulators, such as RAMS Plus, where organisation and procedural settings trigger ATC staff actions which can be simulated with regard to their execution time and their potential results on the overall system capacity. Simulated traffic characteristics should then be linked to adequate economic data, available from aircraft manuals, databases such as BADA, average IATA operating costs information per aircraft type, analytical models, etc. in order to compute the changes in operational costs.

On the environmental side, every operational aspects of the change under assessment should be questioned with regard to the creation or suppression of noise production (flaps, gear, engine thrust, time spent per altitude band, etc.) and emission production (thrust setting, distance/time flown to complete arrival and departure cycles, optimum altitudes etc. under different meteorological conditions). These lists of environmental impacts compared to the alternative procedure will then feed the

environmental impact quantification process, where more detailed assessment of quantities per pollutant type and noise impact will be conducted.

2.3 Quantification of environmental impacts

The quantification of environmental impact is a prerequisite to cost assessment and classification of alternatives. Pollutants to be included in the environmental impact assessment are the following: CO_2, SO_2, NO_x, CO, HC, PM_x, and VOC.

About *emissions quantification*, two situations have to be treated:

- First, for the direct emissions which production is proportional to fuel consumption, extra fuel burn assessment resulting from the operational impact assessment should be reused. CO_2 and SO_2 multipliers can be used for direct computation (3.15 kg CO_2 per kg fuel and 0.8-0.9 kg SO_2 per kg fuel).
- Second, for indirect emissions, more detailed modelling (or even real measurement from flight trials) needs to be applied. As a minimum requirement, average emissions factors per time spent in a given mode (gram of NO_x emitted for gram of fuel burned per specific time in a flight phase, etc.) could be used. These values are available from the ICAO Emissions databank, or could be assessed with emission modelling tools such as TBEC or ALAQS. If historical monitoring at airport or emissions inventories are available, such data could be used for setting up a "do nothing" scenario and to fine-tune or validate emissions forecast with regard to alternative scenarios.

People in charge of tradeoffs assessment should keep in mind that while for global emissions CO_2 is the more important pollutant, for local air quality NO_x and PM are the most important.

About *noise assessment*, noise being not an environmental pollution *per se*, but a source of human annoyance function of social perceptions, performing real noise annoyance quantification is not realistically achievable. Thus, noise quantification should rather focus on counting the population exposed to certain noise thresholds (e.g. >55 Lden, >65 Lden, and >65 Lnight). Additionally, it makes sense to qualify the population in terms of noise sensitivity. Actually, for an equal number of people exposed to noise, a residential area will be more sensitive than a business area, but less than an educational area, where repetitive exposure to noise may cause difficulties to concentrate on studying, or than a health centre area where sleep disturbance may be induced.

Modelling population exposure to noise requires specific assessment tools able to take into account aircraft altitude, engine type and thrust setting, real trajectory footprint, and mapping of geographical information. It is important to note that particular attention should be given to geographical areas situated at the border of a noise contour. As annoyance does not drop completely at the other side of the road, some flexibility in the population counting is needed.

2.4 Evaluation of costs

The evaluation of cost is a key step to perform tradeoffs assessment. It brings together different amounts having, *a priori*, no common denominator. In most cases, which alternative will have a lesser impact cannot be determined on the basis of quantified values (such as noise or emissions). In such cases it is attractive to assess which of the potential impact is the largest. Therefore, potential impacts have to be converted to common units, and the monetary valuation is a very appropriate mean to achieve this goal.

However, costing environmental attributes is raising issues. These can be of several natures. First of all, some criticisms exist (mainly outside of the economic community) concerning the principle of "monetarization" itself. This criticism is most often found as a form of opposition to put a monetary value on human life. Secondly, even among those who accept the feasibility of costing health risk reduction, or climate change, many obstacles remain. These obstacles are linked to the fact that valuation of environmental attribute is subject to individual perception, or sometimes simply a question of awareness.

As no certitude exist in this domain, evaluating the monetary impact of environmental effects should be envisaged as a way to recognize that noise and pollution from aviation have a real impact, rather than an expression of 'truth'. Actually, ignoring these external effects from aviation would be equivalent to attributing them a cost of zero. This choice would simply lead to wrong assessments, and wrong choices, as obviously, even if true costs of externalities are subject to uncertainties, they cannot be completely ignored. Even estimations with a high

range of uncertainty would be better than an error by deliberate omission, provided that cost references are well documented and used in a transparent way.

Briefly, the most common techniques used to valuate external costs can be classified into revealed preferences and declared preferences:

- Revealed preference techniques are often used in noise valuation exercises. For example, the hedonic costing methodology, which consists in observing household market prices variations in function of their degree of exposure to external effects has been extensively applied to aircraft noise valuation.
- Declared preference techniques do not use real prices, but rely on people's declared preferences (whether they would actually behave accordingly or not). In contingent choice surveys, individuals are directly asked about their preference between a set of quality – cost alternatives such as less pollution and more taxes, with different scenarios and sub choices that have to be ranked by respondents.

2.4.1 Emissions costs

In the scope of a project (SOPHOS) for EUROCONTROL Environmental Domain, ENV-ISA conducted a wide literature review of published values applicable to aviation externalities. The investigation process put priority on finding original sources[2] and on the classification of results by methodology and authors, for finally identifying possible bias, trends, and propose ranges of costs per pollutant that can be applied with a reasonable degree of confidence.

It resulted in the construction of an "external costs" database, including around 60 references, corresponding to approximately 400 values for the whole set of pollutants listed in Table 2. The range of published values being extremely large (illustrating both scientific uncertainties and authors motivation which are not always impartial), the synthesis of most probable values is somewhat arbitrary, but statistical analysis of results was used to try reducing the range while accounting for uncertainties. The summary table (Table 2) presents these results.

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[2] The number of original external cost estimations is actually less large than a rapid screening of publications let suppose due to very frequent citations feeding each others with rounding, inflation adjustments, etc. which progressively weaken the link with the original figure.

Table 2: External costs of aircraft emissions (€/tonne)

	Low	Base	High
CO	104	142	205
CO_2	11	37	65
HC	2,569	5,543	8,518
NO_x	4,460	6,414	10,693
PM_x	35,895	179,476	269,215
SO_2	2,110	6,094	11,133
VOC	2,526	7,294	12,061

2.4.2 Noise costs

From the society viewpoint, noise is mainly related to a loss in well being, but for highly exposed populations, health effects and sleep disturbance can be mentioned. For people familiar with external costing techniques, the impact on house prices might be a primary consideration. Others will think about airport noise charges that airlines have to pay, as a function of aircraft type, time of day, etc. Finally, people oriented toward economic expansion and land use planning might also mention that noise has an opportunity cost (potential profit loss due to growth constraints coming from noise annoyance, and loss of constructible land). All these costs are actually true costs from air transport, and noise cost evaluation studies should carefully accounting for all the different facets of noise, while avoiding any double count.

In the same context as for emissions costs, an extensive literature review was conducted to gather the maximum noise cost estimates. As for emissions, large uncertainties lead to important ranges in observed values, although the number of available data is far less important than for emissions. Moreover, results coming from very specific and local situations are difficult to generalize.

Three complementary approaches finally appeared as relatively robust starting points:

- A macroscopic approach that should be used for initial scoping assessment. It is based on overall European noise cost [1] THENA Position Paper on Airport Environment EC DG-TREN Transport Programme, Ref: 16D01INE10
- **[2]** and [4], and people exposure to noise [3]. It results in an overall cost of € 200 to € 600 per person exposed above 55 Lden, per annum.
- A household pricing approach, based on a meta-analysis model [5] which attributes a

relative house price depreciation index, function of local attributes (house prices and average income level). A similar approach was used to cost noise at Heathrow [6]. Typically, depreciation index between 0.5% and 1% per decibel are regularly quoted in the specialized literature.

- A special attention to health effects is needed. Without entering into the details of implementing an impact pathway approach such as the one conducted for Zurich airport [7] it is important to identify areas where noise exposure is severe or susceptible to causing important noise disturbance. General recommendations from [8] suggests that in absence of detailed investigation, the cost of decibels resulting from hedonic pricing studies for population exposed above 65 db(A) should be increased by 30%.

3 Example of application

In the study example a generic airport was chosen with some realistic operational attributes. The generic airport was designed as:

Two-runway airport, with around 400 movements a day (146,000 p.a.) composed of approximately 1/3 of medium jets B737 or A320 type, 1/3 of regional turbo propellers, and 1/3 of business jets, plus a few movements of bigger aircraft B757 and B767 types).

3.1 Scenario Design and Data processing

From this traffic sample, RAMS was used to design and simulate aircraft trajectories under two route scenarios. The first route scenario is a preferred emissions route (PER), and the second is a preferred noise route (PNR), where some population exposure is presumably avoided, but at the detriment of possible fuel and emission inefficiencies. Within both scenarios, each aircraft follows the same horizontal profile (we assume no dispersion in this simplified example) but flies a vertical profile compatible with its specific performance.
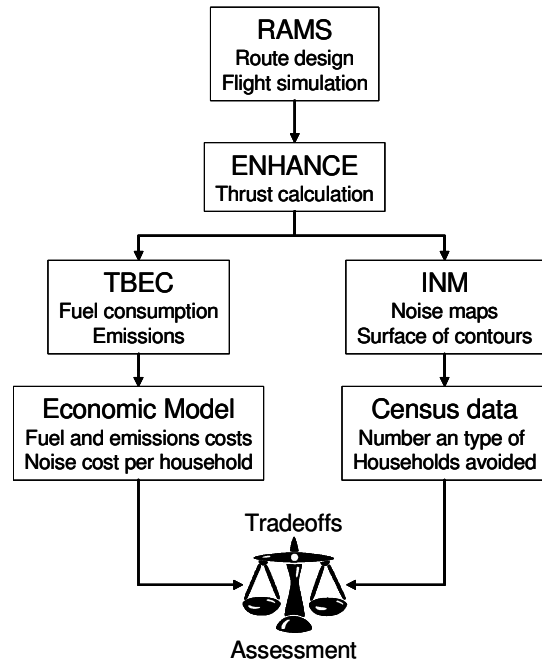

Figure 4: Data processing

As illustrated in Figure 4, RAMS Plus outputs were pre-processed by ENHANCE (which computes thrust for all flights) before being imported into INM to generate the two noise maps relative to the PER and PNR scenarios.

In parallel with INM computations, ENHANCE outputs were processed by TBEC to compute fuel consumption and related emissions relative to all flights under the two scenarios.

3.2 Noise Contour Calculations

Noise contours have obviously different shapes and different surfaces (Figure 5) but the maps shown here are of limited use as the case under examination is a generic one, and the deviation of trajectories does not correspond to the avoidance of real cities, etc. Figure 5 is purely illustrative, and the number of people to be subtracted to the PNR new noise contour compared to the PER noise contour is an unknown metric for which the evaluation stage will estimate threshold values above/under which PNR will be superior/inferior to PER. In real cases, the noise map is an essential tool for checking if the number of people subtracted (and or household's characteristics etc.) can be found within the geographical areas shown in noise maps.
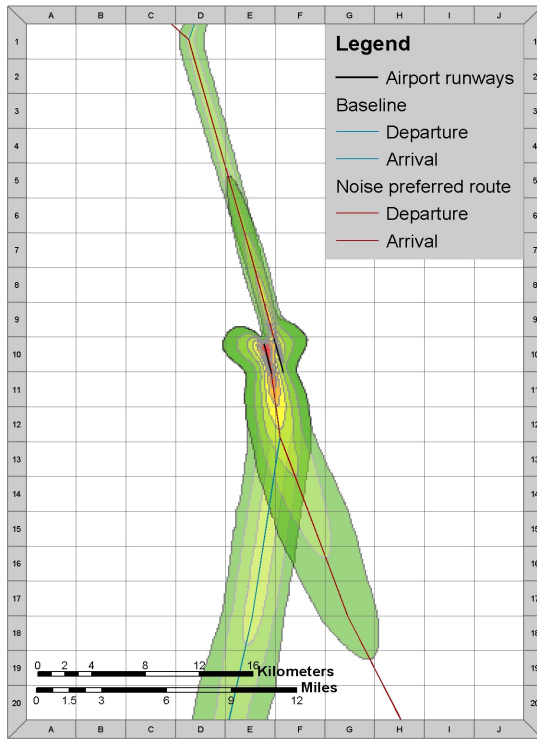
Figure 5: Noise contours relative to alternative procedures

3.3 *Fuel Burn and Emissions Calculations*

In parallel to noise contour calculations, EEC tool TBEC was used to estimate total emissions for two scenarios. **Error! Not a valid bookmark self-reference.** shows the daily estimated increase in emissions and fuel quantities resulting from the PNR. PNR results are logically much higher than the under the PER scenario due to settings that were used in the operational design of departure and approach paths, where PNR routes are significantly longer than PER routes. This fictive scenario does not pretend to be representative of any real airport situation, and simply aims at demonstrating the tradeoffs methodology.

Table 3: Fuel and emissions quantities

	PNR emissions (tonnes)	PER emissions (tonnes)	Savings (PNR – PER)
CO	2.1	1.7	0.4
CO2	1,193	986	206.7
HC	0.3	0.3	0.0
NOx	4.5	4.0	0.6

SO2	0.3	0.3	0.1
Fuel	379	313	65.6

As introduced in paragraph 2.4.1, during Eurocontrol ESAO project, a database of emissions cost applicable to air transport was developed and used in this illustrative example (See Table 4).

Table 4: Fuel and emissions cost per tonne

	Low	Base	High
CO	104	142	205
CO2	11	37	65
HC	2,569	5,543	8,518
NOx	4,460	6,414	10,693
SO2	2,110	6,094	11,133
Fuel	213	255	297

Fuel costs are subject to important variations in time and geographical locations. Figures presented in As introduced in paragraph 2.4.1, during Eurocontrol ESAO project, a database of emissions cost applicable to air transport was developed and used in this illustrative example (See Table 4).

Table 4 correspond to yearly average costs in the US[3] for scheduled and not schedule air traffic. 'Low', 'Base' and 'High' assumptions correspond respectively to average observed prices in 2002, 2003, and 2004.

Based upon emissions and fuel quantities resulting from the PNR and unit costs displayed in As introduced in paragraph 2.4.1, during Eurocontrol ESAO project, a database of emissions cost applicable to air transport was developed and used in this illustrative example (See Table 4).

Table 4, the total annual extra cost of the PNR compared to a PER is 7 to 15 millions Euros, with a 'base'cost around 10 millions Euros. Figure 6 shows among costs considered, fuel costs paid by airlines are the most important (59%), followed by CO_2 (27%) and NO_x (13%)emissions.

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[3] Source US Department of Transport, jet fuel price statistics.

Figure 6: Repartition of PNR extra costs
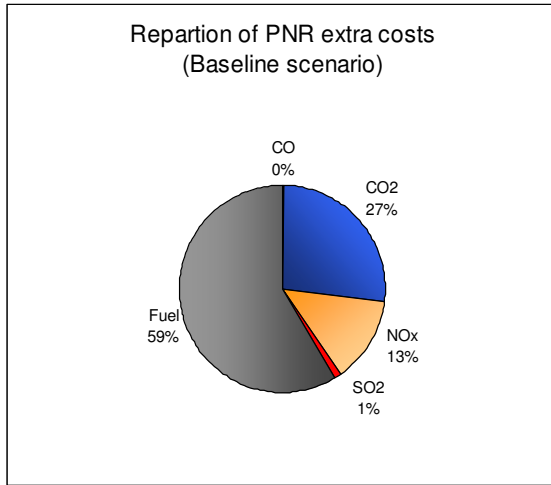(Baseline scenario)

Figure 6: Repartition of fuel and emissions costs

Other pollutants, although having harmful effect on health are relatively less important once the monetary conversion is achieved.

The cost range of fuel and emissions indicates that, to be beneficial, the PNR procedure should result in noise cost savings that are at least equal or superior to 7M – 15 M Euros, as shown in
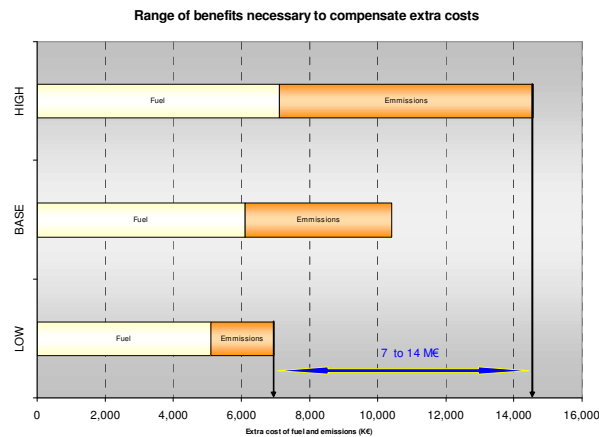

Figure 7: Range of benefits necessary to compensate extra emissions and fuel costs

3.4 Population thresholds

The assessment of the number of people that should be subtracted to noise contour with the PNR requires the use of a 'unit cost' of noise per people exposed.

The simplest way to do so is to use, as a first approximation, the macroscopic values presented in paragraph 2.4.2 (200€ - 600€). Then, when

combining both ranges of noise and emissions & fuel uncertainties, the number of people to be subtracted to PNR contours appears as a very large range delimited by the 'abcd' trapezoid in. Figure 8
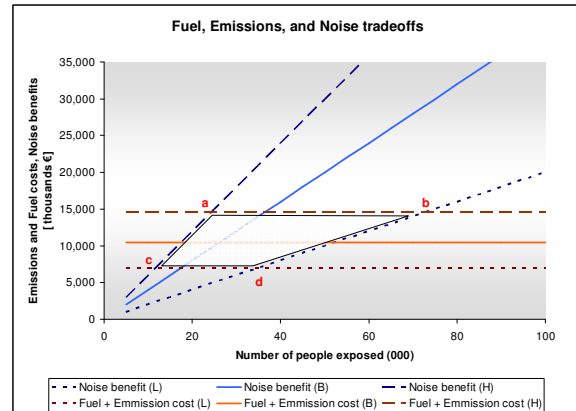

Figure 8: Population assessment

Depending on tradeoffs assessors' preference for low/base/high values, the minimum number of people varies between 12,000 and 73,000 persons. It is at this final stage that the noise map becomes useful, allowing to identify if the number of villages and cities located in areas F,G - 14,15,16,17 (Figure 5) compared to the ones located under E – 15,16,17,18,19,20, (Figure 5) allows to resch such population thresholds.

4 Synergies

The tradeoffs assessment methodology can also be used to identify synergies between projects, and quantify the order of magnitude of gains occurring when solutions are brought in combination instead of individually.

As an example GSE/APU/GPU modernisation for emission optimisation will reduce the pollutants in the airport area. While it can also contribute to ground noise reduction studies (For example GPU use will reduce the APU operational time and correspondingly the noise exposure).

A good land use planning alone can avoid the amplification of noise annoyance while keeping away many people exposed; an effective concentration of trajectories balancing the number of people exposed with air pollution can significantly diminish the number of people exposed to the higher concentrations, and the combination of both can definitely reconcile quality of life and airport development.)

The tradeoffs assessment methodology can also be used to demonstrate the case of win-win solution, such as Continuous Descent Approach, while indicating if the environmental benefits of a win-win solution (improving slightly individual cost sources) is more beneficiary than a real tradeoffs where one cost item in raising, but where huge cost saving can be achieved in absolute value. Thus, even win-win solutions, which may seem very attractive because they are able to achieve consensus across actors should be included in tradeoffs assessment to further validate the real benefit of the win-win solution.

Actually, real benefits of tradeoffs assessment can be obtained when a sequence of best practice options is implemented. Let's assume that at time t, two candidate procedures present the following characteristics:
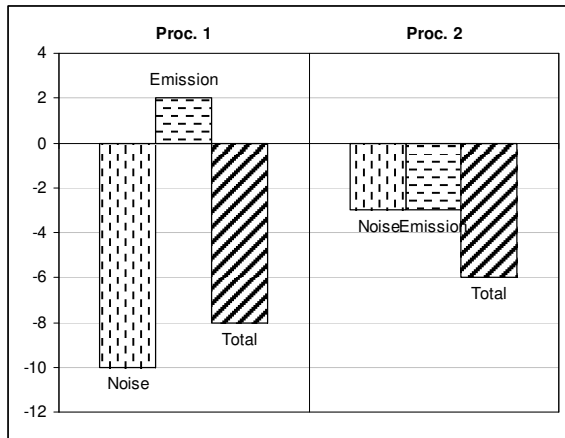

Figure 9: Tradeoffs solution versus win-win solution

Proc. 1 is subject to real tradeoffs between noise and emissions but brings high cost reductions, while Proc. 2 is a "win-win" solution, diminishing both noise and emission costs, but at a smaller scale compared to Proc. 1.

However, it might be that at time t+5, as the airport traffic has increased, the population density increased as well and, the proportion of flight able to commit to Proc. 2 standard has increased, then the balance might shift in favour of Proc. 2, as illustrated in Figure 10.
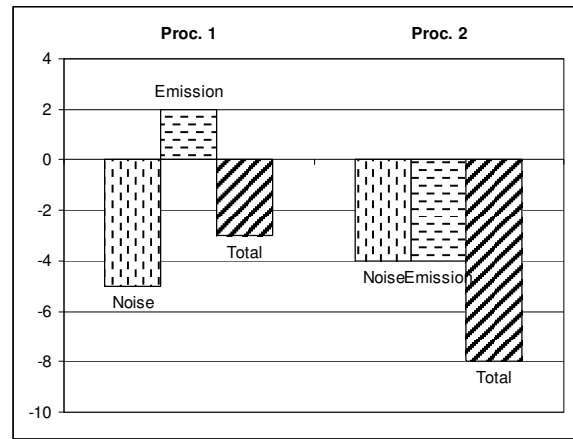

Figure 10: Tradeoffs solution versus win-win solution under a different traffic - population regime

- Actually it could be demonstrated that, under certain circumstances (which will be specific to each airport) the best solution could be:

- Not constant through time

- Not to be implemented if the immediate benefits are only temporary occurring (and depending on the cost of moving from a solution to another

- A research of synergies between alternative procedures might allow to etc…

- List to be completed

5 Conclusion

The aim of this hypothetical study was to develop know-how for trade-off assessment for different environmental aspects of the operational procedures in order to help decisions makings.

The study also shows that cost values were used as a common denominator to value both emissions and noise in order to normalise the effect and the importance of choosing the correct parameters.

With the use of different tools such as airspace simulation tool, environmental tools and cost assessment tool; the overall modelling of the system was achieved and the approach can be used for future studies with real operational data.

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Key Words

Tradeoffs | Noise | Emissions | Fuel | cost | airport operations | RAMS | TBEC | ENHANCE | INM

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