Lufthansa Systems

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Aircraft noise and its effects

01. Aircraft noise and its effects

Abstract

For many living around airports, noise is the most evident environmental impact of aviation. This study examines the sources of noise from aircraft and airports, the effects of noise on people and the implications of government rules for the growth in aviation. Potential technical and policy options to reduce aircraft noise are outlined.

The problem

Aircraft noise has been an issue ever since the introduction of the first jet aircraft, since when the benefits of progressive technological improvements have tended to be offset by the introduction of larger aircraft, more frequent movements (often at sensitive times of day) and growing community expectations. Current aircraft noise can affect the quality of life of millions of people living close to airports.

Increases in air traffic could outstrip technological progress in making individual flights quieter and so worsen the noise climate around many airports over the next 30 years. Especially in Asia air traffic is rapidly increasing. "For example, Indian aviation projections show airport passenger traffic growing from 143 million in 2010/11 to 452 million by 2020/21" (Source: CAPA – Centre for Aviation & India's DGCA – http://centreforaviation.com/analysis/capa-report-india-requires-usd40bn-investment-in-50-greenfield-airports-by-2025-79925; retrieved July 28, 2016).

As a result, more people could be affected by sleep disturbance, annoyance and possible health effects. Aircraft noise "can be one of the most objectionable impacts of airport development" (Department for Transport, 2002) and could constrain airport expansion unless substantial noise reductions are made.

Definition of Aircraft Noise

Aircraft landing and taking off are the chief sources of aviation noise. Individual aircraft have become quieter over the past 30 years, but flight frequencies have increased. As a result, aircraft noise is giving rise to increasing community concern. In particular, landing noise is increasing in importance, and has become the dominant reason for complaints at some airports. In addition, those living close to very large airports may experience 'ground noise' from sources on the airport such as taxiing aircraft, aircraft engine tests, generators or airside vehicular traffic.

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02. Human Health

Annoyance and Interference

Interference is perceived as an objective term, describing something that prevents them from doing what they want to do; it is an interruption or a distraction. For example, people associate a negative reaction “makes me mad,” “causes my blood pressure to rise” – with the term annoyance. Interference can be a short-term occurrence, such that once the noise source has passed the perceived interference ends.

Annoyance, however, because of the emotional component is more long-lasting. It seems reasonable to consider annoyance as the reaction that causes a person to evaluate the experience as negative or to consider registering a complaint (Miller et. al., 1999, P. 14).

Aircraft noise interference can result in annoyance but does not necessarily do so. The aircraft noise probably must exceed a certain level or number threshold before it is perceived as annoying (Miller et. al., 1999, P. 99). In Germany, 12 % of the total population is considerably annoyed by air traffic noise. That is second behind road traffic (30%) and ahead of railroad (8%) and industrial noise (7%) (UBA, 2006).

Noise can lead to people feeling stressed and angry. It may interfere with conversations and leisure activities in the home, disrupt activities requiring concentration, and discourage people from using outdoor spaces. However, while many express concerns over aircraft noise, there remain considerable uncertainties over the precise nature of its impacts. (Postnote, 2003, P. 1) It is apparent that the mix and types of aircraft, their frequency of overflight, the social and economic circumstances of affected people and general levels of environmental awareness and sensitivity have changed since the early 1980s.

If appears that an open information policy from airport operators on where and when to expect noise can to some extend reduce the grade of annoyance. As an example, the operator of Frankfurt International Airport shows current noise levels online on the interrnet. (Fraport, 2016)

Sleep disturbance

Interference with sleep patterns is frequently reported by those living near airports operating night flights. A study of residents in high noise areas close to Heathrow, Gatwick, East Midlands and Coventry airports found between 1 in 5 and 1 in 10 people often reporting difficulty getting to sleep or being woken early (Postnote, 2003, P. 2).

According to sleep physiology daytime hours are by no means unproblematic, especially for the non-adult population and for airports with relevant amounts of traffic during daytime hours, that based on current knowledge it is unclear or calls for individual case analysis whether a core period without air traffic is actually the superior strategy compared to restricted air traffic during the whole night. (Basner et. al., 2007)

Hearing loss

Research indicates that hearing loss is less a product of aging than a result of exposure to transportation related noise (Rosen, 1965). Any sound louder than normal conversation can damage the delicate hair cells in the cochlea, the structure in the inner ear that converts sound waves into auditory nerve signals. Initially damage to the cochlea may be temporary, but with repeated exposure, the damage becomes permanent and tinnitus maybe develop.

Other effects

The WHO points to a ‘weak link’ between frequent exposure to loud noise and effects on the cardiovascular system, but has called for further research before it can offer any guidelines. Additionally, there is limited evidence that noise can affect existing mental illness, but not cause it. In regard to school performance it is not clear whether the performance is directly affected by aircraft noise or from cumulative loss of teaching time where disrupted by loud noise.

03. Definition of noise and mechanisms of sound production

03

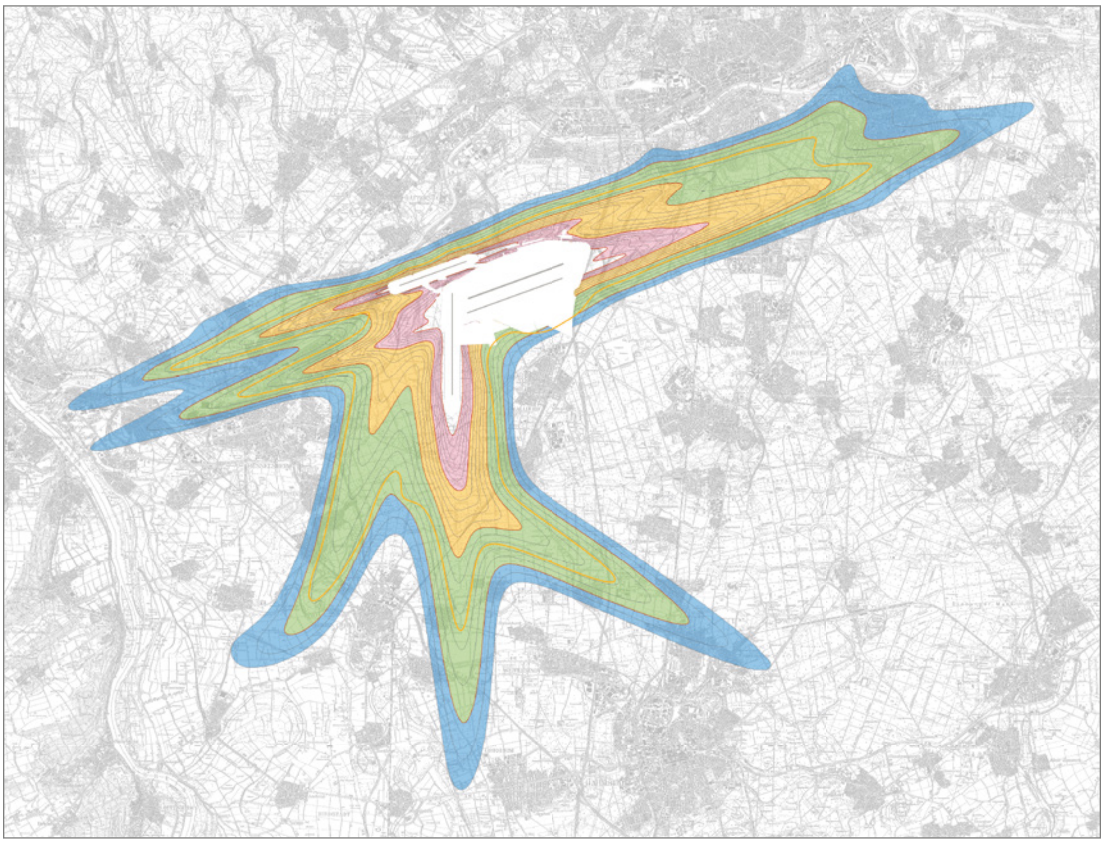
Environmental noise

Environmental noise is measured with reference to the A-weighted decibel scale, dB(A). This reflects the fact that the human ear does not detect all frequencies of sound equally efficiently. To quantify sound levels which vary with time equivalent continuous sound level or Leq is calculated. This indicates the average sound level over a particular time period. For example, an Leq, 24h of 57dB(A) indicates that the sound energy produced by the noise source is equivalent to a constant sound of 57dB(A) over 24 hours. Other measures of noise are also available, that relate to different measurement periods, such as the instantaneous maximum noise level (Lmax), or the average over certain periods. The louder the noise is, the shorter the safe amount of exposure is. Normally, the safe amount of exposure is reduced by a factor 2 for every additional 3 dB. Sometimes, a factor 2 per 4 dB or even per 5 dB is used.

Calculated Noise distribution at Frankfurt Airport (source FRAPORT)

Mechanisms of sound production

A moving aircraft including the jet engine or propeller causes compression and rarefaction of the air, producing motion of air molecules. This movement propagates through the air as pressure waves. If these pressure waves are strong enough and within the audible frequency spectrum, a sensation of hearing is produced. Different aircraft types have different noise levels and frequencies. The noise originates from the three main sources Aerodynamic noise, engine and other mechanical noise and noise from aircraft systems.



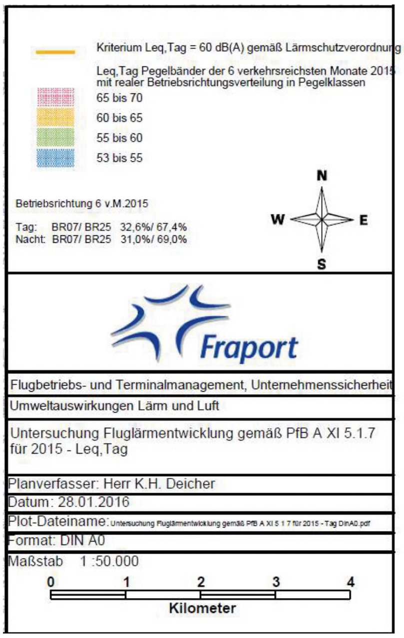
03. Definition of noise and mechanisms of sound production

Aerodynamic noise

Aerodynamic noise arises from the airflow around the aircraft fuselage and control surfaces

This type of noise increases with aircraft speed and also at low altitudes due to the density of the air. Jet-powered aircraft create intense noise from aerodynamics, which is typically broadband. Low flying, high speed military aircraft produce especially loud aerodynamic noise.

The shape of the nose, windshield or canopy of an aircraft affects the sound produced. Much of the noise of a propeller aircraft is of aerodynamic origin due to the flow of air around the blades. The helicopter main and tail rotors also give rise to aerodynamic noise. This type of aerodynamic noise is mostly low frequency determined by the rotor speed.



Engine and other mechanical noise

Noise from jet engines is mainly caused by the high velocity jet leaving the back of the engine. As the noise level is proportional to the jet speed, even modest reductions in exhaust velocity will lead to a large reduction. In addition to the exhaust noise, jet engines with high bypass-ratio turbofans do have considerable fan noise.

Much of the noise in propeller aircraft comes equally from the propellers and aerodynamics.

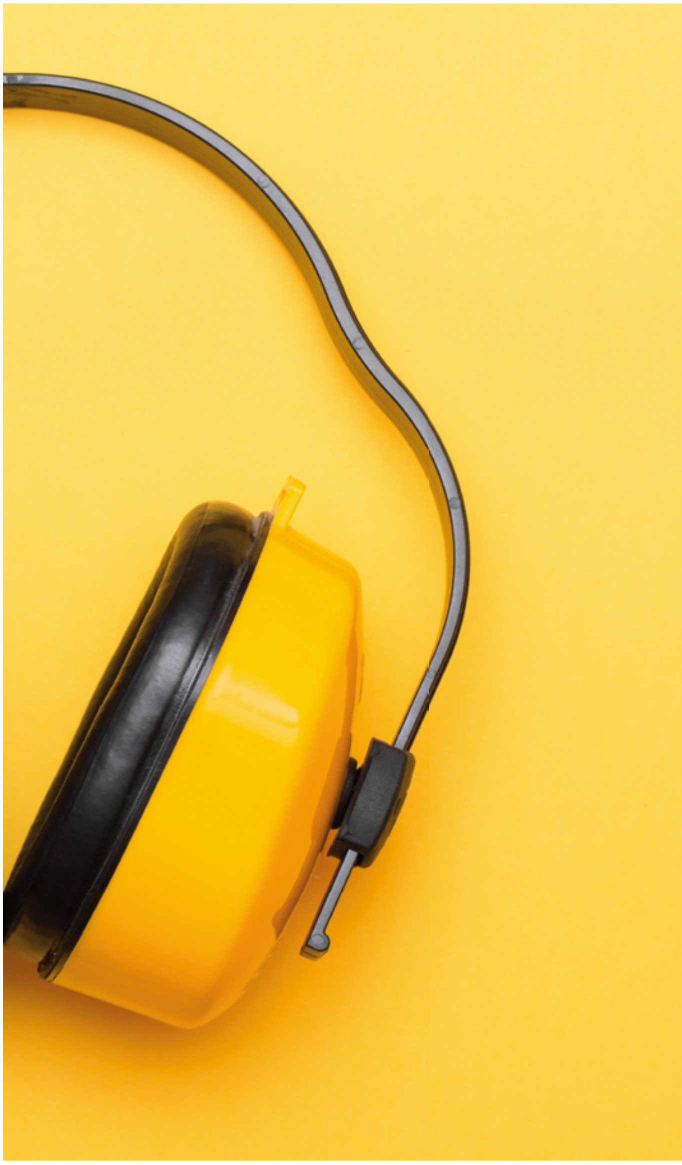
Noise from aircraft systems

Cockpit and cabin pressurisation and conditioning systems are often a major contributor within cabins of both civilian and military aircraft. However, one of the most significant sources of cabin noise from commercial jet aircraft other than the engines is the Auxiliary Power Unit (or APU). An Auxiliary Power Unit is an on-board generator used in aircraft to start the main engines, usually with compressed air, and to provide electrical power while the aircraft is on the ground. Other internal aircraft systems can also contribute, such as specialised electronic equipment in some military aircraft.

03. Definition of noise and mechanisms of sound production

Noise production during takeoff and landing

Landing aircraft descend on a three degree glide path towards an aiming point approximately 300 meters from the runway threshold. This places them at 60 meters (200 feet) above the ground at about 1200 meters (4,000 feet) from the aiming point or 900 meters (3,000 feet) from the start of the runway. This distance is usually outside the airport fence. Departing aircraft normally are over 150 meters (500 feet) above the ground before crossing the end of the runway.



Difficulties with the definition of noise values

The noise index (Laeq) averages out the noise throughout the day. It measures the noise of each aircraft (i.e. the sound energy, in decibels, that each aircraft movement produces) and averages the total out over a 16 hour day to get what is known as an equivalent continuous noise level. This problem with this method is that periods in the day when there are no aircraft noise events are included in the calculation, which leads to reduced average noise levels. Additionally, with this method insufficient weight is given to the incidence of aircraft noise events. The result is, that nowadays the same average noise level is reached with an increased number of less intensive noise events.

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04. Analysis and finding in regard to managing aircraft noise

Operational procedures

The management of airspace for safety, navigation and logistical reasons leads to a concentration of air traffic along a small number of specific airways. The area on the ground affected by noise from departing aircraft depends both on the flight path followed, and on the rate of ascent of the aircraft. There are three main ways to control take-off noise:

Noise preferential routes (NPR) – where aircraft fly over the least populated areas after take-off[1].

Managing thrust – maximum thrust generates extra noise close to the runway, but an aircraft gains height quickly. For residential areas, less thrust may reduce noise, despite the slower climb rate.

Concentrating or 'sharing' noise – an airport may adopt a policy to concentrate noise on a small number of residents under NPRs or to distribute it more widely. Annoyance with aircraft overflights may be reduced by providing information about the likelihood of the overflights; in example by trying to alter expectations. Grouping aircraft together, so that several pass in close succession rather than as individual events, may lower annoyance, though with somewhat less statistical significance than the effects of information discussed above. (Miller et. al., 1999, P. 7)

Where airports are close to populated areas, landing noise is increasingly a more serious problem. Here, final approach paths must operate in straight lines for safety reasons, so there is little flexibility in deciding which areas will be overflown. Reducing noise from landing aircraft has thus focussed on the continuous descent approach (CDA). This is where an aircraft descends smoothly from around 6,000ft, usually at an angle of around 3 degrees, rather than descending through a series of level flights and steeper descents. This allows operation on low power and with low drag, minimising changes in engine tone.
A further option could be to adopt steeper descent angles so that aircraft are higher at any particular distance from the airport during their final approach. However, current air traffic control procedures would find it difficult to safely manage aircraft approaching at different angles. Were future aircraft designs and safety regulations to allow steeper approaches, it would remain challenging to use these procedures while older and larger aircraft were using the same runway. It may be feasible however, to use longer runways for larger aircraft and shorter runways for smaller aircraft approaching more steeply. (Postnote, 2003, P. 4)

Restrictions on the use of the noisiest aircraft

Airports already impose restrictions on certain categories of aircraft at night. However, under an EU directive on aircraft noise (2002/30), restrictions on the noisiest aircraft can be introduced only after land use controls and changes in procedures have been considered.

[1] *The example of Sydney airport is apposite here. Previous policy was to concentrate noise but an Australian Senate inquiry described this policy as discriminatory and policy was changed to disperse aircraft noise over a wider area*

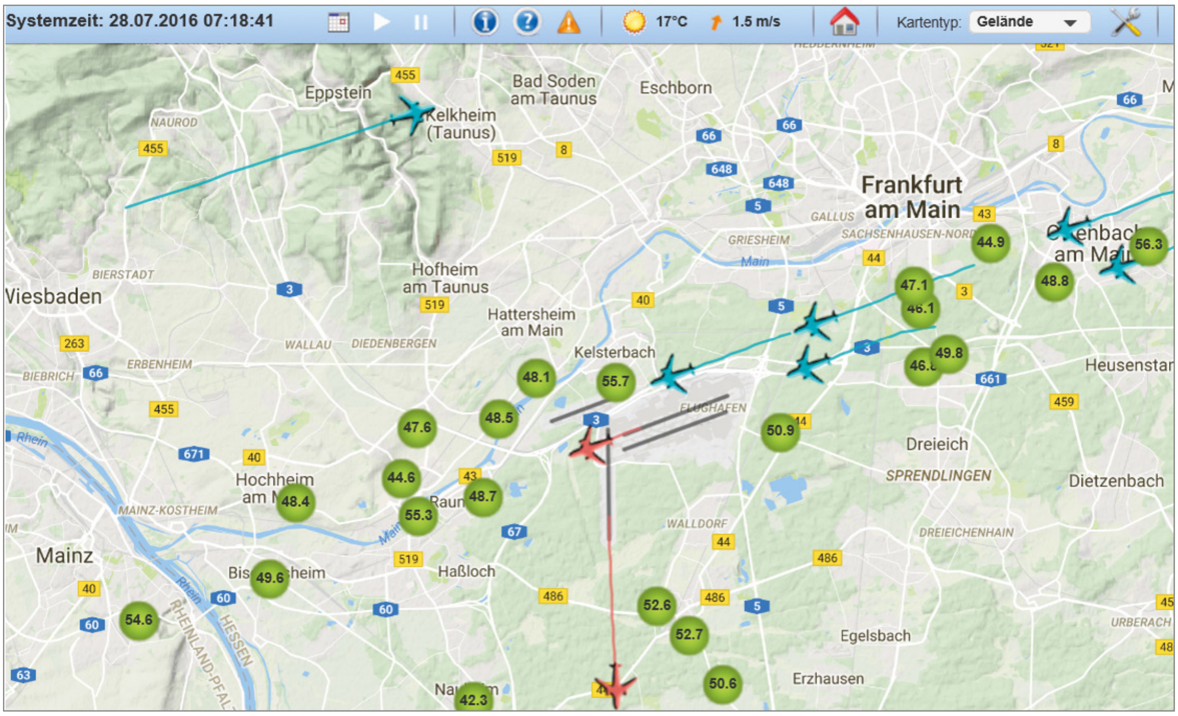
04. Analysis and finding in regard to managing aircraft noise

Further measures to reduce aviation noise

A number of further policy instruments could be used to reduce noise from aircraft, including voluntary initiatives such as agreements between airports and local communities on the number or types of day and night flights; and between airports and airlines on procedures to minimise noise. Additionally, guidance to airport operators on potential mitigation measures such as a list of take-off noise limits realistically achievable by different aircraft types, regulation such as legal sanctions for failure to follow noise preferential routes, take-off noise limits, or the number of night flights, possibly enforced via fines on offending airlines or airports as well as economic instruments such as landing charges that vary according to the noise performance of aircraft, or an airline's record on track keeping could lead to reduce noise from aircraft. (Postnote, 2003, P. 4)

Night-time noise

There are different approaches to regulate and minimize the noise created by night movements of aircraft. At London Heathrow for example, there are restrictions on the total number of aircraft movements at night (11.30pm-6am) and the types of aircraft which can be used at night. In addition, there is a noise 'quota' for the total noise allowed at night at each airport over a whole season (summer or winter) – in effect, the noisiest aircraft are banned between 11pm and 7am. Aircraft used for night movements are assigned points according to how noisy they are, which count towards the noise quota. This can provide a powerful incentive to airlines to operate aircraft in the lowest categories possible for the size and type of aircraft, particularly for many long haul routes to the Far East, whose flights leave the UK in the late evening and arrive in the early morning. (Postnote, 2003, P. 4)



04. Analysis and finding in regard to managing aircraft noise

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Recommendations

Based on the findings presented here, one has to accept that there is no single way that will lead to a solution of the noise discussion as many opposing interests prevent viable solutions that are accepted by all individuals that are significantly involved in the discussion.

It is recommended that all possibilities to reduce noise are applied to the maximum extend possible and affordable. Additionally, information in regard to noise should be given to the public in order to provide a broad understanding of effects and limitations of noise production. Furthermore, everyone involved in the noise discussion has to take into account that the overall goal to conduct air operations in a safe manner is not to be sacrificed by unsafe procedures.

The arguments analysed above are not exhaustive but they are representative for the issues which will confront the developers of future aircraft, aerodromes, airspace structures and operational procedures. They will have to be taken into account in order to avoid costly investments in design and development that might not be accepted by the public.

Conclusions

Airports are a typical example for the NIMBY[2]-effect. Residents oppose the presence, enlargement or new construction of airports even if they themselves and those around benefit from it. The benefits to a city from an airport are economically, but no-one wants it near them because of the noise, pollution and traffic it generates.

Nobody – even within the aviation industry – claims that the level of expansion envisaged in aviation will not result in noise becoming a bigger problem for a greater number of people. The only way to avoid an increase in noise problems would be to reduce the number of aircraft movements, or to see a step-change in the noise of individual aircraft. Neither is on the cards.

While individual aircraft can be made quieter, the rate of innovation and uptake of new technology are likely to be much slower than the rate of growth of air travel. The question remains over whether growth should be constrained to stay within acceptable limits, or whether the environmental impacts arising from meeting anticipated demand can be justified against other social and economic factors.

[2] *Not in my backyard*

05. Background

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Lufthansa Systems is part of the Lufthansa Group. The consulting arm of the company was established when the IT subsidiary was founded in 1995, and it has continued to evolve ever since. This background has produced a unique combination of well-founded expertise in every aspect of airline IT as well as extensive consulting experience covering all airline processes, including operational flight management, passenger service, crew planning, ground handling and revenue management.

Thomas Dohler is management consultant at Lufthansa Systems. Before he joined Lufthansa he has been flying in the military for more than 20 years. The author has been acting commander of a fighter bomber wing and has worked as a staff officer in the German Ministry of Defense (MoD).

During his career, the author has dealt on several occasions with environmental issues related to aviation, especially in regard to military aircraft noise. Additionally, the researcher has been member of the European Military Aviation Authorities Group (EMAAG). Furthermore, the researcher participated in several International Military Aviation Authority conferences and meetings.

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