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Sound Decisions: Moving forward with Acoustics

Update of the WHO evidence reviews and their implications for policy and research

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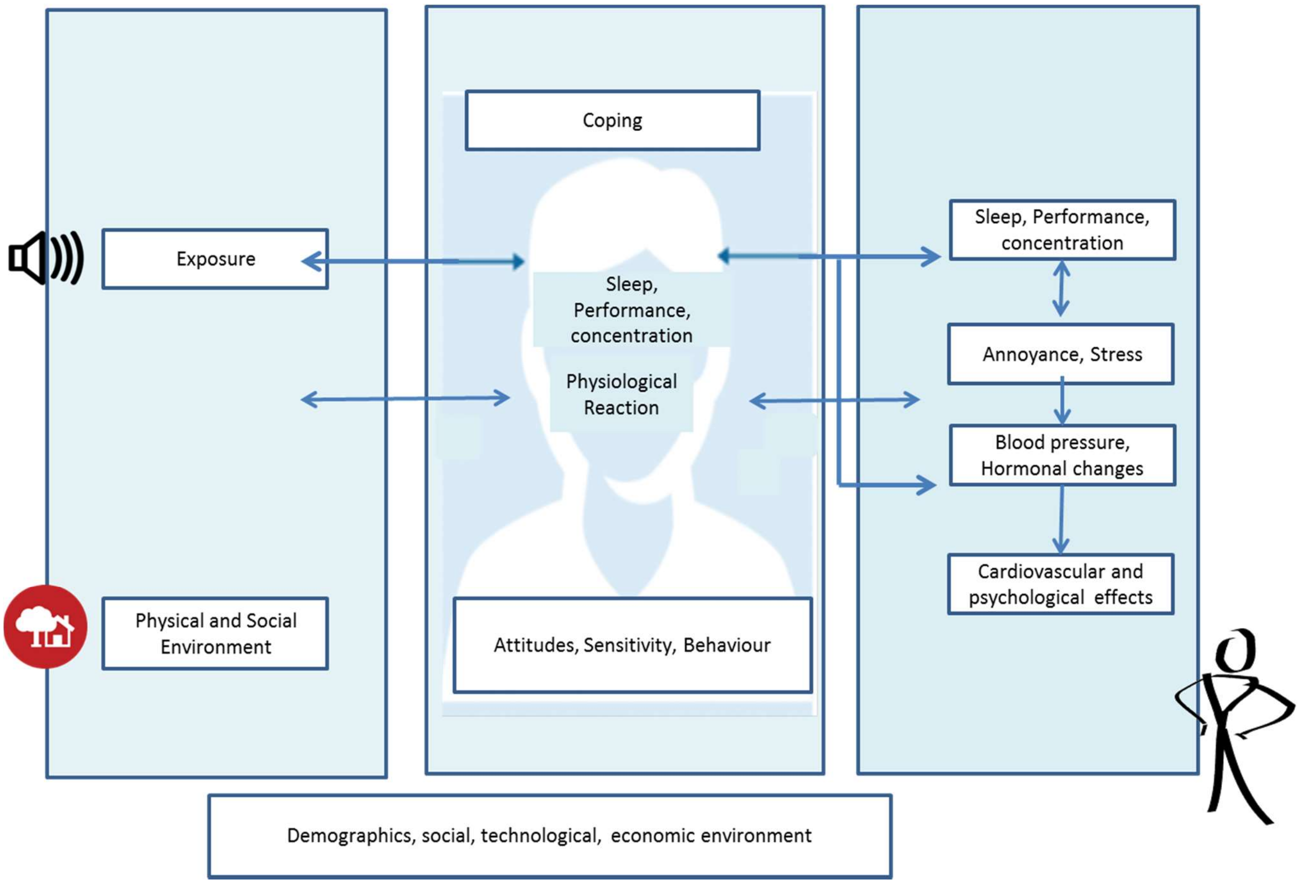
ABSTRACT

It had been a while since the first World Health Organization (WHO) guidelines for health protection against environmental noise were published in 1999. Since then many new studies on the health effects of environmental sound exposure at home have been performed and an update of the WHO environmental noise guideline saw light in November 2018. The earlier guidelines were primarily focused on transportation noise. At the European Ministerial Conference at Parma in 2010, the need for guidelines for other sources, such as wind turbines and leisure noise was emphasized. In order to achieve this, reviews were prepared on the main health outcomes, including annoyance, sleep, cardiovascular disease, cognitive effects, mental health, adverse birth outcomes, hearing impairment and the effectiveness of noise interventions in terms of human response and health. These systematic literature reviews cover the period between 2000 and 2014 and were published in a special issue of the International Journal of Environmental Research and Public Health (IJERPH) in 2017 and 2018). This paper provides an overview of the evidence, including an update since 2014 for some key endpoints. The implications of the findings for noise policy and management are briefly discussed. Finally, some trends and research needs in the field of sound and health are presented.

1 INTRODUCTION

Worldwide, the levels of noise exposure are expected to rise in the years to come and the character of soundscape is expected to change. This is the result of an increasing population, and densification primarily in urban areas and an increase in transport and wind energy facilities. Despite the fact that individual aircrafts, cars and trains are producing less noise, extension of the air, road and rail transportation networks is expected to increase the burden due to noise, specifically in relation to night-time exposures. Exposure to noise from other sources such as wind turbine and leisure noise is also increasing. Unwanted sound can cause annoyance, sleep disturbance, high blood pressure, diabetes, and increase the excretion of the stress-hormone cortisol and via that pathway increase the risk of cardiovascular disease and possibly mental illness. Whether noise negatively affects health not only depends on the noise levels and characteristics, but also on the way it is perceived and the way people cope with it. Sound can also be evaluated as positive and contribute to wellbeing and restoration. This links to the so-called soundscape approach, which considers sound not merely as a waste product but rather as a building block for creating attractive and varied environments (Brown, 2010; Maag et al., 2019).

Figure 1.1 takes these contextual and personal aspects into account and shows the potential mechanisms by which sound can lead to health problems. The model is based on a publication of the Netherlands Health Council (NL Health Council, 1999) and is one of the prevailing approaches to noise and health based on a cognitive stimulus response model. The model assumes that most effects are a consequence of the appraisal of sound as noise. It is generally assumed that stress responses play an important role in the process by which environmental noise leads to health effects.



Source: adapted from (Health Council of the Netherlands, 1999)

Figure 1.1: Conceptual Framework Noise and Health

Research over the past decades has shown that there is sufficient evidence for continuous effects on annoyance, sleep disturbance, and mixed evidence regarding hypertension and ischaemic heart disease. There is also growing evidence for effects on cognition and reading performance in children (Clark and Paunovic, 2018a). There is no or weak evidence for immune system effects and no evidence for a direct relation with mental health (Basner et al., 2014) (Clark and Paunovic, 2018b).

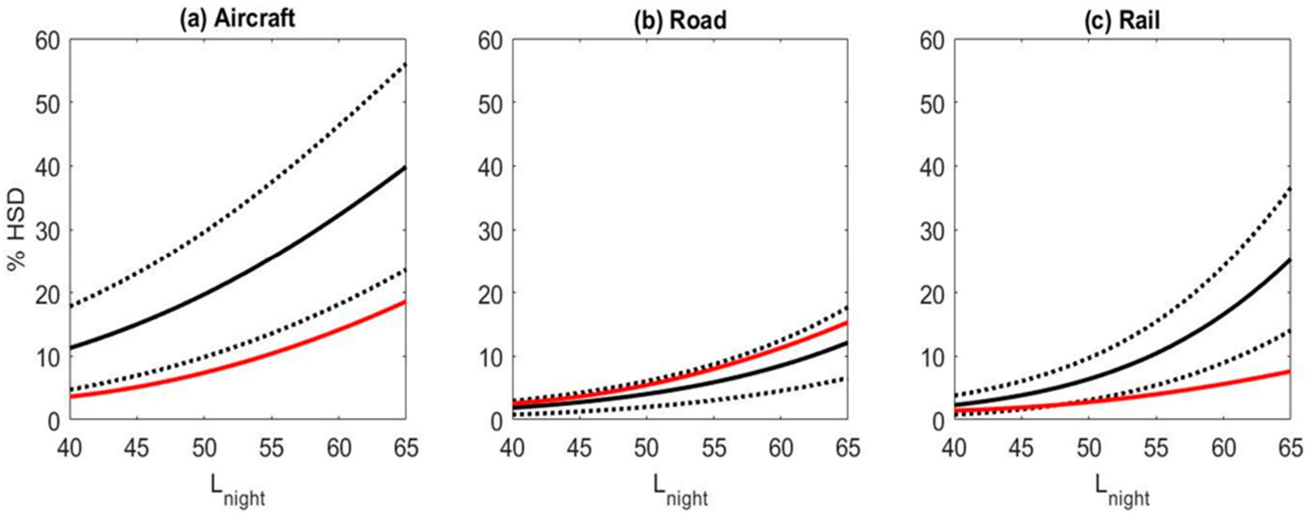
2 WHO EVIDENCE REVIEWS

This section summarises the latest evidence based on the recently published WHO evidence reviews (Basner and McGuire, 2018) (Guski et al., 2017, 2019) (van Kempen et al., 2018) on sleep disturbance, annoyance, coronary heart disease and metabolic effects. For these outcomes, Exposure Effect Relations (EERs) are available to relate the noise exposure (expressed in terms of Lden and Lnight) to the health outcome. EERs are also available for cognitive effects, however these fall outside the scope of this paper. The WHO evidence reviews cover a period up to 2014/2015, and follow the GRADE method (Alonso-Coello et al., 2016). This method is used to assess the quality of a body of evidence synthesized in a systematic review. The assessment facilitates judgements about the certainty of effect estimates, which increases with the quality of the body of evidence. The quality can be rated high, moderate, low or very low.

2.1 Sleep Disturbance

There is evidence of sufficient strength for sleep disturbance due to environmental noise (Basner and McGuire, 2018). In studies investigating the association between noise and sleep disturbance, the percentage of the population highly sleep disturbed (%HSD) is based on a standardised survey question referring to noise (per source). In principle, EERs for %HSD related to Lnight are available for transportation noise (sources aircraft, railway, and road traffic). For other noise sources, such as wind turbine and other stationary noise sources (e.g.

industry), the evidence is only emerging and it is not possible to derive reliable EERs yet. It is acknowledged that self-assessments of sleep disturbance can be problematic, as sleepers are unaware of themselves and their surroundings during large parts of the night. For this reason, it would be advantageous to use EERs based on physiological indicators of sleep quality/disturbance, such as the number of additional awakenings rather than self-reported indicators. However, the number, size, and generalisability of studies on the effects of noise using these measures of sleep are currently not sufficient. Furthermore, an effect such as the number of additional awakenings is related to maximum noise levels of noise events (LAmax), which are very difficult to model with the current noise models. Besides, LAmax is not the primary indicator in the European Noise Directive (END), even though supplementary indicators are allowed. For sleep disturbance, at present, the percentage of highly sleep disturbed (%HSD) is recommended as the preferred indicator. The source-specific EERs for sleep disturbance show considerable variation within studies and between studies. This indicates that deviations in the %HSD can occur at national/regional/municipal level as compared to %HSD calculated using the generalised EERs described in this document. The heterogeneity of the studies thus limits the value of the generic EERs.

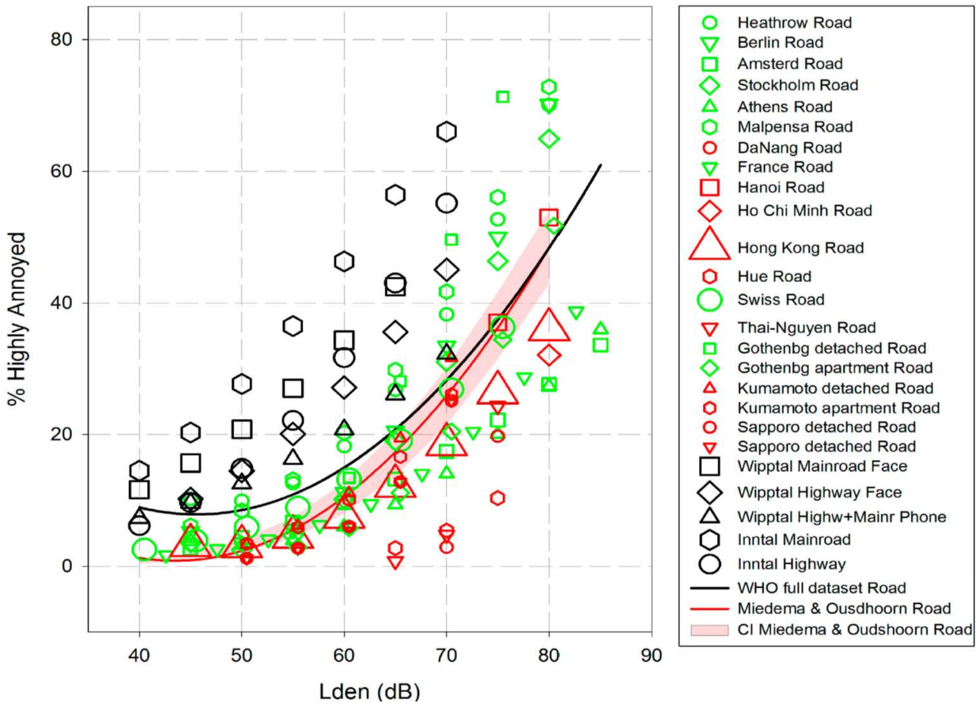


Source (Basner and McGuire, 2018)

Figure 2.1 Percentage highly sleep disturbed (%HSD, black solid lines) based on responses to questions on awakenings, difficulty falling asleep, and sleep disturbance for aircraft, road and rail noise, and 95% confidence (black dashed lines). Red solid lines represent the highly sleep disturbed exposure-effect curves from (Miedema and Vos, 2007)

2.2 Annoyance

There is evidence of sufficient strength for environmental noise annoyance (Guski et al., 2017). Studies investigating the association between noise and annoyance established a percentage of highly annoyed (%HA) on a standard survey question (ISO, 2003) that referred to the noise source considered. In principle, EERs for the %HA related to Lden are available for aircraft, road, and rail noise. For other noise sources, such as wind turbine and other stationary noise sources (e.g. industry), the evidence is only emerging and it is not possible to derive reliable EERs yet. The source-specific EERs for severe annoyance show considerable variation within studies and between studies. This indicates that deviations in the %HA can occur at national, regional or municipal level as compared to %HA calculated using the generalised EERs.



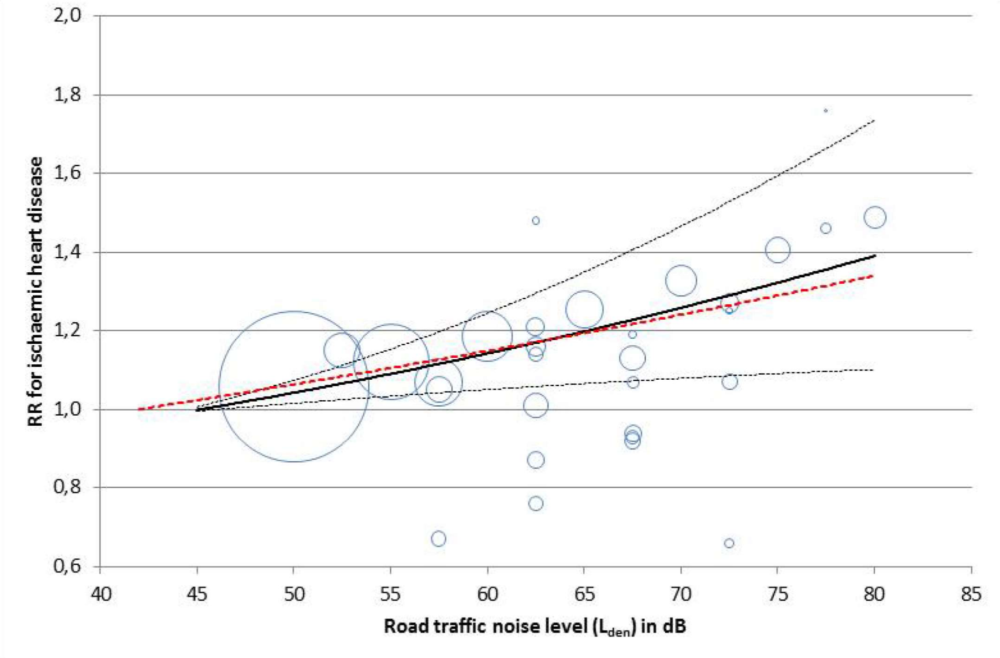
Source (Guski et al., 2017)
Figure 2.2: Data points (scaled to the size of the study) for the 25 road traffic noise studies retained for the WHO evidence review and estimated ERR for the aggregated data (black line), compared to the exposure-response function previously derived by Miedema and Oudshoorn, 2001 (red line).
For further details, refer (Guski et al., 2017)

2.3 Cardiovascular Effects

There is evidence of sufficient strength for an association of coronary heart disease (CHD) and stroke (morbidity and mortality) with environmental noise (Van Kempen et al., 2017, 2018). The most comprehensive evidence available at the time of review was for road traffic noise and Ischemic Heart Disease (IHD). Combining the results of seven longitudinal studies revealed a significant Relative Risk (RR) of 1.08 per 10 dB Lden increase for the association between road traffic noise and the incidence of IHD (see figure 2.3). The quality of the evidence was rated as high. Only a few studies reported on the association between transportation noise and stroke. The quality of evidence for these associations was rated from moderate to very low, depending on transportation noise source and outcome. End points such as high blood pressure changes in children and hypertension were also considered as health outcomes in the WHO evidence review. However, according to the evidence reviews, the quality of the evidence supporting an association between traffic noise exposure and hypertension, and between traffic noise exposure and blood pressure in children, was considered to be very low, indicating that any estimate of an effect is very uncertain.

2.4 Metabolic effects

At the time of the reviews, evidence on diabetes and obesity was limited, since a smaller number of existing studies compared to the number of studies on CHD. The number of studies retained in the WHO reviews that investigated the impact of noise on markers of obesity was limited to four and of diabetes to one. Overall, the researchers rated the quality of the evidence supporting an association between traffic noise and diabetes or markers of obesity, as low. For a comprehensive assessment of the impact of noise exposure on metabolic system, more and better quality evidence is needed.



Source (Van Kempen et al., 2017)

Figure 2.3: Pooled exposure-response association between road traffic noise exposure (Lden) and Relative Risk (RR) established for the WHO evidence review based on seven longitudinal studies. Red dashed line: linear relationship derived (RR = 1.08 per 10 dB) and validated against a restricted cubic spline model (black solid line, with 95% confidence interval represented by black dashed lines). The open circles indicate the relative risk of IHD in individual studies, at different levels of exposure; their size is proportional to the precision (inverse of variance). For further details, refer (Van Kempen et al., 2017)

Table 2.1: WHO Health related guideline values (WHO, 2018)

Source	WHO health related guideline value in dB		Strength of recommendation
	Lden	Lnight	
Road	53	45	Strong
Rail	54	44	Strong
Air	45	40	Strong
Wind turbines	45	-	Conditional
Leisure	70	-	Conditional

2.5 Guideline values

Based on the evidence reviews, the WHO (2018) derived a set of guideline values for each noise source considered. These values refer to the exposure levels above which the experts were confident that there is an increased risk of adverse health effects. Exposure is hereby expressed in yearly averaged Lden and Lnight, measured outdoor, in free field, at the location of the highest exposed façade. The method used is the benchmark exposure method, which is borrowed from the field of toxicology. Table 2.1 presents the guideline values for the different sources, and the strength of the guideline recommendation, established consistently with the strength of evidence of health outcomes for the considered source.

Defining the strength of the recommendations was a final step in the guideline development, guided by the GRADE methodology (Alonso-Coello et al., 2016). According to this approach, strength of recommendation can be set as either strong or conditional (WHO, 2014). A strong recommendation can be adopted as policy in most situations. A conditional recommendation requires a policy-making process with substantial debate and involvement of various stakeholders, due to a higher uncertainty in the quality of the evidence and to opposing values and preferences of individuals and populations affected. Parameters determining the strength of the recommendations include the quality of evidence, the balance of benefits and harms, the values and preference related to the outcomes of interventions to exposure, the resource implications, the priority of the problem, the equity and human right context and the acceptability and feasibility of interventions (Morgan et al., 2016). The guideline development group (GDG) evaluated the strength of the recommendations based on these parameters, following a two-step procedure. Initially, the strength of each recommendation was set as strong or conditional based on an assessment of the quality of evidence. The GDG then identified and assessed contextual factors and adapted the recommendation.

3 UPDATE OF THE EVIDENCE

The WHO Guidelines for Environmental Noise for the European Region (WHO, 2018) are based on evidence published between 2000 and December 2014/August 2015, for sleep disturbance as well as cardiovascular and metabolic effects. Since then, several high quality studies have been published, which may further develop the knowledge and understanding, in particular of the link between noise exposure and metabolic health outcomes. In addition, the reviews underlying the new WHO Guidelines do not include the health effects of industrial noise, neighbourhood and neighbour noise (as defined by Noise Policy Statement for the UK) and noise from building services such as ground- and air source heat pumps. At the request of DEFRA, the UK Department for Environment, Food & Rural Affairs (van Kamp, et al., 2019, in press), the WHO evidence reviews have been updated to include the literature up to 2019.

This section provides a summary of the new publications identified and the selection of eligible studies conducted as part of the review of literature published between 2015 and 2019 on the effects of environmental noise on annoyance, sleep disturbance, metabolic and cardiovascular effects. This review considers the noise sources reported in the WHO guidelines (road, rail and air traffic and windfarms), as well as industrial noise, neighbour noise and neighbourhood noise, and building services equipment including heat pumps, ventilation systems and cooling systems. Implications of the findings for noise policy and noise management practice, in the light of some trends and research needs in the field of sound and health are discussed in the subsequent section.

3.1 Overview of the reviewed literature

Using the same bibliographic search protocol as was used in the WHO evidence review, a considerable number of new studies or new publication on existing studies were identified. (Van Kamp et al., 2019, in press)

Covering the period between 2015-2019 the new search revealed 40 studies studying the effects of noise on annoyance, and 39 studies addressing the effects of noise on sleep, 30 studies into the effects of noise on the cardiovascular system and 8 studies into the effects of noise on the metabolic system. These studies were selected based on size, sample, outcome and exposure risk of bias and considered eligible to be included in a meta-analysis. The number, size and quality of the new studies warrant new meta-analyses over a range of sources and effects included in the WHO evidence reviews. The number of new studies is presented per noise source and outcome in table 3.1. This table also gives a recommendation for updates of meta-analysis.

Table 3.1: Number of new studies per source and outcome.
A recommendation for update of meta-analysis is signalled by an asterisk (*)

	Air	Road	Rail	Wind
Annoyance	13*	10*	8*	9*
Sleep	12*	10*	6*	11*
Hypertension incidence	2*	8*	2*	1
IHD incidence	3*	15*	2	2
IHD mortality	2	5*	2	0
Stroke incidence	3*	8*	2	1
Diabetes	3*	3†	2	1
Change in body mass index	1	3*	3*	0
Change in waist circumference	0	2*	2	0

3.2 Anticipated outcomes

The proposed updates may allow for the development of guideline values that consider a wider range of health outcomes (e.g. stroke and metabolic effects) rather than change the guideline values. The updates might also strengthen existing recommendations. For example, they may result in a potential upgrade of the strength of conditional recommendations (e.g. for wind turbine noise or leisure noise) to strong, if found to be justified.

In view of the issues raised by Guski et al. (2017) and the current debate (Gjestland, 2018; Guski et al., 2019; Gjestland 2019) regarding the effect of selection of studies in the WHO meta-analyses on the Guideline values, closer examination would be worthwhile from a scientific, as well as a policy point of view.

4 IMPLICATIONS FOR POLICY AND RESEARCH

4.1 Guidance for a Health Impact Assessment

Taking the WHO guidelines for environmental noise as a starting point, the Dutch National Institute for Public Health and the Environment (RIVM) prepared a guidance document at the request of the European commission and in the framework of an update of Annex III of the European Noise Directive 2002/49/EC (END). In this guidance document (Van Kamp et al., 2018), the steps of a health impact assessment (HIA) are summarised and the decisions and conditions that inform the evaluation process supporting the HIA are explained. A health impact assessment is a means of assessing the health impacts of policies, plans and projects in diverse economic sectors using quantitative, qualitative and participatory techniques. It can be performed for a specific exposure, in this case environmental noise.

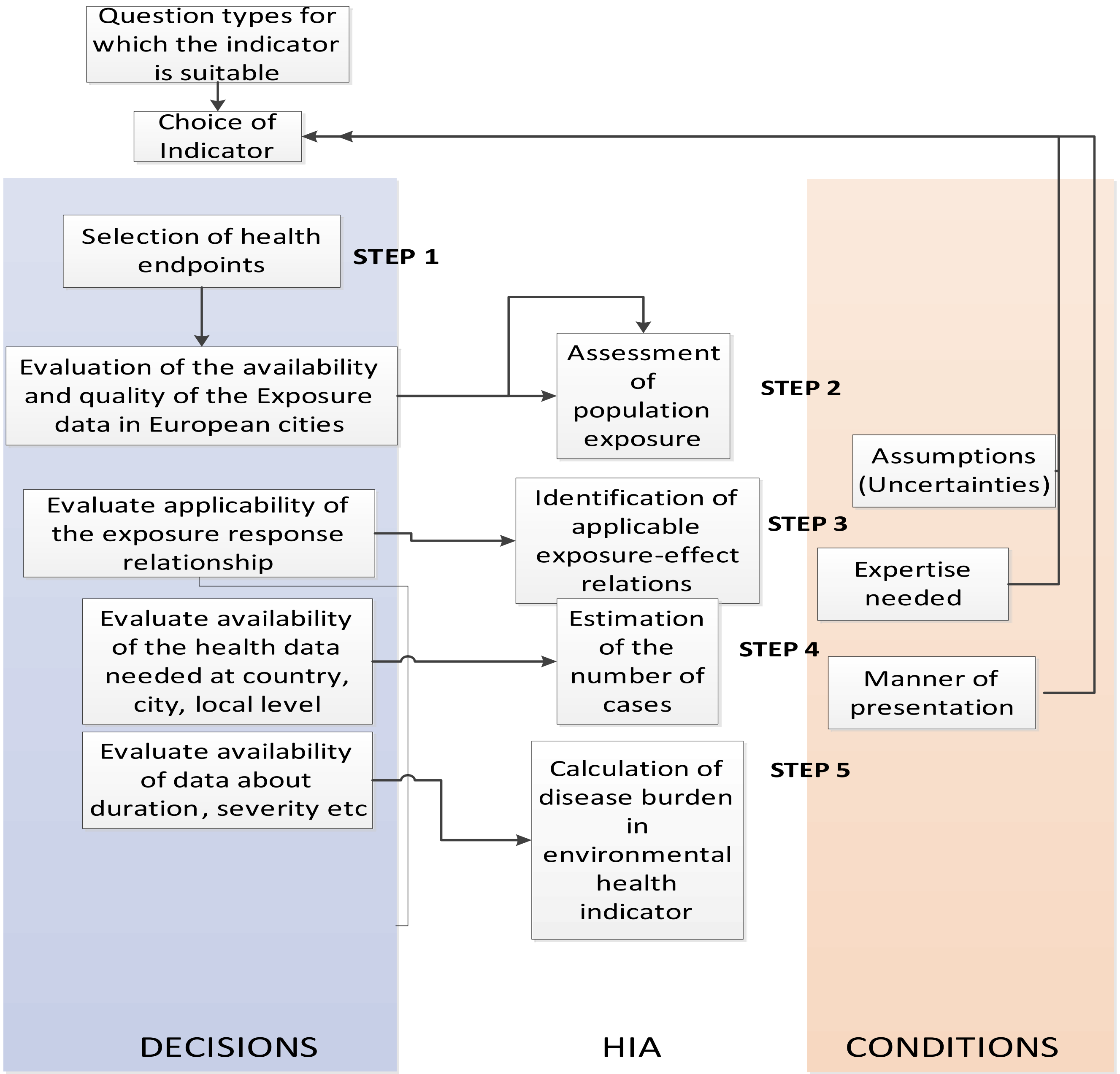
The starting point is the set of policy questions to be addressed. These questions strongly determine whether a HIA is a suitable tool to answer the questions and whether a given environmental health indicator is fit for purpose. They do not only pertain to environmental noise, but are often part of larger issues relating to the impacts of infrastructure plans or decisions for intervention (known as actions in the END) at specific locations. In the context of the END, the focus was placed on the noise related questions. Roughly, these questions can be subdivided in the following main policy questions:

1. What is the current magnitude of environmental noise exposures and what are their health effects at different scale levels, and for different social groups?
2. How and where can the negative impacts be reduced?
3. Which mitigating actions will have the highest impact?
4. What was the actual effectiveness of the different mitigating actions (described in the noise action plans)
    - Evaluation of health impact of deviations from limit values;
    - Efficiency analysis of a set of interventions needed?

Figure 4.1 overleaf describes the different decisions to be made preceding a HIA and the key steps of an impact assessment. These steps are accompanied by a set of decisions to be made – with regard to, for example, the quality of exposure data, the availability of health data and the applicability of the EERs needed at a given scale level (left column) – and by a set of conditions to be met, which include the underlying assumptions, the expertise needed to perform the HIA and the preferred way and scale of presenting the results (right column). Once these decisions are made and these conditions are met, the actual HIA can be undertaken.

4.2 Practical example of HIA

The actual process of quantifying the burden of disease discerns five steps: 1) selection of health outcomes 2) the assessment of population exposure 3) the identification of exposure response relations 4) the estimation of the number of cases and 5) the calculation of the disease burden.
Following these steps the Environment Agency of Düsseldorf (EAD), in Germany, calculated the anticipated impact of ground transportation noise interventions, including predictions of the change in the number of exposed residents for two road traffic noise mitigation actions, which will be taken as examples here. These two interventions both consisted in the implementation of noise reducing road surfaces and a speed limit change from 50 km/h to 30 km/h. The underlying main question was: “What are the impacts of these selected noise actions on health?”



Source : (Van Kamp et al., 2018)
Figure 4.1: Detail of the steps for the different stages of an evaluation process

In preparing the quantitative HIA the following input data were obtained:

a) The fraction of residents per noise category of the study area

By linking noise maps that were created in the framework of the END for the 3rd round in 2017, to the home addresses of the residents of Dusseldorf, the EAD provided population-exposure distributions. For aircraft, road traffic and railway noise. Numbers of exposed people were available in 1 dB bands for both Lden and Lnight. The Lden bands ranged from below 40 to 78 dB for road traffic noise and to 90 dB for railway noise. The Lnight bands included noise levels from below 40 dB to 69 dB for road traffic noise and to 81 dB for railway noise. For aircraft noise data, the EAD provided the number of exposed people in 1 dB bands within the range 45 dB to 75 dB Lden and to 66 dB Lnight.

b) Demographic data of the study area

Demographic and social distributions were extracted from an official report by the City of Düsseldorf, which included. In particular, data on age groups and gender in 2016. Data per age group was needed since the EERs applied in this assessment had to be applied to the adult population (18 years and older) and to children in the age of 7 to 17 years.

c) Disease and mortality data valid for the study area

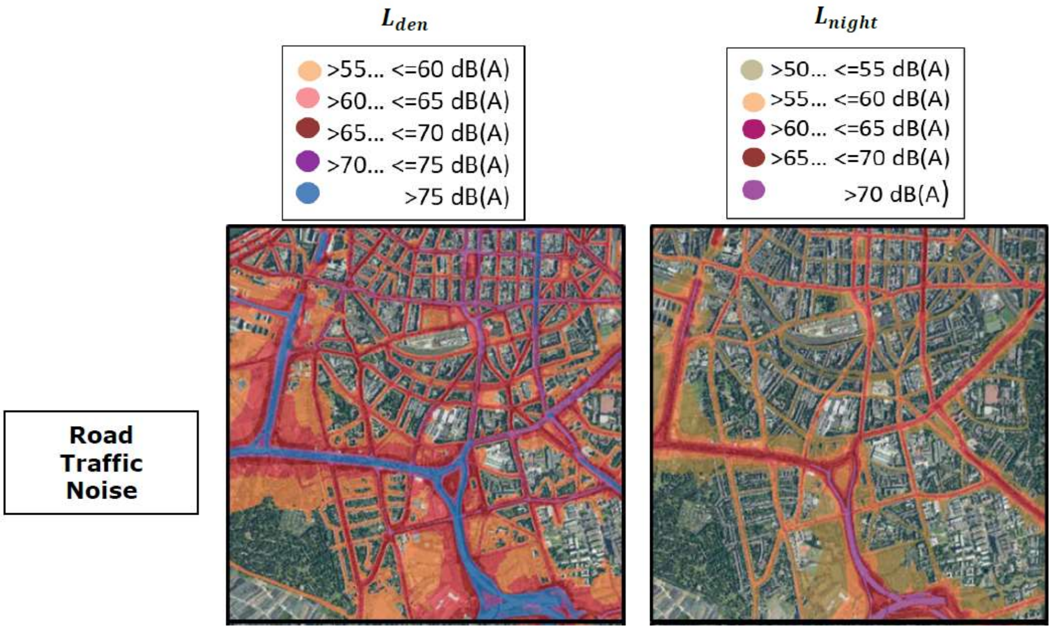
Since no local disease and mortality data were available, this data was obtained from (inter)national sources. Mortality data for coronary heart disease were extracted from the WHO Mortality database for Germany, the most recent data being from 2015. Hospital discharges (total) was used as the indicator for the incidence of coronary heart diseases (CHD) obtained from the European Hospital Morbidity Database of the WHO office for Germany for the year 2014. It should be noted, that although incidence data for CHD was also available, the calculation was based on hospital discharge rates. Disability-adjusted life years (DALYs) could then be calculated by summing up the years lived with a disease (YLD) with the year of life lost due to premature death (YLL). Both YLL and YLD due to coronary heart disease were derived from the WHO Burden of Disease project for 2016, for which disease and mortality data is referred the whole of Germany. For simplification in this exemplar HIA, the data was assumed to be valid for Düsseldorf.

d) Exposure response relations

Part B of the RIVM guidance document (Van Kamp et al., 2018) recommends using local EERs when estimating the number of highly annoyed people and/or the number of highly sleep disturbed people in a study area. Unfortunately, no reliable and valid exposure-response function (ERF) data from Düsseldorf or from elsewhere in Germany that could be applied in this case were available. Therefore it was decided to apply the generalised ERFs for high annoyance and high sleep disturbance that were recommended and presented in the guidance document.

Combining the noise maps with the percentage of adults (18 years and older) obtained from the demographics report of the City of Düsseldorf, the number of exposed persons per 1 dB Lden and Lnight bin was calculated. Figure 4.3 demonstrates the day and night-time noise exposure levels of people in the city district of Dusseldorf-Bilk before and after the intervention (noise reducing road surfaces and speed limit reduction).

For the estimation for the second policy question (evaluation of action plans) the HIA assessment of the impact of noise abatement actions was carried out for two simulated interventions: the first addresses road traffic noise with noise-reducing road surfaces and speed limit reduction to 30 km/h (from 50 km/h) and the second consisted in mitigating tram noise. For brevity, only the first intervention is presented here, considering two approaches: the number of people affected method (NafP, method 1) and the DALYs (method 2).



Source : (Van Kamp et al., 2018)
Figure 4.3: Noise maps for the city district of Düsseldorf Bilk

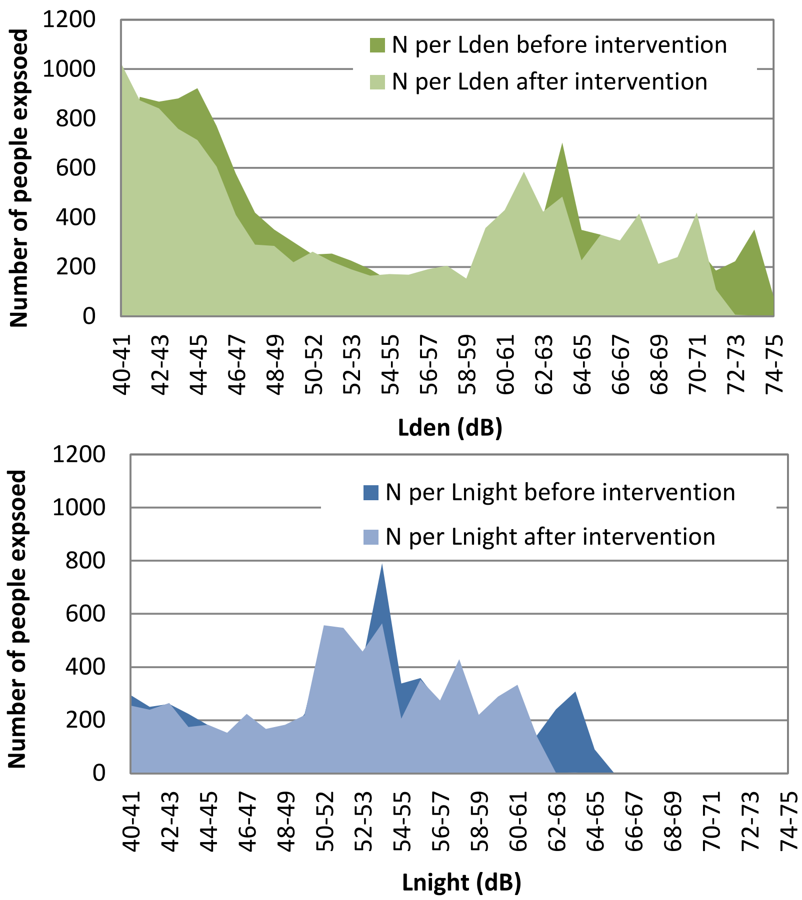


Figure 4.4: Number of adult residents exposed of the city district Düsseldorf-Bilk before and after simulated road surface noise reduction and speed limit reduction (day and night)

As a next step, the generalised EERs for the percentage of highly annoyed persons (%HA), the percentage highly sleep disturbed (%HSD) was applied and the Relative Risk (RR) of CHD (incidence and mortality) per unit change in noise exposure level were derived as per the WHO evidence reviews (refer tables 4.1 and 4.2).

Table 4.1: Generalized EER for high annoyance (%HA) in relation to Lden for road traffic

Noise source	Source-specific exposure-response equation for high annoyance
Road traffic	(78.927 – 3.1162*Lden+ 0.0342*Lden2)/100

Table 4.2: Relative Risks per 10 dB Lden for the association between road noise and coronary heart disease (EC: ecological study, CC: case-control study, CO: cohort study; RR: relative risk; CHD: coronary heart disease)

End point	Noise source	RR (95%CI) per 10 dB Lden	Number and design of studies
Incidence CHD	Road	1.12 (0.85 – 1.48) 1.08 (1.01 – 1.15)	1, EC 7, CC CO
Mortality CHD	Road	1.05 (0.97 – 1.13)	3, CC CO

The number of affected people (NafP) was calculated separately for each outcome and noise source that is included in the HIA. Further details on the determination of the NafP can be found in to section 3.5 of (van Kamp et al., 2018). The health impact, expressed in the number of people affected by the two interventions, aimed at reducing road traffic noise is shown in table 4.3.

Table 4.3: Theoretical display of number of affected people, NafP (method 1) and DALYs (method 2) before and after noise reducing measures: noise-reducing road surfaces and speed limit restriction to 30 km/h

Health end Point	Average number of affected people			Average DALYs due to road traffic noise		
	Before intervention	After intervention	Difference (after – before)	Before intervention	After intervention	Difference (after - before)
High annoyance	1490 (11.3%)	1385 (11.6%)	-106 (0.3%)	14.90	13.85	-1.06 (7.1%)
High sleep disturbance	289 (2.2%)	263 (2.0%)	-26 (0.2%)	6.66	6.05	-0.60 (9.0%)
CHD Incidence	2	2	-0	0.38	0.34	-0.04 10.5%)
CHD mortality	8	7	-1	9.76	8.81	-0.95 (9.7%)
DALY II	--	--	--	31.70	29.06	-2.65 (8.4%)

In line with the calculated reduction in noise levels, the health gain of the two interventions is evident

The road traffic intervention causes a reduction of 0.3% (106 persons) in high annoyance and 0.2% in high sleep disturbance. For the two noise abatement actions for road traffic noise, the number of DALY II – defined as DALYs due to CHD, noise annoyance and sleep disturbance – would decrease by 8.4% and one person less would die due to coronary heart disease caused by noise exposure.

5 TRENDS AND FUTURE NEEDS

The new WHO noise guidelines for the European region and a recent update of the literature provide a solid base for noise policies relevant not only to the European Union, but also to other regions. The new evidence published since 2014, justifies extended meta-analyses on the health effects of transport and wind turbine noise. While much is now known about the relationship between noise and health, little is known about the relationship between noise abatement (interventions) and health. More intervention studies are needed in particular for noise sources other than road traffic noise, and for health outcomes other than or in addition to annoyance. The future studies should be of high quality, following a standardised protocol for a (before - after) differential study design (Brown & van Kamp, 2017).

Making use of the WHO scientific guidelines, the health impacts can now be quantified. As an example the usability of the different approaches (NafP and DALYs) was tested for two cases in Düsseldorf (van Kamp et al., 2018). The methodology described is primarily valid at city level. The methodology and actual calculations of the health burden of noise, could support local authorities to assess the health impacts of their noise action plans and compare the impact against alternative options. Although the 2018 WHO guidelines form an important milestone in noise regulation and management, several gaps were identified. These include theoretical gaps, gaps in study design, exposure characterisation and the health effect of combined exposures, the role of non-acoustic factors and, finally, the need for standardisation of health outcomes other than annoyance.

The current Global Burden of disease protocols require that disability weights associated with each health condition are fixed across social, cultural and environmental contexts worldwide (de Hollander, van Kamp, 2019). The downside of this principle is that DALY-calculations are unable to detect changes in the impact on health conditions that are attributable to changes in the environmental context. Access to a quiet side in homes for example or the close proximity of quiet, low-traffic parks would offer noise-sensitive residents some freedom of choice to escape the noise and recover.

With the current knowledge, the health impact assessment method at regional and local level might be refined to include contextual and personal differences, instead of calculating generic impacts only. In quantifying the health impacts of noise action plans and comparing the impacts against alternative solutions, differences between social groups and groups with varying levels of resilience should be accounted for.

As the example in Dusseldorf showed, there is still a long way to go in terms of data needs, but the adapted method has great potential for future policy. Public Health specialists tend to emphasise the generics, rather than the specifics. In order to understand the differences in effect between groups of people, we need to improve our understanding of interrelationships, between the different effects, between co- exposures, context factors and their implications. At the individual exposure level, improvement of measurement is needed, when estimating of the personal “dosage”. In addition, there is a clear call for the use of alternative metrics supplementary to average noise levels, and the harmonisation of the methods for estimation. To fill these gaps, more longitudinal studies are needed.

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