PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Valuing impacts of noise on health –exposure response relationships in current UK guidance and the WHO Environmental Noise Guidelines 2018

Benjamin FENECH[1]; Georgia RODGERS[1]

[1] Public Health England, UK

ABSTRACT

Following the publication of the Environmental Noise Guidelines for the European Region (ENG), a lot of debate has focused on the Guideline Recommendations, in particular the specific guideline levels and the strength of the recommendations. A sizeable proportion of the UK population is currently exposed to noise levels above the WHO recommendations, and it is important that policy and decision makers have access to an accurate quantification of the associated burden of disease. From this perspective, the systematic reviews of the scientific evidence, and the recommended exposure response functions are an equally important aspect of the ENG.

In the UK the current recommended methodology for valuing health impacts associated with environmental noise is outlined in two documents published by the Department for Environment Food and Rural Affairs and the Interdepartmental Group on Costs and Benefits Noise Subject Group. This paper will look into the studies that informed the exposure response functions recommended by these two documents. A comparison is then made with the more recent studies that informed the ENG, followed by discussions of which aspects could have led to differences in the exposure response functions.

Keywords: Noise, Health, WHO

1. INTRODUCTION

The publication of the World Health Organization (WHO) Environmental Noise Guidelines for the European Region (ENG) in 2018 (1) stimulated a fair amount of debate amongst the UK acoustic profession, particularly on the specific guideline levels and the strength of the recommendations. Strategic noise mapping carried out by the Department for Environment Food and Rural Affairs (Defra) (2) shows that a sizeable proportion of the UK population is currently exposed to noise levels above the WHO recommendations. It is important that policy and decision makers have access to an accurate quantification of the associated burden of disease. From this perspective, the recommended exposure response relationships derived from the systematic reviews commissioned by the WHO are an equally important aspect of the ENG. These systematic reviews focused predominantly on scientific evidence published since 2000.

In the UK the current recommended methodology for valuing health impacts associated with environmental noise is outlined in two documents published by Defra and the Interdepartmental Group on Costs and Benefits Noise Subject Group (IGCBN) in 2010 and 2014 (3,4). The relevant health outcomes are annoyance, sleep disturbance, hypertension and acute myocardial infarction.

This paper presents a brief overview of the evidence that informed the exposure response functions (ERF) in the current UK guidance and the ENG. Aspects of the studies that could influence their applicability to a local population are discussed. For example, annoyance and self-reported sleep disturbance depend to some extent on a cognitive appraisal of the stressor (in this case noise), and the ERFs are only partially explained by the noise exposure (5). The ENG notes that (1):

"This is especially true for noise annoyance, for which there is often considerable heterogeneity in effect sizes of studies because estimates vary between noise sources and are to some degree dependent on the situation and context. Furthermore, cultural differences around what is considered annoying are significant, even within Europe."

[1] CRCE-Noise@phe.gov.uk

Other aspects discussed are study design and situational factors. Many of the studies that inform the current UK guidance are now 20-50 years old, and their relevance to current and future infrastructure schemes may be questioned. Furthermore the heterogeneity in effect sizes of noise annoyance and sleep disturbance studies suggests that using a single averaged ERF may not be the best approach when carrying out scheme-specific noise impact assessments.

2. A BRIEF OVERVIEW OF THE UK'S METHODOLOGY FOR VALUING NOISE IMPACTS

In the UK, a requirement to quantify the impacts of transportation noise has been in place since the early 2000s (6). For example, an update to WebTAG (the Department for Transport's Transport Appraisal Guidance) Unit 3.3.2 in 2004 required the appraisal of noise impacts to include a quantitative assessment of noise annoyance. A monetary valuation of noise impacts was introduced in 2006, based on a hedonic pricing study carried out in Birmingham, UK (7). The resulting values were transferred to UK average levels by Nellthorp et al. (8), and this approach was recommended for the valuation of amenity impacts for residential receptors.

Meanwhile better quality scientific evidence on the effects of noise on sleep and the cardiovascular system was becoming available (9,10). Individuals exposed to noise may not be fully aware of these health effects, and hence such impacts would not be reflected in property values. In recognition of these shortcomings, an Interdepartmental Group on Costs and Benefits, Noise Subject Group (IGCBN) was convened by Defra. In their first report (11) the group recommended the application of an impact pathway approach for quantifying noise impacts. The group commissioned Berry and Flindell to review the state of the art evidence on noise impacts (12). Based on their findings, the IGCBN made several recommendations in 2010 (4), including:

- to include the risk of acute myocardial infarction (AMI) into the monetary valuation;
- to continue using monetary values for annoyance based on a hedonic pricing approach; and
- to use indicative quantification of hypertension and sleep disturbance impacts.

Following the IGCBN's 2010 report two major reports on noise and health were published by the WHO – the Night Noise Guidelines in 2009 (13) and the Burden of Disease (BoD) from Environmental Noise in 2011 (14). The latter provided a methodology (15) to quantify the burden of disease attributable to noise in terms of Disability Adjusted Life Years (DALYs) (16). As a result, Defra published the current appraisal methodology in 2014 (3), recommending:

- using a DALYs approach to quantify and monetise annoyance and sleep disturbance impacts;
- using a two-step approach to monetise hypertension-related impacts; and
- using the methodology for valuing AMI outlined in the 2010 IGCBN report.

3. SLEEP DISTURBANCE

The current UK guidance recommends that sleep disturbance impacts are monetised where it is proportionate to do so, in addition to presenting the number of people sleep disturbed (3). Sleep disturbance is defined as "*being aware that sleep has been disturbed and attributing the disturbance to the effects of transport noise*" (ibid.). The guidance acknowledges that this approach does not capture any consequential impacts of sleep disturbance on productivity or physiological chronic health impacts (some of which may be captured by the appraisal of AMI and hypertension effects).

The equation for valuing sleep disturbance is:

Value of sleep disturbance = S x B x C, where
S – number of people highly sleep disturbed
B – Disability Weight (DW) of the health outcome
C – Monetary value of one DALY

The recommended DW follows the recommendation in the WHO BoD methodology (14), i.e. 0.07 with an uncertainty range between 0.04-0.10. The monetary value of one DALY was set at £60,000 in the IGCBN 2010 report (4) in accordance with the central estimate value of a QALY applied across central government departments in England.

The definition of "highly sleep disturbed" (HSD) used in the evidence underpinning the current UK guidance is the percentage of responses about sleep disturbance that exceed a cutoff of 72 on a scale of 0 to 100 (19). The UK guidance provides three recommended exposure response functions (ERFs)

describing the percentage of people HSD (%HSD) from road, air or railway noise exposure, as a function of the average outdoor nighttime level (L_{night}). The equations are equivalent to those presented in the WHO BoD (2011) report. These equations are polynomial approximations derived from meta-analysis carried out by Miedema et al. (17,18), based on data from 28 original datasets from 24 field studies, including six from the UK (1967 – 1986). To be included, studies had to (19):

- quantify self-reported sleep disturbance to individual transportation noise sources;
- quantify noise exposure of respondents with sufficient accuracy such that average noise exposure level during the nighttime period could be derived;
- not have been conducted after major changes to the noise situation.

Participants with exposure levels <45dB L_{night} were excluded from the analyses because their exposure data was deemed to be rather inaccurate, and exposures to other sources may have been more important. Participants with exposure levels >65dB L_{night} were excluded because the risk of self-selection of people not bothered by noise was deemed to be relatively high at such exposures (19). Nevertheless the WHO BoD suggests that the synthesized curves can be used within 40 – 70 dB L_{night}.

Miedema et al. noted large variation in the wordings and scales used to measure sleep disturbance across studies. Many studies included more than one question regarding sleep disturbance; these questions could be broadly grouped into three categories:

- difficulty falling asleep due to noise;
- waking up or being disturbed by noise during the night; and
- waking up early in the morning due to noise.

For the pooled analysis Miedema & Vos used the "most general questions that did not refer to either the beginning or the end of the night (i.e. the second category)" because the L_{night} metric "pertains to the whole night" (19).

The error variance in the resulting exposure response model was similar for road and rail, but a much larger variance for aircraft noise was found. The authors suggest that the following factors may have contributed to this larger variance (17,18):

- Larger differences in the time pattern of noise exposures around different airports, because of different regulations such as nighttime curfews;
- The sleep disturbance question wording for aircraft noise appears to be even more variable;
- A potential time trend towards higher self-reported sleep disturbance at the same L_{night}. For example the most recent study included in the analyses had the highest self-reported sleep disturbance, and a more recent aircraft noise study from the Netherlands was excluded from the analyses, because its results were so high that it was considered to be an outlier.

The authors also suggested that uncertainties regarding the nighttime noise exposure, fear of aircraft accidents and expectations regarding future airport developments may have contributed to the individual variance within the aviation noise studies (18).

Miedema et al. therefore concluded that the curves presented for aviation were only indicative of the self-reported sleep disturbance, and that "*recent trends lead to higher self-reported sleep disturbance than indicated by these curves*." (18) These uncertainties were also echoed in the WHO BoD (2011) report, which added that using the curves for aviation may result in "*a possible underestimation of the response at a given aircraft noise exposure level*" (14).

3.1 SLEEP DISTURBANCE EVIDENCE UNDERPINNING THE WHO ENG 2018

The WHO-commissioned systematic review on environmental noise and sleep (20) considered both physiological outcomes (polysomnography-measured cortical awakenings) and self-reported sleep outcomes. Only self-reported outcomes are considered here. The review focused on the "three most common outcomes" of noise-induced sleep disturbance, i.e.

- Recalled awakenings from sleep during the period from sleep onset to final awakening;
- The process of falling asleep (the transition from wakefulness into sleep); and
- Sleep disturbance (internal/external interference with sleep onset or sleep continuity).

Most of the studies that satisfied the inclusion criteria used the ICBEN 5-point verbal or 11-point non-verbal scale (21). "Highly sleep disturbed" (HSD) was defined as responses in the top two (5pt) and top three (11pt) categories. For the few questions that referred to the frequency of symptoms, symptoms occurring three times or more per week were considered as an indication of high sleep disturbance. The analysis was based on L_{night} levels between 40 and 65dB. No studies from the UK satisfied the systematic review inclusion criteria.

3.2 COMPARISON BETWEEN ERFs IN UK GUIDANCE AND THE WHO ENG

The sleep disturbance systematic review presents a comparison between the exposure-response functions (ERFs) derived from the more recent studies and the ERFs derived by Miedema & Vos (which feature in the current UK guidance). The Miedema & Vos ERF for road falls within the confidence intervals of the new WHO ENG curve. For rail, the ENG ERF suggests a higher %HSD at L_{night} >48dB. For aviation, the ENG ERF suggests a higher %HSD throughout the entire noise exposure range (40-65dB). Basner & McGuire provide the following potential reasons for the observed increase in the %HSD by aircraft and railway noise (20):

- different methodologies used to derive the model;
- year of study – (≥ 2000 in the WHO systematic review; <2004 in the Miedema & Vos's analysis, with many of the studies dating back to the 1970's and 80's);
- location of studies – many of the studies in the WHO systematic review are from east Asia, compared to a dominance of European studies in the analysis by Miedema & Vos;
- question wording – older studies tended to refer to *annoyance* due to sleep disturbance in general, whereas more recent studies include questions on the severity/frequency of sleep disturbance, awakenings and difficulty falling asleep;
- more night-time events reported in more recent railway noise studies.

Basner & McGuire also note that one included study occurred after the opening of a new terminal building, where the L_{night} increased by 2dB at nine of the 11 sites investigated. There was a non-statistically significant difference in the odds ratio of being HSD when compared to the results from the study conducted before the new terminal was opened.

4. ANNOYANCE

The current UK guidance recommends the use of DALYs to quantify the value of community annoyance from environmental noise (3). The equation to value annoyance is:

Value of annoyance = A x B x C, where
A – number of people highly annoyed
B – Disability Weight (DW) of the health outcome
C – Monetary value of one DALY

The DW follows the recommendations in the WHO BoD (2011) methodology, i.e. 0.02 with an uncertainty range between 0.01-0.12. The definition of "highly annoyed" (HA) is the percentage of responses about annoyance that exceed a cutoff of 72 on a scale of 0 to 100 (22). The UK guidance provides three exposure response functions (ERFs) describing the %HA from road, air or railway noise exposure, as a function of day-evening-night level (L_{den}). These equations are polynomial approximations derived from a meta-analysis carried out by Miedema & Oudshoorn for a Position Paper for the European Commission (23), based on data from 54 field studies, including nine from the UK (1967 – 1984). The study inclusion criteria reported were (24):

- noise exposure and annoyance pertain to only one source of transportation noise;
- %HA is directly derived from responses to a question about the general noise annoyance from the source concerned (i.e. it is not based on, for example, an index constructed from multiple questions concerning specific disturbances or a ranking of sources by respondents); and
- %HA is derived with a cutoff point sufficiently close to 72 on a scale from 0 (no annoyance at all) to 100 (very high annoyance).

The references do not clarify whether any of the studies included in the meta-analysis took place during a change in noise exposure. As for sleep disturbance, upper and lower exposure cutoffs of 65dB and 45dB L_{den}, respectively, were used.

In recent years a number of studies, including the cross-European HYENA study (25), and a subsequent meta-analysis of aviation studies by Janssen et al. (26) – have shown an increase in annoyance over the years for aviation noise. This was acknowledged in the WHO BoD (2011) guidance (14):

"*there are strong indications that the exposure–response relationships for aircraft noise have changed, so that the curves presented here probably underestimate the annoyance at a given aircraft noise exposure level.*"

One group of researchers supporting the use of the Community Tolerance Level (CTL) methodology disagree, arguing that they did not observe a significant temporal trend in CTL values in

an analysis of studies carried out over the past 50 years (27). Instead they attribute changes in the ERF for aircraft noise to a larger number of studies carried out during or after changes to airport infrastructure in recent years. As the CTL-approach assumes that the shape of the %HA curve follows the duration-corrected loudness estimated from L_{dn}, it is not clear whether this method is able to identify small differences in the slope of ERFs of recent vs earlier studies arising from a temporal trend in annoyance (28).

4.1 ANNOYANCE EVIDENCE UNDERPINNING THE WHO ENG 2018

The WHO-commissioned systematic review on environmental noise and annoyance looked at studies published between 2000 and 2014 (29). The inclusion criteria were:

- cross-sectional or longitudinal surveys with an explicit protocol for selecting participants;
- study participants that are members of the general population (residential noise exposure);
- studies reporting long-term outside noise levels expressed as $L_{Aeq,24h}$, L_{dn}, L_{den} (or can be easily converted from similar acoustic variable)
- noise levels determined from reliable calculation procedures or based on measurements for a minimum of one week;
- individual annoyance response (outcome measure) measured by a survey question and response format that followed (or very close to) the recommendations in ICBEN (21) and/or ISO TS 156666;
- paper or author provided at least one original table, formula or graph representing an exposure response relationship; and
- study published in English, French, Dutch or German language.

In total 57 studies were included in the meta-analysis. Only one study from the UK satisfied the inclusion criteria (HYENA, 2003). The fifth criterion led to a much more consistent wording of the annoyance question across studies when compared to the studies analysed by Miedema & Oudshoorn (22). The exposure range varied by source, but results are typically presented between 40 – 80dB L_{den}.

4.2 COMPARISON BETWEEN ERFs IN UK GUIDANCE AND THE WHO ENG

For road traffic noise, Guski et al. presented two ERFs: one curve derived from all 25 studies, and one curve from a subset of 10 studies excluding Alpine and Asian studies. The justification for the latter is that Alpine studies are characterized by a rather unique topography, and the housing stock in Asia is predominantly air conditioned; therefore one can argue whether these studies are generalisable. The curve derived from the full set of studies shows higher %HA at lower exposure levels (40-60dB L_{den}) when compared to the curve by Miedema & Oudshoorn. The curve excluding the Alpine and Asian studies is similar to the Miedema & Oudshoorn curve up to 70 dB $L_{den,}$ and higher above this level.

The ERF for rail traffic presented in the WHO systematic review shows a steeper increase in %HA with increasing L_{den} when compared to the corresponding curve by Miedema & Oudshoorn.

For aviation noise, the ERF in the WHO systematic review shows considerably higher %HA than the curve by Miedema & Oudshoorn. The ERF in the systematic review is based on 12 surveys, six of which are from the HYENA study (29).

Guski et al. identify a number of potential reasons that could have led to differences in the ERFs when compared to the older curves derived by Miedema and Oudshoorn, including (29):

- Several studies took place in the context of an abrupt change to the relevant infrastructure and/or number of vehicular movements and/or public debate about the associated noise.
- The six HYENA-studies (air and road) only included residents aged 45–70. There is conflicting evidence on the relation between age and annoyance (30,31), however the authors suggest that this may have introduced a certain bias towards higher annoyance.
- The road traffic data set includes five studies from Alpine valleys in Austria. The rail traffic data set includes three studies in the same setting. The propagation of sound in valleys is different from flat areas. Three of the five Alpine road studies used 60% of the annoyance scale as a criterion for being highly annoyed, as opposed to the 72% cutoff used by Miedema and Oudshoorn. Some of the Alpine research sites were subject to long-lasting discussions about heavy transalpine road and rail traffic, and a large increase of freight traffic was reported on these routes.
- The full road traffic data set includes ten studies from Asia, where many participants live in air-conditioned homes. This may have contributed to a lower degree of annoyance.

- The rail traffic data set includes one study where trains generated both noise and perceptible vibration.

The systematic review includes comprehensive sub-analyses and/or discussions on how these factors may have influenced the results.

In a subsequent analysis (32) of annoyance from aviation noise by the same authors, the results from seven additional studies published after 2014 were added. No significant changes to the averaged annoyance response function derived in the ENG systematic review were observed. This analysis included the results from the Survey of (Aviation) Noise Attitudes (SONA) 2014 study from the UK (33).

5. CARDIOVASCULAR OUTCOMES

The current UK guidance recommends the valuation of Acute Myocardial Infarction (AMI) and two hypertension-related outcomes: stroke and dementia. The AMI valuation methodology, outlined in the IGCBN 2010 report (4), mirrors the methodology proposed in the WHO BoD (2011) (14). The exposure response function used to estimate the incidence of AMI as a function of daytime noise is from a meta-analysis (34) of studies carried out in Caerphilly and Speedwell, UK and in Berlin, Germany. These studies investigated the association between the road traffic noise level during the day and the incidence of AMI. The study subjects were all men. The common set of covariates considered in all the studies were age, sex (males only), social class, school education, employment status, shift work, smoking and body mass index. Some of the studies also considered physical activity during leisure time, family history of ischaemic heart disease or myocardial infarction, prevalence of pre-existing diseases, noise exposure at work and marital status. In one study, the effect estimates were further adjusted for hypertension and diabetes mellitus. Although the meta-analysis only included studies on road traffic noise, the UK guidance recommends that the ERF is used for road, rail and aircraft noise sources.

For noise-related hypertension, the current UK guidance recommends that the consequential impact on dementia and stroke is quantified and valued. The methodology is based on a study by the Health and Safety Laboratory (35). The attributable cases of hypertension are calculated using the following odds ratios within the noise exposure range 50-75dB L_{den}:

- Road: 1.07 per 10dB increase in L_{den} (from van Kempen & Babisch 2012 (36))
- Aircraft: 1.13 per 10dB increase in L_{den} (from Babisch & van Kamp 2009 (37))
- Rail: 1.07 per 10dB increase in L_{den}.

5.1 CARDIOVASCULAR EVIDENCE UNDERPINNING THE WHO ENG 2018

The WHO-commissioned systematic review on environmental noise and cardiovascular effects looked at studies published between 2000 and 2015 (38). The review evaluated 22 studies that investigated the association between exposure to noise from air, road, and rail traffic and ischaemic heart disease (IHD). The association between aircraft noise and the incidence of IHD was statistically significant, and a risk ratio (RR) of 1.09 per 10 dB was estimated after aggregating the results of two ecological studies. An increase in road traffic noise was associated with statistically-significant increases in the prevalence and incidence of IHD. A RR of 1.08 per 10 dB (L_{den}) was estimated for the association between road traffic noise and the incidence of IHD, after combining the results of three cohort studies and four case-control studies. The data suggested that the risk of IHD increases continuously for road traffic noise levels from about 50 dB L_{den}. There were no studies to allow an estimate for the risk of incidence of IHD from railway noise.

The authors evaluated 37 studies that investigated the impact of transportation noise on the risk of hypertension. The strongest associations were observed in cross-sectional studies, which formed the largest part of the available evidence. Only the association between road traffic noise and the prevalence of hypertension was statistically significant: after aggregating the results of 26 studies, a RR of 1.05 per 10 dB L_{den} was derived. No increased risk of hypertension due to transportation noise was observed in the two cohort studies investigating the association between transportation noise and the incidence of hypertension. The reason for the apparent discrepancy in the findings between the cross-sectional studies and the cohort studies was unclear.

6. FINAL REMARKS

This paper provides a brief overview of the evidence that informed the current UK guidance on

valuing noise impacts, published in 2010 and 2014. A comparison is made with the systematic reviews that underpin the latest WHO Environmental Noise Guidelines for the European Region.

For annoyance and sleep disturbance, the WHO-commissioned systematic reviews looked at studies published between 2000-2014/5, whereas the current UK guidance is based largely on studies published before 2000. The studies included in the WHO systematic reviews tended to measure the relevant health outcomes in a more consistent way – both in terms of the question wording and the scale. However, a large heterogeneity in effect size continues to be observed across studies. The WHO systematic reviews identified only one study (annoyance) that took place in the UK since 2000 (road and aviation). A more recent study (SONA 2014) was not included because it was published in 2017. Given the uncertainties associated with transferability of exposure response functions there is a clear need for new research on noise annoyance and sleep disturbance effects in the UK population.

The WHO systematic reviews suggest that some of the exposure response relationships for annoyance and sleep disturbance have changed when compared with those in the current UK guidance. This is particularly the case for aviation and railway noise, and potential reasons for the observed changes have been proposed. This conclusion has sparked some debate, despite similar conclusions being drawn for aviation noise in the past (14,25,26). There seems to be a consensus that annoyance around airports undergoing significant change is higher (27,28,29). The disagreement appears to be whether there has been a temporal shift in annoyance, irrespective of change. There are many reasons that may lead to people's perceptions and appraisal of the noise environment to change, for example:

- changes in the temporal and frequency characteristics of the noise source (e.g. quieter vehicles, but more of them; more/less low and high frequency content);
- changes in the distribution of the noise throughout the day and week (e.g. 24hr economies), and changes to the periods of relative quiet in between vehicle passbys;
- changes in housing stock (where houses are built, housing density and housing construction);
- changes in societal values (including a growing awareness of the influence of the environment on health, people's perceptions of the environmental credentials of specific modes of transport, people's dependence on a specific mode of transport);
- changes in the need for quiet when at home; and
- changes in people's activities when at home (e.g. shift work (sleeping during the day), working from home, etc).

For the cardiovascular health outcomes, the evidence on road traffic noise and ischæmic heart diseases (IHD) has strengthened considerably since the UK valuation methodology was published in 2010. Despite recent improvements, IHD is still the top cause of death and disability in the UK (39), and the certainty of the effect estimate is very important for national burden of disease calculations. Equally relevant is the emerging evidence of associations between environmental noise and stroke and diabetes – ranked as the 5th and 9th top causes of death and disability in the UK, respectively (39).

REFERENCES

1. WHO Regional Office for Europe. Environmental Nosie Guidelines for the European region. 2018.
2. Defra. Draft Noise Action Plans, October 2018.
3. Defra. Environmental Noise: Valuing impacts on: sleep disturbance, annoyance, hypertension, productivity and quiet. 2014.
4. The Interdepartmental Group on Costs and Benefits Noise Subject Group (IGCB(N)) Noise & Health – Valuing the Human Health Impacts of Environmental Noise Exposure. 2010.
5. Job RFS. Community response to noise: a review of factors influencing the relationship between noise exposure and reaction. J. Acoust. Soc. Am. 1988; 83: 991–1001.
6. Gühnemann A., Kelly C., Mackie P., et al. International Comparison of Transport Appraisal Practice - Annex 1 England Country Report. Research Report. 2013.
7. Bateman IJ, Day BH., and Lake I. The valuation of transport-related noise in Birmingham. Non-technical report to the Department for Transport. 2004.
8. Nellthorp J., Bristow A., & Mackie P. Developing Guidance on the Valuation of Transport-Related Noise for inclusion in WebTAG. Leeds. 2005.
9. WHO. Guidelines for community noise. Geneva: World Health Organization 1999.
10. Babisch W. Transportation noise and cardiovascular risk, Review and synthesis of epidemiological studies, Dose-effect curve and risk estimation. WaBoLu-Hefte 01/06. 2006.
11. Defra. An Economic Valuation of Noise Pollution – developing a tool for policy appraisal. 2008.
12. Berry BF. & Flindell IH. Estimating Dose-Response Relationships between Noise Exposure and Human

Health Impacts in the UK. Technical report. 2009.
13. WHO Regional Office for Europe. Night noise guidelines for Europe. Copenhagen: WHO Regional Office for Europe. 2009.
14. WHO Regional Office for Europe and European Commission Joint Research Centre. Burden of disease from environmental noise Quantification of healthy life years lost in Europe. 2011.
15. WHO Regional Office for Europe and European Commission Joint Research Centre. Methodological guidance for estimating the burden of disease from environmental noise. 2012.
16. Murray CJL., & Acharya AK. Understanding DALYs. Journal of Health Economics 1997; 16 703-730.
17 Miedema HME., Passchier-Vermeer W., Vos H. Elements for a position paper on night-time transportation noise and sleep disturbance. Delft, TNO, Rep. No. Inro 2002-59. 2003.
18. Miedema HME., & Vos H. Self-reported sleep disturbance caused by aircraft noise. Delft, TNO, Rep. No. INRO 2004-15. 2004.
19. Miedema HME., & Vos H. Associations between self-reported sleep disturbance and environmental noise based on reanalyses of pooled data from 24 studies. Behavioral Sleep Medicine, 2007; 5:1–20.
20. Basner M., McGuire S. WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Effects on Sleep. Int. J. Environ. Res. Public Health 2018; 15, 519.
21. Fields, JM. et al. Standardized noise reaction questions for community noise surveys: Research and a recommendation. J. Sound Vib. 2001; 242, 641–679.
22. Miedema HME., Oudshoorn CGM. Annoyance from transportation noise: relationships with exposure metrics L_{dn} and L_{den} and their confidence intervals. Environmental Health Perspectives, 2001; 109:409–416.
23. European Commission. Position Paper on dose response relationships between transportation noise and annoyance. Luxembourg, Office for Official Publications of the European Communities. 2002.
24. Miedema HME., Vos H. Exposure-response relationships for transportation noise. J Acoust Soc Am 1998; 104(6):3432–3445.
24. Fields JM. A review of an updated synthesis of noise/annoyance relationships," NASA Report 194950, Georgia Institute of Technology, Atlanta, GA. 1994.
25. Babisch W. et al. Annoyance due to aircraft noise has increased over the years—Results of the HYENA study. Environment International 35 (2009) 1169–1176.
26. Janssen SA. et al. Trends in aircraft noise annoyance: The role of study and sample characteristics. J. Acoust. Soc. Am. 2011; 129 (4).
27. Gelderblom FB. et al. On the Stability of Community Tolerance for Aircraft Noise. Acta Acustica united with Acustica 103 (2017) 17 – 27.
28. Janssen SA. & Vos H. Dose-response relationship between DNL and aircraft noise annoyance: contribution of TNO. TNO report TNO-060-UT-2011-00207. 2011.
29. Guski R., Schreckenberg D., Schuemer R. WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Annoyance. Int. J. Environ. Res. Public Health 2017; 14, 1539.
30. Van Gerven PWM. et al. Annoyance from environmental noise across the lifespan. J. Acoust. Soc. Am., 2009; 126, 187–194.
31. Guski R. et al. Comment on Gjestland, T. A Systematic Review of the Basis for WHO's New Recommendation for Limiting Aircraft Noise Annoyance. Int. J. Env. Res. Pub. Health 2018, 15, 2717. Int. J. Environ. Res. Public Health, 2019; 16(7), 1088.
32. Guski R., Schreckenberg D., Schuemer R. Aircraft noise annoyance - Present exposure-response relations. Proceedings to Euronoise 2018.
33. Civil Aviation Authority. Survey of noise attitudes 2014: Aircraft. Report CAP 1506, 2017.
34. Babisch W. Transportation noise and cardiovascular risk. Review and synthesis of epidemiological studies: dose–effect curve and risk estimation. Dessau, Umweltbundesamt, 2006 (WaBoLu-Hefte 01/06)
35. Harding AH. et al. Quantifying the links between environmental noise related hypertension and health effects. Health & Safety Laboratory MSU/2011/07, 2011.
36. van Kempen E. & Babisch W. The quantitative relationship between road traffic noise and hypertension: a meta-analysis. J Hypertension 2012; 30:1075-86.
37. Babisch W., van Kamp I. Exposure-response relationship of the association between aircraft noise and the risk of hypertension. Noise Health 2009; 11: 149-56.
38. van Kempen EEMM. et al. Cardiovascular and metabolic effects of environmental noise. RIVM Report 2017-0078. 2017.
39. http://www.healthdata.org/united-kingdom. 2017 figures.