MEMO

MARSHALL DAY Acoustics

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We understand that questions have been raised by Waimakiriri District Council as to the relevance of the Taylor Baines Study to the Kaiapoi community. The 2002 Taylor Baines Study involved a community noise annoyance survey of residents subjected at that time to noise from Christchurch International Airport.

The Taylor Baines study is a tiny part of a large body of research that has been done internationally to establish the relationship between community annoyance and aircraft noise. These types of community annoyance studies have been going on since 1978. A dose-response relationship (annoyance versus noise level) established by Miedema and Oudshoorn (2001) has been widely used over the past 20 years as the best amalgamation of research into aircraft noise annoyance. This 2001 study amalgamated the results from a large number of different airports around the world.

In 2002 Taylor Baines were engaged by the Christchurch City Council and Canterbury Regional Council to carry out a community annoyance survey to examine whether the noise sensitivity of a New Zealand community was any different to communities overseas and therefore the extent to which New Zealander's were more or less sensitive than people living overseas and exposed to the same level of airport noise.The Taylor Baines study confirmed that if anything people exposed to noise from Christchurch Airport were more annoyed than their overseas counterparts at that time.

It is not relevant that the New Zealanders surveyed were not living in Kaiapoi (or Selwyn). The survey was designed to understand the sensitivity of those currently living exposed to specific noise levels so that predictions can be made about how those living in areas such as Kaiapoi or Selwyn or in other locations in New Zealand would react to levels of noise exposure which would be reached in the future as an airport grows and noise levels increase. In 2002 residents of Kaiapoi would only have been subjected to airport noise levels of less than 50 dB L_{dn} so surveying them would have been of little value.

However more importantly, both the Miedema & Oudshoorn and the Taylor Baines Studies have now been superseded by a number of large recent international studies. Marshall Day Acoustics was recently engaged to prepare a comprehensive review of international research into community response to aircraft noise annoyance from 2001 to 2021 (see Rp 001 Community Response to Aircraft Noise - Literature Review).

The overview of the 2022 literature review was that levels of annoyance have increased markedly among populations living around airports over the last 20 years. The results of the different studies are shown graphically below in Figure 1 but in summary;

- the Miedema and Oudshoorn studies shows that at 50 dB L_{dn}, 5% of people were found to be highly annoyed by aircraft noise.
- The Taylor Baines showed higher levels of annoyance with 10% of the population 'Highly Annoyed' at 50 dB L_{dn}.
- The two most prominent recent studies, published by the WHO in 2018 and the FAA in the United States in 2021, yielded much higher levels of annoyance where 18% and 19 % respectively of people were found to be highly annoyed by aircraft noise at 50 dB L_{dn}.

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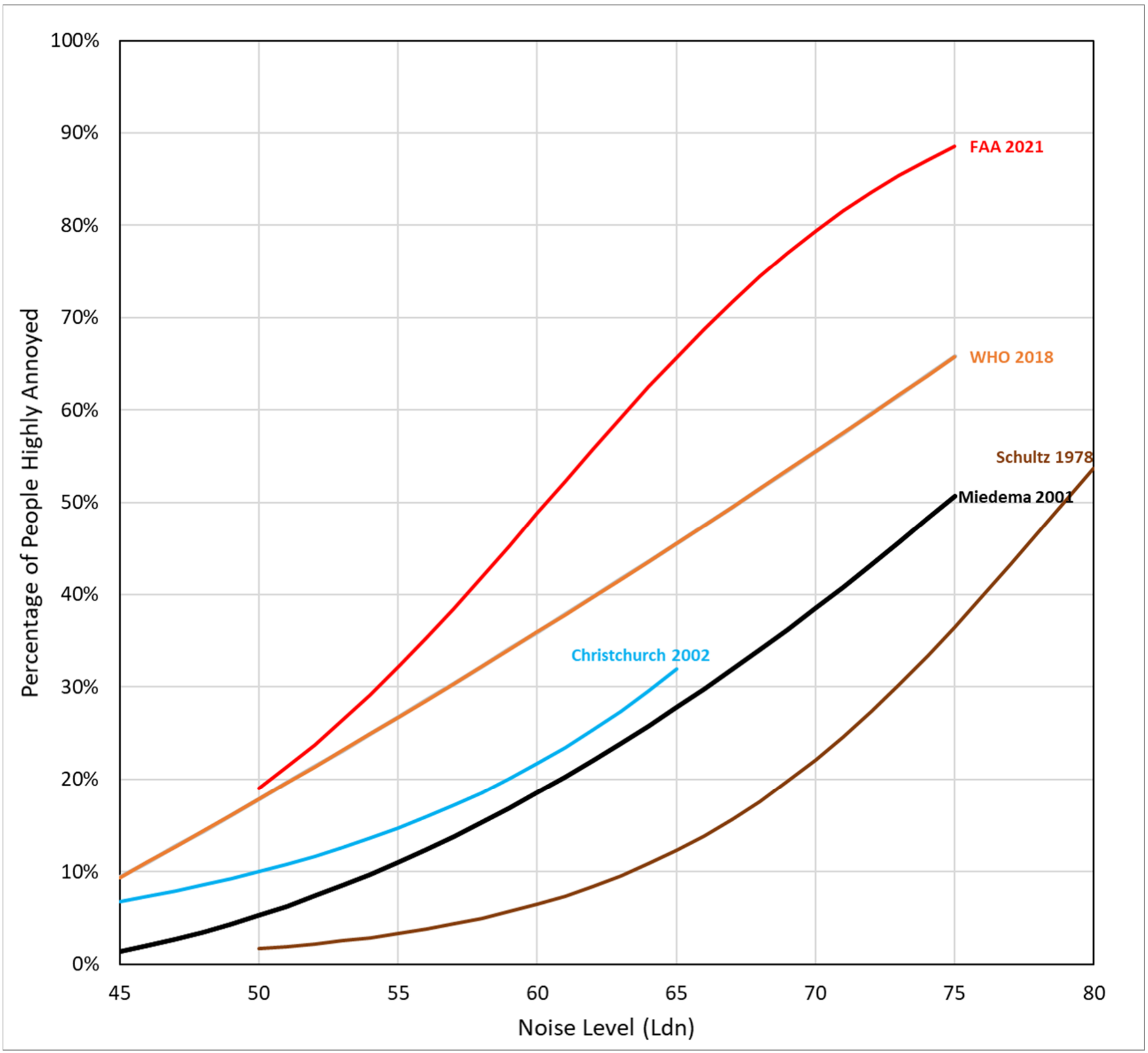
Figure 1: Community response to aircraft noise



The latest overseas research confirms that community annoyance due to aircraft noise is increasing and that, at 50 dB L_{dn} and above, a proportion of the population will be highly annoyed by aircraft noise. This is not a desirable noise environment in which to locate additional residential development (or intensification) if it can be easily avoided. There is no plausible reason (or research available) to suggest that residents of Christchurch, Kaiapoi or Selwyn would have a different subjective response to aircraft noise than the many thousands of residents surveyed in the international research .

It is therefore appropriate, from an acoustics perspective, to prevent development and intensification within the 50 dB L_{dn} Air Noise Contour in order to protect the health and amenity of the community, as well as to avoid reverse sensitivity effects on the operations of CIA.

None of the Marshall Day reports or the historic planning procedures around Christchurch Airport are dependent on the Taylor Baines Study. The current planning regimes were based on the earlier (and lower annoyance) Miedema and Oudshoorn studies and the Taylor Baines report simply gave us confidence that we could rely on the results of overseas studies to predict responses in greater Christchurch and New Zealand generally . Future land use planning procedures are not proposed to be changed significantly – only the location of the contours is proposed to be changed based on updated information and projections. The recent increases in community annoyance suggest that lower noise contours (further out from the airport) should be used for planning purposes, but this is not being proposed at this stage.

Complaints

We understand that some parties have suggested that aircraft noise is not a problem in Kaiapoi because nobody is complaining.

There are several reasons for the lack of complaints about aircraft operational noise from Christchurch International Airport. First is that residents of Kaiapoi have to date only been receiving noise levels of less than 50 dB L_{dn} . That will change in future as the airport grows and noise levels increase.

Secondly, the historic land use planning has meant that there are relatively few people exposed to aircraft noise in Christchurch.

Thirdly, people do not complain if they assume their complaints are likely to have no effect. If the airport is operating in its normal mode and they are annoyed, they know nothing can be done about the noise. The Taylor Baines study shows that of the relatively few people exposed to current levels of aircraft noise at Christchurch, there are a number who are 'highly annoyed' but are not complaining significantly during normal airport operations.

However, when an airport grows (as Christchurch will) and/or the airport changes an operation (flight paths or runway length) then significant complaints can arise. The 2017 trial in Auckland of alternative arrival procedures caused the number of complaints to jump from 2 per month to around 500 per month. These complaints came from a relatively low aircraft noise area.

The comments that "I live in this area and the planes don't bother me", overlook the fact that the noise contours (and thus land use planning) are based on future noise levels – not current noise levels. The number of aircraft movements predicted to occur in future in the operative Air Noise Contours in the current Waimakiriri District Plan, are over double the current movements.

Road Traffic Noise

We also understand that it has been suggested that decision makers should be looking at road traffic noise as the Taylor Baines Study showed more people in Christchurch were annoyed by road traffic noise than by aircraft noise.

The international community noise surveys have actually found that aircraft noise is more annoying than road traffic noise. The reasons the Taylor Baines study found that a larger number of people in Christchurch were annoyed by traffic noise than by aircraft noise, is very simply because there are far more people exposed to high levels of road traffic noise in Christchurch than there are to aircraft noise. Christchurch has high residential densities around roads and low densities around the airport. This is due to the excellent land use planning that has historically been implemented around Christchurch Airport for many years to avoid people being exposed to aircraft noise – exactly what is proposed to be maintained through the current process.

It is too late to reduce the noise effects on the community from existing roads by land use planning, but this can very much be achieved by responsible planning around Christchurch International Airport.

CHRISTCHURCH AIRPORT
COMMUNITY RESPONSE TO AIRCRAFT NOISE
LITERATURE REVIEW

Rp 001 20201126 | 16 May 2022

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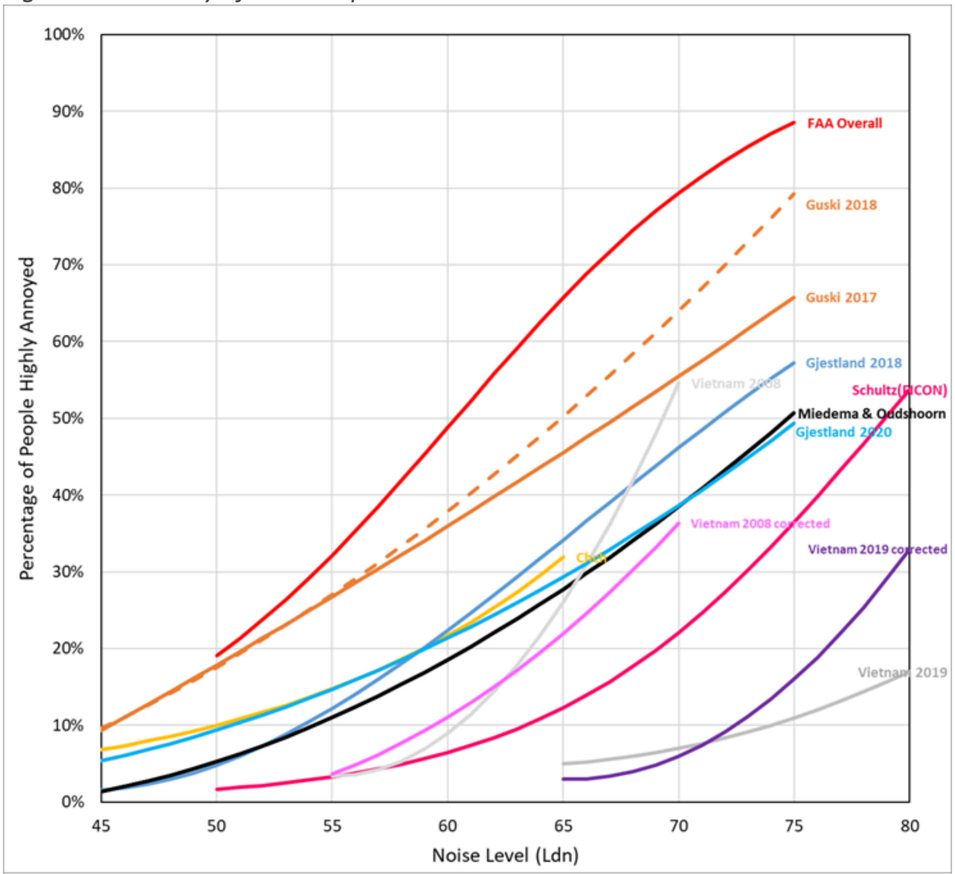
SUMMARY

Marshall Day Acoustics was engaged by CIAL to carry out a literature review of the research into community response to aircraft noise since 2001. A total of 45 studies have been reviewed and this report summarises the 14 most significant. Figure 1 below reflects the percentage of people highly annoyed based on each of the studies reviewed.

Figure 1 shows the dose-response curves from the studies reviewed. A 'dose-response curve' is the graphed results of the percentage of people highly annoyed based on the noise level (Ldn) they experience. With regards to community noise annoyance over time, six reported an increase, one reported a decrease, four reported no change and three did not provide comment on a change.

Figure 1: Summary of Dose-response curves



Summary of annoyance studies reviewed

A summary of our findings is broken down into four main regions: Europe, United States, Asia and New Zealand.

Europe Studies

In Europe, the Miedema and Oudshoorn 2001 dose-response curve is currently used. This shows that 10% of people were highly annoyed by aircraft noise at approximately 55 dB L_{dn}.

In 2017, the WHO commissioned a synthesis of studies that found the level of noise annoyance to be much higher; 10% of people highly annoyed at 45 dB L_{dn}. This conclusion informed the 2018 WHO Noise Guidelines, which recommends reducing noise from aircraft to 45 dB L_{dn}. International bodies around the world are considering whether to update their policies, and the WHO Noise Guidelines could provide the latest scientific knowledge.

United States Studies

The FAA currently use the Schultz 1978 dose-response curve, which is based on older data that includes all forms of transportation (aircraft, road, rail).

The FAA has since conducted a 20 airport study, which demonstrates the highest levels of annoyance out of all the studies reviewed. The study only considers noise from 50 dB Ldn and above. The level of annoyance at 50 dB Ldn is around 19% compared to 5% for the Miedema and Oudshoorn 2001 curve.

The FAA has not commented on whether this will be used to justify moving away from the Schultz curve. While there is no published literature critiquing the findings of this study yet, we consider it to be extremely robust and worth consideration.

Asian Studies

Our review is limited with regards to airports in Asia. We assess results from a Vietnam-specific study which is of relevance to Christchurch. However, in our opinion this should not hold much weight as culture and attitudes towards airport noise may be quite different.
There are Asian airports included in the WHO study along with airports in Europe so results from this region have been included in the overall data.

New Zealand Studies

New Zealand has use the Miedema and Oudshoorn 2001 dose-response curve in the past.

There are very few community response studies in New Zealand – we are only aware of the Taylor Baines study (which showed 10% of people highly annoyed at 50 dB L_{dn}) conducted for Christchurch Airport in 2002, and a recent road and rail noise study conducted by NZTA in 2019.

The NZTA study only looked at road and rail noise. Whilst this study did not consider aircraft noise, we have included it as it gives a basis for noise annoyance in New Zealand and shows that noise annoyance is higher in New Zealand when compared to the Miedema and Oudshoorn 2001 curves for road and rail.

However, the NZTA study had several short comings (some identified by the authors) including the issue that the noise annoyance questions were not masked. For these reasons we are of the opinion that little weight should be placed on the results.

Method of calculating annoyance dose-response curves

Most of the studies we have reviewed use the conventional method of predicting dose-response curves for noise annoyance. This method is not based on a set shape, but rather a 'best fit' based on the data contained in the survey.

Another possible approach is looking at the Community Tolerance Level (CTL). CTL is based on the assumption that the shape of the dose-response curve generally follows a set sigmoidal relationship, but that the onset of noise annoyance (i.e. the position of the curve relative to the noise axis) depends on non-acoustic factors. Most other studies fit a dose-response curve that is not a set shape but is a best fit based on the data contained in the survey or synthesis of surveys. This approach has been critiqued as actual dose-response curves are a different shape for different airports and often deviate from the standard sigmoidal shape assumed by CTL.

There has also been investigation into reasons why annoyance levels may have increased over time. Things such as the year of the study, the type of contact (phone, postal, face to face etc), the response rate and the annoyance scale (5-point vs 11-point scale) were investigated to see if they has some impact on the results.

Of these factors, statistically only the scale (5 point vs 11 point) could account for the trend of increased annoyance in more recent studies. Although other studies which have investigated this further have ruled it out as a satisfactory explanation.

Sleep Disturbance

Literature on sleep disturbance research over the past 30 years has been reviewed to determine its relationship to aircraft noise. We conclude that energy equivalent metrics such as L_{night} are insensitive in respect to sleep disturbance. Metrics that consider the noise level of single aircraft events have been researched and cumulative indices have been developed that look at the effects of multiple night-time events. However, the complex assumptions and methodology that underpins these types of methods have not been evidenced with confidence.

We conclude that there is currently not an accepted approach in the literature to accurately assess the effects of aircraft noise on sleep disturbance. More research in this area is needed to determine a meaningful relationship and assessment methodology.

Non-acoustic factors

Non-acoustic factors are those, other than the noise level itself, which contribute to annoyance. Non-acoustic factors moderate an individual's sensitivity to noise, which is. subjective and can be influenced by elements such as age, gender and the attitude of the noise receiver. The resulting annoyance may influence behaviour in terms of how people live and whether they take action against noise.

The literature highlights that these play a potentially significant part in determining the level of annoyance in the community. However, we acknowledge that more research is needed to quantify the effect each of these factors has on noise annoyance.

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1.0 HISTORICAL COMMUNITY RESPONSE STUDIES

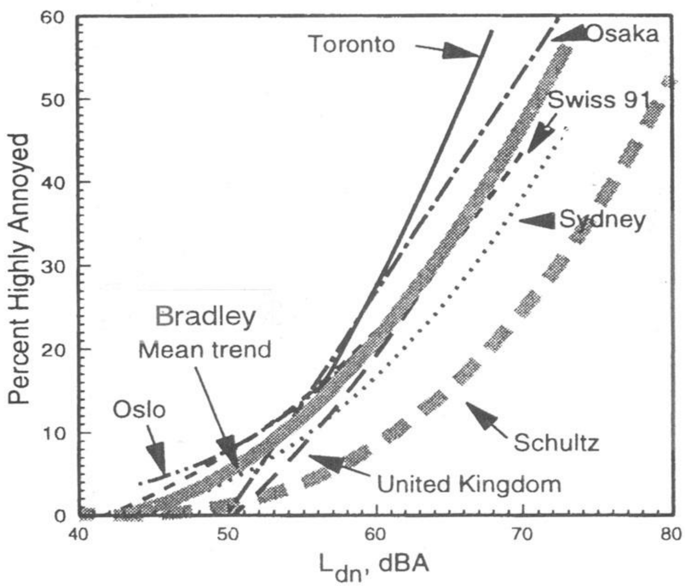
1.1 Introduction

A large number of overseas studies have been carried out over time to investigate community response to environmental noise. The general approach of these studies is to question residents (verbally or in writing) as to their level of annoyance to a particular noise source. The noise level at the respondent's location is then determined by either measuring it or by using calculated noise contours. 'Noise levels' are normally measured/calculated as L_{dn} – the Day/Night Level which involves a summation of the noise energy over 24 hours with a 10 dB penalty for noise at night. Analysis of these widely varying results allows a 'dose-response curve' to be prepared showing the percentage of people highly annoyed versus the level of noise they are exposed to. Many studies in Europe use L_{den} as opposed to L_{dn}. L_{dn} includes only a 10 decibel weighting for night-time events between 10pm and 7am. L_{den} adds an additional weighting for flights in the evening period from 7pm of 5 decibels. The difference between these two metrics has been demonstrated to be around 0.5dB only and thus we use the terms L_{dn} and L_{den} interchangeably through this report.

Schultz 1978 provided the first synthesis of various studies into community response to transportation noise. The results were combined into a single dose-response curve that showed the community annoyance increasing with noise level (the Schultz curve is shown below in Figure 1). It is important to note that the Schultz 1978 curve was meant to represent noise from all forms of transportation (air, road and rail). Later studies noted differences in levels of annoyance between different sources of noise and separated out the dose-response curves.

In the 1990's, Bradley combined the results of a number of specific aircraft noise studies, to provide a relationship for community response to airport noise. The resulting graph (Figure 1 below), shows the various individual airport studies and the overall 'Bradley Mean Trend' for all studies (along with the Schultz curve).

Figure 1: Dose-Response Curves – Schultz 1978 & various others



Source: Bradley 1996

Use of the Bradley study came under specific scrutiny during a previous Environment Court hearing. In Gargiulo v Christchurch City Council (Unreported, C137/00, Environment Court at Christchurch, 17/8/2000, Jackson J) paragraph [29] the decision states.

> *"Consequently we accept his [Mr Day's] evidence in its entirety including his opinion that the figure as to community response to noise was accurate and could be relied on because it derived from Mr Bradley".*

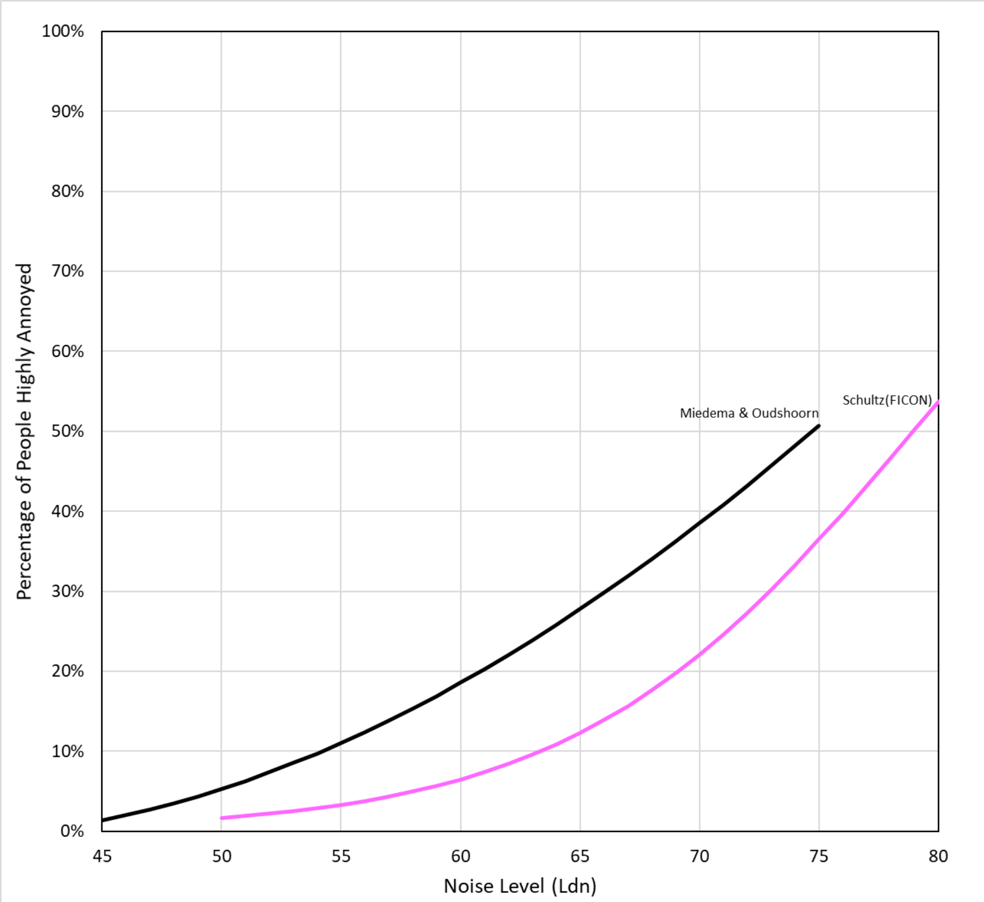
1.2 Miedema & Oudshoorn 2001 Synthesis of Studies

In 2001 Miedema and Oudshoorn examined studies from additional airports and used improved methods for establishing the regression curves. Their aircraft noise dose-response curve was based on 20 studies from around the world which include over 40 airports (some studies looked at multiple airports) with 34,214 respondents. The years of the surveys ranged from the 1960s to the 1990s with most studies in the earlier years.

Europe and New Zealand have adopted the dose-response curves from the Miedema and Oudshoorn study in 2001. This 2001 curve has generally replaced the earlier Schultz 1978 and Bradley 1996 curves apart from in the United States which still uses the Schultz 1978 curve.

Figure 2 compares the dose-response curves from Schultz 1978 with Miedema and Oudshoorn 2001.

Figure 2: Dose-Response Curves – Miedema and Oudshoorn 2001 vs Schultz 1978



1.3 The Taylor Baines Christchurch Study 2002

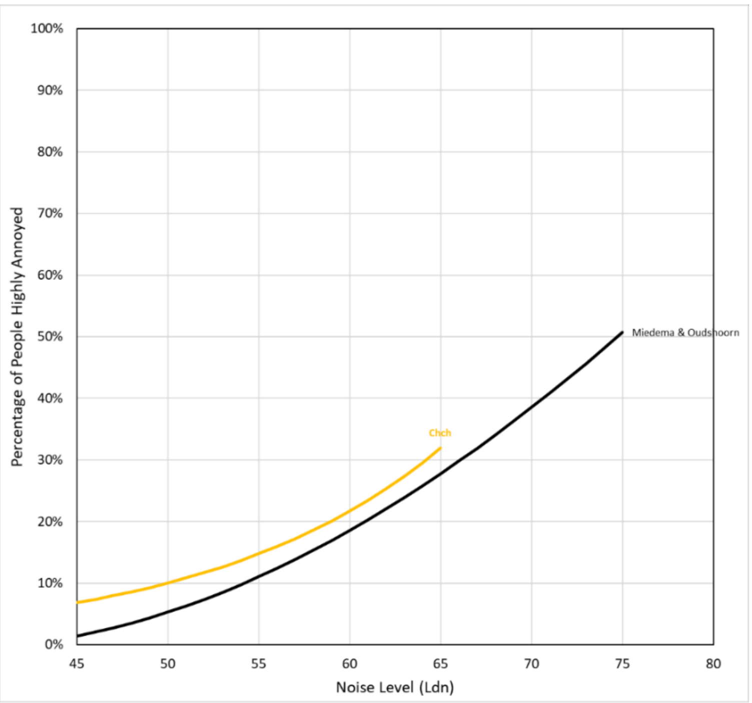
1.3.1 Study Summary

In 2001, Taylor Baines & Associates and Marshall Day Acoustics were engaged to conduct a noise annoyance survey in Christchurch. The study was conducted to investigate how the Christchurch community responded to environmental noise when compared to the previous overseas studies (Schultz, Bradley and Miedema). The Christchurch Study examined aircraft noise, road traffic noise and industrial noise in separate sub-groups. This review looks at the results from the airport noise study group only (498 responses).

Figure 3 compares the Taylor Baines dose-response curve with the Miedema and Oudshoorn 2001 curve. The resulting curve shows the Christchurch community experiences a higher level of annoyance (particularly at lower noise levels) than the Miedema & Oudshoorn 2001 study.

The study surveyed in five sample areas and was a masked survey which asked about other things in people's neighbourhood (parks, industry etc). Physical details of the dwelling were also asked along with respondent details and household composition. A total of 498 responses were received. The responses contained more responses from females and older people than the proportions shown in the 1996 Census.

Figure 3: Taylor Baines Study 2002 vs Miedema and Oudshoorn 2001



1.3.2 Study Design

Five sample areas were chosen to represent areas that were inside the current District Plan 50 dB L_{dn} contour and which would likely be in the future District Plan 50 dB L_{dn} noise contour. The Council provided a list of all the known addresses of residences within each sample area. For each sample area a random proportionate sample of separate residential addresses (sufficient to allow for non-responses) was drawn from all the known addresses within the specified geographical area.

The survey used masked questions and asked about other things in people's neighbourhood (parks, industry etc). Physical details of the dwelling were also asked along with respondent details and household composition. Two mail outs in March 2002 were required to achieve the agreed level of responses. These occurred a week apart from each other.

2.0 COMMUNITY RESPONSE STUDIES SINCE 2001

Marshall Day Acoustics was engaged by CIAL to carry out a literature review of the international research into community response to noise carried out since 2001. A total of 41 studies have been reviewed and this report summarises the most significant 14 studies. A full bibliography is attached as Appendix B.

2.1 Summary of all Studies

Table 1 gives a summary of the 14 studies:

- 6 reported an increase in noise annoyance over time (FAA, Guski x3, WHO, Janssen and Vos)
- 1 reported a decrease (Vietnam)
- 4 reported no change (Gjestland x 2, Fidell, Gelderblom)
- 3 did not report on a change (NZTA, Brink, Gjestland 2021

Figure 4 shows the dose-response curves for each study. It appears that the difference in opinion exists between two main groups. Guski et al (includes Brink, Jannsen and Vos) and Gjestland et al (includes Fidell). We feel upon review of the literature that the evidence from Guski et al has more weight due to the fact that it was adopted by the WHO and also includes backing from Henk Vos who was the original author of the Miedema and Vos 1998 study which formed the basis of the Miedema and Oudshoorn 2001 dose-response curves.

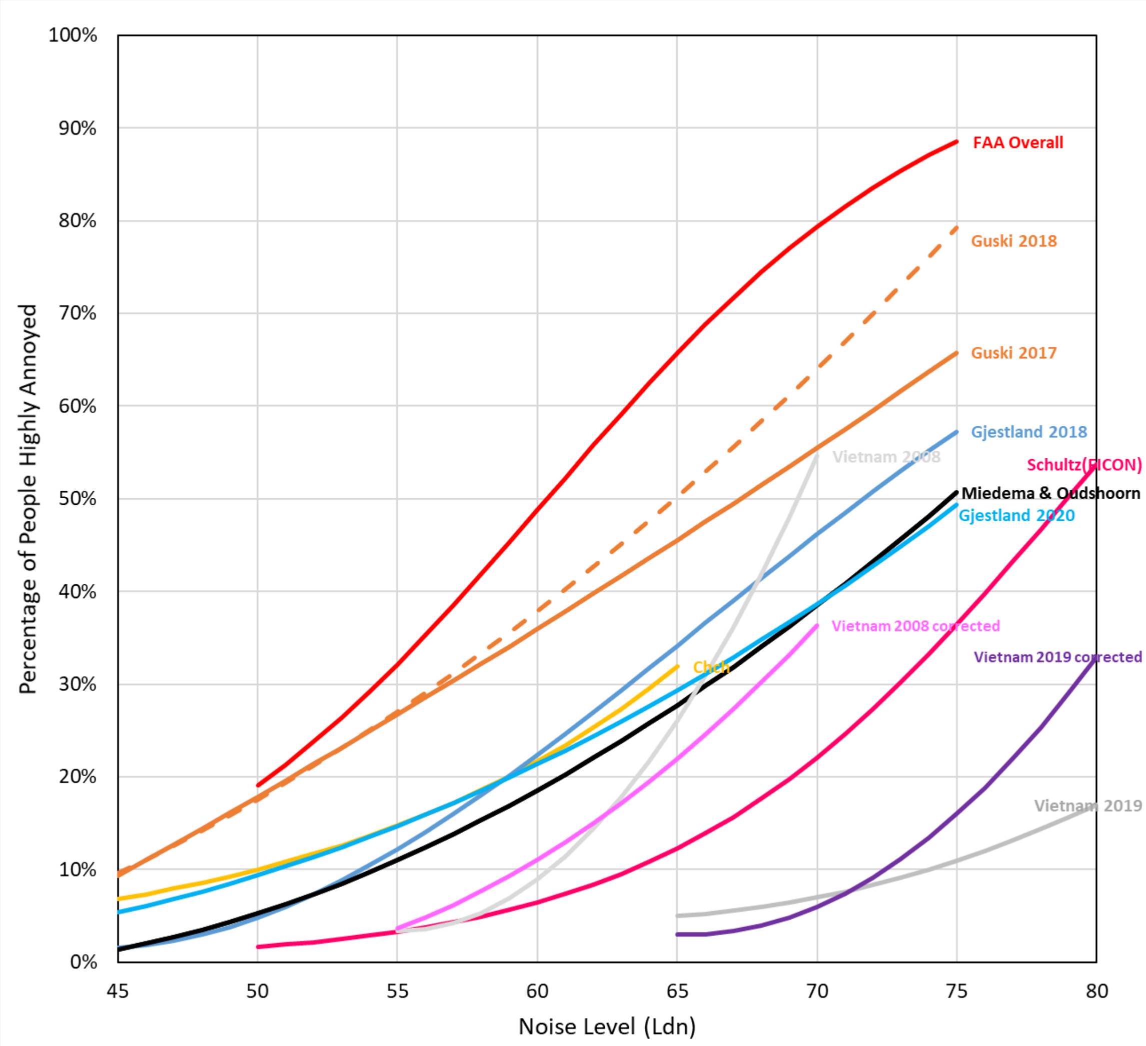
Also, there appears to be no other literature out there from different authors critiquing the WHO 2018 noise guidelines and the issues raised form Gjestland et al have been refuted by Guski et al by reanalyzing the data to show no or little change in the dose-response curves from the original 2017 analysis. On this basis it seems appropriate to adopt the findings of the Guski 2017 study and resultant dose-response curves.

Table 1: Summary of Studies

Study	Increase/Decrease in Annoyance	Suggested Limit (if any)	No. Surveys	No. Responses	% HA @ 50 Ldn	% HA @ 65 Ldn	Results Challenged
Historical Studies							
Schultz 1978	-	-	11	Unknown	1%	15%	-
Bradley	-	-	Unknown	Unknown	5%	35%	-
Miedema 2001	-	-	20	34,214	5%	28%	-
Taylor Baines 2002	Increase	50 Ldn	1	498	10%	32%	-

Study	Increase/Decrease in Annoyance	Suggested Limit (if any)	No. Surveys	No. Responses	% HA @ 50 Ldn	% HA @ 65 Ldn	Results Challenged
			Studies Since 2001				
FAA 2021	Increase	-	20	10,328	**19%**	66%	N
NZTA 2019	-	-	3	801	5-8%	25-32%	Y
Vietnam 2009	Decrease	-	1	880	-	20%	N
Vietnam 2019	Decrease	-	1	502	-	3%	N
Guski 2017	Increase	45 Ldn	12	17,094	**18%**	46%	Y
Guski 2018	Increase	45 Ldn	19	39,309	**18%**	50%	Y
Gjestland 2018	No change	53 Ldn	18	16,047	5%	34%	Y
Guski 2019	Increase	45 Ldn	12	17,094	**18%**	46%	Y
Gjestland 2020	No change	-	65	93,000	9%	29%	Y
Brink 2020	-	-	-	-	-	-	Y
Gjestland 2021	-	-	-	-	-	-	Y
Fidell 2011	No change	-	43	76,000	5%	29%	Y
Gelderblom 2017	No change	-	62	58,867	-	-	Y
Janssen and Vos	Increase	-	41	48,369	-	-	N

Figure 4: Summary of Dose-Response Curves



2.2 The FAA Study 2021

2.2.1 Study Summary

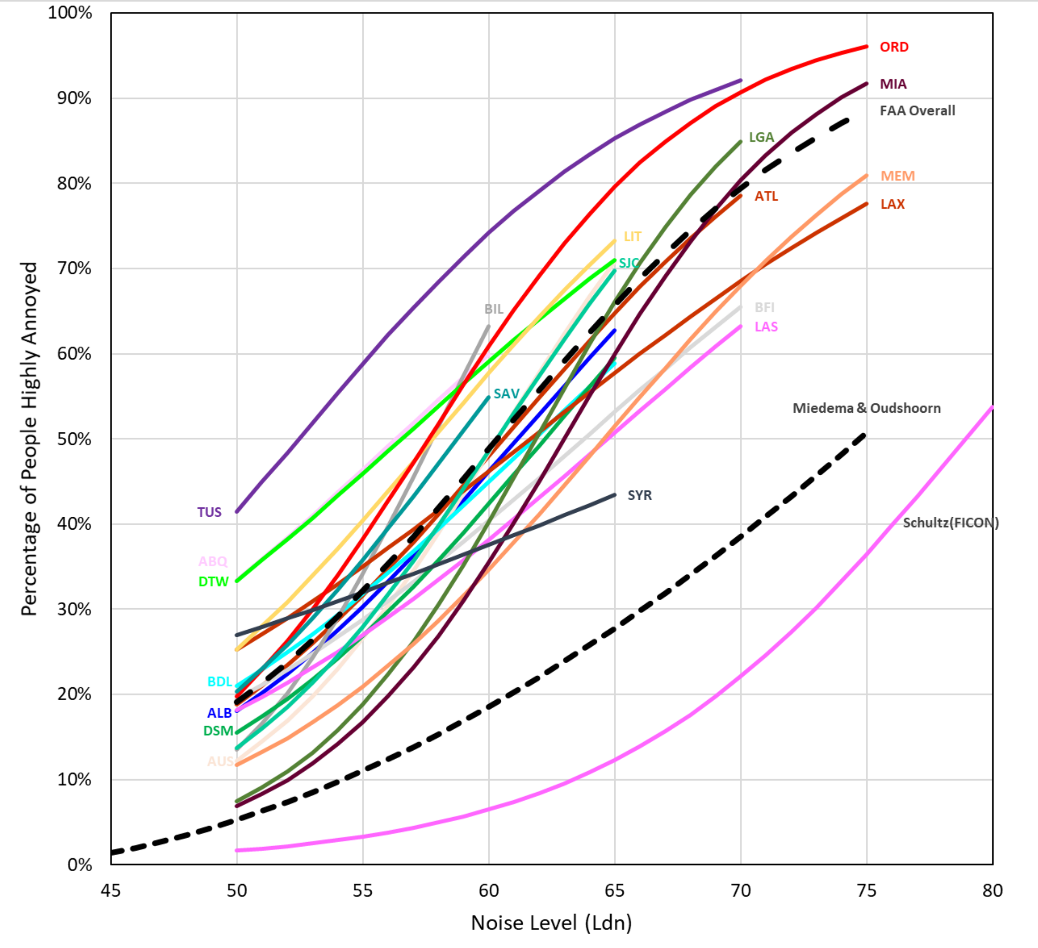
The US Department of Transportation conducted the Neighbourhood Environmental Survey (FAA Study) in 2021. The FAA conducted the study to Investigate whether the Schultz 1978 curve, which is used in the Unites States, needs to be updated.

The study included twenty airports and over 10,000 respondents. The study used the logistic regression model used to create the Miedema and Oudshoorn 2001 curve.

The resulting curves show much higher levels of annoyance than the Miedema & Oudshoorn 2001 curve and result in a trebling of the number of people predicted to be highly annoyed at most noise levels.

Figure 5 compares the dose-response curves from the FAA study with the Schultz 1978 and Miedema and Oudshoorn 2001 curves.

Figure 5: Dose-Response Curves – FAA Study 2021 vs Miedema and Oudshoorn 2001



2.2.2 Survey Design

This study used an initial mail out survey along with a follow up telephone survey to canvas more detailed questions such as respondents' opinions on noise, exposure to aircraft noise, relationship to the airport, concerns about aircraft operations, views on airport community relations, among others. The survey used masked questions and asked about other things in people's neighbourhood (parks, industry etc)

The study considered other survey forms such as web and in person surveys, but these were not used because:

- In person surveys were too costly
- Web based surveys were unlikely to provide adequate coverage of those with no access to the internet.

Hybrid survey forms were considered (using web and mail etc) but this was rejected as such approaches are shown to depress response rates.

The ACRP 02-35 research study published by Miller in 2014 required sample sizes of 500 respondents per airport to provide an adequate sample size.

The main annoyance questions in the survey were based on recommendations by ICBEN[4]. Demographic questions were asked but studies show that demographics do not impact noise annoyance. Selected attitudes such as fear of noise, distrust of the noise maker etc have an impact however and these were investigated further on the longer phone surveys.

The ACRP 02-35 study recommended the mail survey results be used to update the dose-response curve for the following reasons:

- The ACRP project's telephone survey had a response rate of only 12 percent compared to the mail survey's 35 percent
- Mail surveys have fewer coverage issues compared to telephone
- Most mail survey households adhered to the respondent selection protocol, providing evidence against the concern that those most annoyed would self-select into the survey
- The mail survey respondents were closer to Census figures on demographic variables collected
- While acknowledging small sample sizes, there is no evidence that there was a difference in annoyance between respondents to the mail survey and respondents to the telephone survey.
- Further, considering the above reasons, if any differences in annoyance existed, it could indicate improved data on the mail survey due to a more robust representation of the population.

2.2.3 Selection of Airports

A sampling frame criteria identified 95 airports that could be eligible for this study based on the following criteria:

- Located within the contiguous US
- Have at least 100 average daily jet operations
- Have at least 100 people exposed to greater than or equal to 65 dB L_{dn}
- Have at least 100 people exposed to noise levels between 60 dB L_{dn} and 65 dB L_{dn}

[4] International Commission of Environmental Effects

Of these 95 eligible airports, 20 airports were selected for the study. Three international airports were included automatically with the remaining 17 selected using a range of balancing factors to get a representative sample. These balancing factors were:

- Location
- Temperature
- Percentage night-time operations
- Number of flights
- Fleet mix ratio
- Population within 5 miles

2.2.4 Selection of Addresses

The target was to get 500 responses from each airport (10,000 in total). It was assumed that the response rate would be around 40%. Therefore, 1,300 houses at each airport (26,000 in total) would need to be sent a survey to meet the response target.

The study considered houses exposed to noise levels above 50 dB $L_{dn.}$ The 1,300 sample at each airport was broken down evenly into bands (stratum) from 50-55, 55-60, 60-65, 65-70 and 70+ $L_{dn.}$ This meant there were around 250 surveys sent out to a random sample of houses at each airport in each noise band. Noise bands that contained no houses had their sample transferred evenly into the other bands to ensure the overall sample size was still 1,300 for each airport.

Surveys were sent out over a year long period to account for seasonal differences. To ensure that the first wave was a representative subsample of the initial sample, it was formed by sorting the initial sample within each airport noise stratum by county, census tract, block group, and block; then selecting an equal probability systematic sample within each airport noise stratum. Waves 2 through 6 were formed by randomly assigning the remaining addresses to five approximately equal-sized waves.

2.2.5 Calculation of Noise Levels

Noise levels at each site were calculated in the INM[5] for the annual average day for 2015 at each of the selected airports. Movements were allocated to the different runways and tracks based on radar data captured.

[5] Integrated Noise Model

2.3 The NZTA Study 2019

2.3.1 Study Summary

The 2019 NZTA[6] study investigated noise annoyance from road and rail. Whilst this study did not consider aircraft noise, we have included it as it gives a basis for noise annoyance in New Zealand.

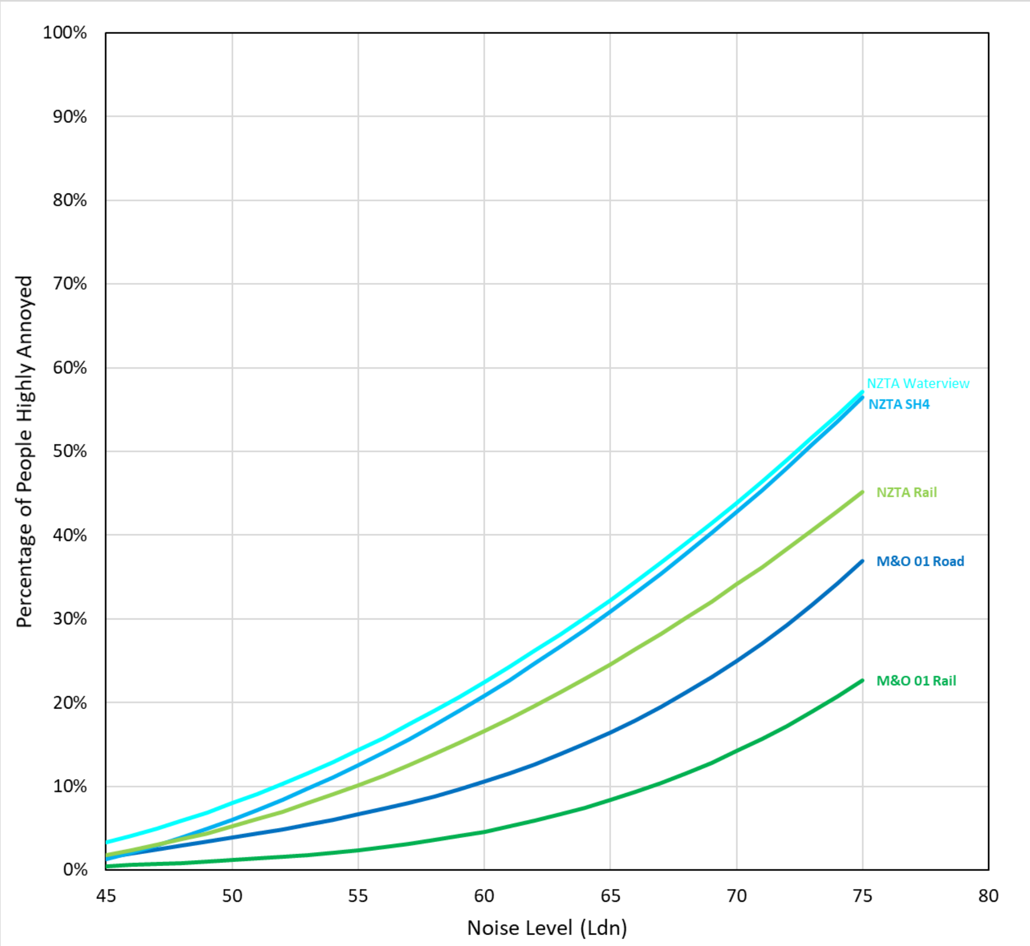
The main conclusion from the study was:

> *"The analysis suggests that the New Zealand population is more sensitive to noise as the onset of significant community response occurs at lower sound levels, approximately 13 dB lower for rail and 6 dB lower for road, when compared with Miedema and Vos."*

A total of two roads (557 responses) and one rail corridor (224 responses) were included in the study and dose-response curves were developed for the road and rail sources separately. The resulting curves show higher levels of annoyance than the Miedema and Oudshoorn 2001 curves, particularly at higher noise levels

Figure 6 compares the dose-response curves from the NZTA study with the Miedema and Oudshoorn 2001 road and rail curves.

Figure 6: Dose-Response Curves – NZTA Study 2021 vs Miedema and Oudshoorn 2001



[6] The New Zealand Transport Agency (Waka Kotahi)

2.3.2 Survey Design

The survey was designed initially as a phone survey (for the SH1 Survey) and then was converted to an online survey tool (for the Waterview and the rail study). The survey did not use masking and the purpose of the survey (noise annoyance) was known to participants. Demographic details were also recorded. The survey was designed around ISO/TS 15666: 2003[7]. This standard has subsequently been updated in 2021.

A letter was sent out to households a week before and then a phone call was made. Only houses with phone numbers available were able to be included in the phone surveys. For the Waterview and rail survey areas the number of houses within the sample area was low and the phone surveys were converted to a mail survey to try and boost numbers.

This study had several short comings (some identified by the authors) including the issue that the noise annoyance questions were not masked. In a letter to the NZTA the authors identify the following issues with the study:

- The population size sampled was small and could have been increased by conducting more surveys on different roads/rail corridors to boost the number or respondents
- The calculated noise levels were based on a generalised noise model and could have been improved with better data inputs and calculation methodology
- The choice to use landlines as the primary survey technique likely reduced the number of potential respondents
- The study did not allow for atypical noise sources in the annoyance questions and therefore it is uncertain whether the respondents were basing their responses on the overall noise environment, or their responses were biased towards these events.
- The survey did not include questions about the time-of-day noise annoyance occurred

Compared with the Auckland 2013 census data the sample across each study area has a greater proportion of older individuals and a lower number of individuals in employment. Age has been demonstrated as a factor that influences annoyance with annoyance peaking at 45 years old. This could account for the higher annoyance levels measured

For these reasons we are of the opinion that little weight should be placed on the results. NZTA is currently undertaking a new community response to noise study.

2.3.3 Selection of Sites

The aim of the study was to assess dose-response relationships for annoyance from a new or altered road, existing road and existing rail site.

- 18 roads were evaluated for their suitability (12 new, 6 existing)
- 11 rail corridors were evaluated for their suitability (6 passenger, 5 freight).

The number of receivers within 500m of the road/rail route was assessed for each site. The number and spread of receivers was the main factor for site selection along with preference for high traffic flows and recently opened roads. The target response size was 400 for each site.

State Highway 1 – South Auckland and Auckland's southern rail corridor were selected for the existing sites based on the above criteria. Roads of National Significance were then looked at to pick the 'new or altered' road site. Of these projects five were investigated more closely. The final project chosen was Waterview.

[7] ISO/TS 15666:2003 *Acoustics — Assessment of noise annoyance by means of social and socio-acoustic surveys*

2.3.4 Selection of Addresses

The target was to get 400 responses from each study area. The following number of houses were invited to take the survey for each site:

- State Highway 1 – 2000 invited / 400 completed (phone)
- Waterview - 1,771 invited / 157 completed
- Rail – 1,657 invited / 244 completed

The study considered houses exposed to noise levels above 46-48 dB $L_{Aeq(24hr)}$ for roads and 44.5 dB $L_{Aeq(24hr)}$ for rail. The samples were broken down into three categories of low, medium, and high noise as shown below to ensure an even distribution over various noise levels as much as possible.

Table 4.1 Noise level groupings ratings for the three study sites

Noise level band	$L_{Aeq\ (24h)}$ / dB		
	SH1	Waterview	Rail
Low	<48.5	<46.0	<44.5
Medium	48.5-53.0	46.0-50.3	44.5-50.3
High	>53.0	>50.3	>50.3

The State Highway 1 study area had surveys completed in September 2016. The Waterview and the rail corridor followed in October 2016 and March 2017. Th mail surveys to top up the phone surveys for Waterview and the rail project were sent out in April 2017.

The noise level groupings for the responses are given below:

Table 5.3 Noise level grouping

Noise level band	Total	Rail	SH 1 south	Waterview
	%	%	%	%
Low	39	22	48	41
Medium	26	39	16	30
High	35	39	35	29

Table 5.4 Noise level ranges within study areas

Noise level band	$L_{Aeq(24h)}$ dB		
	Rail	SH 1 south	Waterview
Low	35-43	40-49	32-46
Medium	45-50	49-53	46-50
High	50-64	53-72	50-64

2.3.5 Calculation of Noise Levels

Noise levels were calculated in CadnaA[8] using the most recent traffic flow and rail movement data. The study used traffic data and train movements (from sources such as Mobile Road, Auckland Transport and Kiwirail. The data used was not as detailed as what would normally be required to model a new road but was considered to be sufficient for establishing noise exposure.

More detailed noise models would have been beneficial to allow calculation at building façades rather than an the centre of the parcel.

[8] Computer Aided Noise Abatement

2.4 The Vietnam Study 2020

2.4.1 Study Summary

The Vietnam Study summarises two community response studies done in 2008 and 2019 at Vietnam's main international airport Tan Son Nhat. The main conclusion is that:

> *"The L_{den} –% HA relationship of the 2019 survey is lower than that of the 2008 survey and different from the relationship established in the European Union Position study (Miedema & Oudshoorn curve)"*

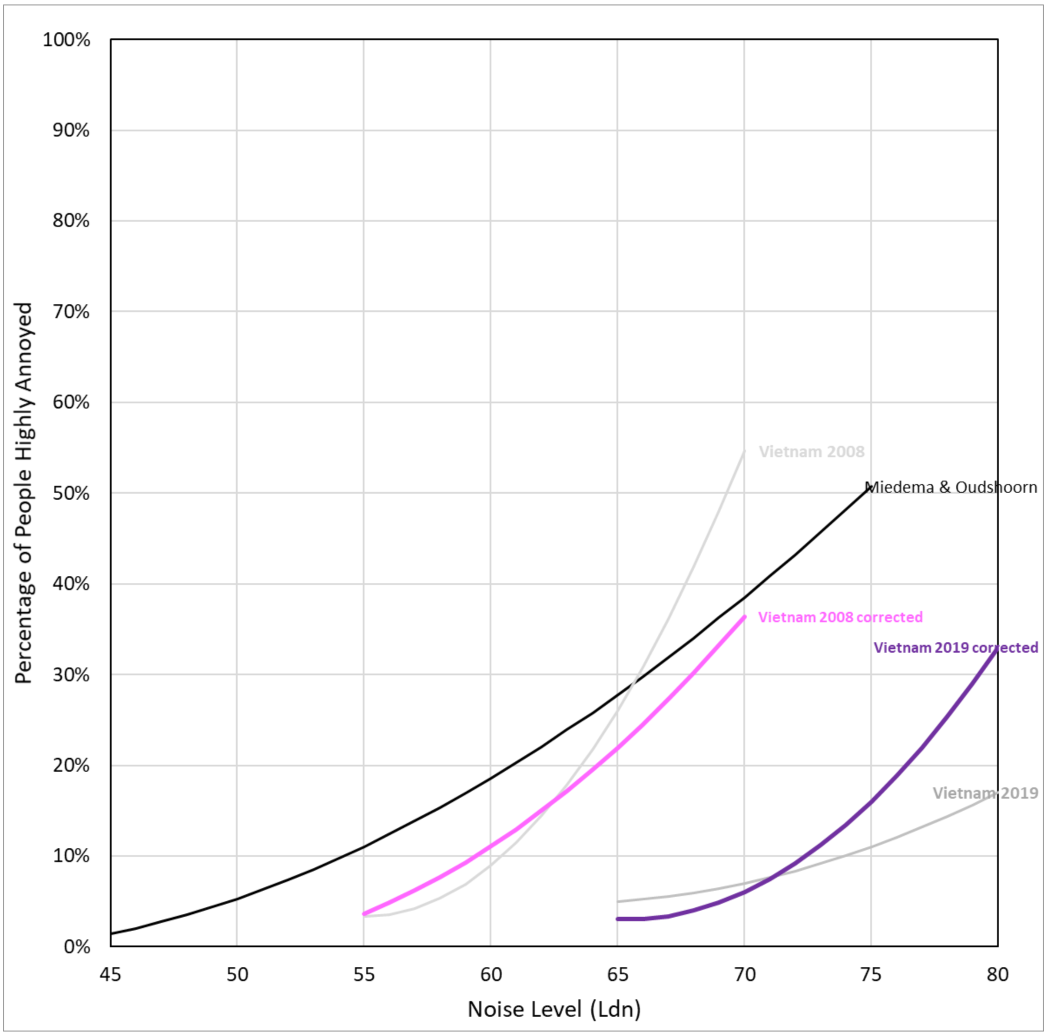
Figure 7 compares the dose-response curves for the 2008 and 2019 studies with the Miedema and Oudshoorn 2001 curve.

A total of 880 and 502 responses were obtained in the 2008 and 2019 surveys, respectively. Flights have tripled from 2008 to 2019 with noise levels found to increase markedly at most sites.

The initial dose-response curves (in grey) produced did not account for non-acoustic factors. When these were accounted for the resulting dose-response curves are quite different as shown in Figure 7 in pink and purple.

The dose-response curves that account for the non-acoustic factors show lower levels of annoyance that the Miedema and Oudshoorn curves.

Figure 7: Dose-Response Curves – Vietnam Study 2020 vs Miedema and Oudshoorn 2001



2.4.2 2008 Study Design

For the 2008 study ten residential areas were selected around Tan Son Nhat airport. These include eight areas that were directly underneath the flight paths. The site selection was meant to represent noise exposure at a range of different distances from the airport.

The original 2008 survey was conducted using face to face interviews. The survey included a balance of genders and ages and only included those over 18 years old. The questionnaire was designed to follow the Technical Specification of ISO/TS 15666: 2003 and was a masked survey which included questions about the general environment as well as noise. Both the 5- and 11-point scales were used to assess noise annoyance as per the ICBEN guidelines. This standard has subsequently been updated in 2021.

Field measurements in Ho Chi Min city were used to quantify the noise exposure in each area and a week of noise data was recorded and analysed. Flight operation data was also collected for the same period.

2.4.3 2019 Study Design

The 2019 study looked at the same ten areas in the 2008 survey. Two new areas were added to act as control areas as they were not impacted by aircraft noise. Face to face interviews were used again in this survey and the same questions were used as the previous survey. Data on the health status of residents was also collected to investigate the effects of noise around the airport.

The noise levels were quantified using weeklong measurements, as occurred in the 2008 study. Flight operation data was also collected for the same period.

2.4.4 Results

A total of 880 and 502 responses were obtained in the 2008 and 2019 surveys, respectively. The response rate in the 2008 study was higher and contained a lower proportion of older people.

The number of flights at the airport has increased markedly (3.3 times) from 200 per day in 2008 to 720 per day in 2019. Night-time flights in the 2019 survey experienced an even larger (4.3 times) increase.

Noise levels were found to increase between 2008 and 2019 with noise levels found to increase by 10 dB or more at four of the sites with the remaining sites experiencing a change in noise level ranging from 2-7 dB.

The initial analysis showed there was a general decrease oi noise annoyance between 2008 and 2019 with the exception of 2 sites. A marked decrease of over 35% was observed at sites 5, 6 and 7.

The study was refined further to consider the following non-acoustic factors:

- noise sensitivity
- length of residence
- total floor area of the house
- the frequency of opening windows
- the area preference
- evaluation of the surrounding quietness

A significant difference between surveys was found for noise sensitivity, length of residence, and area preference. Noise sensitivity had the greatest effect on the results. The corrected dose-response curves that account for these factors are shown in the graph in Section 2.4.1 along with the original uncorrected curves. The graph shows a narrowing between the dose-response curves when corrected for non-acoustic factors with the 2019 study showing slightly higher levels of annoyance than previously.

2.5 Guski 2017 Synthesis of Studies (to inform WHO 2018 noise guidelines)

The Guski 2017 study is a synthesis of more recent dose-response studies from 2001-2014 and supports the claim that noise annoyance has increased when compared to the Miedema and Oudshoorn 2001 dose-response curve. This study informed the 2018 WHO noise guidelines.

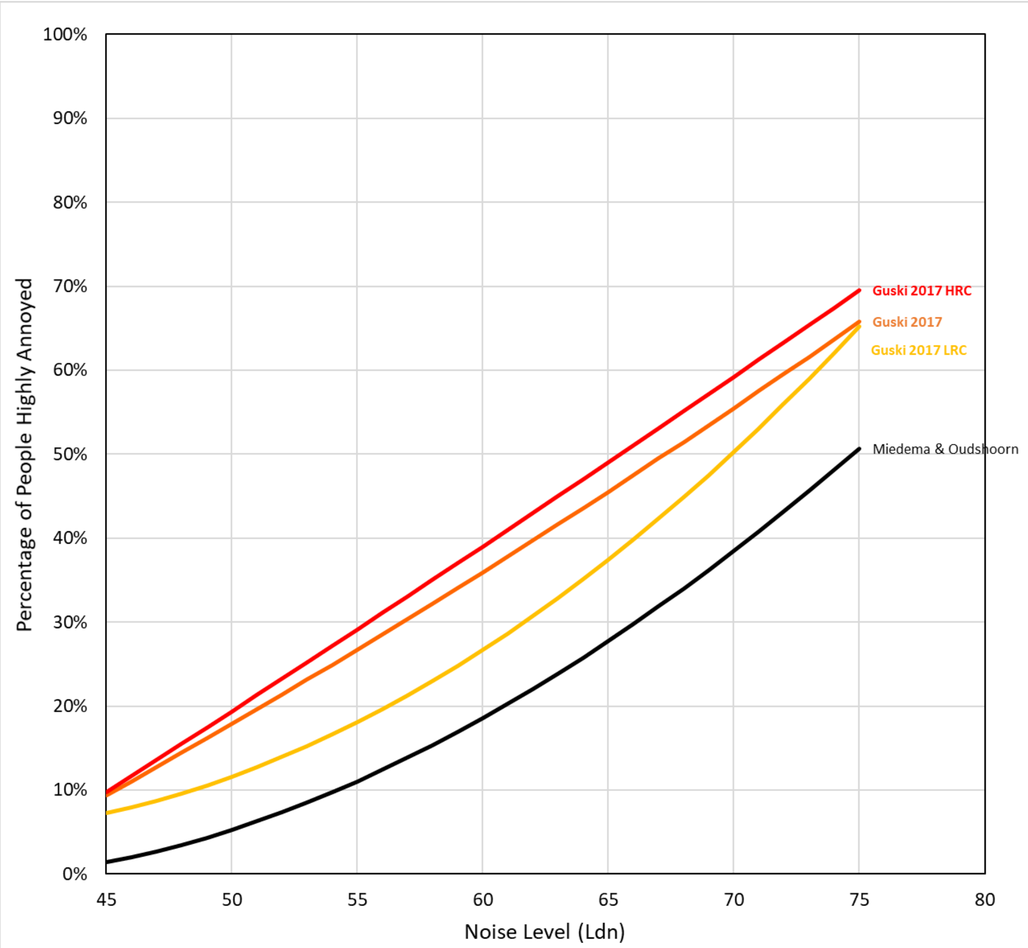
This study concludes that:

> *"The increase of %HA in newer studies of aircraft, road and railway noise at comparable L_{den} levels of earlier studies point to the necessity of adjusting noise limit recommendations"*

The aircraft noise dose-response curve in this study is based on 12 surveys from around the world and over 17,000 responses. The years of the surveys ranged from the 2001 to 2014. The dose-response curve is significantly higher than the Miedema and Oudshoorn 2001 Curve.

Figure 8 compares the dose-response curves from this study with the dose-response curves from Miedema and Oudshoorn 2001.

Figure 8: Dose-Response Curves – Guski 2017 vs Miedema and Oudshoorn 2001



Some studies have suggested that the increase in noise annoyance levels shown in more recent studies is due to most modern airports having a high rate of change (HRC) in flight movements than the earlier studies which happened to include mainly airports with a low rate of change (LRC).

This study considers whether some of the change in the number of people highly annoyed could be explained by airports that have a HRC in flights vs a low LRC.

A HRC airport is defined as one that has experienced an abrupt change in the number of flights defined by a significant deviation in the trend of aircraft movements from the trend typical for the airport. HRC airports also include those that have had public discussion about operational plans within three years of when the survey was conducted.

From the twelve studies considered, five were considered HRC, five LRC and two unclassified. Figure 8 show the HRC and LRC dose-response curves in relation to the overall curve. The two dose-response curves overlap at the highest and lowest noise levels, but the LRC curve shows lower annoyance levels overall.

However, the LRC dose-response curve still shows 5-15% higher annoyance levels than the Miedema and Oudshoorn 2001 curve. This finding may be seen to confirm the conclusions of other studies in saying that noise annoyance has increased over time.

2.6 WHO 2018 Environmental Noise Guidelines

The WHO noise guidelines published in 2018 (ref Figure 9) recommend reducing aircraft noise levels to below 45 dB L_{den}. This is a 10 dB reduction from the 55 dB L_{dn} limits specified in NSZ6805:1992. The rules are copied below.

These recommendations are based on the results of the Guski 2017 synthesis of studies which shows a level of 10% of people highly annoyed at 45 dB L_{den}. In the past 10% has generally been used as the threshold where limits are set. The Miedema and Oudshoorn 2001 curve has 10% of people highly annoyed at around 55 dB L_{dn}.

Figure 9: WHO 2018 noise guidelines

3.3 Aircraft noise

Recommendations

For average noise exposure, the GDG **strongly** recommends reducing noise levels produced by aircraft below **45 dB** L_{den}, as aircraft noise above this level is associated with adverse health effects.

For night noise exposure, the GDG **strongly** recommends reducing noise levels produced by aircraft during night time below **40 dB** L_{night}, as aircraft noise above this level is associated with adverse effects on sleep.

To reduce health effects, the GDG strongly recommends that policy-makers implement suitable measures to reduce noise exposure from aircraft in the population exposed to levels above the guideline values for average and night noise exposure. For specific interventions the GDG recommends implementing suitable changes in infrastructure.

2.7 Gjestland 2018 Synthesis of Studies (Updated from 2017)

The Gjestland 2018 study critiques the Guski 2017 study which informed the new WHO 2018 noise guidelines. The study investigates another selection of other 21st century studies (16,000 responses) and yields a different result.

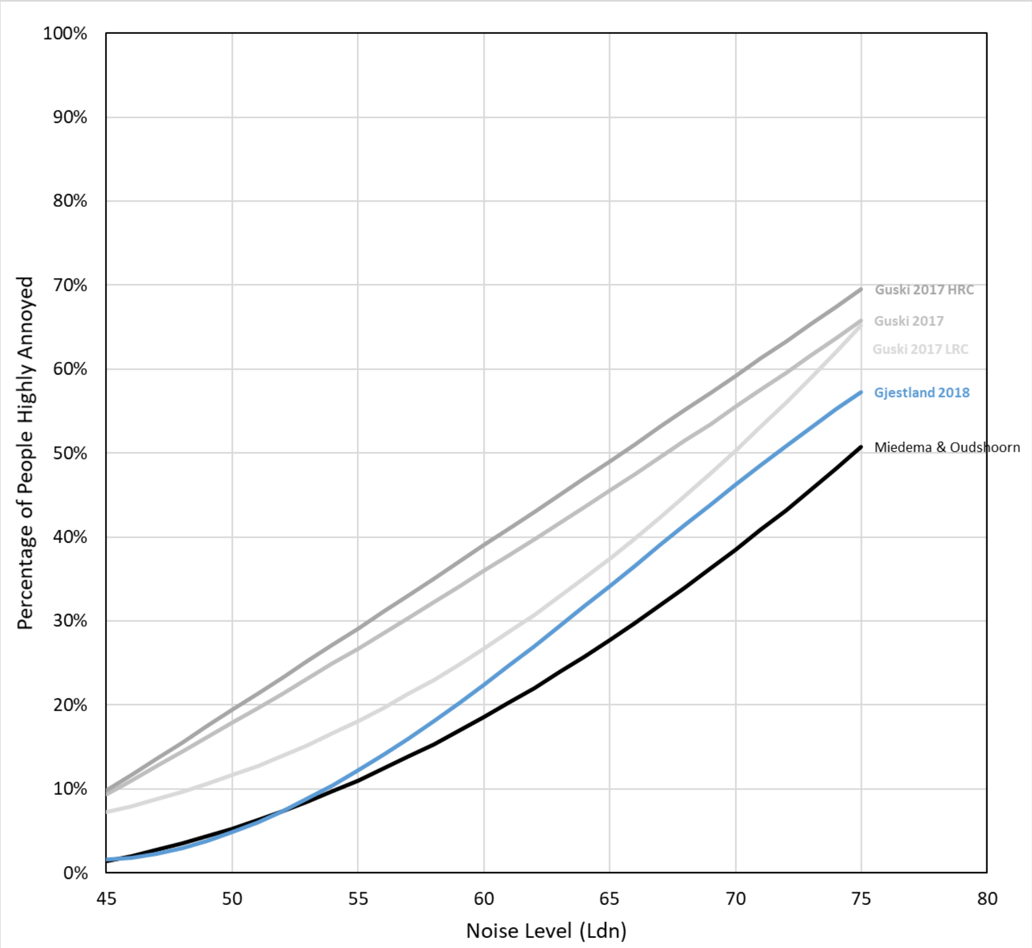
The main conclusion from the study is:

> *"The moderate quality evidence report (Guski 2017) was used by the WHO Guidelines Development Group to strongly recommend a limit of L_{den} 45 dB to avoid adverse health effects from aircraft noise.*
>
> *A separate dataset has been compiled from 18 post-2000 aircraft noise surveys…The results of this effort indicate that the recommended exposure limit to avoid adverse health effects from aircraft noise should be L_{den} 53 dB."*

Figure 10 compares the dose-response curves from the Miedema and Oudshoorn 2001. Curves have also been plotted for HRC/LRC airports.

The calculated dose-response curve is much closer to the Miedema and Oudshoorn curve than what the Guski 2017 study showed with values only differing by 3 dB. Based on this the study could not conclude whether the two curves are statistically different.

Figure 10: Dose-Response Curves – Gjestland 2018 vs Miedema and Oudshoorn 2001



This study calculated a dose-response curve for 18 post 2000 studies that the authors felt were a better selection than those included in the Guski 2017 study. Only six of these studies were included in the Guski 2017 study which informed the WHO 2018 noise guidelines. This synthesis of studies included 16,047 participants with half of the airports HRC and half LRC.

The Guski 2017 curve includes results from the HYENA study in Germany which only surveyed residents from 45-70 years of age. van Gerven 2009 has shown that age has been demonstrated as a factor that influences annoyance with annoyance peaking at 45 years old.

The Miedema and Oudshoorn dose-response curve included studies that looked at all ages. As the HYENA dataset comprises 28% of the total respondents in the synthesis of studies, it would have an impact on the results. The HYENA study also asked specific questions about night-time and daytime noise which was not included in the other studies and does not conform to the standard ICBEN questions.

Moreover, two airports in the HYENA study which experienced recent airplane crashes were included in the data even when the authors of the HYENA study excluded them from the analysis. Overall, all these factors could add to the higher level of annoyance measured.

Gjestland also asserts that the Guski 2017 study does not account for the numbers of survey respondents in the dose-response curve and that over 40% of the dataset for instance is from Amsterdam airport which would skew the results. Gjestland states that:

> *"Any specific non-dose factor that may be present at this airport will therefore have a prominent and disproportionate influence on the final exposure–response function."*

Gjestland concurs with the assessment that LRC airports have lower annoyance levels than HRC ones. A study by Gelderblom in 2017 assesses that there is a 9 dB difference between LRC and HRC airports. Guski 2017 states that this gap is 6 dB.

2.8 Guski 2018 Synthesis of Studies (Updated)

The Guski 2018 study is a follow up to the Guski 2017 study and a response to the Gjestland 2018 study discussed in Section 2.7. The study adds seven more airport surveys to the mix to give a total of 19 and a total of over 39,000 responses. This study supports the claim that noise annoyance has increased when compared to the Miedema and Oudshoorn 2001 curve.

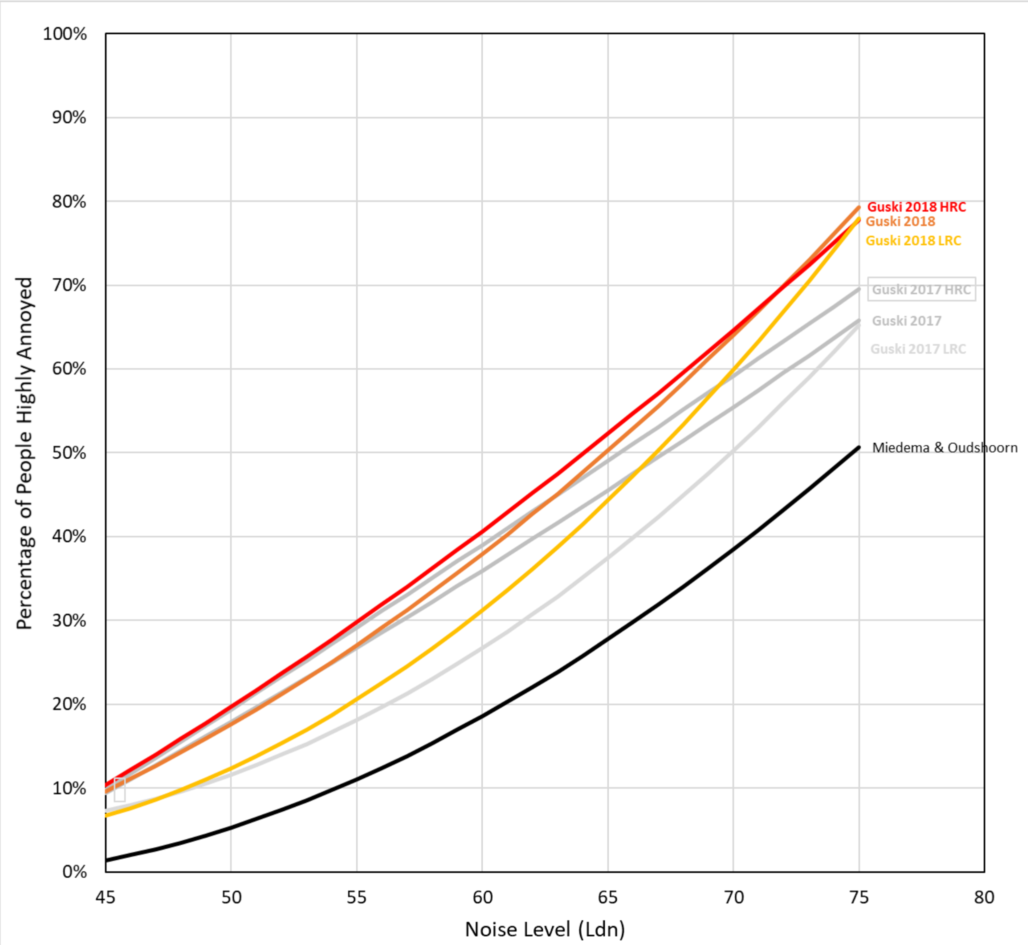
The main conclusion from the study was:

> *"Recent publications found a considerably higher percentage of highly annoyed residents as compared to the so-called EU standard curve for aircraft noise. This is partly due to the rate of change of the airports under study. However, even in relatively stable conditions, an increase of the %HA at comparable continuous sound levels can be observed."*

Figure 11 compares the dose-response curves with the Miedema and Oudshoorn 2001 curve.

The curve is significantly higher than the Miedema and Oudshoorn 2001 curve with 10% people Highly Annoyed at 45 dB L_{dn} versus 55 dB L_{dn}. The results show higher levels of annoyance at higher noise levels than what was presented in the Guski 2017 study.

Figure 11: Dose-Response Curves – Guski 2018 vs Miedema and Oudshoorn 2001



This study goes on to describe three reasons which might explain the differences in the results we see from the earlier Miedema and Oudshoorn 2001 synthesis of studies and this study. As summarised below.

Methodological differences (sample size, response rate, calculation methods)

- Meta-analysis of different studies has determined that:
  - Face to face surveys and telephone surveys have lower annoyance than postal surveys (older surveys generally face to face)
  - Higher response rates significantly associated with a decrease in reported annoyance (higher response in older surveys)
  - Annoyance judgments higher on the 11 points scale than the 5-point scale, maybe not statistically significant though (5-point scale used in older surveys mainly)
- Older surveys mainly used sampling strategies that looked at very high and very low noise levels leaving out the mid-range whereas newer surveys look at all noise levels. Comparison of the older ANIS study and newer ANAISE British aircraft noise studies which used these two types of stratification show that higher annoyance levels were observed in a more stratified sample as occurs today.
- Prediction of noise level on the ground has improved significantly for newer surveys with better availability of data on movement numbers and flight paths. Also, the calculation software algorithms have changed over time generally resulting in smaller noise contours meaning noise level at larger distances from the airport are calculated to be lower.

Situational differences (rate of change, fleet mix changes)

- Some studies have claimed that older studies generally looked at stable airports that had a LRC and that newer studies mainly looked at airports that had a HRC (as defined previously in Guski 2017).
- The Guski 2017 and Guski 2018 studies showed that HRC airports do have slightly higher levels of annoyance than the LRC airports (7-10%), but that even the LRC dose-response curves are still significantly above the Miedema and Oudshoorn 2001 curve.

Societal changes (change in values/expectations)

- People may have become more attentive to environmental dangers and to their individual health and wellbeing as their standard of living has increased.
- There is no indication in past noise surveys that personal noise sensitivity has increased over time. However, this could be a factor to explore in more depth.

2.9 Guski 2019 (response to Gjestland 2018)

The Guski 2019 study is a response paper to the Gjestland 2018 study which critiqued the previous Guski 2017 synthesis of studies. The Guski 2017 study informed the WHO 2018 noise guidelines.

The main conclusion from this paper is:

> *"There were no specific flaws, faults, or inaccuracies in the analysis of the available evidence in the bespoke systematic review. We are convinced that the WHO Guideline Development Group did not come to false conclusions and that their recommended guideline value for aircraft noise is not unjustifiably"*

One of Gjestland 2018 critiques of the Guski 2017 study was that it included the HYENA study which only surveyed residents from 45-70 years of age. Gjestland 2018 asserts that age has been demonstrated as a factor that influences annoyance with annoyance peaking at 45 years old and that therefore the dataset should not be included.

Guski 2019 responds by saying that more recent evidence shows that age is not so much of a factor on annoyance and points towards the NORAH study which reports a weak non-linear effect of age. A study by Brink 2019 shows the same findings.

Gjestland 2018 critiques the fact that the Guski 2017 study did not apply weightings to the different studies for the number of survey respondents and that over 40% of the dataset for instance is from Amsterdam airport which would skew the results. Guski 2019 concurs that weighting can induce bias instead of reducing it.

In response to this Guski 2019 has undertaken a weighting of the original dataset based on the square root of the sample size which is a commonly used procedure. This weighting is non-linear which reduces the impact of the absolute sample size for larger samples. The overall effect of this weighting is minimal as shown in Figure 12 below especially for level around 50 dB L_{dn} where there is little change.

Figure 12: Weighted (red) vs non-weighted (black) dose-response curves

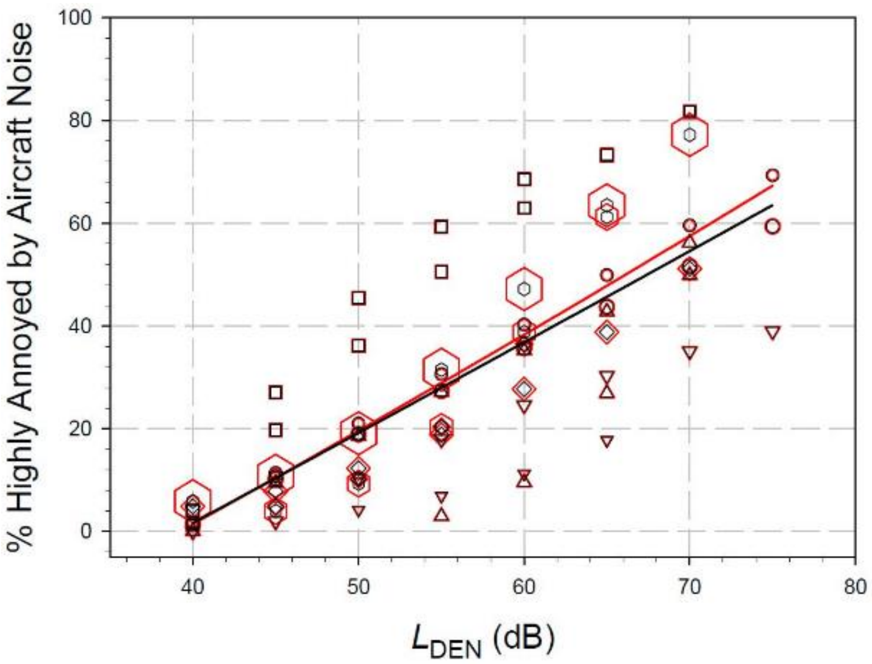


Figure 1. Exposure–response curves for aircraft noise annoyance responses in the WHO dataset [2]. "Highly annoyed" refers to respondents using ≥73% of the annoyance response scale. The red data points and regression line refer to study size weighting according to sample size; the black data points and curve refer to the same dataset without study size weighting.

The Gjestland 2018 study proposes CTL should be used to define and analyse community response to noise at different airports. This allows you to set a noise annoyance curve at each airport. Guski 2019 states a few issues with the CTL approach. Firstly, that CTL curves are based on a set sigmoidal curve form and slope which assumed the exposure-response function is the same at all airports.

Guski 2019 asserts that this is contrary to their findings where the dose-response curve shape for different airports varies quite a bit as shown in Figure 13 below. Guski 2019 is doubtful that a single curve shape can be derived at all due to the variability of the shape of different dose-response curves and that therefore CTL is not necessarily a more reliable method of defining a dose-response relationship.

Figure 13: Dose-response curve shapes for different airports in the Guski 2017 study

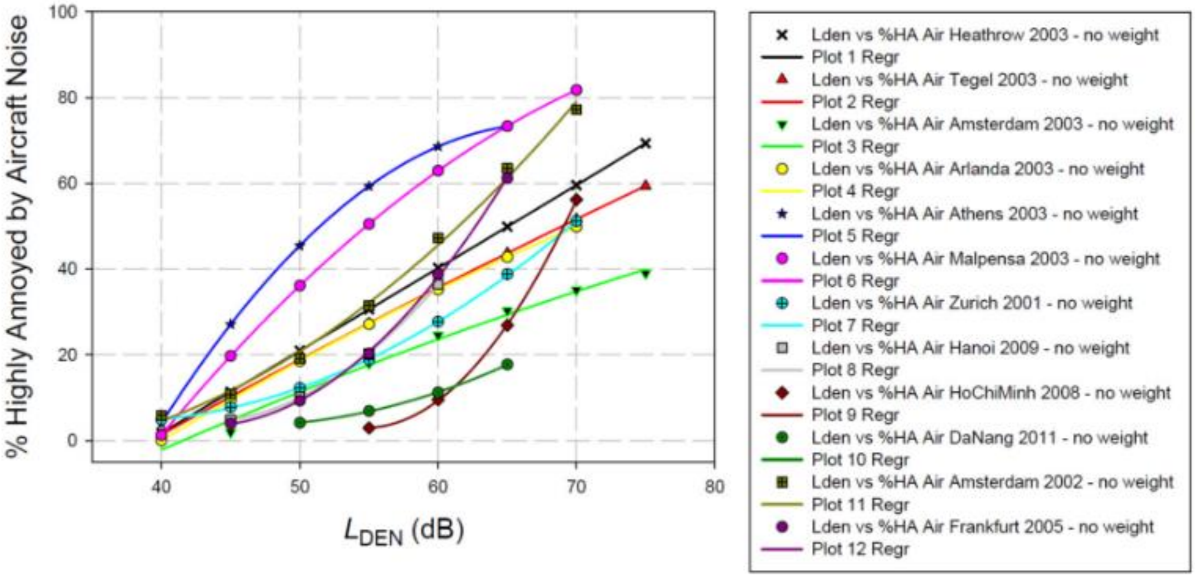


Figure 2. Individual exposure–response curves for aircraft noise annoyance responses in the 12 studies of the full WHO dataset [2]. % Highly Annoyed (%HA) refers to respondents using ≥73% of the annoyance response scale (same definition as in Figure 1). No weighting according to sample size is applied here.

2.10 Gjestland 2020 Synthesis of Studies (1961-2014)

The Gjestland 2020 study critiques the new WHO 2018 noise guidelines and the Guski 2017 study which informed them. The study investigates a number of studies since the 1960s (93,000 respondents) and gives a dose-response curve based on analysis of these.

The main conclusion from this study was:

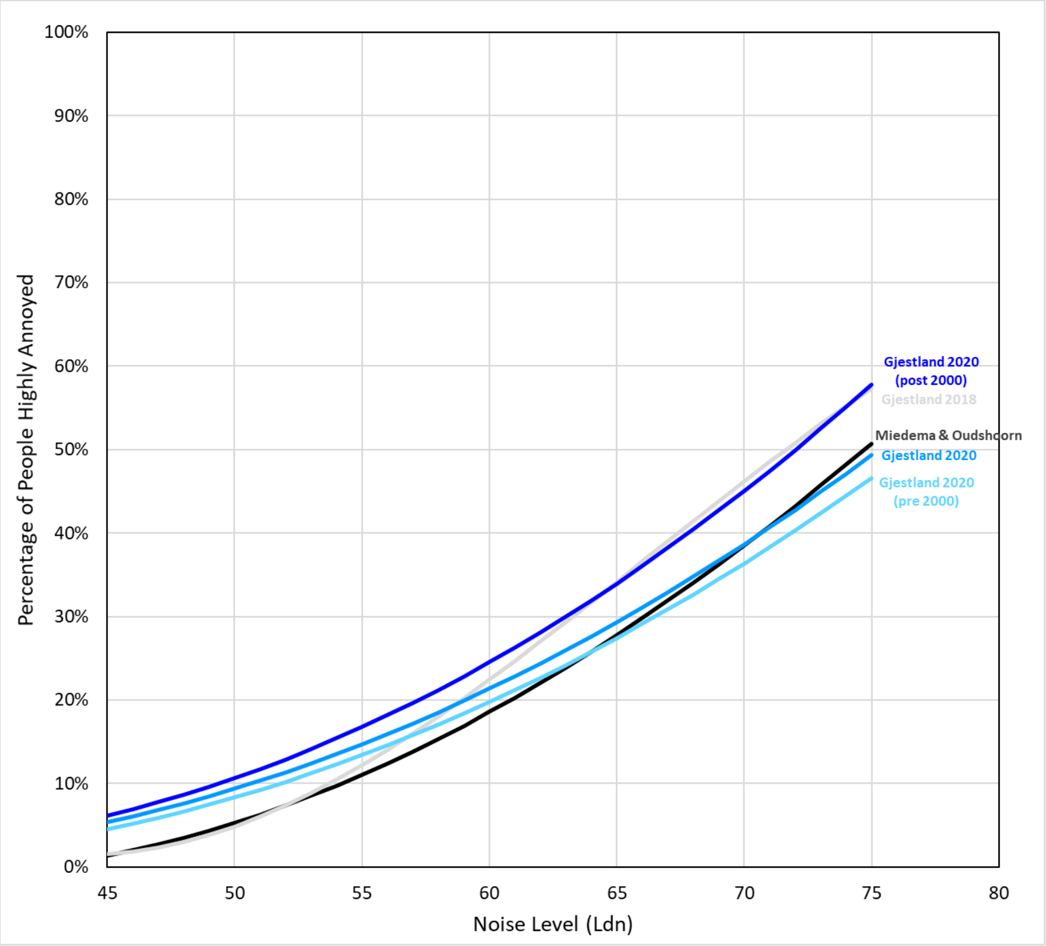
> *"A re-analysis of a larger and more representative selection of studies that relies on standard procedures shows that no meaningful changes in prevalence rates of high annoyance with aircraft noise have occurred and that existing evidence does not support WHO's revised recommendations."*

The study looks at 65 surveys completed between 1961 and 2015. The surveys from the HYENA study have not been included due to the study only including older respondents over 45 years of age as discussed previously in Gjestland 2018.

As there are some questions around the validity of older datasets, the study splits the data up into three datasets (1961-2015, 1961-2000 and 2000-2015) and plots regression curves for each. The number of respondents in the pre and post 2000 period was around 69,000 and 24,000 respectively.

The dose-response curves for each time period vary little and are generally similar to the Miedema and Oudshoorn 2001 curve. However, the curve for post 2000 study is slightly higher (about 5%) where 10% of people become highly annoyed at around 50 dB L_{dn}.

Figure 14: Dose-Response Curves – Gjestland Study 2020 vs Miedema and Oudshoorn 2001



A multi-step analysis procedure, the same as that used in the Guski 2017 study, was applied to this data to derive the dose-response curve. Gjestland 2020 critiques the multi-step analysis procedure used by Guski 2017 and states that the procedure used overestimates noise levels, but that it was used in this case to enable a fair comparison.

He applies the multi-step analysis procedure used in the Guski 2017 study to the original Miedema and Oudshoorn 2001 datasets to show how the Guski method alters the curve. Figure 15 shows the original Miedema and Oudshoorn 2001 curve as a solid blue line and the modified Miedema and Oudshoorn 2001 curve using the Guski 2017 multi-step analysis (dotted blue line). The Guski 2017 method overestimates noise at lower noise levels mainly because the Guski method does not include a bottom out of the curve at 42 dB as occurred in the Miedema and Oudshoorn 2001.

Based on this finding Gjestland 2020 concludes that the Guski 2017 curve should not be used as it does not use the correct approach to determine the regression curves. However, even in we concede to using the multi-step analysis procedure used by Guski 2017 the level of 45 dB L_{den} is still considered too low as a better selection of studies as discussed by Gjestland 2020 gives a level of 50 dB L_{dn} for 10% of people highly annoyed instead of 45 dB L_{dn}.

Reading back on the original Miedema and Vos 1998 paper it was initially decided to exclude results below 45 dB L_{dn}. But it turned out that the air, road, and rail curves all reached 0 at around 42 dB L_{dn} anyway, so the curves were altered to bottom out at 42 dB L_{dn} based on the underlying data.

On balance, in our view it would be wrong to apply the 42 dB bottoming out approach to new datasets coming through as the level at which the dataset bottoms out should be determined by looking at the underlying data for the dataset at hand rather than assumptions from previous studies.

Also, the change this makes to the Miedema and Oudshoorn 2001 curve is not large with the percentage of people highly annoyed at 55 dB L_{dn} going from about 11% in the original dataset to around 9% when the assumption of bottoming out at 42 dB is removed. At 45 dB L_{dn} it goes from around 3% to 2%.

Figure 15: Miedema & Oudshoorn 2001 curve: Original (solid blue) vs without bottoming out at 42 dB (dashed blue).

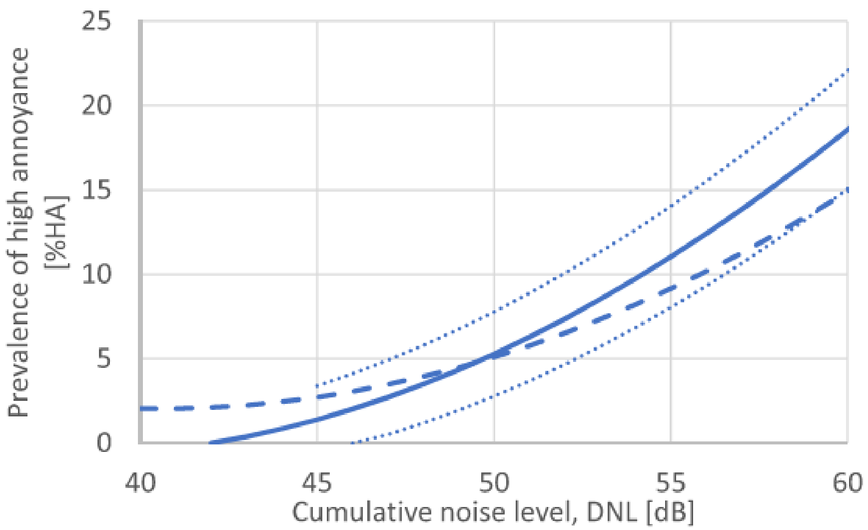


FIG. 7. (Color online) The lower end of the EU reference curve for aircraft noise annoyance (solid line) with its flanking 95% confidence intervals (dotted lines). A similar ERF is shown for an identical dataset with the method used by Guski *et al*. (2017) (dashed line).

2.11 Brink 2020 (response to Gjestland 2020)

The Brink 2020 study is a response paper to the Gjestland 2020 study which critiques a previous synthesis of studies done by Guski 2017. The Guski 2017 study informed the WHO 2018 noise guidelines.

The main conclusion from the paper is that:

> *"As long as the question of whether aircraft noise annoyance has increased or not over the last decades is not addressed by means of a sound meta-analysis, which is driven by a clearly formulated research question, including the disclosure of criteria for study selection and description of data extraction, we will not know. (1) if air-craft noise annoyance has increased or remained stable over the last decades, and (2) if the WHO guideline value for air-craft noise is appropriate or not. Gjestland's article cannot answer these questions."*

Brink 2020 asserts that Gjestland 2020 provides little information about the study objective, data sources and data extraction methods making it has to review his findings.

The study selection process was not defined and the criteria for inclusion/exclusion is not disclosed making it hard to critique the studies selected.

In addition, the Gjestland 2020 study looks at surveys from 1961-2014 in contrast to the Guski 2017 study which looks at studies from 2000-2014. Brink 2020 asserts the early studies (1960s/1970s) are questionable as there was a lack of standardised study measures and questionnaires meaning the results from these earlier studies could differ widely with surveys done in the 2000s.

However, the Gjestland 2020 study does break the dataset down into studies from 2000-2015 and plots a regression curve for this which is similar to the curve for the whole dataset, so this critique seems ill-founded.

2.12 Gjestland 2021 (response to Brink 2020)

The Gjestland 2021 study is a response paper to the Brink 2020 study which critiques a previous paper by Gjestland 2020.

Broadly, Gjestland 2021 disagrees with Brink 2020s assessment that older studies should not be included in the analysis and contends that many older studies used very similar survey techniques as are used now and thus the data is still valid.

He also refutes that assertion by Brink 2020 that Gjestland 2020 provides little information about the study objective, data sources and data extraction methods making it hard to review his findings saying that:

> *"Little imagination is needed to restate the title of the Gjestland article ("Recent World Health Organization regulatory recommendations are not supported by existing evidence") as a formal research question"*

As a final conclusion Gjestland 2021 states that even the WHO 2018 noise guidelines state that the evidence used to justify a level of 10% high annoyance at 45 dB L_{den} is of moderate quality which brings into questions the validity of the guidelines.

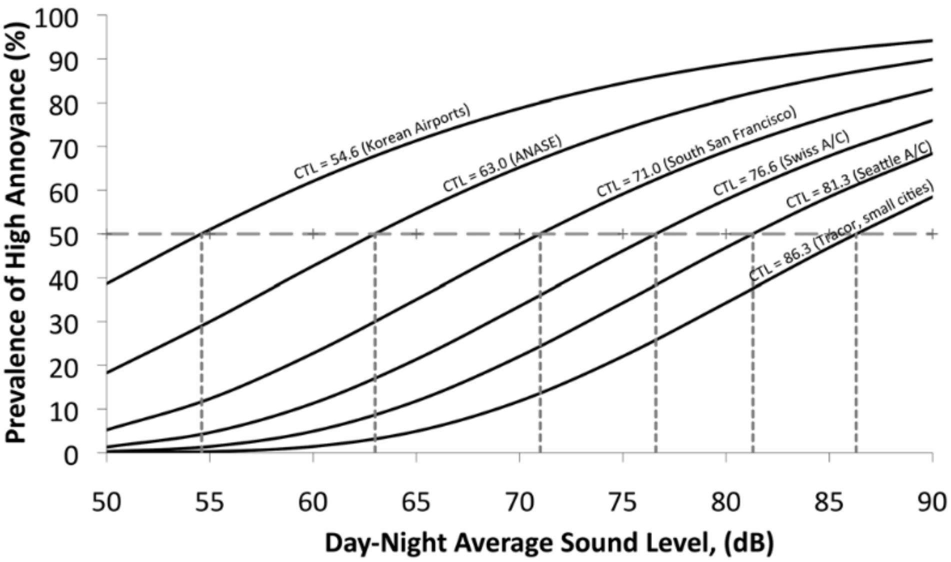
2.13 Fidell Study 2011 – Community Tolerance Level

The Fidell 2011 study suggests a different approach to assessing the level of annoyance in the community by using the Community Tolerance Level (CTL). CTL is based on the assumption that the shape of the dose-response curve generally follows a set sigmoidal relationship but that the onset of noise annoyance (i.e., the position of the curve relative to the noise axis) depends on non-acoustic factors.

The graph below shows an example of CTL curves for various airports. A set sigmoidal CTL curve is plotted and then slid left and right along the X-axis to fit the survey data for each airport. The CTL value is then obtained by reading off the noise level where 50% of people are highly annoyed (an arbitrary anchor point).

This study plotted CTL curves for 43 airport studies that contained 76,000 respondents. Figure 16 shows a selection of six airport CTL curves from this study. As you can see, each airport has a different curve

Figure 16: Examples of CTL



The mean CTL for all 43 studies considered was 73.3. Table 2 shows the predicted annoyance levels at 55, 60 and 65 dB L_{dn} for the mean CTL and for 1 standard deviation either side which is thought to approximate annoyance in two thirds of communities.

For the mean CTL, the levels of annoyance correspond well to those found in the Miedema and Oudshoorn 2001 dose-response curve. However, there is a large variance from airport to airport which shows that a bespoke dose-response curve for each airport using CTL may be better to approximate noise annoyance in specific communities.

Table 2: Predicted Annoyance Levels

TABLE III. Predicted annoyance prevalence rates for three levels of noise exposure and three degrees of community tolerance for noise exposure.

DNL	%HA FOR $L_{ct} = 73.3$ dB	%HA FOR $L_{ct} = 66.3$ dB	%HA FOR $L_{ct} = 80.3$ dB
55 dB	8.6%	1.9%	22.0%
60 dB	17.6%	6.0%	34.3%
65 dB	29.3%	13.6%	46.9%

2.14 Gelderblom 2017 Synthesis of Studies

The Gelderblom 2017 study uses the Community Tolerance Level (CTL) method as described in Section 2.13 to determine whether noise annoyance has changed over time. Specifically in relation to LRC and HRC airports and whether HRC airports yield higher annoyance levels than LRC airports.

The overall conclusion from this study was that:

> *"No evidence was found for a large enough temporal trend in aircraft noise-induced annoyance prevalence rates to justify updating existing exposure-response curves"*

This study calculated CTL values for 62 studies in total between 1961 and 2015 (top left graph) and concluded initially that people's tolerance for aircraft noise is about 8dB lower that it was in the 1960s and 4.5 dB lower for the 1970s. This is less than half the difference found by Guski 2017 as shown in the top left graph of Figure 17.

It was hypothesised that the increase in noise annoyance over time could potentially be explained by the differences in the types of airports being surveys in more modern surveys. More modern surveys seemed to contain airports that were classified as having a high rate of change (HRC) whereas older studies contained mainly studies that included airports with a low rate of change (LRC). HRC airports have been documents to increase levels of annoyance in communities.

The top right graph of Figure 17 shows the results split out into HRC and LRC airports. The graph shows that there are no significant trends in the data when aggregated by HRC/LRC. Moreover, it was deemed that improvements in survey techniques meant that estimations from studies more than 30-40 years old were more uncertain. Due to this a cut-off of 1978 was implemented and the data analysed again for all surveys in this period (not split by LRC/HRC). This updated analysis (bottom graph) showed no significant trends in the data and supports the conclusion that there has been no change in noise annoyance over time.

Figure 17: Results from the initial analysis (top left) and further refined results when aggregating by LRC/HRC airports (top right) and surveys conducted post 1978 (bottom)

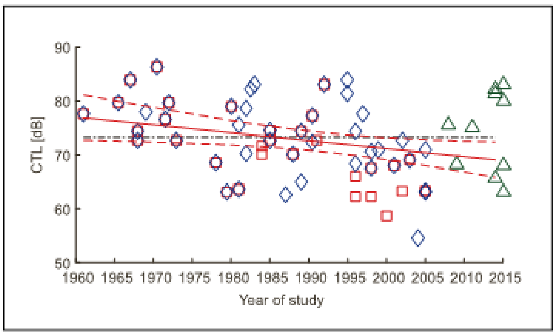


Figure 1. (Colour online) CTL values for 62 aircraft noise annoyance studies conducted between 1961 and 2015 (diamonds: Janssen and Guski, squares: Fidell *et al.*, triangles: Vietnam and Norway. The solid line (R^2 = 0.09) shows the linear fit of all data, including confidence intervals (dashed lines). The dash-dot line shows a constant CTL of 73.3 dB for comparison with the EU guideline.

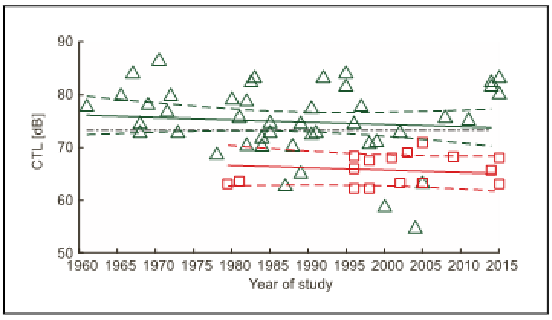


Figure 2. (Colour online) CTL values for 62 aircraft noise annoyance studies conducted between 1961 and 2015 categorized by HRC (squares) or LRC (triangles) (see text). The solid upper and lower lines show their respective linear fits (R^2 = 0.33), including confidence intervals (dashed lines). The dash-dot line shows a constant CTL of 73.3 dB for comparison with the EU standard curve.

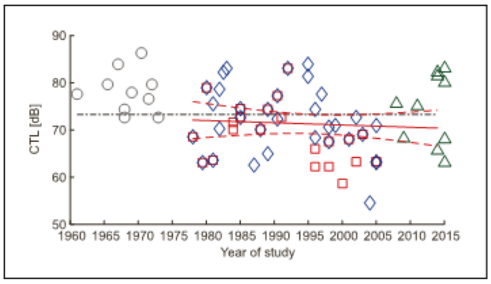


Figure 3. (Colour online) CTL values for 52 aircraft noise annoyance studies conducted between 1978 and 2015 (diamonds: Janssen and Guski, squares: Fidell *et al.*, triangles: Vietnam and Norway). The circles indicate excluded studies. The solid line shows the linear fit of all data (R^2 = 0.005), including confidence intervals (dashed lines). The dash-dot line shows a constant CTL of 73.3 dB for comparison with the EU standard curve.

2.15 Janssen and Vos 2011 Synthesis of Studies

The Janssen and Vos 2011 study analysed results from 34 studies from 1967 to 2005 many of which were included in the original Miedema and Oudshoorn 2001 dose-response curve. Seven newer studies were also analysed to bring the total number of respondents to 48,369.

The main conclusion from the study was that:

> *"A significant increase over the years was observed in expected annoyance at a given level of aircraft noise exposure. Several study characteristics can be put forward as possible explanatory factors on the basis of the present analysis. Of these factors, only the (annoyance) scale could account for the trend of increased annoyance in more recent studies. Although other studies which have investigated this further have ruled it out as a satisfactory explanation."*

A significant increase was observed in annoyance over the years at a given level of aircraft noise exposure. Data from each study was analysed to determine whether certain factors could explain these trends.

These factors included the year of the study, the type of contact (phone, postal, face to face etc), the response rate and the annoyance scale used (5pt vs 11pt).

Figure 18 shows that higher annoyance is predicted in later studies. Also, higher annoyance is predicted in those with postal surveys, those with low response rates and those with larger scales (11-point vs 5 point). All these characteristics are commonly found in more recent surveys with the older surveys using face to face surveys, having high response rates, and using 5-point scales.

Of these factors, statistically only the scale could account for the trend of increased annoyance in more recent studies. Although other studies which have investigated this further have ruled it out as a satisfactory explanation. The other factors could not statistically account for the change. This suggests that there could be increased annoyance in the population which cannot be attributed to other factors.

Figure 18: Annoyance vs study characteristics

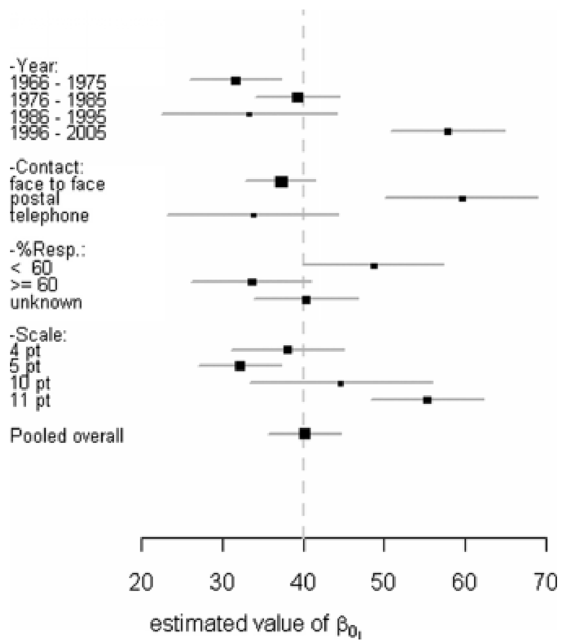


FIG. 2. The estimated mean annoyance on a 100-point scale (β_{0i}) at the overall mean exposure level plotted against study characteristics, with associated 95% confidence intervals and with size of the data-points proportional to the inverse variance (SE_i^2) in β_{0i}.

3.0 SLEEP DISTURBANCE

Literature on sleep disturbance research over the past 30 years has been reviewed to determine its relationship to aircraft noise. To summarise the reviewed literature, and the path of change over the last 30 years, we conclude that energy equivalent metrics such as L_{night} are insensitive in respect to sleep disturbance.

Throughout the years, researchers have endeavoured to improve understanding of the way in which multiple night-time events interact cumulatively, and in independence, as well as the most appropriate acoustic metric to describe the noise level (e.g. L_{max} or SEL). The ANSI standard detailed the most comprehensive way to assess sleep disturbance effects based on the number of noise events and their noise level. However, this standard has been withdrawn due to complex assumptions and supporting data that was not evidenced with confidence.

We conclude that there is currently not an accepted approach in the literature to accurately assess the effects of aircraft noise on sleep disturbance. More research in this area is needed to determine a meaningful relationship and assessment methodology.

4.0 NON-ACOUSTIC FACTORS

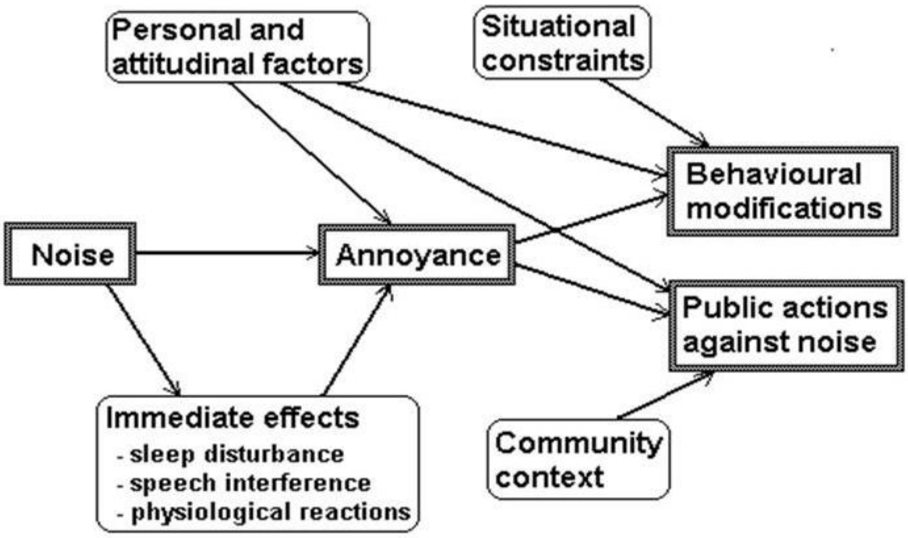
The research literature acknowledges that non-acoustic factors play a potentially significant part in determining the level of annoyance in the community. Non-acoustic factors are those factors other than the noise level which contribute to annoyance. Both Schultz and Miedema note in their papers that non-acoustic factors are thought to be a significant contributor to noise annoyance. There are reports that non-acoustic factors could potentially account for more than 2/3 of the variance in the data.

Non-acoustic factors moderate an individual's sensitivity to noise which in turn can affect their level of annoyance. Figure 19 show the various factors that can impact noise annoyance. These include 'acoustic factors' such as the noise level and its immediate effect on sleep disturbance and speech interference. The diagram also shows non-acoustic attitudinal factors which influence annoyance and subjective response. These include things such as:

- Age
- Gender
- Socioeconomic status
- Attitude of the noise receiver to aviation
- Attitude of the noise producer to the receiver

The resultant annoyance can then translate into behavioural modifications in terms of how people live and can also result in public actions against noise depending on the community context.

Figure 19: Noise Annoyance and Non-acoustic Factors



There are a number of papers that have been published in recent years which have tried to determine the relationship between various non-acoustic factors and annoyance. Miedema and Vos in 1998 surmised that the differences observed between air, road and rail annoyance curves (annoyance is less for road/rail sources) could be due to a fear of aircraft crashes and other non-acoustical factors that did not exist for road/rail sources.

Similar findings were reported in a paper published by Van den Burg in 2018 which looks and the relationship between worry and annoyance at Schiphol airport. This paper showed a strong correlation between worry/fear about living underneath or near a flight path/airport with the level of annoyance experienced with those more worries experiencing significantly higher levels of annoyance. This paper also found that females, those above 35 years of age and those having a high risk for anxiety/depression or being in bad health had increased levels of worry and thus increased levels of annoyance.

A paper by Clark investigated the results from the National Noise Attitude Survey in 2012 in the UK and found that noise sensitivity was more strongly associated with sociodemographic factors than with dwelling or geographic factors. The main findings were that higher noise sensitivity was recorded for:

- Older respondents (40+)
- Females
- People who had a mortgage
- People without children in the house
- Those not working full time (excluded retired people which had a lower noise sensitivity)
- Those with a higher social class

Bauer in 2014 published a paper which looked at results from the COSMA study which was a study of three European airports. This study identified factors which appeared to increase/decrease noise annoyance which include:

Factors that increase annoyance:

- Night/early flights
- Disturbed work or relaxation
- Noise felt as a health hazard

- Noise that required coping mechanisms to be implemented
- Personal noise sensitivity

Factors that decrease annoyance

- Feeling fairly treated by the airport
- Belief that you can get used to aircraft noise
- Belief that the airport is economically important
- Satisfaction with noise insulation
- Satisfaction with residential area

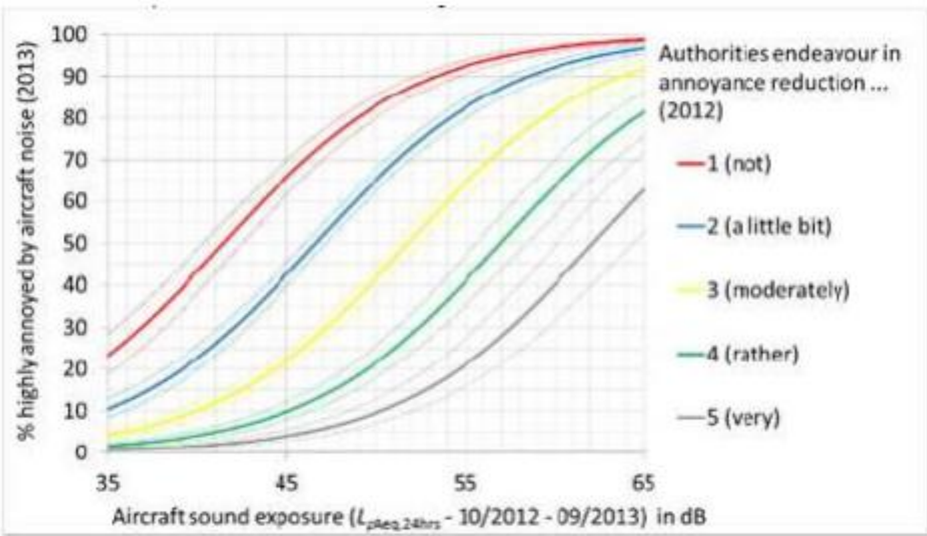
This report summarises that at one of the airports, the non-acoustical factors were found to account for 55% of the variance in the data. This variance it thought to vary from airport to airport which confirms the assumptions of the CTL approach.

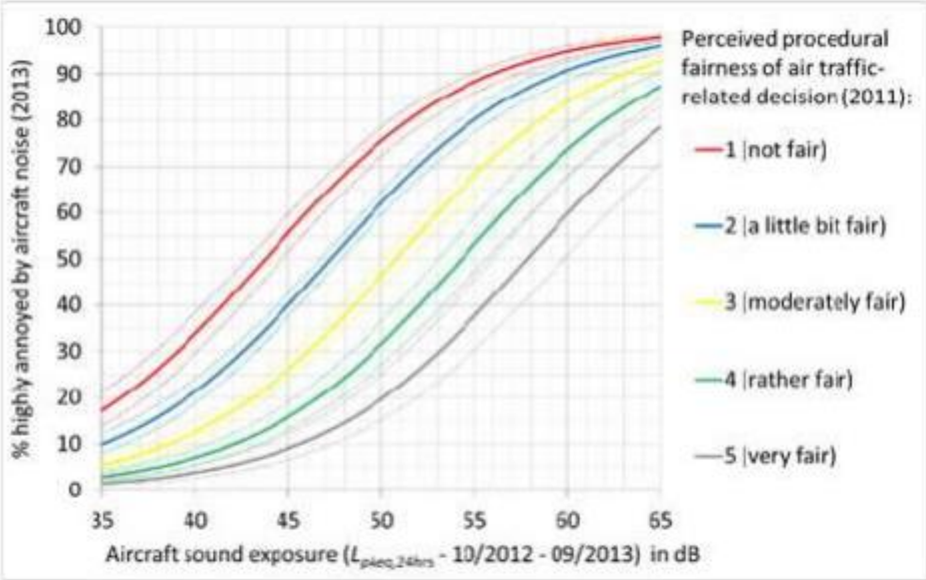
Schreckenburg published a paper in 2017 which looked at the results from the NORAH study. He looked at things such as whether trust in authorities to endeavour to reduce annoyance, perceived procedural fairness and expectation that air traffic supports regional development could account for variance in the data.

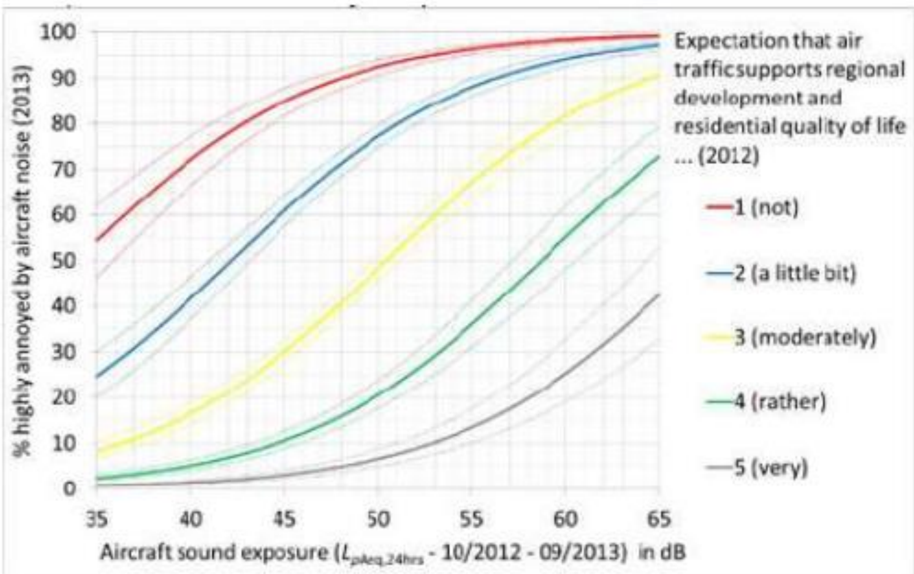
The Figures below show the dose-response curves from the NORAH study split out into the different responses. The graphs show a large variance between respondents who trust the airport, think the airport has procedural fairness and believe that air traffic has a positive effect on regional development to those that do not believe this.

The graphs show that for the same noise level, agreeing/not agreeing with these statements has a large impact of the level of annoyance. For example, those that have a high level of trust in the airport authority report a level of annoyance of around 15% at 55 dB $L_{Aeq\ (24hr)}$), whereas those who rate their trust in the airport authority at low report level of annoyance at around 95% at 55 dB $L_{Aeq\ (24hr)}$.

Figure 20: NORAH Study – Levels of annoyance







5.0 CONCLUSIONS

Aircraft noise can result in adverse effects on communities including annoyance and sleep disturbance effects. A literature review has been undertaken to determine the latest research in these areas.

Recent literature on annoyance shows that annoyance levels have increased markedly compared to the 2001 Miedema study. The two largest studies conducted recently were the World Health Organisation (WHO) study in 2018 and the Federal Aviation Administration (FAA) study in the US in 2021. The WHO 2018 noise guidelines now recommend noise limits for aircraft noise of 45 dB L_{dn} as a result of this research. This is 10 dB more stringent than the recommendations of NZS6805 which recommends prohibiting noise sensitive development within 55 dB L_{dn}.

International bodies around the world are considering whether to update their policies, and the WHO Noise Guidelines could provide the latest scientific knowledge. We consider that the WHO curve represents the latest research in this area internationally and should replace the Miedema curve for assessing the effects of aircraft noise on communities.

Whilst the FAA study is also valid, this study only considers the annoyance response from one country whereas the WHO curve is an amalgamation of data from European and Asian cities.

The research showed that non acoustic factors play a potentially significant part in determining the level of annoyance in the communities. More research is needed in this area to quantify the effect each of these factors has on noise annoyance. However, the research clearly highlights that good management of an airport, transparency and positive engagement with communities in relation to aircraft noise and overflights can significantly lower annoyance levels. These things should not be seen as a 'nice to have' but rather as critical part of managing annoyance around airports.

There have been a number of studies on sleep disturbance from aircraft noise over the past 30 years. There is currently not an accepted approach in the literature to accurately assess the effects of aircraft noise on sleep disturbance.

The literature shows that energy equivalent metrics such as L_{night} are insensitive in respect to sleep disturbance. Metrics that consider the noise level of single aircraft events have been researched and cumulative indices have been developed that look at the effects of multiple night-time events. However, the complex assumptions and methodology that underpins these types of methods have not been evidenced with confidence.

APPENDIX A GLOSSARY OF TERMINOLOGY

Noise	A sound that is unwanted by, or distracting to, the receiver.
dB	Decibel The unit of sound level. Expressed as a logarithmic ratio of sound pressure P relative to a reference pressure of Pr=20 µPa i.e. dB = 20 x log(P/Pr)
dBA	The unit of sound level which has its frequency characteristics modified by a filter (A-weighted) so as to more closely approximate the frequency bias of the human ear.
A-weighting	The process by which noise levels are corrected to account for the non-linear frequency response of the human ear.
L_{dn}	The day night noise level which is calculated from the 24-hour L_{Aeq} with a 10 dB penalty applied to the night-time (2200-0700 hours) L_{Aeq}.
L_{den}	The day evening night noise level which is calculated from the 24-hour L_{Aeq} with a 5-decibel penalty applied to the evening (1800-2200 hours) L_{Aeq} and a 10-decibel penalty applied to the night-time (2200-0700 hours) L_{Aeq}.
Noise dose-response curve	A dose–response relationship is the magnitude of the response (in this case annoyance) of a person to a certain dose of a stimulus or stressor (in this case noise). Dose–response relationships can be described by dose–response curves. Dose-response curves are created by graphing the magnitude of the response (level of annoyance) for each individual against the dose (noise level) and performing a statistical analysis on this data to create a single dose-response curve for the population.
Air Noise Contours	The noise contours published in the District Plan (50 L_{dn} | 55 L_{dn} | 65 L_{dn}).

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