Special Session - Towards a Silent Aircraft:

Assessment of Silent Aircraft-Enabled Regional Development and Airline Economics in the UK

Ryan Tam,[*] Peter Belobaba,[†] Karen R. Polenske[‡] and Ian Waitz[§]
Silent Aircraft Initiative, Cambridge-MIT Institute, Cambridge, MA, 02139, USA

We use the concept of an advanced technology, low-noise commercial aircraft as a basis for considering the complex relationships among airport noise, regional economic development, and airline profitability for two airport-regions in the United Kingdom. We identify sizable economic impacts from aviation growth at the regional level, both from the air transport sector itself and also from its wider catalytic effects on economic productivity. We also assess the changes in community noise that would be associated with the introduction of an advanced technology, low-noise aircraft under different aviation growth scenarios. Finally, we identify the fuel price, capital cost, maintenance cost and environmental regulation scenarios under which such low noise aircraft would be attractive to airlines. Altogether, our analysis highlights some of the important interdependencies within the air transportation system as they relate to regional economics, industry economics and community noise.

I. Introduction

While the growth of aviation has enhanced mobility and enabled global supply chains throughout the world, it has also exposed over 20 million people around the world to high levels of aircraft noise.[1] The advent of quieter high-bypass ratio turbofan engines and other technological improvements have reduced aircraft noise by about 20 decibels since the 1950s.[1] In the United States, there has been a 95% reduction in the number of people exposed to high noise levels since 1975 amidst a sixfold growth in commercial passenger traffic.[2,3]

Despite the major decline in the number of residents exposed to noise, noise issues continue to generate substantial opposition to airport and aviation expansion projects.[4] Economic theory suggests that aircraft noise problems exist because aviation users are not fully accounting for the externalities created. The United Kingdom government is currently promoting the use of economic instruments, such as taxes or other price mechanisms, to help encourage industries to adapt, innovate, and foster sustainable development.[5] Under such polluter-pays principles, airline passengers may bear additional environmentally-related taxes as a means of addressing impacts of noise and emissions on airport-area residents.[6]

Although aircraft noise is relatively well-understood from scientific and engineering perspectives, the wider socioeconomic linkages are complex. It is unclear whether or not economic measures that are in place are effective, or if those that might be imposed in the future would be effective. Furthermore, researchers at the Massachusetts Institute of Technology and the University of Cambridge, among others, have considered the conceptual design of commercial aircraft that may reduce the airport noise footprint to near-ambient urban noise levels. Such step-changes in aircraft design may have the potential to make significant improvements in

[*]PhD Candidate, Department of Urban Studies and Planning, Massachusetts Institute of Technology.
[†]Principal Research Scientist, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology.
[‡]Professor, Department of Urban Studies and Planning, Massachusetts Institute of Technology.
[§]Professor, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology.

the noise environment of communities immediately around major airports. Here, we analyze the relationships among aviation technology and operations, airport noise, regional socio-economic development, and the airline industry in order to assess the economic implications of such a technological change.

II. Methodology

We integrate several accepted analytical tools within a common set of scenarios to highlight some of the key relationships and interdependencies which may influence the adoption of aircraft with advanced low-noise technology, and the impact that such aircraft may have on local noise damages and regional economic development. Our approach is to use an economy-wide modeling framework to compare the monetary value of the noise impacts on residential properties to the regional economic gains associated with increases in aviation capacity and air traffic. Analyzing the noise and economic benefit externalities in terms of a common (monetary) reference unit allows for a comparison with other costs and benefits that are expressed in monetary terms,[7] and gives local and regional stakeholders additional opportunities for dialogue and policy innovation. We recognize, however, that monetary metrics serve as only simplified surrogates for the complex effects of noise on people, and therefore may over- or under-estimate the value placed on noise by populations living around airports.

We analyze the relationships among aviation activity, airport noise, local housing prices, and regional economic growth around two airports and their surrounding regions: London Heathrow and East Midlands Airport. These two cases are differentiated in terms of airport size, projected air traffic growth, surrounding urbanization, and regional economic activity. They provide a good contrast for considering the potential range of impacts associated with aviation. We present a regional economic analysis because the economic impacts of air services extend far beyond those neighborhoods directly affected by airport noise. Further, we introduce a number of scenarios that incorporate an advanced technology, low-noise aircraft design (the SAX-40 described by Hileman, et. al., 2007)[8] to study the sensitivity of the aviation system to aircraft noise-reduction technology.

We start by evaluating the role of aviation within regional socio-economic growth. To analyze the wider sensitivity of the economy to changes in the air transport sector and related industries, we use the REMI-ECOTEC econometric input-output model (UK Policy Insight 6.0). In doing so, we also investigate the wider, long-term catalytic impacts of aviation on investment and productivity. Next, we consider the local community noise impacts of aviation growth by applying the U.S. Federal Aviation Administration's Integrated Noise Model (INM 6.2) under different airport activity growth scenarios and mobility projections. To estimate the aggregate monetary impacts of the noise damages on residential housing values–or inversely, the benefits of lower noise[9]–we apply a hedonic price model based on meta-analyses of airport noise impacts throughout the world. Hedonic price models rely on the variation in average housing sale prices to reveal the implicit value of an attribute such as noise, and are the most widely used technique for evaluating the social costs associated with noise.[10] Alternative contingent-valuation methodologies use surveys to reveal how much people are willing to pay for silence, but only a limited number of such studies exists for airports in the United States and Canada.[11,12] As noted above, we recognize that a hedonic price model serves as a simplified average proxy for the complex response of communities to aircraft noise. There are many other metrics such as sleep disturbance or poorer learning in schools which could be used to more fully represent the complex relationships between aircraft noise and community annoyance. Finally, we develop and apply an airline business model to understand the financial and environmental regulatory conditions under which an advanced technology, low-noise aircraft would be attractive to the airline industry.

We jointly consider the results of these models to illustrate the interrelationships of noise and economic growth within the air transportation system. Given the long-term uncertainty of socioeconomic conditions and air travel demand, our analysis focuses on the differences between the model scenarios rather than the absolute values of the various summary metrics we present. Our aim is not to create a single index that captures the full complexity of the relationships among aircraft noise, aviation growth, and regional economic performance. Instead, we establish a set of plausible relationships and sensitivities that could be further explored by others with alternative modeling strategies.

III. Regional Economic Impact Analysis

In the United Kingdom, overall air mobility has increased nearly fourfold over the last three decades, with revenue passenger-kilometers (RPKs) increasing from 60 million in 1975 to 290 million RPKs in 2005.[13,14] At London's Heathrow Airport, for example, annual air transport movements have increased by about 30% between 1990 and 2005—from 370,000 to 470,000 movements.[15,16] The rise of aviation in recent years is often closely associated with economic growth and globalization, and we use the regional economic impacts associated with aviation to frame the local noise damage costs and advanced technology, low-noise aircraft business case analyses. While traditional studies focus on the local spending impacts from local airport-related activities such as airline or aircraft servicing jobs, we also study the wider effects of economic geography and the longer-term catalytic effects on regional productivity.

We use the dynamic economic forecasting framework of the REMI-ECOTEC Policy Insight model (UK Version 6.0). This econometric input-output model can be used to illustrate how industries and people interact due to changes in employment, inter-regional competition, investment, government spending, and other factors. As regional industrial output changes due to an exogenous policy intervention, for example, the various feedbacks in the model will affect personal income, consumer spending, population migration, prices, and regional market shares.[17]

A. Air Transport Sector

First, we consider the direct and indirect economic impacts of purchases by the air transport industry and its suppliers, respectively, as well as the induced economic impacts from spending by households employed in the air transport industry. Table 1 shows the REMI-ECOTEC baseline economic forecast for 2005. The baseline forecast is developed using a 53-sector version of the 2002 UK national input-output tables, as well as data on employment, wage rates, productivity, occupational characteristics, and growth rates from the UK Office of National Statistics, Eurostat, the United Nations, and other sources. Long-term regional demographic trends such as population, survival rates, migration, and labor force are also integrated into the model parameters and are based on data from the UK Actuary Department. Inter-regional commodity and labor flows are calibrated using data from the United States and Europe, while the response rates to economic stimuli are set to be faster than in Europe in general, but slower than in the United States.[18]

The air transport sector is a sizable industry, and was estimated to be responsible for about 43,000 jobs in London and 2,200 jobs in the East Midlands in 2005. The sector generated about £15.1 billion (in 2002 pounds) in total output throughout the UK in 2005 and £6.4 billion pounds in Gross Regional Product (GRP). Slightly more than half of the total air transport output was created in the Greater London region. East Midlands accounted for about £300 million pounds of output and about £130 million pounds in regional value added. Value-added refers to the total monetary output minus the inputs—and can be thought of as wages and profits of an industry.[19] The air transport sector is also expected to play an increasing economic role in both regions through 2030, with its share of total regional value-added increasing from 1.5% up to 1.9% in London and from 0.19% to 0.26% in the East Midlands.

B. Air Transport Growth Scenarios

Next, we consider how UK regional socio-economic growth may be affected by changes in aviation. Growth in the aviation sector, for example, could slow as airports reach capacity limits or as environmental policies (for noise or other effects such as climate change) increase the price of air travel. We analyze these different air transport growth rates to assess the sensitivity of the regional economy to changes in aviation. We use the REMI-ECOTEC model forecasts of about 2.2% average growth in the monetary value of the output of the air transport industry as the baseline for comparison. Our "Low Growth" scenario reduces air transport growth by 50% compared to the REMI-ECOTEC baseline scenario, and roughly corresponds to the most conservative estimates of passenger growth developed under the European Constrained Scenarios on Aviation and Emissions (CONSAVE).[20] We double the REMI-ECOTEC air transport growth forecasts under a "High Growth" scenario to approximate the UK Department for Transport forecasts of annual air passenger growth increases of about 4.5% through 2020.[21] Finally, we consider a "Medium Growth" scenario with air transport rates 50% higher than the REMI-ECOTEC baseline.

Table 1. **REMI-ECOTEC Baseline Regional Control Forecasts, 2005**

Socioeconomic Indicator	Greater London	East Midlands	UK Total
Total Value Added (millions)	£212,600	£66,800	£1,100,000
Air Transport Value Added (millions)	£3,200	£130	£6,400
Air Transport Output (millions)	£7,700	£300	£15,100
Total Employment	4,000,000	1,770,000	26,620,000
Air Transport Sector	43,200	2,200	92,600
Total Population	7,490,000	4,330,000	59,980,000

Value added in millions of £2002. Source: REMI-ECOTEC UK Version 6.0

We find that there are sizable regional economic impacts resulting from changes to growth of the air transport industry, and that these impacts vary across different regions. Figure 2 shows the percentage differences in regional value added (or the total profit and wages) for the various growth scenarios relative to the 2030 REMI-ECOTEC baseline. The "Low Growth" scenario would reduce the gross regional product of the East Midlands by £300 million pounds in value-added relative to the REMI-ECOTEC baseline forecast, while Greater London would have £3.8 billion pounds less in value-added. In contrast, the doubling of aviation output under the "High Growth" scenario would increase the gross regional product by £900 million pounds of value-added in the East Midlands and £11.8 billion pounds in Greater London relative to the REMI-ECOTEC baseline. We find that the London economy had the highest sensitivity to changes in air transport. This is partially due to the large size of the air transport sector there—air transport will account for about £5.8 billion pounds in value-added and 59,000 jobs in 2030 under the REMI-ECOTEC baseline forecast.

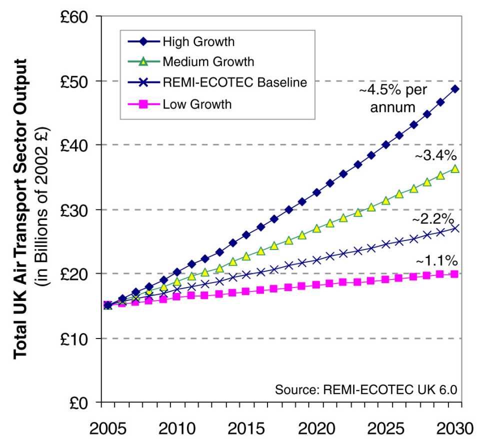

Figure 1. Total output of the UK air transport sector under alternative growth scenarios, 2005–2030.

We also find that in London, export-related services such as banking and finance or research and development were the most sensitive sectors to changes in air transport output. Figure 3 shows a percentage breakdown of the differences in value-added between the low-growth scenario and the REMI-ECOTEC baseline scenario by industry sector. In the East Midlands, manufacturing was the most sensitive sector to changes in air transport, and is responsible for almost 30% of the difference between the alternative growth scenarios and the REMI-ECOTEC baseline forecast. Manufacturing represents about 25% of the economy in the East Midlands (compared to less than 1% in Greater London). Export-related services represented nearly 40% of the economy in Greater London, but less than 20% in the East Midlands.

C. Interregional competition and catalytic impacts

Our analysis of the socio-economic effects of aviation not only considers the air transport sector itself, but also includes the regional impacts of changes to accessibility—the underlying impacts of regional air services. We found that there are substantial socioeconomic impacts beyond those that are traditionally associated with the air transport sector. The REMI-ECOTEC model implements economic geography principles by assuming that productivity increases when producers and consumers have access to more variety (commodities or labor, for example), and that distance and transportation costs affect overall commodity prices and regional market shares.[17] We simulate the effect of increased air services by modifying the commodity access coefficients

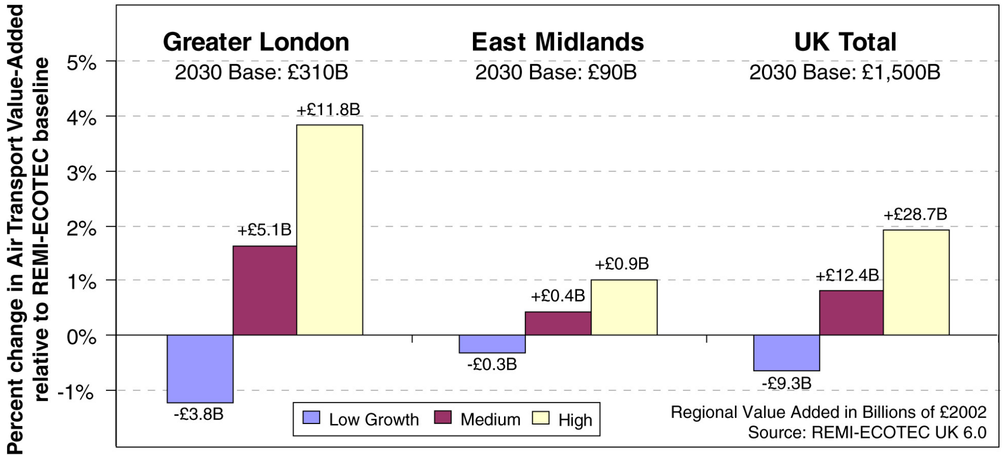

Figure 2. Gross regional product under air transport growth scenarios: Percent difference relative to REMI-ECOTEC baseline, 2030.

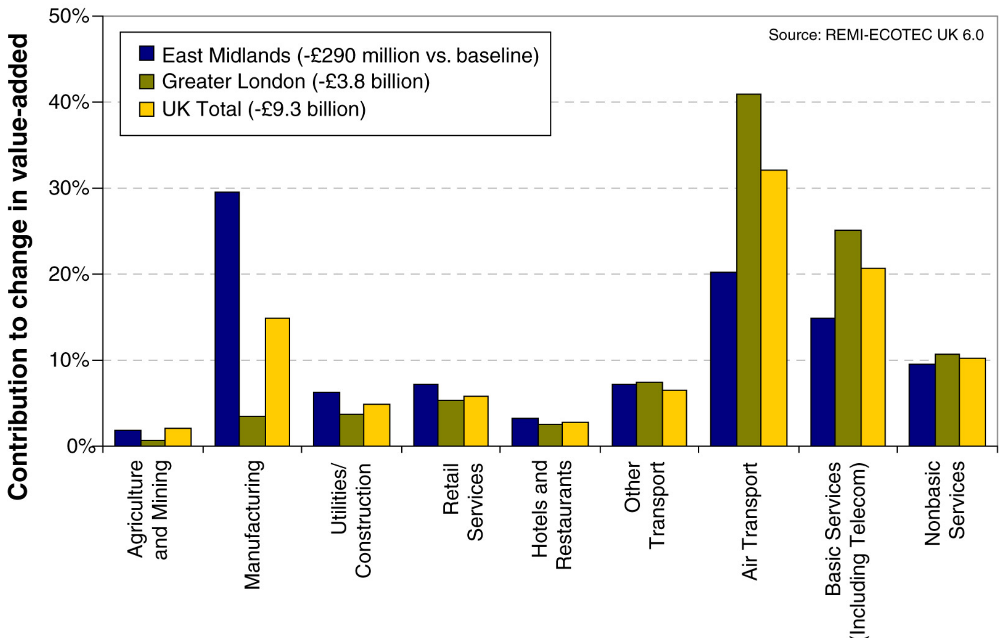

Figure 3. Sectoral breakdown of differences in value-added: Low Growth scenario versus REMI-ECOTEC baseline, 2030.

for the air transportation sector within the model, and then analyzing the resulting changes in industrial productivity and the regional market shares. We found that a 2.5% increase in access to air transport in the East Midlands raised the region's GRP in 2030 by £24.5 million above the baseline scenario. The cumulative net increase in GRP through 2030 was about £471 million pounds.

We also attempt to model the way in which aviation enables regional restructuring of the economy, favoring economic sectors that require access to global markets and suppliers. Analysts have begun quantifying these "catalytic" relationships among transport usage, business investment, and underlying total factor productivity. Total factor productivity is economic growth which is not attributed to increases in labor productivity or capital stock.[22] Increases in factor productivity enable the same output to be produced using less labor and capital.[19] Oxford Economic Forecasting (OEF), in their 1999 study on the UK aviation industry, estimated that a 10% increase in the output of all transport industries was associated with a 1.3% increase in total factor productivity between 1979 and 1997. They calculate that aviation accounted for a majority of this productivity increase, and that air transport has increased the UK gross domestic product by about £550 million annually–about three percent of the £17.5 billion pound average annual increase in UK Gross Domestic Product (GDP).[23]

To examine the magnitude of these catalytic effects of aviation at the regional level, we tested several increases in total factor productivity for private nonfarm industries in the East Midlands. Given the relationship identified by OEF, a 1.3% growth in aviation output–such as under our low-growth scenario–should increase the total factor productivity by 0.18%. We found that an increase in total factor productivity of 0.18% results in about a £170 million increase in GRP above the baseline by 2030. Similarly, we considered productivity increases of 0.46, and 0.61 for the medium growth, and high growth scenarios, respectively. A 0.46% increase in productivity translates into an increase of about £455 million in GRP, wihle the effect is about £600 million for a 0.61% increase in productivity. Although these economic impacts can only be conceptually related to the scenarios shown in the previous section (Figure 1), these results do suggest that the catalytic effects of aviation can be a significant contributor to overall regional economic growth—especially over the long-term. Additional research is needed to further analyze the extent of the catalytic relationship between air transportation and economic productivity.

IV. Noise Impact Analysis

Having established the magnitude of the impacts of air transport on regional socio-economic growth, we now consider how aviation noise affects the local neighborhoods around the East Midlands and London Heathrow airports. In particular, we focus on housing prices as an economic proxy for noise damages. We determine the noise impacts under several different future traffic growth scenarios that are based on capacity limits and long-term traffic forecasts developed by the UK Department for Transport and the UK Civil Aviation Authority (CAA). For London Heathrow, we include a medium growth scenario that fully maximizes the use of the existing runways under mixed-mode operations and a high growth scenario that also relies on mixed-mode operations but adds a third runway.[a] We also use similar traffic forecasts and scenarios at East Midlands. To assess how changes in aircraft technology may mitigate these noise impacts, we also analyze the Heathrow high growth scenario under varying amounts of low-noise technology aircraft operations using the Silent Aircraft Initiative's SAX-40 design as an example.

We use the Federal Aviation Administration's Integrated Noise Model (INM) Version 6.2 to calculate the average daily noise levels around London Heathrow and East Midlands under the different airport traffic scenarios.[b] Flight track data was obtained from the DfT and the East Midlands Airport. Our long-term traffic growth scenarios are based on forecasts developed for the UK Aviation White Paper[26,27] and also the East Midlands Airport Draft Master Plan.[28] We use airline schedule and operational data to allocate the flights by time-of-day (day, evening, or night) and aircraft noise class, using five aircraft types (Dash-8, 737-700, 767-300, 747-400, and 747-200) as a coarse approximation for the fleet operated at each airport.[29] In the medium and high growth scenarios, we maintain the same fleet mix and flight timings as in the base

[a]The runway alternation scheme at London Heathrow segregates the operations under a multi-week schedule so that all landings occur on one of the parallel runways and all takeoffs occur on the other in order to provide noise relief for communities living near the airport. Eliminating this scheme is predicted to increase runway capacity by 15-20%.[24]

[b]Although our contours for London Heathrow were 20 to 30 percent smaller than the official DfT contours, this is within the expected range of differences between INM and the proprietary model used in the UK (ANCOM 2).[25]

case.[c] While these simplified assumptions do not take fleet replacement into account and will thus somewhat overstate the growth of the noise contours, they enable us to focus on the contribution of an advanced technology, low-noise aircraft to the noise environment.

For each of the different airport noise scenarios, we calculate the theoretical appreciation in residential property values due to reductions in noise exposure levels. We use a geographic information system to identify the population and number of housing units within each noise contour band. Our housing unit data are based on population-weighted output-area centroids from the UK 2001 census, with each centroid representing about 300 residents and 130 dwelling units. We use census ward-level housing sales price data to determine the average value of the homes within each noise contour band. Note that we do not assume any changes in population growth nor housing values in order to focus on the sensitivity of the noise contours themselves rather than the effects of socioeconomic growth.[d]

We use a range of Noise Depreciation Index (NDI) values to identify the effect of aircraft noise on housing values. We apply NDI values of 0.51% to 0.67% per decibel in noise change, following Nelson's recent findings in a meta-analysis of previous studies.[30] To evaluate the total noise damages, our calculations assume that the 57-dBA 16-hour LEQ noise contour contracts inwards to the airport boundary, and thus that no residential dwellings around the airport would experience noise levels above 57-dBA. Dwellings within the existing 72-dBA contour, for example, would experience noise reductions of up to 15-dBA, while dwellings inside the existing 60-dBA contour would experience reductions of only 3-dBA on average.

A. East Midlands Damage Costs

The scenarios at East Midlands include a roughly 100% increase in operations under the medium growth scenario and 350% increase under the high growth scenario. As shown in Figure 4, the area of the 57-dBA contour grows by about 75% under the medium growth scenario and about 200% under the high growth scenario. Although the geographic extent of the noise impacts grows somewhat modestly relative to the increase in operations, the number of housing units affected increases more steeply. Under the current airport operational scenario, there are about 390 dwelling units within the 57-dBA contour. As the traffic levels increase, the contour area grows to include about 1,300 dwelling units under the medium growth scenario and 4,200 dwelling units under the high growth scenario–increases of about 200% and 1000%, respectively.

There is a disproportionate increase in the noise damage costs relative to the increase in capacity. Table 2 shows that the current noise damage costs range from about £0.18 to £0.24 million pounds. Under the medium growth scenario, the noise damage costs increase by about 300% to about £0.7–£1.0 million pounds—a greater change than the population or dwelling units affected. Under the high growth scenario, the noise damage costs increase to £3.2—£4.2 million pounds, an increase of about 1,600%.

Table 2. Noise damage cost calculations around East Midlands Airport under different traffic growth scenarios

	Current	Medium	High
Annual ATMs	57,400	122,300	262,200
57 dBA Contour Area (hectares)	9.4	16.6	29.2
Affected Population	890	3,000	9,930
Affected Dwelling Units	390	1,300	4,200
Damage Costs (millions)	£0.18–0.24	£0.7–1.0	£3.2 –4.2

Source: Authors' calculations using INM 6.2 and ArcGIS 9.0

[c]The only exception is that under the medium- and high-growth scenarios, we did assume that the handful of noisiest aircraft operations (represented by the 747-200) are replaced by 747-400s.

[d]The REMI-ECOTEC baseline model forecasts a relatively low population growth for these regions (0.3% per year for Greater London and about 0.9% for the East Midlands).

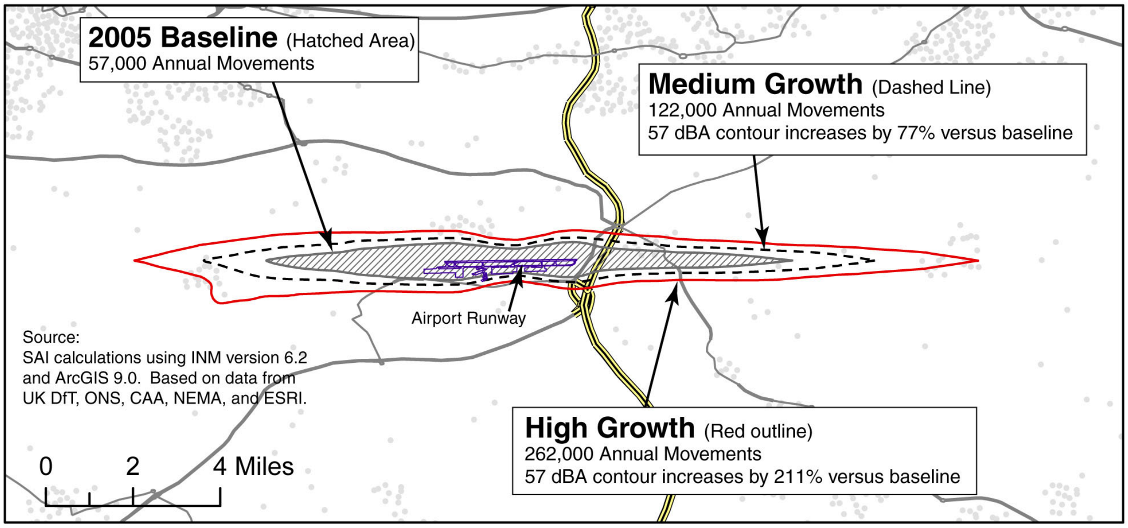

Figure 4. Current and future 57-dBA 16-hour LEQ contours at East Midlands Airport

B. London Heathrow Damage Costs

Figure 5 shows our calculations for the current and future noise contours for London Heathrow. Again, note that these are likely to be overestimates of the damage costs, due to expected reductions in the noise generated by conventional aircraft in the future that we do not model. The medium and high growth scenarios represent about 20% and 64% increases in capacity over current levels. The increase in the size of the contour is disproportionate to the increase in capacity; the 57-dBA contour increases by about 12% under the medium growth scenario and 57% under the high growth scenario. The population and housing units both grow by about 16% and 64% under the medium and high growth scenarios. The noise damages rise more than the increases in population or housing. As shown in Table 3, the current noise damages are about £180–£230 million pounds. The noise damages increase by about 24% to £220—£290 million under the medium growth scenario, and increase by £69 percent to £300–£390 million under the high growth scenario. This higher sensitivity to the noise damages (with respect to the population and housing units affected) reflects the location of several high-income communities under the flight tracks at the edges of the current 57-dBA noise contours.

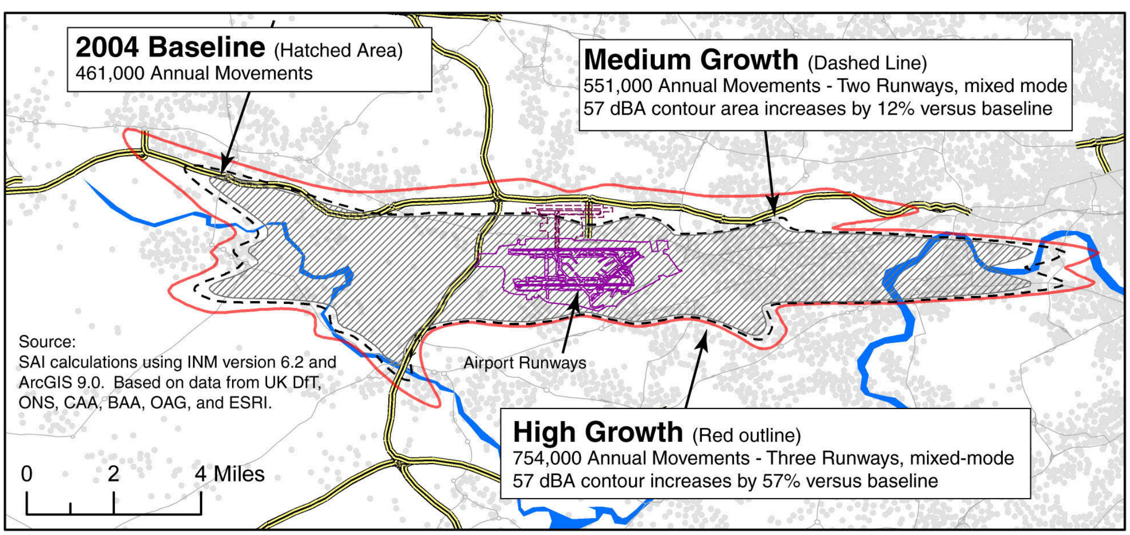

Figure 5. Current and future 57-dBA 16-hour LEQ noise contours at London Heathrow airport

Table 3. Noise damage cost calculations at London Heathrow under different traffic growth scenarios

	Current	Medium	High
Annual Air Transport Movements	461,000	551,000	754,000
Contour Area (hectares)	89.1	99.8	139.4
Affected Population	176,700	203,400	288,800
Affected Dwelling Units	72,700	85,500	119,500
Damage Costs (millions)	£180–280	£220–290	£300–390

Source: Authors' calculations using INM 6.2 and ArcGIS 9.0

C. London Heathrow Damage Costs with Low-Noise Aircraft

Finally, we consider the changes in noise damages at London Heathrow if an advanced, low-noise aircraft were to be introduced in the fleet.[e] For this scenario, we assume that by 2030, SAX-40 or similar advanced technology, low-noise aircraft are readily available for incorporation in the fleet. We stress that this is a scenario and may not reflect what is probable in this time period. We consider the high growth scenario (754,000 annual air transport movements) as a basis for reference. Figure 6 shows our noise contour calculations for a "Limited SAX" scenario under which the SAX-40 replaces all Noise Class 4 aircraft (represented by the 767), and an "Intermediate SAX" scenario under which the SAX-40 replaces both Noise Class 4 and 5 aircraft (represented by the 767 and 747, respectively). Again, note that the noise characteristics of all other (conventional) aircraft remain unchanged

Under the Limited SAX scenario, the noise contour area shrinks by about 16% relative to the high growth scenario. Table 4 shows that the corresponding housing damage costs decline by about 33% to £200–£260 million pounds (versus £300–£390 million). Under the Intermediate SAX scenario, the noise contour area shrinks by about 43% relative to the high growth scenario, while the noise damages declines more steeply–by about 68% to £100–£130 million pounds. The net change in damage costs relative to the current noise damages is a 14% increase for the Limited SAX scenario and a 46% decrease for the Intermediate SAX scenario.

Table 4. Noise damage cost calculations at London Heathrow under advanced technology, low-noise aircraft scenarios

	High Growth	Limited SAX	Intermediate SAX
Annual Air Transport Movements	754,000	same	same
Contour Area (hectares)	139.4	116.5	79.2
Population	288,800	220,600	127,700
Affected Dwelling Units	119,500	89,700	49,900
Damage Costs (millions)	£300–390	£200–260	£100–130

Source: Authors' calculations using INM 6.2 and ArcGIS 9.0

V. Airline Business Case Analysis

In this section of the paper, we connect the aircraft noise performance and aviation growth to airline industry economics. We analyze the operating economics of the Silent Aircraft Initiative's final design concept

[e]Our analysis is based on the estimated performance of the SAX-40 concept aircraft.[31,32] We did not develop a set of advanced low-noise technology aircraft scenarios for the East Midlands Airport, because medium- and long-haul aircraft currently represent a small percentage of operations there.

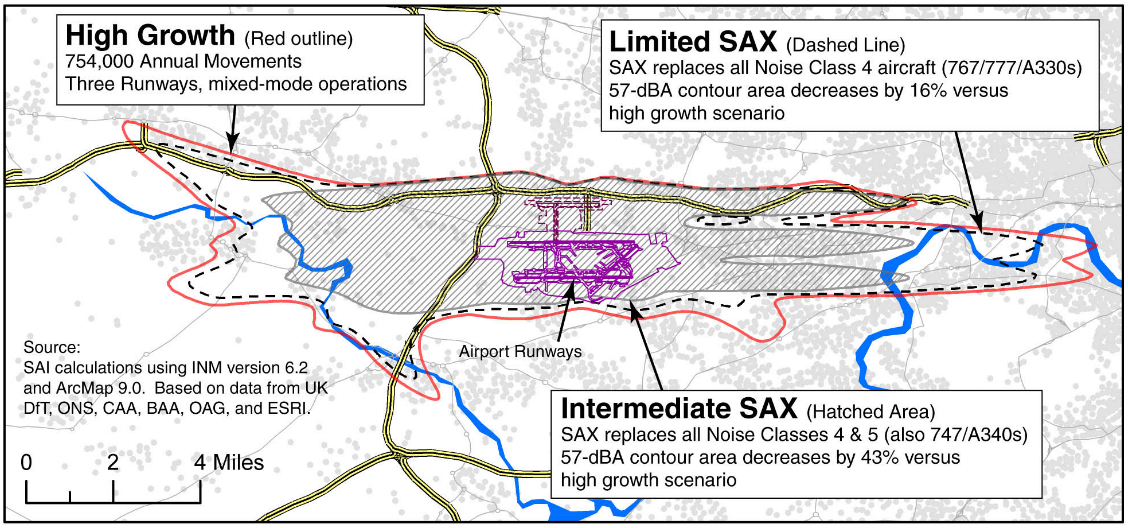

Figure 6. 57-dBA 16-hour LEQ noise contours under alternative advanced technology, low-noise aircraft replacement scenarios, as compared to the "High Growth" scenario

(SAX-40). We develop an airline business model to compare an airline's relative profit per aircraft per year for an advanced technology, low-noise aircraft and to competitors in the same seat-class. The SAX-40 concept aircraft seats 215 passengers in a 2-class international configuration and has a maximum range of 5,000 nautical miles. Our comparison includes conventional aircraft with a similar capacity and range, including the Boeing 767-300ER (1980s-technology) and a current-technology (2006) mid-size international aircraft. We also extrapolate fuel burn improvements to illustrate how a 2020-technology aircraft may compare to the SAX-40. We then assess how ownership and maintenance costs may differentiate an advanced technology, low-noise aircraft from conventional aircraft under a range of noise-related scenarios for noise regulations and landing fees.

A. Profitability Model

Our top-down fleet planning model[33] uses various parameters for operating costs and revenues in order to understand how the operational performance of an advanced technology, low-noise aircraft may affect airline profitability. Operating revenues per block-hour are assumed to be the same for all aircraft types, although the yield on night flights is discounted by 10% to reflect the lower desirability of late-night departure or arrival times. Our assumption of an average yield of 11 cents per revenue-passenger mile is based on ICAO and US DOT transatlantic airfare data for an average stage length of 3,000 nautical miles. Our revenue calculations are based on an average load factor of 80% and include cargo revenue totalling 12% of the total passenger revenue.

The operating costs are based on the US Department of Transportation Form 41 financial reports of US airlines.[34] Indirect operating costs such as passenger and aircraft servicing or administrative costs are assumed to be the same for all aircraft. We assume that some direct operating costs such as crew costs are the same for all aircraft types. Other direct operating costs, such as maintenance, are based on block-hour utilization, while ownership costs are the aircraft purchase price depreciated over 20 years with a 10% residual value. The purchase prices are based on extrapolated trends of average price per seat; our model assumes a B767-300ER price of $128 million, a 2006-technology aircraft price of $142 million, and a purchase price of $161 million for both the SAX-40 advanced technology, low-noise aircraft and the 2020 conventional technology aircraft.

To illustrate how aircraft technology may affect profit and performance, our model includes key differences in fuel burn, speed, and average utilization. We model the B767-300ER as having a fuel burn of about 1250 gallons per block-hour. The 2006-technology aircraft assumes a 20% reduction in fuel burn relative to the B767-300ER (about 1000 gallons per block-hour). We assume a further 20% reduction in fuel burn for the

2020-technology aircraft (about 800 gallons per block-hour). The SAX-40 is estimated to have a fuel burn of 670 gallons per block-hour.[8] The other key driver in the profitability model is aircraft speed, and thus average daily aircraft utilization. The B767-300ER and the advanced technology, low-noise SAX-40 operate at Mach 0.80, while the 2006- and 2020-technology aircraft are assumed to operate at Mach 0.85. Aircraft utilization is also affected by average flight stage length, which is based on an analysis of typical and feasible destinations from London. We assume an average aircraft stage length of 3,000 nautical miles.

B. Regulatory Scenarios

We frame the analysis using a set of local policy scenarios that represent the operational restrictions and costs that are imposed by local communities on the air transportation system in response to the noise damages. The "Light Green" and "Dark Green" scenarios provide progressively greater operational and financial penalties for airlines that operate conventional, noisier aircraft, as well as incentives to operate an advanced technology, low-noise aircraft. Conventional aircraft, for example, are assumed to have landing charges that are 50% higher than today under the light green scenario and 100% higher landing changes under the dark-green scenario. In contrast, we include a relative incentive to operate an advanced technology, low-noise aircraft, with landing charges increasing by only 30%.

The policy scenarios also affect the average aircraft utilization and thus overall operating costs and revenues. Heathrow airport currently employs a quota system to limit the total number of operations at night. The Light Green scenario assumes that these restrictions remain in place for conventional aircraft, but that night flying restrictions are removed for the advanced technology, low-noise aircraft as an incentive. Under the Light Green scenario, the average daily utilization for such an aircraft would be 11.8 block-hours per day compared to 11.2 block-hours for a conventional aircraft. Under the Dark Green scenario, all aircraft would be forbidden between 11pm and 7pm except for the advanced technology, low-noise aircraft—further increasing the SAX-40 utilization up to 14.2 block-hours per day, while decreasing the conventional aircraft utilization to 10.6 block-hours.

Our finding is that the SAX40 outperforms the conventional aircraft under all regulatory scenarios tested under current operating cost and revenue assumptions–assuming that its purchase price and maintenance costs are no greater than conventional aircraft alternatives. Under the Dark Green scenario, it is the only profitable aircraft. Landing fees–such as those related to noise restrictions–represent about 1% of the total operating costs under the base case, and thus have only a moderate impact on the relative profitability of conventional aircraft.

C. Maintenance and Ownership Cost Scenarios

Because the SAX-40's embedded multi-fan, single-core engines and blended fuselage-wing is a more complex design than that of conventional aircraft, we conducted sensitivity tests to assess the impact of higher maintenance and ownership costs.[f] We modeled a 30% increase in maintenance costs for the SAX-40 relative to other aircraft. This results in the SAX-40 having a slightly lower profit than the nominal 2020 aircraft technology under the Base Case scenario, but higher profit than the other aircraft under all other scenarios. Increasing the purchase price of the SAX-40 by 25% up to $200 million makes the SAX less profitable than other aircraft under the Base Case and Light Green scenarios, but it still remains the only profitable aircraft under the Dark Green scenario. Note that these scenarios for maintenance and ownership costs are only intended to illustrate the tradeoffs. The differences in maintenance and/or ownership costs for an advanced technology, low-noise concept aircraft such as the SAX-40 are not known.

For the higher purchase price and/or maintenance cost scenarios we considered, an advanced technology, low-noise aircraft would be more attractive than a conventional 2020 technology aircraft only if there were regulatory changes. The SAX-40 is attractive under the Dark Green scenario, even with increased maintenance and aircraft purchase costs. The diagonal lines in Figure 8 illustrate the tradeoffs between maintenance costs and purchase price that would keep an advanced technology, low-noise aircraft competitive with the 2020-technology aircraft.

[f] For a Boeing 767-300ER, ownership represents about 16% of the total costs, while maintenance is about 8%.

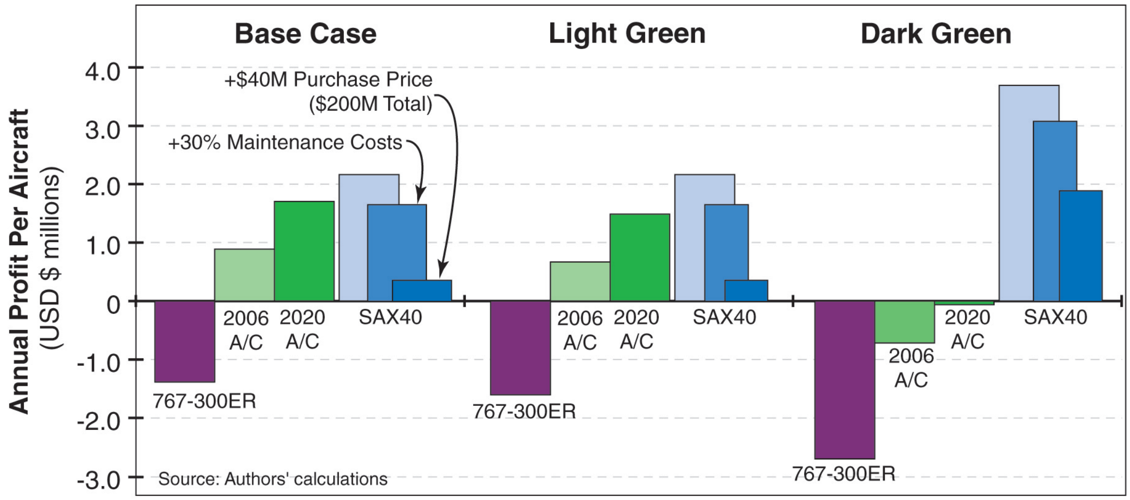

Figure 7. Annual Total Profits under various scenarios (3,000 nm average stage length)

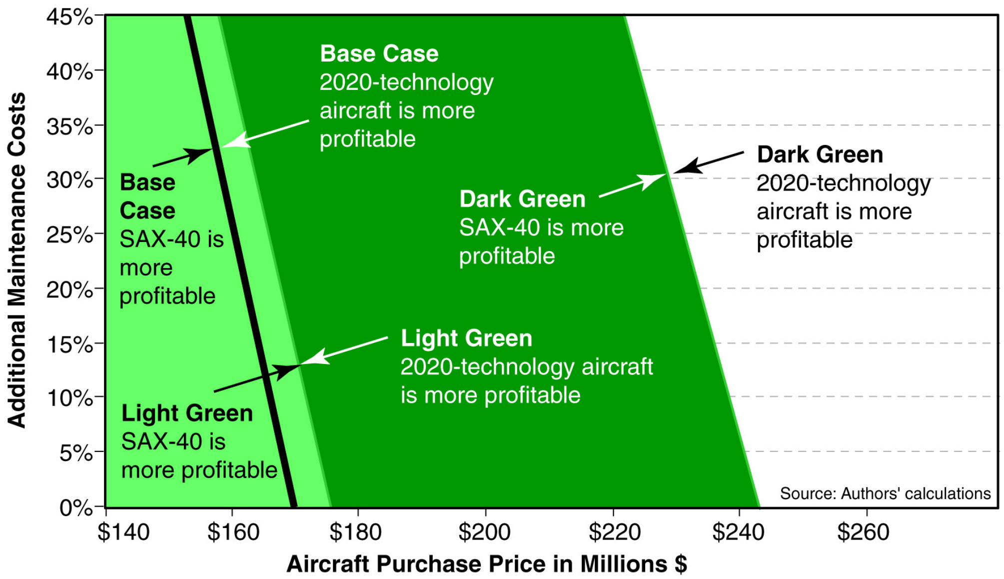

Figure 8. Tradeoffs between maintenance costs versus purchase price: advanced technology, low-noise aircraft versus 2020-technology aircraft

VI. Conclusion

Our objective was to highlight some of the interrelationships and potential trade-offs between aircraft technology and economics, and also between local communities and regions. We found that there is a sizable economic impact directly from the aviation sector, but also that there are longer-term regional impacts due to increased competitiveness and changes in economic geography. We found that a technological step-change such as an advanced technology, low-noise aircraft may significantly mitigate impacts on the community (using a noise depreciation index and changes in housing values as a proxy for the value placed on a low-noise environment by the community)—especially within the context of aviation growth. We also illustrated, at a high level, the economic and regulatory scenarios under which an advanced technology low-noise aircraft may be attractive relative to conventional aircraft expected to be available in 2020.

By considering the relationships among aircraft noise, property values for airport-area homeowners, regional economics, and airline business profitability, we give greater consideration to the larger context of community, the economy, and industrial competitiveness than is often done with traditional aviation cost-benefit and cost-effectiveness studies. Balancing the commercial needs of the air transportation system and regional growth with local impacts and costs always presents a challenging dilemma for policymakers. Our analysis highlights important interdependencies and potential trade-offs among community impacts, the airline industry and regional economics.

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