Decision making analysis to assess the silent aircraft project

R. Morimoto & C. Hope
Judge Institute of Management, University of Cambridge, U.K.

Abstract

There is increasing concern about aircraft noise as a result of the rising demand for air transport. This paper presents a simple decision making model that examines whether it is worth trying to develop a silent aircraft in order to solve the current aircraft noise problems. The model includes eight variables: benefits from noise abatement, reduced ground travel, and extra flights as well as development cost, extra capital cost, and extra casualty cost as the main cost variables. Operation and air pollution costs associated with the new silent aircraft could either increase or decrease depending on the technologies, therefore they can be costs or benefits. The model also considers a possibility that the development will not be successful, and the silent aircraft will never be brought into use. The model is designed to capture a first approximation of all aspects of the decision, and the findings give a broad picture of the current state of silent aircraft development. The model is simple, but probabilistic and comprehensive enough to make a first estimate of the business case of this long-term project with huge uncertainty. The predicted mean cumulative net present value of the decision to develop a silent aircraft is US$13 billion. The result shows that initially the huge development cost dominates, and benefits from noise reduction, extra flights, as well as better location of an airport would grow once silent aircraft are developed and introduced. According to the model, although a substantial amount of time - approximately 70 years in the mean case - would be needed until costs are recouped by noise reduction and other benefits, the project of developing a silent aircraft seems just to be worthwhile.

Keywords: aircraft noise, CBA, net present value, uncertainty.

1 Introduction

The UK Department for Transport's official forecasts predicted in 2000 that passenger volumes at UK airports are expected to increase at an average rate of
4.3% per year [1]. Long-term demand for air travel could be even higher than previously thought, especially due to rapidly expanding low cost airlines (Daily Telegraph 19/05/03). According to the US National Science and Technology Council, environmental impacts of aircraft, including serious noise problems, are likely to limit air transportation growth in the 21st century [2]. One example in the United Kingdom is the current debate over the expansion of UK airports (BBC News Tuesday 16/12/03). There are many protesters against the plan of building new runways, who are especially concerned about the possible increase in aircraft noise levels (BBC News Tuesday 16/12/03).

There is increasing concern about aircraft noise as a result of the rising demand for air transport. Thus deeper economic understanding of this field is urgently required in order to tackle the issue. It has been estimated by EU [3] that approximately 20% of the European Union’s population suffer from noise pollution. It is also estimated that up to 170 million citizens of the EU are living with noise levels that cause ‘serious annoyance’ during the daytime [3]. Van Praag and Baarsma [4] show that about 2% of the households living in the wider Schiphol area in the Netherlands are always annoyed; 5.2% often annoyed; 10.6% regularly annoyed; 37.6% sometimes annoyed by noise.

In order to reduce the impact of noise on these people, the legislation of aircraft noise is becoming stricter, especially in developed countries. An independent research and consultancy organization CE [5] recommends that the Commission for Integrated Transport (CfIT), an independent body advising the UK government on integrated transport policy, should introduce noise charges or tradable noise permits based on certified aircraft noise production and time of arrival or departure. On the manufacturing side, huge investments are being made to create much quieter, environmentally friendly aircraft.

This paper presents a simple decision making model that examines whether it is worth developing a silent aircraft. The model is simple, though comprehensive enough to make a first estimate of the business case of this novel project with huge uncertainty. Following the introduction in Section 1, the silent aircraft technology development process is described in Section 2. The model developed in this study is presented with the explanations of the basic concept in Section 3. Section 4 presents the initial findings with the preliminary data sets to examine the reasonableness of the model. Section 5 concludes the study and discusses the strengths and weaknesses of the model.

2 Silent aircraft technology development process

Although the form of civil transport aircraft has remained largely unaltered for the past forty years, advances in engineering design capability now enable consideration of step changes in templates for aircraft design and operations. The case study of the paper is the silent aircraft initiative project being conducted jointly by University of Cambridge and Massachusetts Institute of Technology with an involvement of industrial partners. The term ‘silent aircraft’ is defined as an aircraft whose noise is reduced to the point where it would be virtually unnoticeable to people outside the airport perimeter in a typical built-up area.
Such aircraft would enable an expansion in air transportation by creating opportunity for new airports and allowing increases in operating hours at existing sites. Silent aircraft require improvements in engines, airframe, integration, and operational procedures. Consideration of the operational side such as ‘continuous descent approach’ is implicitly included in the analysis of silent aircraft together with technological improvements. The development cost is so large because this new aircraft requires a radical conceptual change, especially in terms of the aircraft body shape and the engine system.

The greatest risk of such a project is to follow a similar path to Concorde; a great engineering feat with no commercial success. Air France/British Airways Concorde, capable of flying at twice the speed of sound, which has been described as a technological marvel since entering commercial service in 1976, flew into retirement on 26 November 2003, having made a cumulative loss. Britain invested £40 million a year in Concorde between 1962 and 1974, though, there will probably be no direct recovery of any part of the Concorde research and development costs in straight accountancy terms. Airbus or Boeing would probably be capable of producing a silent aircraft in 20 years time as they are currently conducting extensive research on noise issues. However, investigating the market and demand for silent aircraft at the design stage is crucial.

3 Model

3.1 Cost benefit analysis

A probabilistic cost benefit analysis (CBA) approach using Monte Carlo simulation is applied in this paper. This particular aggregated probabilistic approach is used since this is the first attempt to assess the impacts of this silent aircraft technology on the global scale. Thus, all the possible major economic, environmental and social impacts are included in the analysis, rather than looking into specific impacts, such as only economic impacts. This probabilistic CBA, a real option approach, and input-output econometric model are complementary, however they are used for different purposes and objectives. The CBA model developed for this project calculates the benefits and costs from proposed development of a silent aircraft in order to examine whether the project is justifiable.

3.2 Model structure

The decision making model that assesses the silent aircraft project is structured in the following manner. Silent aircraft will be introduced over time, if the
development is successful, involving extra capital costs, and possibly extra pollution and operating costs in exchange for noise reduction benefits and net benefit from extra flights. Silent aircraft would technically allow us to have extra flights including night flights, as there will be no noise restriction. However, political issues attached to night flights still need to be solved. Once the proportion of aircraft that are silent has exceeded a threshold, new airports can start being introduced over time nearer to city centers, giving ground travel benefits, as well as extra casualty costs if a plane crashes in the crowded residential area. Silent aircraft technologies would allow us to have extra flights, which would increase the number of accidents. The damage becomes even larger if the airport is built closer to city centre, as that involves more victims on the ground since a greater population will live around the airport and under flight paths. The model also includes the possibility that the development will not be successful, and the silent aircraft will never be brought into use, as there is a chance that silent aircraft project fails due to technological reasons. There is also a possibility that even if the project is a success in terms of engineering, there might not be a market for it and demand might not follow. The concept of the model is illustrated in Figure 2. The details of the model including equations are found in Morimoto and Hope [6].

Figure 2: Concept of the model.

Is this assumption of relocating airports due to silent aircraft technology reasonable? Currently, regional airports in the UK such as Stansted airport are expanding as airports like Heathrow airport are reaching their capacity, low cost carriers favour smaller airports due to lower costs, noise issues are less pressing at smaller airports due to the smaller population around the airports. However, people do use and favour city airports, especially business people in the City of London, as saving travel time is very important for business travellers. London City Airport has achieved significant market penetration for domestic and European flight by business people in the City of London partly due to its ease of accessibility. According to an Oxford Economic Forecasting survey, 20% of business travellers from the City use London City Airport [7]. Furthermore, 23% of those travelling direct to or from their home would prefer flights from London City Airport [7]. In order to attract more business passengers, regional airports like Stansted or Luton airport have to construct fast rail link with London.
4 Data

The model is highly aggregated, therefore the scale of the analysis is the whole fleet and the whole world. The initial data used in this paper are collected from various sources such as reports, the scientific literature, and web pages. The main inputs are listed in Table 1. They are the most representative currently available data based on our investigations in this field. Because the model is aggregated, and looks far into the future, the data are given as ranges and are assumed to follow a triangular distribution in order to deal with the huge uncertainty involved in the input parameters. Some of the data are not very accurate or precise, because of the project complexity or simply because they have not yet been adequately measured or collected. The best effort was made to obtain reasonable figures using our knowledge of the literature and discussion with people working in air transport related industries.

Table 1: Summary of the main inputs.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Minimum</th>
<th>Most likely</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount rate</td>
<td>%/year</td>
<td>3(^a)</td>
<td>7(^a)</td>
<td>10(^a)</td>
</tr>
<tr>
<td>Base year flights per aircraft</td>
<td>Flights</td>
<td>200(^b)</td>
<td>420(^b)</td>
<td>700(^b)</td>
</tr>
<tr>
<td>Flights per aircraft growth rate</td>
<td>%/year</td>
<td>-0.1(^c)</td>
<td>0.5(^c)</td>
<td>1(^c)</td>
</tr>
<tr>
<td>Base year noise valuation per flight</td>
<td>$/flight</td>
<td>60(^d)</td>
<td>300(^d)</td>
<td>3000(^d)</td>
</tr>
<tr>
<td>Base year reduced travel cost to the airport</td>
<td>%/passenger</td>
<td>10(^e)</td>
<td>12(^e)</td>
<td>30(^e)</td>
</tr>
</tbody>
</table>

Source: 
- \(^a\) value suggested by FAA cost-benefit guidance for infrastructure projects: also used by Morrison et al. [11]; 
- \(^b\) Average number of airbus operations [12];
- \(^c\) In 2000, the total number of taking-offs and landings increased by 0.5\% at JFK airport [13];
- \(^d\) Best estimation based on compensations per flight at Schiphol airport in 1999 (f61 per flight), and Long island Macarthur airport noise surcharge of $50,000 per flight on all aircraft operations between 11pm-6:30am effective on Sept 30 2001 [4];
- \(^e\) London city to Heathrow costs approx $12 return [14].

Using ranges instead of a single figure for inputs also enhances the credibility of outcomes. Wide ranges represent those inputs where we have less certainty. It is fairly difficult to determine the probability of success when new technologies are developed. Therefore, a wide range is used for this input. A wide range of discount rates is also used. This is because the choice of discount rate is ultimately a political issue according to Hanley [8], Winpenny [9]. Lind [10] argues that the appropriate discount rate is project-specific. It depends on a multitude of factors relating to the structure of the economy, the nature of
market-imperfections, the behaviour of government, nature of the financing, and the nature of the benefits and the costs.

A modified Monte Carlo simulation technique is applied, using @RISK from Palisade Corporation. Repeated runs of the model obtain a probability distribution of possible outcomes, which is a more defensible procedure than just using single values for inputs that are in reality not well known.

5 Findings

5.1 Net present value

Figure 3 shows the mean value of the cumulative present values of the different categories of costs and benefits by year. Note that, with the exception of the development cost, these values are multiplied by the probability of success. Initially, the huge development cost dominates. Benefits from extra flights, noise reduction benefits and reduced ground travel benefits would grow once silent aircraft are developed and introduced. The finding shows that the extra casualty costs do not appear to be significant, however this was not an obvious prediction before conducting the analysis. It is also a matter of morality to include casualty costs as considering this cost in the business case reflects our responsibility to society.

Figure 3: Mean cumulative values of costs and benefits by year. Source: model run.

The 5th percentile, mean and the 95th percentile of the cumulative NPV are US$ - 51, 13 and 139 billion respectively. The result contains a huge uncertainty as can be seen from the wide gap of the 90% range in Figure 4. Although Figure 4
indicates that a substantial amount of time - approximately 70 years in the mean case - would be needed to reach the break-even point, the project seems just to be worthwhile.

Figure 4: Cumulative NPV. Source: model run.

5.2 Sensitivity analysis

Sensitivity analysis using regression identifies the input parameters that are most significant in determining the output, in this case cumulative NPV. The student b coefficient is a coefficient calculated for each input parameter in the regression equation. These are the regression statistics provided by the @RISK package. The results show that the discount rate and base year flights per aircraft have the most significant impacts on the cumulative NPV. Their student b coefficients are −0.46 and +0.4 respectively. Hence, using a lower discount rate, or increasing the number of extra flights would make the break-even point shorter. The finding also confirms the importance of choosing appropriate discount rates in project assessments. Each parameter has a correct sign, consistent with the model: those parameters where an increase would increase the expected benefit have positive signs and those parameters where an increase would decrease the expected benefit have negative signs.

6 Conclusion

This paper presents a simple decision making technique that is applied to assess the proposed silent aircraft project. The approach is particularly robust for this type of project with huge uncertainty and a long time horizon, as it is probabilistic.

The parameterisation is conducted as simply as possible: for example all the growth rates are constant and the rate of introduction is linear. The strength of the model is its simplicity, focusing upon the most influential variables for developing silent aircraft, and requiring only the most general input data. More details would be hard to justify given the uncertainties. The model is designed to
capture a first approximation of everything that needs to be analysed, and the findings give a broad picture of the current scene of silent aircraft development.

The assumption of relocating all airports nearer to city centers within a few decades of the market penetration of silent aircraft might be fairly optimistic. All sorts of political, land use and planning constraints would have to be overcome. However, it is more likely that city airports will be more favored without the constraints of aircraft noise in the decision concerning where to locate a new airport in the future. At least, more airports will likely to be built close to city centers, and the current majority of airports that are far from city centers, would be in less favor if that happens.

The main weakness of the analysis is the lack of accuracy of the data used. We have used the most reliable and reasonable data we could obtain at this stage, however further improvement in the accuracy of the data will enhance the analysis. Many refinements such as regional splits, reduced landing fees, stimulation of demand, substitution of planes for other modes of ground transport, multiplier effects on the economy through improved infrastructure and more employment opportunities around the existing as well as relocated airports are omitted at this stage. The multiplier impact on economy is supposed to be significant and long lasting. This can be illustrated by an example of Luton airport. After the large motor vehicle industry closure, the airport is the only major employer in the Luton area and is expected to be the major economic driver to regenerate the region. The airport expansion would highly likely to attract more business to move into the region, such as aerospace or engineering related industries. Thus, these impacts should also be considered in future research. Furthermore, damage costs on reputation of airlines cause by accidents would also be included in the model in the future research, One example which illustrates the importance of this reputation cost is the events of September 11 that led to huge losses for airlines.

The model in this research is fairly simple compared to those detailed models, such as input-output models that try to capture indirect effects as much as direct effects. This model is indeed just a starting point; further modification is planned to improve its robustness. However, it can already be considered to make a useful contribution to the development of simple integrated assessment models for major, long-lived projects.

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