Before Independent Hearing
Commissioners at Christchurch

I MUA NGĀ KAIKŌMIHANA
WHAKAWĀ MOTUHAKE
KI ŌTAUTAHI

Under	the Resource Management Act 1991
In the matter of	The hearing of submissions and further submissions on Plan Change 14 to the Operative Christchurch District Plan

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Evidence of John-Paul Barrington Clarke

On behalf of submitters: Miles Premises Limited (883) and Equus Trust (2102)

20 September 2023

Applicant's solicitors:
Sarah Eveleigh | Sarah Eveleigh
Anderson Lloyd
Level 3, 70 Gloucester Street, Christchurch 8013
PO Box 13831, Armagh, Christchurch 8141
DX Box WX10009
p + 64 3 379 0037
sarah.eveleigh@al.nz | sarah.eveleigh@al.nz

anderson
lloyd.

Introduction

1 My full name is John-Paul Barrington Clarke.

2 I am a Professor at The University of Texas in Austin, Texas, USA; where I have an appointment in the Department of Aerospace Engineering and Engineering Mechanics, and hold the Ernest Cockrell Jr. Memorial Chair in Engineering.

3 I have three degrees from the Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts, USA. I received the Bachelor of Science (S.B.) in Aeronautics and Astronautics in June 1991; the Master of Science (S.M.) in Aeronautics and Astronautics in September 1992; and the Doctor of Science Degree (Sc.D.) in Aeronautics and Astronautics in February 1997.

4 I am a globally recognized expert in aircraft trajectory prediction and optimization, especially as it pertains to the development of flight procedures that reduce the environmental impact of aviation. My research has been instrumental in changing both the theory and the practice of flight procedure design, and has spurred the global effort to reduce the environmental impact of aviation via changes in operational procedures.

5 I am also recognized globally for my work in noise propagation modelling. I was an integral member of the team that was the first to quantify how the noise directivity patterns of aircraft with wing-mounted engines differ from the noise directivity patterns of aircraft with fuselage-mounted engines, and then subsequently developed the state-of-the-art model that is used in the Integrated Noise Model (INM) to predict the "excess ground attenuation" that is observed for aircraft that are close to the ground, as they are near airports (Fleming et al., 2002). I have also developed multiple models for predicting the propagation of noise in non-standard atmospheric conditions. One such model is particularly useful for predicting noise propagation at night, when temperature inversions increase the distance over noise propagates (Clarke et al., 2004).

6 Further, I am an expert in the development and use of stochastic models and optimization algorithms to improve the efficiency and robustness of airline, airport, and air traffic operations. My research has changed long-

established views regarding the need for and the best way to achieve robust schedules, particularly in the airline industry.

7 I have received several awards for my work. Those most relevant to the matters being addressed are the 1999 AIAA/AAAE/ACC Jay Hollingsworth Speas Airport Award, the 2003 FAA Excellence in Aviation Award, the 2006 National Academy of Engineering Gilbreth Lectureship, the 2012 AIAA/SAE William Littlewood Lectureship, and the 2015 SAE Environmental Excellence in Transportation (E2T) Award.

8 In addition to my work in academia, I have served as a consultant for airports and community groups around the world on matters of noise prediction and regulations for over 20 years. Further, I have consulted for several airlines around the world on matters pertaining to their operations, including the schedule of flights and maintenance events.

9 In 2007, I was engaged by the Selwyn District Council to serve as their expert in the deliberations surrounding the appropriate extent of the noise contours around Christchurch International Airport. I ultimately ended up chairing the group, often referred to as the 'Panel of Experts,' that estimated the future operations at Christchurch International Airport and subsequently developed noise contours.

10 In 2016, I was engaged in the matter of the Resource Management Act 1991 and the Canterbury Earthquake (Christchurch Replacement District Plan) Order 2014 and in the matter of the General Rules and Procedures Proposal (Stage 3) as an expert by the following submitters (with associated submitted number): Bruce Campbell (2489); David Lawry (2514); Mike Marra (2054); Vanessa Payne (2191); John Sugrue (2567); Gerrit Venema (2091).

11 This statement of evidence has been developed in collaboration with Truls Gjestland.

12 Mr. Gjestland graduated as a civil engineer (eguivalent to M.Sc.) from the Norwegian Technical University (NTH) in 1967. Since then, he has been employed at the research institute SINTEF, interrupted only by a year as a visiting researcher at the American high-tech company Bolt, Beranek & Newman. At SINTEF, he has held positions as researcher and research

director, and continues (since his retirement) as a part-time, senior researcher. In the period 1981–1983, he was a member of SINTEF's board.

13 He developed the noise management plan for the Emirate of Abu Dhabi and has for periods acted as an adviser to the World Health Organization (WHO), the International Civil Aviation Organization (ICAO), the European Aviation Safety Agency (EASA) and the Federal Aviation Administration (FAA).

14 He is also a member of the EU's Noise Expert Group and has been a member of the "International Commission on Biological Effects of Noise" for more than 40 years.

15 His many honors include being named an Honorary member of the East-European Acoustical Association (2002), an Honorary member of the Norwegian Acoustic Society (2005), Silencer of the Year by the Norwegian Noise Association (2010), a Fellow of the Acoustical Society of America 2016, and a Distinguished International Member of the Institute for Noise Control Engineering (2023). He has also been awarded The King's Medal of Merit among other things for his achievements in acoustics (2023).

16 I confirm that the issues addressed in this statement of evidence are within my area of expertise and that of my colleague Truls Gjestland. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

17 I reviewed the following documents in the preparation of this evidence:

(a) New Zealand Standard for Airport Noise Management and Land Use Planning, NZS6805-1992, Standards Association of New Zealand, 1992.

(b) 2023 Updated Christchurch International Airport Noise Contours

(c) Christchurch Airport Remodelled Contour - Independent Expert Panel Report, Ricondo, June 2023

(d) The PC14 Section 32 report – s77K Airport Related Qualifying Matters in the Christchurch District Plan, RMG, 11 July 2022

(e) Airbiz Report – Airport Operations and Safeguarding, 14 June 2022

(f) Review of international and domestic freight trends through Christchurch International Airport – Richard Paling Consulting, June 2022

(g) Christchurch Airport Recontouring Assessment of Noise Effects – Annual Average Updated Contours – Marshall Day Acoustics – 21 July 2022

(h) Christchurch International Airport Land Use Planning, Marshall Day Acoustics, 23 May 2022

Scope of Evidence

18 The evidence is based on the combined expertise of myself and Mr. Gjestland, and will be focused on the following topics:

(a) Whether the noise modeling assumptions were appropriate;

(b) Whether 50 DNL is the appropriate noise control boundary.

Executive Summary

19 By making worst-case assumptions with respect to aircraft noise characteristics and air traffic management procedures, i.e., by assuming that aircraft source noise characteristics as well as the air traffic management procedures and thus the resulting flight tracks will not change over the next 60 years, the modelers have ensured that the contours will be significantly larger than reality. It does not make sense to assume that aircraft noise will not decline over the next 60 years.

20 In 60 years, when the demand in forecast by CIAL to be near the practical capacity, single-aisle aircraft will likely be at least 5dB quieter than the current generation of single-aisle aircraft, and the variability in flight tracks will be much lower.

21 Further, the use of an “outer envelope” contour introduces an absolute worst-case scenario for which there is no known relationship with annoyance. The dose-response curves that have been developed

internationally are based on “a yearly average exposure” and they should not be applied to an outer envelope.

22 No data has been presented that should warrant a change in today’s policies regarding acceptable exposure limits for aircraft noise. Most countries that have noise regulations for land use planning have limits corresponding to about Ldn 55 dB or higher for aircraft noise.

23 Reports on an alleged increase in aircraft noise annoyance is most likely caused by non-acoustic factors such as the selection of study areas, survey procedures, and response scales.

24 There are no indications that the noise sensitivity among residents of New Zealand is higher than in similar populations.

25 The new WHO Environmental noise guidelines recommending a limit of Lden 45 dB for aircraft noise to avoid adverse health effects, is a European document not adopted by the other WHO regional offices. Aside from the European Commission, no other regulatory authority has endorsed this limit.

26 After the publication of the WHO Environmental noise guidelines for the European Region, two European countries, Switzerland, and UK, have presented new evidence that an exposure limit for aircraft noise around Ldn 55 dB is a reasonable and correct choice.

Were the noise modeling assumptions appropriate?

27 When determining whether noise modeling assumptions are appropriate, it is necessary to consider the individual and collective reasonableness of the assumptions over the entire period being modeled.

28 The CIAL Expert Team chose to use the term “ultimate capacity”, defining it as the point where demand approaches the practical capacity rather than the theoretical maximum daily capacity.

29 We agree with the use of a “practical capacity” versus the theoretical maximum capacity.

30 This approach recognizes the fact that no airport, even if it is open for operation for the entire day, will have its runways fully utilized during the

entire day. This is particularly relevant for an airport such as CHC where there is a limit to the times of the day when passengers and cargo would seek to fly to and from CHC because of its location relative to global population centroids.

31 This approach is also consistent with the fundamental principles of queuing theory, where demand below the maximum theoretical capacity produces elevated but still acceptable levels of delay, rather than the “unrecoverable” delays that occur when the demand is closer or equal to the maximum theoretical capacity.

32 A practical capacity of 200,000 is in the realm of possibility given the current state of the art in air traffic management at airports in the United States that operate primarily in visual meteorological conditions and where modest delays are deemed acceptable (Gentry, Duffy, & Swedish, 2014; de Neufville, Odoni, Belobaba, & Reynolds, 2013), the proposed improvements in air traffic management that are currently under development and are likely to positively impact on the efficiency of terminal area and runway operations.

33 However, I do not believe that this practical capacity will be utilized based on the historical trends in traffic growth at CHC and other airports at extreme geographical locations relative to population centroids, and the fact that air traffic control efficiency in the US is typically greater than in other countries.

34 That said, the CIAL Expert Team now projects that aircraft movements will not exceed 200,000 movements until FY2084, rather than FY2063 as previously projected due to the COVID-19 pandemic and to lower growth rate in both passengers and aircraft movements. Of further concern is the lack of any consideration of increasing aircraft seating capacity. A 10% or more increase in seat capacity in the average aircraft will increase passenger count by that amount without increasing operations. This is the airlines primary response to aircraft operational constraints whether by regulation or airport capacity

35 This increase in the time horizon over which the noise impact is modeled means that the assumptions regarding fleet composition, aircraft source noise characteristics, as well air traffic management procedures and the

resulting flight tracks must be collectively valid throughout the entire period ending in FY2084.

36 The assumption regarding fleet composition is reasonable given the statements by both Airbus and Boeing that the next generation of single-aisle (narrow-body) aircraft will likely be certified between 2035 and 2040 and will thus only become a substantial part of the fleet in the 2050 timeframe when the aircraft that are currently being sold are retired.

37 Single-aisle aircraft make up the majority of the fleet at most airports and thus dominate the noise impact.

38 The assumptions regarding aircraft source noise characteristics, as well as air traffic management procedures and the resulting flight tracks are not reasonable within the context of an evaluation period ending in FY2084.

39 The modelers have collectively assumed that:

(a) The next generation of single-aisle aircraft will have the same source noise characteristics as the current generation of single-aisle aircraft; and

(b) The air traffic management procedures that are currently in use will still be in use in FY2084, thus the spread in the flight tracks will be the same.

Aircraft Source Noise Characteristics

40 It is not reasonable to assume that next generation of single-aisle aircraft will have the same source noise characteristics as the current generation of single-aisle aircraft.

41 Over a 60-years period commencing with the certification of the B707-200 in 1957, there has been a significant (approximately 30dB) reduction in the lateral noise level (in EPNdB) of aircraft (see Figure 1).

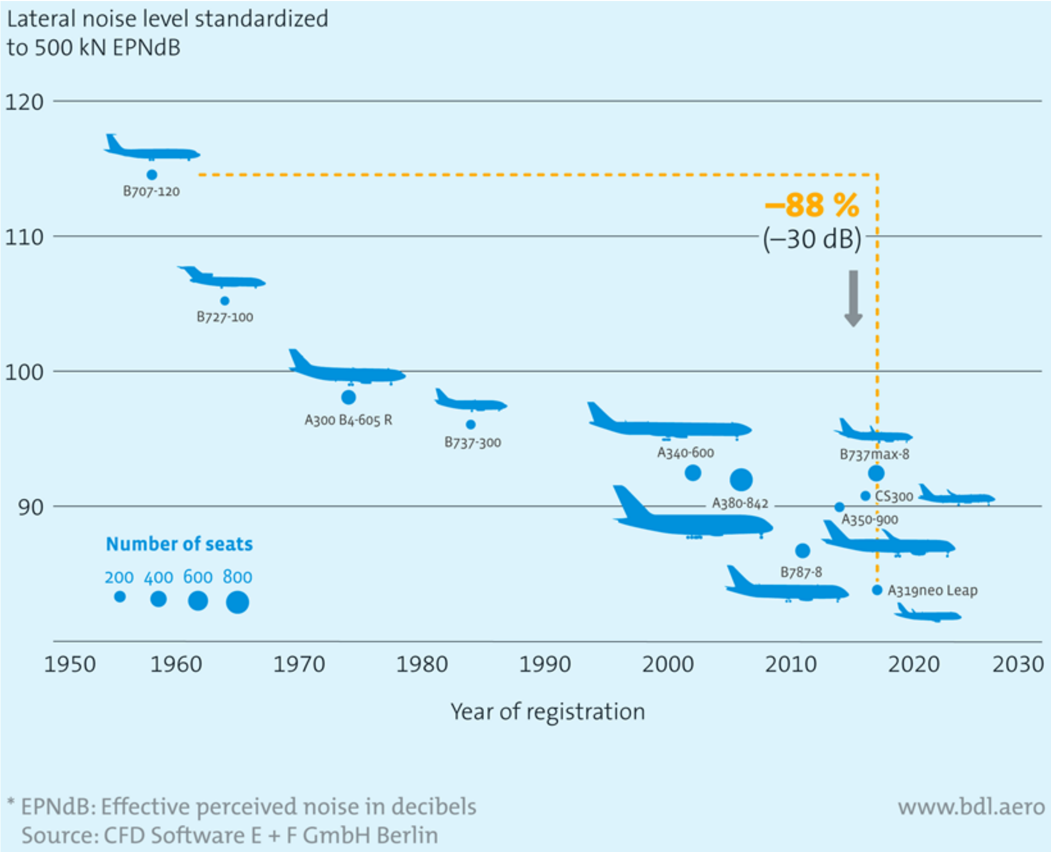

Figure 1: Lateral noise levels of commercial jet aircraft.

42 This 30dB reduction is significant because the lateral noise level has been shown to be the best predictor of the noise impact around airports.

43 While is true that there are diminishing returns overall with respect to the reduction in lateral noise of aircraft, i.e., an exponential curve with a negative exponent has a higher r2 (a measure of the goodness of fit) than a linear curve with a negative slope, the next generation of single-aisle aircraft will likely be at least 5dB quieter than the current generation of single-aisle aircraft.

44 This assertion is supported by a simple comparison of the 727-100, 737-300, and the A319-neo Leap.

45 These three aircraft have similar seating capacities, and the best fit curve though those three points for these aircraft in Figure 1 would be a straight line, indicating that there are likely to be substantive improvements in the next generation of single-aisle aircraft.

Air Traffic Management Procedures and Flight Tracks

46 It is not reasonable to assume that the air traffic management procedures that are currently in use will still be in use in FY2084.

47 Several improvements in flight control systems are being developed or are already being deployed to ensure that aircraft will fly more precisely and consistently.

48 The observed dispersion in flight tracks are typically due to manual overriding of automated/programmed flight procedures by air traffic controllers.

49 The need for and prevalence of such overrides will dimmish over time given the expected flight control improvements.

50 Further, no account is made for improvement in aircraft controller training and capabilities (with and without automated aids) that would improve precision with which aircraft are flown and delivered.

Average versus Outer Envelope Contours

51 Separately, it is not reasonable to use the highest 3-month usage for each runway THEN also apply the peak factor to establish a 'worst case' 3-month contour AND add 10% to account for potential climate change effect on Runway 11/ 29.

52 This introduces an absolute worst-case scenario for which there is no known relationship with annoyance. The dose-response curves that have been developed internationally are generally based on “a yearly average exposure” and they cannot be applied to an outer envelope.

Conclusions

53 By making worst-case assumptions with respect to aircraft noise characteristics and air traffic management procedures, i.e., by assuming that aircraft source noise characteristics as well as the air traffic management procedures and thus the resulting flight tracks will not change over the next 60 years, the modelers have ensured that the contours will be significantly larger than they should be.

54 In 60 years, when the demand in forecast by CIAL to be near the practical capacity, single-aisle aircraft will likely be at least 5dB quieter than the current generation of single-aisle aircraft, and the variability in flight tracks will be much lower.

55 Further, the use of an “outer envelope” contour introduces an absolute worst-case scenario for which there is no known relationship with annoyance. The dose-response curves that have been developed internationally are based on “a yearly average exposure” and they cannot be applied to an outer envelope.

Is Ldn 50 dB the appropriate noise control boundary?

56 The report from Marshall Day entitled “Christchurch airport – Community response to aircraft noise,” Rp 001 20201126, May 2022, authored by Laura McNeill, is a literature review of recent articles on aircraft noise annoyance. A total of 45 aircraft noise studies have been reviewed and the 14 most prominent ones have been summarized. Comparisons have been made between the reported results and the standard reference curve published by Miedema and Vos (1998) and later refined by Miedema and Oudshoorn (2001).

57 Many of the comparisons and comments that are being made in the Marshall Day report comprise survey results that have been derived using different methodologies, and they cannot therefore be readily compared.

58 The main conclusions in the Marshall Day report are that annoyance from aircraft noise has increased markedly and that international bodies around the world are considering adopting the new WHO guidelines for environmental noise. The Marshall Day report provides no documentation to back this statement.

59 In contrast to these conclusions, the prevalence of high annoyance with aircraft noise has been stable over a long period of time, and there are no indications that people today are more annoyed by aircraft noise than they were, say, 25 or 50 years ago. Likewise, the noise sensitivity in populations similar to that of New Zealand has not changed.

The difference between regulatory limits and WHO guideline values

60 It is important to recognize the difference in approach for the two quantities. When the World Health Organization issues guidelines to avoid health issues due to noise annoyance, the perspective is that no resident should be annoyed by noise, whereas a regulatory authority usually will accept a certain risk for health impairment.

61 In 2000 WHO issued its first guidelines for community noise (Berglund, Lindvall, Schwela, & Goh, 2000). The document defined guideline values for various noise situations. The limits were stated in 16-hour equivalent levels, and they were non-source-specific. However, by applying the transformation tables provided by Brink et al. (2017) the recommended values can be transformed into quantities that can readily be compared with today's guidelines and regulatory limits.

62 The 2000 WHO-recommended guidelines to avoid serious annoyance or moderate annoyance from aircraft noise were Lden 57 dB and Lden 52 dB respectively[1]. The rationale for choosing these values was simply: during the daytime few people are annoyed by activities with these levels.

63 The WHO rationale became more evident in the next guideline publication (World Health Organization, 2018). In this document the guideline value for annoyance is defined as the level corresponding to 10 % highly annoyed. This equals roughly the percentage of a normal population that consider themselves very noise sensitive. This is confirmed by Heinonen-Guzejev, Vuorinen, Mussalo-Rauhamaa, & Kaprio (2004) presenting data for Europe and Finland in particular, and Shepherd, et al. (2000) presenting data for New Zealand. In other words, WHO assumes that their recommendation for environmental noise limits will protect the majority of a normal population from experiencing any noise annoyance at all, and only those that are very noise sensitive will be affected.

64 A regulatory authority, on the other hand, must take other aspects than merely the presence or absence of a negative health effect into account. In

[1] In this report the two quantities Lden and Ldn is used interchangeably. The difference between them is usually less than 0.5 dB for aircraft noise.

most cases negative effects cannot be completely avoided. Therefore, these effects must be assessed together with other aspects such as prevalence risk, disability weight, etc. The WHO publication "Burden of disease from environmental noise" (WHO, 2011) describes procedures that are relevant for such calculations. The “cost” of annoyance must be compared to other societal costs and benefits such as for instance easy access to transportation. Necessary trade-offs between costs and benefits must be done in a systematic way.

65 A new Swiss report gives a detailed description of the considerations that form the basis for new limit values for environmental noise in Switzerland (FNAC, 2021). The Swiss Commission considers 25 % highly annoyed corresponding to Lden 55 dB for aircraft noise according to Swiss-based exposure-response curves[2] as a suitable limit for acceptable noise exposure.

66 In short: a WHO guideline limit considers only the health aspects of the exposure to a certain agent, whereas a limit defined by a regulatory authority has a more holistic approach and considers the specific exposure in connection with other relevant factors.

Comparison of survey results

67 Surveys to assess the annoyance from environmental noise have been conducted since the 1960's, but only recently have such surveys been standardized. The International Commission on Biological Effects of Noise, ICBEN, published two papers in 1997 and 2001 attempting to facilitate cross-survey comparisons (Fields, et al., 1997) (Fields, et al., 2001). Subsequently these recommendations were adopted as an ISO Technical Specification, ISO/TS 15666, which was revised in 2021 (ISO, 2021). However, even if the survey is conducted according to this Technical Specification, there are several details that will affect the results (Gjestland, Issues affecting the results of noise surveys around airports, 2022a).

68 The Technical Specification recommends two different response scales for assessing the annoyance from various environmental noise sources, a

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[2] Switzerland favors surveys with mailout questionnaire

verbal 5-point scale and an 11-point numerical scale. The prevalence of high annoyance is defined differently for the two scales. When assessing the results from a survey it is therefore necessary to know which scale is being used. People responding to a 5-point verbal scale seem to be more annoyed than people responding to a numerical scale. Gjestland and Morinaga (2022) have analyzed 43 recent surveys where both response scales were being used. The average difference between the two results was equivalent to a 6 dB shift in the noise exposure. People responding to a numerical scale seem to tolerate 6 dB higher noise levels to express the same degree of annoyance.

69 Also, the way the survey questions are presented is important. A survey involving an interview with a live agent either face-to-face or via telephone, seems to produce lower annoyance than a postal survey with a written questionnaire. This issue was recently studied in the US 20 airport survey (Miller, et al., 2021). This large survey, comprising about 10,000 respondents, was conducted as a mail survey. However, in order to check the influence of the mode of presentation, an additional 2,000 interviews were conducted via telephone. Miller et al. found that the average difference between the two modes was equivalent to a 5dB shift in the noise exposure. So, on average people being interviewed via telephone seemed to tolerate 5 dB higher noise levels than people responding to a written questionnaire in order to express the same degree of annoyance. Fidell et al. have compared the results from 45 different surveys conducted either as face-to-face or telephone interviews or via mail (Fidell, Mestre, Gjestland, & Tabachnick, 2022). They found no difference between face-to-face or telephone interviews, but an average difference between these two and postal mode equivalent to a 10dB shift.

Selection of representative airports – High/low-rate change

70 A "general purpose" dose-response curve can be constructed on the basis of survey results from a selection of representative airports. The first general-purpose curve of this type was presented by Schultz (1978). His curve was updated in 1991 on the basis of more recent surveys (Fidell, Barber, & Schultz, 1991), and later on Miedema and Vos presented source-specific dose-response curves for annoyance due to transportation noise (Miedema & Vos, 1998). These were later refined by Miedema and

Oudshoorn (2001). These curves, commonly referred to as “the Miedema curves”, have become a de facto standard reference. The curve for aircraft noise is based on 20 surveys conducted over a period of about 30 years comprising more than 50 different communities in Europe, North America and Australia which Miedema and Vos considered “representative airport communities”.

71 Janssen and Guski conducted a meta-analysis of a large number of recent surveys and observed that the airports being studied could be divided into two different categories. Most airports experience a gradual increase in traffic whereas others may experience abrupt changes in traffic volume or operations such as the opening of a new runway or if a carrier moves its operation from another airport.

72 Janssen and Guski defined two categories of airports. The default situation is a low-rate change, LRC airport where changes are slow and gradual. If abrupt changes occur within a specified period, the airport is categorized as a high-rate change, HRC airport. Even an announcement of planned but not yet implemented changes may yield an HRC categorization. Likewise, bad public relations and unfavorable press qualify for an HRC category (Janssen & Guski, 2017).

73 Janssen and Guski applied their change rate categorization to a set of recent surveys and found that the average difference between the two types was equivalent to a 6 dB shift in annoyance. Residents in an HRC community tolerate on average 6 dB less noise than residents in an LRC community in order to express the same degree of annoyance.

74 Gelderblom et al. (2017) did a similar analysis of 62 surveys conducted between 1961 and 2017 and found an average difference equivalent to a 9 dB shift in the exposure.

75 When selecting surveys for a meta-analysis it is important to have a typical distribution of HRC and LRC airports in order to get at representative result.

Has annoyance due to aircraft noise increased?

76 Some authors claim that annoyance with aircraft noise has increased over the years. Others say the annoyance has decreased and still others have

observed no change. The Marshall Day report (McNeill, 2022) repeats the claim of the first group: Recent literature on annoyance shows that annoyance levels have increased markedly compared to the 2001 Miedema study (p.39).

77 The Marshall Day report reviews in detail 14 studies conducted since 2001 (p.12). Five of these studies report an increase, two studies report a decrease, four studies say no change, and three studies do not comment on a possible change. These studies therefore hardly justify the conclusion that annoyance levels have increased markedly.

78 In the summary (p.11) Marshall Day erroneously report six cases of increase (WHO must be identical to Guski 2017) and only one decrease (one study from Vietnam missing).

79 Various factors have been listed to explain the alleged increase in people's annoyance due to aircraft noise. More knowledge of health risks, increased noise sensitivity, increased environmental awareness, etc. However, it is difficult to explain why only annoyance with aircraft noise has increased. The same trend has not been observed regarding other environmental noise sources such as road traffic or rail traffic.

80 We find it plausible that the alleged increase can be explained inter alia by differences in survey protocols and in the selection of airports that have been studied.

81 The Miedema and Oudshoorn dose-response curves (Miedema & Oudshoorn, 2001) are based on surveys using face-to-face or telephone interviews, and the definition and scoring of high annoyance closely resembles counting people that respond to the upper three categories of an 11-point numerical scale as highly annoyed.

82 When making comparisons, results from surveys that are not conducted according to the same protocol, must be properly adjusted.

83 The Taylor Baines study from 2002 concludes that the annoyance has increased compared with the Miedema and Oudshoorn curve (see figure 3, p.10 in the MD report). The exposure levels corresponding to 10 percent highly annoyed are Ldn 50 dB and Ldn 54 dB respectively. However, the

Taylor Baines study used mail outs as opposed to telephone interviews. According to Miller et al. (2021) and Fidell et al. (2022) this difference in survey mode is equivalent to 5 to 10 dB shift in the exposure level. So, if the Taylor Baines curve is shifted 5 to 10 dB to the right in the figure, the two curves can be regarded similar or perhaps the Taylor Baines curve shows a slightly lower annoyance. In other words, there has been no real change in the annoyance response.

84 The FAA 2021 study was conducted as a mail out study and high annoyance was defined as the two upper response categories of a verbal 5-point scale. For comparison with the Miedema and Oudshoorn curve the FAA curve must be adjusted 5 dB for mail vs. telephone mode (documented in the study itself), and 6 dB for verbal vs. numerical scale. The adjustments would be more evident if the analysis had been done according to the CTL method, but the 19% HA point at Ldn 50 dB would be shifted to about Ldn 61 dB which is very close to the Miedema and Oudshoorn curve. In other words, no meaningful change in the annoyance response, especially not for low exposure levels which are of primary interest for regulatory purposes.

85 The three Guski reports have been critically questioned by Gjestland (2018) in peer-reviewed journals. Guski et al. (2019) wrote a rebutal to Gjestland's critical remarks, but they failed to have a plausible answer to the most prominent comments. Half of the airports included in the Guski et al. (2017) analysis for WHO came from the HYENA (Hypertension and Exposure to Noise Near Airports) study[3]. Due to other considerations the age range for respondents in this study was restricted to 45 to 70 years only. Despite evidence that the annoyance response is age dependent and the annoyance peaks around 45 years of age, in their rebuttal Guski et al. assumed that the age effect could be neglected. Likewise, the HYENA study did not use standardized annoyance questions. Instead of asking for overall annoyance in general, the respondents were asked to assess the annoyance during the day and during the night separately. Guski et al. cited the authors of the HYENA report: They assumed that the overall annoyance

[3] Wolgang Babisch et al: "Annoyance due to aircraft noise has increased over the years - Results of the HYENA study," Environment International, vol. 35, pp. 1169 - 1176, 2009.

(day + night) is mostly determined by the annoyance during the daytime. In other words, half of the survey results in the Guski et al. report to WHO are based on assumptions that have not been properly verified.

86 Gelderblom et al. (2017) have analyzed the results from 62 different studies on aircraft noise annoyance conducted between 1961 and 2015. The complete dataset comprises about 650 paired observations of aircraft noise exposure and prevalence of high annoyance extracted from more than 100,000 responses. The raw data indicate that there has been a gradual increase in annoyance, and that people today tolerate about 8 dB less noise than they did in the 1960's in order to express a certain degree of annoyance. However, if the survey results are divided in high-rate change (HRC) and low-rate change (LRC) airports as proposed by Janssen and Guski, no temporal change in the annoyance response could be observed.

87 Social surveys are time-consuming and expensive to conduct. New surveys are therefore more often than not carried out at airports “where noise has become an issue”, in other words a typical HRC airport. An increasing number of HRC airports will cause an apparent increase in the annoyance, unless the two types of airports are handled separately.

88 In the summer of 2014 UK authorities conducted a survey on aircraft noise annoyance referred to as SoNA – Survey of Noise Attitudes. The objectives were to either confirm the existing or to establish new national dose-response curves for United Kingdom. Face-to-face interviews were conducted at 9 large airports in England, addressing 2000 residents exposed to aircraft noise levels above LAeq,16h = 51 dB. A dose-response function showing the prevalence of highly annoyed residents as a function of the chosen noise index was derived by conventional regression techniques (UK CAA, 2021). The sixteen-hour day equivalent level can be converted to DENL using the conversion tables proposed by Brink et al. (2017). The SoNA dose-response curve indicates a slightly smaller prevalence of annoyance than the curve derived by Miedema and Oudshoorn as shown in Figure 2. When the confidence intervals are taken into account, the two curves must be considered equal. In other words, for a given noise exposure in 2014 people in the UK seem to be equally annoyed by aircraft noise than what was predicted by the dose-response

curve presented by Miedema and Oudshoorn (2001). This last curve is based on surveys going back to the 1960ies.

89 In other words, the annoyance response seems to have remained stable over a period of 50 years, and no temporal increase can be observed.

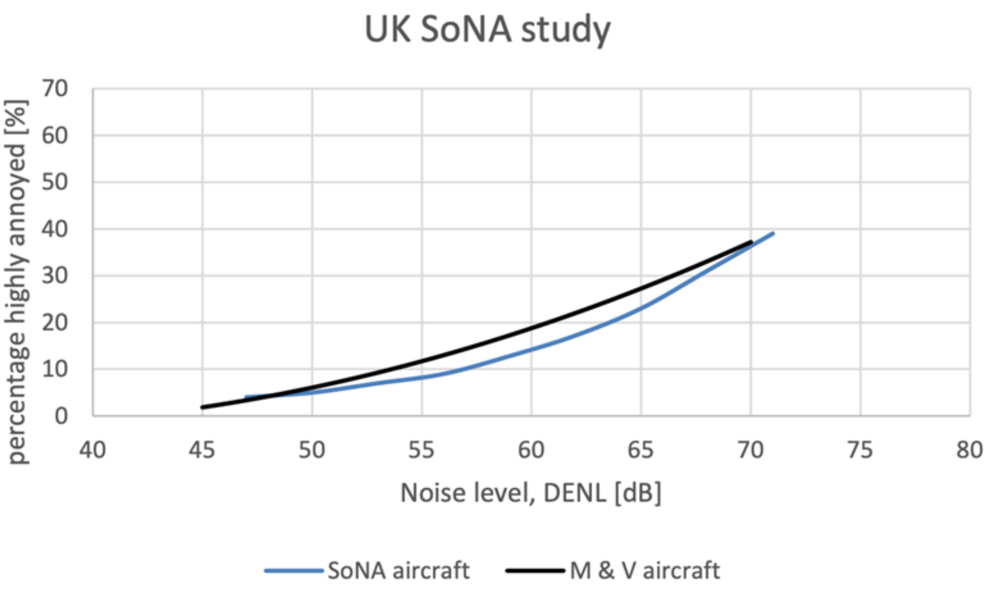

Figure 2. Results from the 2014 SoNA study. The new UK dose-response curve (blue line) compared with the curve derived by Miedema and Oudshoorn 2001 (Miedema and Vos 1998)

90 The 2019 NZTA survey used a mix of telephone interviews and postal questionnaires. The results can therefore not be directly compared with Miedema and Oudshoorn curves. The conclusion that New Zealand population has become more sensitive to noise is therefore not substantiated. This claim is also contradicted by the observations by Shepherd et al. (2000) who states that the noise sensitivity among the New Zealand population is similar to what has been found in comparable countries.

91 The two surveys conducted around Vietnam's main international airport Tan Son Nhat show a much lower prevalence of annoyance than the Miedema curve. The results do not in any way support the statement that annoyance with aircraft noise has increased.

Status of the WHO guidelines

92 The World Health Organization is the United Nations agency that connects nations, partners, and people to promote health. The WHO member states are grouped in 6 regions. In order for a report to be published as a general WHO document, consensus must be reached among all the regional offices.

93 The Marshall Day report states that "international bodies around the world are considering whether to update their policies, and the WHO guidelines could provide the latest scientific knowledge" (p.3). This is hardly correct. The WHO document Guidelines for Community Noise (Berglund, Lindvall, Schwela, & Goh, 2000) had been approved by all the regional offices. This is not the case for the new guidelines. Therefore, the full title of this latter document is Environmental Noise Guidelines for the European Region (World Health Organization, 2018). It has been published by the WHO European Office for Europe only. The reason for this is that no consensus could be reached among the other regions.

94 In the new guidelines for the European region, it is stated explicitly that this document supersedes the previous 2000 Guidelines (Berglund, Lindvall, Schwela, & Goh, 2000) and the 2009 Night noise guidelines for Europe (WHO Europe, 2009). In the remaining 5 WHO regions, the 2000 Community Noise Guidelines document has not been withdrawn. These guidelines specify noise limits for various activities and situations. The guideline limit for what is called critical health effects in general outdoor living areas is LAeq 55 dB for the 16-hour daytime period. This can be translated to Lden 57 dB for aircraft noise.

95 The European Commission has endorsed the new WHO guidelines for the European region, but to this author's knowledge no national or international regulatory body has yet adopted these guidelines. On the contrary, some European regulatory bodies (FNAC, 2021) (UK CAA, 2021) have recently introduced environmental noise limits that deviates substantially from the new WHO guidelines (i.e. less stringent noise limits).

Choice of limit exposure level to avoid adverse effects

96 Most countries that have imposed regulatory limits on aircraft noise exposure, specify a limit around Ldn 55 dB for "onset of adverse effects". The prevalence of highly annoyed residents at that exposure level matches the prevalence of very noise sensitive people in a general population, about 10 %. This implies that at the limit exposure level, only those that are very noise sensitive will experience high annoyance, and the remaining ca 90 % of the population will be less affected. A similar strategy is being used for other environmental noise sources as well (road and rail).

97 The 1999 WHO community noise guidelines recommend a limit for a general outdoor noise situation equivalent to Ldn 57 dB because during the daytime few people are annoyed by activities with these levels. The most recent studies with the objectives to update national noise exposure limits, recommend Ldn 55 dB (Switzerland, 2021) and Ldn 57 dB (UK, 2021). The UK has established a new exposure-response curve, and Ldn 57 dB corresponds to 10 % highly annoyed.

98 The recent 20-airport study (US, 2021) was conducted according to a very different survey protocol than these two, so a direct comparison cannot be made. However, with reasonable adjustments 10 % highly annoyed can be found at approximately Ldn 54 dB.

99 The Miedema curve which is widely used as a reference yields 10 % highly annoyed at Ldn 54 dB. This curve is derived from a representative mix of HRC and LRC airports. The corresponding curve for CHC, being a typical LRC airport, would indicate a higher tolerance for noise yielding 10 % highly annoyed at a higher level, typically 55 dB < Ldn < 60 dB.

100 This lower limit for aircraft noise-induced restrictions does not mean that noise sensitive buildings (residences, day-care facilities, hospitals, etc.) cannot be established inside this contour. Many countries have a limit 10 dB above the "onset contour" inside which development of noise sensitive buildings is discouraged or restricted. The US FAA, for instance, defines Ldn 65 dB as the limit for significant impact.

101 Outside the outer limiting contour (around Ldn 55 dB) very few people will be affected, and only sporadic noise complaints will be registered. The number of complaints will remain relatively stable for exposure levels even below this limit as there will always be a small percentage of complainers that will react negatively no matter how low the limit exposure level is defined.

The use of noise predictions for land use purposes

102 Noise maps are often calculated/predicted for an airport on a decennary (i.e., 10-year) basis. Noise prediction programs used for this purpose are accurate within typically plus/minus 1-2 dB. These noise maps show expected yearly average noise levels on the basis of anticipated traffic growth. Regulatory limits are typically shown as noise contours. The current guideline limit for aircraft noise for critical health effects endorsed by the Western Pacific Regional Office of WHO is equivalent to Ldn 57 dB (Berglund, Lindvall, Schwela, & Goh, 2000).

103 If it should be considered desirable to impose lower limits the general background noise must be taken into account. In most cases there will be infrastructure like major roads and railroads that make large contributions to the background noise level in a particular location. It makes little sense to restrict land use due to aircraft noise above a certain level if the general background noise level is higher.

104 The noise contours reflect the flight paths. They extend in the direction of the trajectories but may cover a more limited area to the sides. An increase in traffic will therefore typically stretch the contour lengthwise in the direction of the flight path with a relative smaller increase to the sides. Locations to the side of the trajectories are therefore less impacted by an unexpected growth in the traffic volume than locations under the flight path.

Conclusions

105 No data has been presented that should warrant a change in today's policies regarding acceptable exposure limits for aircraft noise. Most countries that have noise regulations for land use planning have limits corresponding to about Ldn 55 dB or higher for aircraft noise.

106 Reports on an alleged increase in aircraft noise annoyance is most likely caused by non-acoustic factors such as the selection of study areas, survey procedures, and response scales.

107 There are no indications that the noise sensitivity among residents of New Zealand is higher than in similar populations.

108 The new WHO Environmental noise guidelines recommending a limit of Lden 45 dB for aircraft noise to avoid adverse health effects, is a European document not adopted by the other WHO regional offices. Aside from the European Commission, no other regulatory authority has endorsed this limit.

109 After the publication of the WHO Environmental noise guidelines for the European Region, two European countries, Switzerland, and UK, have presented new evidence that an exposure limit for aircraft noise around Ldn 55 dB is a reasonable and correct choice.

110 Most countries that have regulatory limits for aircraft noise allow development inside the outer noise contour (typically around Ldn 55 dB. This contour is considered the onset of adverse effects and special low-noise features may be recommended. Development of noise sensitive buildings is typically discouraged or restricted at a level 10 dB above the "onset contour".

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