Ambient noise

Ruud Ummels and
Karin Elbers

A series of research papers on a second Gatwick runway

gacc
GATWICK AREA CONSERVATION CAMPAIGN

Ambient noise in aircraft noise modelling

Abstract

Airports impact their surroundings in social, economic and environmental areas. The environmental impact of aircraft noise is acknowledged to be the most significant local impact. Sound is a value, whilst noise annoyance is subjective. In addition to aircraft noise (the target noise source), ambient noise is present as well. It includes any noise, other than that from the target noise. Noise consist of factors related to acoustic and non-acoustic characteristics. This indicates that ambient noise influences the perception of noise annoyance. The objective of this paper is to identify if there is a need to take ambient noise into account when calculating aircraft noise annoyance. Literature suggests that residents in areas with high ambient noise levels are less annoyed by a second noise source than those in a quiet environment. This thought is supported in this paper, where:

(1) ambient noise is identified as a factor that influences the perception of noise annoyance and
(2), a second noise source with almost the same sound exposure level is difficult to distinguish from the ambient noise.

Even though the level of ambient noise effects noise annoyance, it is not taken into account on a local scale within current aircraft noise modelling. It is therefore suggested to explore the development and application of local dose-response relationships to accurately determine the local impact of aircraft noise in order to take the perception of local noise annoyance into account.

Introduction

It is self-evident that there will be parties that are both in favour and against airport development. Whilst support and opposition may come from a combination of social, economic, and environmental concerns *(Schaar & Sherry, 2010*), aircraft noise is acknowledged to be one of the most significant local environmental aspects associated with airport development *(Lever & Thomas, 2003)*.

Noise is not sound, nor the loudness of sound. The word noise already implies that it has a negative impact on people, even though it is a highly subjective matter. A sound that is beautiful to one could be a terrible noise for the other. Hence, sound becomes noise only after one has given the sound a particular, subjective, appraisal *(Stallen, 1999).*

Noise annoyance is a function of the noise appraisal. Understanding noise annoyance requires the understanding of noise and the subjective appraisal. The subjective appraisal of noise annoyance suggests that the level of annoyance varies amongst annoyed residents. This thought is illustrated in the study of Fields *(1992)*, where he concludes that for equal amounts of noise exposure the degree of noise annoyance varies considerably.

This variance in annoyance is explained by three elements: acoustic characteristics and non-acoustic factors *(Guski, 1999).* The third element remains uncertain, and could in part be attributed to measurement errors *(Sanchez, Naumann, Porter, 2015).* In other words, not only the primary characteristics of sound, the acoustic factors, influence the perception of sound, but also secondary characteristics, such as sociological factors. These secondary influences are the non-acoustic factors.

Acoustic and non-acoustic factors

The acoustic and non-acoustic factors that influence noise annoyance are shown in Table 1 *(below)*, these factors are derived from different studies *(Kroesen, 2006; Sanchez et al, 2015 and OAK, 2006).*

In literature the level of background noise,the so-called ambient noise, is considered both an acoustic factor and a non-acoustic factor. This implicates that authors disagree in which category ambient noise belongs. Kroesen *(2006)* clearly identifies background noise as an acoustic factor. Background noise is after all a sound. On the other hand, Sanchez et al. *(2015)*, classified ambient noise as a non-acoustic factor. They divide non-acoustic factors into personal, social and situational factors. The latter refers to characteristics in which the noise event takes place. Background noise is therefore not the sound event itself, but a non-acoustic situational factor. Whether ambient noise is an acoustic or a non-acoustic factor is not the topic of this paper, but it clearly illustrates the influence of background noise on noise annoyance.

ACOUSTIC FACTORS	NON-ACOUSTIC FACTORS
Sound level	Noise sensitivity
Frequency	Fear of noise source
Duration	Personal benefits and costs of airport operations
Flight route	Attitude towards noise source authorities
Spectral composition	Perceived health effects
Change in noise environment	Awareness of non-noise source problems
Season and meteorological conditions	Perceived control and coping
Level of background noise	Expectations and predictability
	Preventability
	Noise insulation
	Level of background noise

Table 1. Acoustic and non-acoustic factors

Objective of the paper

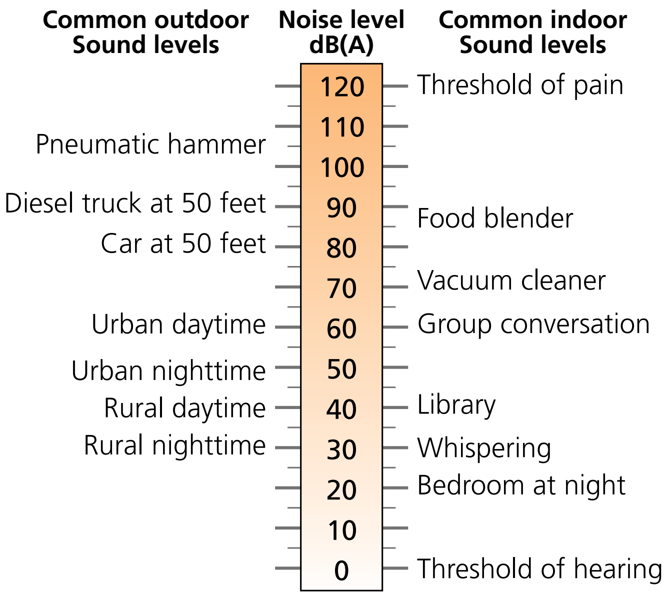
Aircraft noise annoyance has been considered the most important environmental problem at airports and, in many cases, public tolerance of aircraft noise has been diminishing *(Graham, 2008).* The noise policies adopted by national governments in relation to major airports mainly focus on reducing the level of noise exposure and the number of people who are exposed. Aircraft noise modelling is extensively used in airport noise management.

The objective of this paper is to identify if the level of ambient noise needs to betaken into account when calculating aircraft noise annoyance. In the next section, human audibility, the definition of ambient noise and level of aircraft noise is explained. Subsequently, the level of ambient noise will be combined with aircraft noise, to identify if there is a difference between the impact of aircraft noise on rural and urban locations. Thereafter, the methodology to model aircraft noise is illustrated, to identify if ambient noise levels are taken into account.

What can the human ear detect?

The typical hearing range with regard to sound pressure level and frequency is between 20 Hz and 20,000 Hz. The lower frequency is harder to detect. In sound metrics, the A-weighted decibel is used to account this effect. The weighing expresses the frequency in one number, the A-weighted decibel, dB(A). Figure 1 shows common dB(A) sound levels.

Figure 1. Common dB(A) soundlevels (van Deventer2014)



If two sources of noise with equal frequency (Hz) are compared, the human ear will judge the sound with the highest sound pressure level as the sound with the highest loudness *(Ruijgrok, 1993)*. In the case of the A-weighted dB, two sounds of 70 dB(A) give a total sound exposure level of 73 dB(A). The second sound will account for 3 dB(A).

When two sounds are audible with a sound level of 70 dB(A) and 65 dB(A), the total sound exposure level is 1,2dB(A) higher than the highest sound. In this case 71,2 dB(A). Under controlled laboratory settings, a person can barely detect a sound level change of 1 decibel in the mid-frequency range *(OAK, 2006)*. The healthy human ear can detect a change of 3 dB(A) for an ordinary noise. A 5 dB(A) change is noticeable while a 10 decibel change is judged by most people as a doubling of the sound. It is considered that a 3dB(A) change is discernable *(OAK, 2006)*.

Ambient noise

The British Standard *(BS4142)* defines ambient noise as an all-encompassing sound at a given location, at a given time, usually composed of sounds from different sources near and far *(British Standard, 1997)*. This definition implies that all sounds together form the ambient sound level. The target and background noise are divided in the definition of the World Health Organisation: *"The term background noise can be defined as the level of noise that is not the target noise for measurement purposes" (World Health Organisation, 2009)*. In other words, ambient noise includes any noise, other than that from the target noise source, which is present in the environment.

The level of ambient noise differs between rural and urban locations. This quietness theory assumes that residents who live in quiet areas are the types of people who value quietness. Residents, who choose to live in a city or near a busy highway, are assumed to place less value on quietness and are thus less sensitive to a second noise.

The difference in impact of noise on rural or urban areas is acknowledged in the British Standard *(BS4142)* for industrial purposes, and is recognised by the International Organisation for Economic Co-operation and Development *(OECD)* for transportation purposes. The OECD recommends limits on sound levels in dB(A) for transportation noise sources in urban and rural outdoor locations *(table 2, page 5)*.

Spatial area	*Time period*	*Average sound level dB(A)*
Rural	Daytime	50dB(A)
	Nighttime	45dB(A)
Urban	Daytime	55dB(A)
	Nighttime	45dB(A)

Table 2. Limits on sound level for transportation noise sources in spatial areas (source: Schomer, 2005)

In the particular case of aircraft noise, ambient noise is usually dominated by road traffic noise and community noise *(Fields, 1992).* Fields suggests that levels of ambient noise may have little effect on reactions to aircraft noise. Nevertheless the responses from the focus groups in the study of Heaver *(2002)* and those of Diamond et al *(2000)* suggest that those in areas with high ambient noise level are less annoyed by an additional source than those in an otherwise quiet environment *(Sanchez et al., 2015).* Lim et al. *(2008)* concurred, finding that subjective responses to aircraft noise decreases with increasing background noise levels.

What is the target noise?

Noise generated by an aircraft can be broadly categorised into two sources: aerodynamic and engine noise. Aerodynamic noise occurs when air passes over the aircraft fuselage and wings, which causes friction and noise as a result. The flap position, gear position and balance of the aircraft (nose up or down) all influence the sound exposure level. The engine noise is created by the rotation itself, and the exhaust behind the engine as it mixes with the surrounding air. Additionally, the level of noise depends on the phase of the flight: arriving, departing or taxiing.

In aircraft noise models, several metrics are used to calculate or explain noise. The sound generated by one single aircraft movement is often expressed as the highest noise level during a noise event, a single event metric which is called the maximum noise level, or LAmax. Another metric is the Sound Exposure Level (SEL). This metric includes a duration correction (duration of the event) next to the maximum noise level. SEL can be defined as the constant noise level during one second, that produces the same acoustic energy during the event (van Deventer, 2014). The Leq metric is an average sound level during a time period. In theUKtheLAeq16h metric is used. The Leq16h shows the noise exposure of the number of events between 07.00 and 23.00 hours. Lden is an Leq based noise metric adopted by the European Commission which weighs day noise by 1 dB(A), evening noise by 5 dB(A) and night-time noise by 10 dB(A) (ECAC, Doc29).

The effect of a target noise on ambient noise

An example is given to illustrate the effect of aircraft noise on ambient noise. The ambient noise of an urban area in the vicinity of Amsterdam Airport Schiphol *(The Hague)* and rural area *(Oostrum, a small village in the South of the Netherlands)* are compared. The Dutch Government published an online-tool, which allows anyone to research the sound exposure for each postal code. In The Hague, the background noise level is between 61-65 dB(A) Lden. The rural village has an ambient noise level of 46-50 dB(A) Lden. These values are on average and vary during the day.

In figure 2, these ambient noise levels are combined with aircraft noise levels during an overflight.

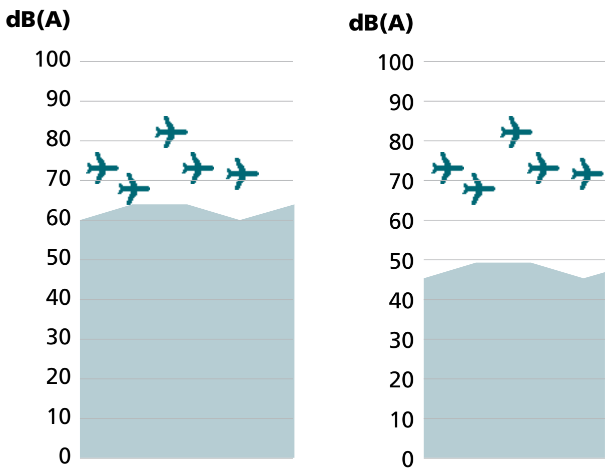


Figure 2. Urban and rural ambient noise in relation to aircraft noise levels

As can be seen, the difference between aircraft noise and ambient noise in urban area is less than in a rural area. It is expected that within the urban area it is less feasible to distinguish aircraft noise from other noise sources. In the rural area it is illustrated that aircraft noise has a significant higher sound exposure level than ambient sound, and therefore easier to distinguish from other sources. The percentage of annoyed residents is likely to be higher in areas with low ambient noise than in high ambient noise areas. It can be concluded that ambient noise is important in relation to aircraft noise annoyance for two reasons: the level of ambient noise (1) is identified as a non- and an acoustic factor that contributes to noise annoyance and (2) ambient noise influences the perceived level of aircraft noise annoyance. So how is ambient noise accounted for in the calculation of aircraft noise exposure?

Aircraft noise modeling

The standard approach to assess aircraft noise exposure around airports is a mathematical model. The generic model is visualised in figure 3.

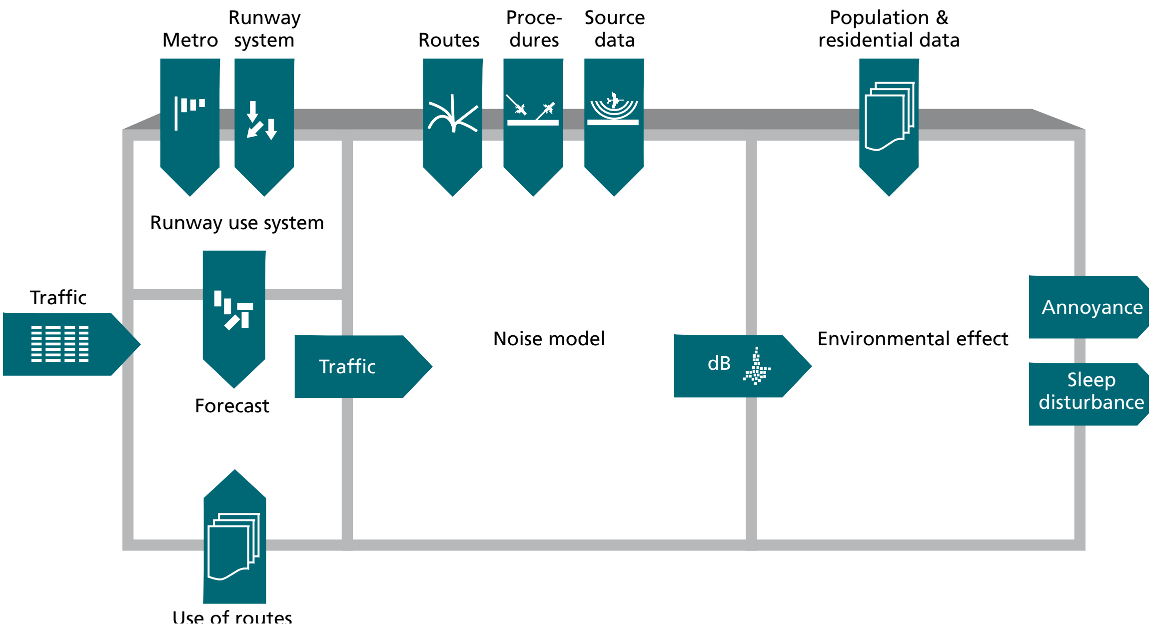


Figure 3. Aircraft noise model (Source To70)

The left side of the model provides the input: weather conditions, availability of the runways and the traffic forecast. These elements together form the detailed traffic. It consists of the number of air traffic movements for each runway, aircraft type and time of day. The core of the noise model is the calculation of aircraft noise in dB(A). This calculation is based on the recommended practices set in *ECAC Doc29Vol 3*. The right side of the model is where some of the non-acoustic factors are taken into account. It is the part where noise exposure is quantified as noise annoyance. In other words, the percentage of annoyed people (the response), at a given level of noise exposure (the dose). The dose-response metric is used to predict the level of noise annoyance in a given population, which is needed for noise impact analysis and for the development of noise mitigation strategies. In Europe the Miedema dose-response relationship *(Miedema & Oudshoorn, 2000)* is often applied.

Even though the aircraft noise model and the dose-response metric is widely recognised and used, it can be argued that this metric does not include factors of local noise annoyance. It is an average of potential annoyed residents. The uncertainty in the dose-response relationship is relatively high for low noise levels and low for high noise levels. This is likely to be caused by these local differences in areas further away from the airport. It can be misleading to compare noise annoyance between different airports, when these local differences are not taken into account. Hence, the local difference between ambient noise levels should always be taken into account when calculating the annoyance. This would require a local dose-response relation for each airport where annoyance is modelled.

Concluding thoughts

The noise policies adopted by national governments in relation to major airports mainly focus on reducing the level of noise exposure. The aircraft noise model can be used to calculate the sound exposure level and the effect on noise annoyance of annoyed residents. Whilst, on a high level scale the aircraft noise model is useful, on a local scale it is necessary to include local factors that influence annoyance. As the level of ambient noise influences the perception of noise exposure, and therefore the subjective appraisal of noise annoyance, it is necessary to include ambient noise; especially when considering airport development or airspace changes. As the percentage of annoyed residents is likely to be higher in areas with low ambient noise than in high ambient noise areas, it can be suggested that the number of people annoyed is likely to be higher than shown by Leq or Lden metrics, where local factors that influence annoyance are not taken into account. It is therefore suggested to explore the development and application of local dose-response relationships to accurately determine the local impact of aircraft noise in order to take the perception of local noise annoyance into account. The population varies by urban residential, rural and work environments. These spatial variations need to be included when calculating noise annoyance. It has to be noted that the number of variations are large and these grow as more and more spatial detail is applied to the model.

The authors

Ruud Ummels

Ruud is managing director and senior aviation consultant at To70 Aviation. He has a broad knowledge in aviation, ranging from airport and airspace planning and optimisation studies to policy advice and the analysis of aviation's impacts. Ruud is a member of the ACI EUROPE Noise Task Force and the Environmental Strategy Committee. Previously he has been a member of several noise modelling networks such as the EU X3-Noise network and the ECAC noise modelling working group Airmod. He was an independent adviser to the Australian Aircraft Noise Ombudsman for three years and has published several papers on aircraft noise, including at Inter-Noise 2011.

Karin Elbers

Karin studied Aviation Management at the Amsterdam University of Applied Sciences. As aviation consultant at To70, Karin has experience in various aspects of aviation, ranging from safety management studies to airspace design and noise impact studies.

References

Airports Commission. (2015). *Final Report.* London: Airports Commission.

British Standard. (1997). *Method for rating industrial noise affecting mixed residential and industrial areas.* London: Health and environment sector board.

CAA. (2015). *Measuring the impact of continuous noise*. Retrieved from Noise contours: https://www.caa.co.uk/Environment/Environmental-information/Information-by-environmental-impact/Noise/Measuring-and-modelling-aviation-noise/Measuring-the-impact-of-continuous-noise/

CAPA. (2013, October 15). *UK Airports Commission*. Retrieved from Centre for aviation: http://centreforaviation.com/analysis/uk- airports-commission-the-uks-runway-capacity-farce-continues-as-opponents-dig-in-133415 Commission, A. (2013). *Aviation Noise*. London: Airports Commission.

ECAC. (2005). *Doc 29 Vol 2.* ECAC.

ECAC. (2005). *Doc29 Vol 1*. ECAC.

Federation, A. E. (2015, January 26). *People increasingly disturbed by aircraft noise.* Retrieved from Government noise attitudes survey: http://www.aef.org.uk/2015/01/26/government -noise-attitudes-survey-people-increasingly-disturbed-by- aircraft-noise/

Fidell, S., & Pearsons, K. (1998). Community response to environmental noise. In M. Crocker, *Handbook of acoustics* (pp. 907-915). New York: Wiley-Interscience Publication.

Fields, J. (1992). *Effect of personal and situational variables on noise annoyance.* Atlanta: US department of transportation. Graham, A. (2008). Managing airports, an international perspective. Oxford: Elsevier Ltd.

Guski, R. (1999). Personal and social variables as co-determinants of noise annoyance. *Noise Health*, 45-56.

Guski, R. (2004). How to forecast community annoyance in planning noisy facil ities. Noise Health, 59-64. Kroesen, M. (2006). *Noise annoyance and Schiphol.* Delft : Delft University of Technology.

Kroesen, M., Molin, E., & van Wee, B. (2008). *Testing a theory of aircraft noise annoyance.* Delft: Delft University of Technology.

Lever, M., & Thomas, C. (2003). Aircraft noise, community relations and stakeholder involvement. In P. Maughan, D. Upham, & D.Raper, *Towards sustainable aviation*. New York: Earthscan publications.

Lim, C., Kim, J., Hong, J., & Lee, S. (2008). Effect of background noise levels on community annoyance from aircraft noise. *Acoustical society of America,* 766-771.

London Gatwick . (2015). *Causes of aircraft noise.* Retrieved from Noise explained: http://www.gatwickairport.com/business - community/aircraft-noise/air-traffic-noise-explained/causes-of-aircraft-noise/

LVNL. (2007). *Noise annoyance mitigation at airports by non-acoustic measures.* Amsterdam: Air Traffic Control the Netherlands. Miedema, H., & Oudshoorn, C. (2000). *Elements for a position paper on relationships between transportation noise and annoyance.* TNO.

OAK. (2006). *Aircraft noise, OAK Master Plan*. Portland: Oakland International Airport.

Overheid. (2008). *Hinderbeleving en gezondheidseffecten.* Retrieved from decentrale regelgeving: http://decentrale.regelgeving.overheid.nl/cvdr/images/Groningen%20%28Gr%29/i45501.pdf

Ruijgrok, G. (1993). *Elements of aviation acoustics.* Delft: Delft University Press.

Sanchez, D., Naumann, J., Porter, N., & Knowles, A. (2015). Current issues in aviation noise management: A non -acoustic factors perspective. *The 22nd International Congress on Sound and Vibration.* Florence: International Institute of Acoustics and Vibration.

Schaar, C., & Sherry, L. (2010). Analysis of airport stakeholders. Fairfax: ICNS.

Schomer, P. (2005). *Criteria for assessment of noise annoyance*. Reston: Institute of Noise Control Engineering. Stallen, P. (1999). A theoretical framework for environmental noise annoyance. *Noise Health*, 69-80.

van Deventer, F. (2014). *Handboek basiskennis vliegtuiggeluid.* Capelle aan de IJssel.

World Health Organisation. (2009). *Night noise guidelines for Europe.* Copenhagen: WHO.

A series of research papers on a second Gatwick runway

gacc

GATWICK AREA CONSERVATION CAMPAIGN