M60/M62/M66 Simister Island Interchange

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ENVIRONMENTAL STATEMENT APPENDICES

APPENDIX 12.2 HUMAN HEALTH LITERATURE REVIEW AND EVIDENCE

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ENVIRONMENTAL STATEMENT APPENDICES
APPENDIX 12.2 HUMAN HEALTH LITERATURE REVIEW AND EVIDENCE

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Appendix 12.2 Human health literature review and evidence

1 Introduction

1.1.1 This appendix has been prepared to report the literature review into evidence for links between highway projects and human health. It has been prepared to support Chapter 12: Population and Human Health of the Environmental Statement (TR010064/APP/6.1) in relation to the M60/M62/M66 Simister Island Interchange (the 'Scheme').

1.1.2 The literature review has sought out peer reviewed systematic reviews where available. Systematic reviews provide a summary of all the literature available on a particular topic which meets pre-defined eligibility criteria. These are more helpful as an evidence base as they synthesise the available research and help to reduce the overall level of bias which may influence an individual research paper.

1.1.3 Well-designed transport infrastructure is essential for health and well-being. It connects people to employment, essential services and recreational resources. It can support community interaction and help people to socialise. However, there are also many adverse health effects associated with transport, particularly motorised road transport. While air pollution and traffic collisions are relatively obvious aspects of transport which adversely affect health, there are also many other direct and indirect effects of transport which may influence health at a population level. For example, the reliance on cars as a key mode of transport has resulted in increased sedentary lifestyles and lower levels of physical activity. The top three causes of premature death in the UK (cancer, heart disease and stroke) can all be linked to a sedentary lifestyle.

1.1.4 This appendix contains relatively technical language and refers to epidemiological measures of disease.

1.1.5 While the appendix provides information on evidence for associations between particular risk factors and health outcomes, it should be noted that the research is not necessarily generalisable to the baseline context of the Scheme since it is likely that the population profiles and sensitivities will differ from populations studied in the research. Therefore expert judgement is applied as to what is considered relevant within the Scheme context.

1.1.6 Furthermore, some of the research referenced in this appendix identifies statistically significant associations between particular risk factors and health outcomes, however this does not necessarily translate to significance in Environmental Impact Assessment (EIA) terms. For example, the scientific literature may demonstrate to a high statistical probability that a measured association between a risk factor and health outcome was unlikely to happen by chance (and therefore significant in scientific terms) but the health outcome may be relatively mild or affect very few individuals within a population and therefore be of a very small contribution to an overall health burden. In EIA terms *'the assessment of significance relies on informed experts' judgements about what is important, desirable or acceptable with regards to changes triggered'* by the Scheme (European Commission, 2017). The human health assessment in Chapter 12: Population and Human Health of the Environmental Statement (TR010064/APP/6.1) sets out the significance criteria used to determine the level of significance ascribed to a particular effect. The judgement of significance is in part informed by the health evidence presented in this appendix. For each association between a traffic or highway related risk factor and a health outcome, an interpretation is provided to set out how the evidence has been considered in terms of informing the judgement of significance.

2 Traffic-related noise and related health effects

2.1 Introduction

2.1.1 Noise pollution remains a major environmental health problem in Europe, with the transport sector being a major cause. Road traffic is the dominant source of noise pollution in Europe and the United Kingdom (European Environment Agency, 2014).

2.1.2 Noise from road traffic alone is the second most harmful environmental stressor in Europe, behind only air pollution from fine particulate matter (PM) (World Health Organisation (WHO), 2018). The harmful effects of noise arise mainly from the stress reaction it causes in the human body, which can also occur during sleep.

2.1.3 The Environmental Noise Guidelines for Europe (WHO, 2018) set out recommendations for road traffic noise and other sources of environmental noise, following a series of systematic reviews of the current evidence on the following 'critical' health outcomes: Annoyance, sleep disturbance, cardiovascular disease, and cognitive impairment. Systematic reviews were also carried out for evidence relating to the effect of environmental noise on adverse birth outcomes, quality of life, wellbeing and mental health; and metabolic health outcomes.

2.2 Annoyance

2.2.1 Noise annoyance is defined in the WHO Noise Guidelines as '*a feeling of displeasure, nuisance, disturbance or irritation caused by a specific sound*' (Ouis, 2001). In the current guidelines, "annoyance" refers to long-term noise annoyance' (WHO, 2018).

2.2.2 The WHO Environmental Noise Guidelines use the percentage of the population highly annoyed (%HA) assessed on a standardised scale as the outcome measure.

2.2.3 A systematic review on environmental noise and annoyance was undertaken by Guski *et al.* (2017). Environmental noise annoyance as observed in surveys is a retrospective judgement, comprising past experiences with a noise source over a certain time period. The noise annoyance response usually contains three elements: behavioural, emotional/attitudinal and cognitive response (Guski *et al.*, 2017).

2.2.4 The systematic review identified 62 studies from 20 databases, of which 57 studies were used in the quantitative meta-analysis. The results of the systematic review and meta-analysis indicated a statistically highly significant correlation between annoyance scores and road traffic noise levels. The results were that:

- The evidence of exposure-response relations between road traffic noise levels and the %HA is low
- The evidence of odds ratios (OR) representing the %HA increase by a certain noise level increase is moderate/high for road traffic noise

2.2.5 The main limitation for the systematic review was a variance in the definition of noise levels and %HA used across studies.

2.2.6 The odds ratio referring to the %HA for 10 decibels (dB) increase in road traffic noise was 2.7 (95% CI 1.9, 4.0). This means that the probability to be ‘highly annoyed’ is about three times higher when the road traffic noise level increases by 10 dB (Guski *et al.*, 2017).

2.2.7 The Environmental Noise Guidelines note that ‘*Large proportions of the population are affected by noise annoyance, even at relatively low exposure levels. Annoyance may be in the causal pathway to cardiovascular disease*’. They apply a disability weight for %HA of 0.02. Disability weights are ratings that vary between 0 and 1, in which 0 indicates no disability and 1 indicates the maximum amount of disability. The rates are derived from large population surveys in which people are asked to rank a specific disease for its impact on several disabilities and are used for the calculation of the burden of disease. The disability weight of 0.02 indicates it is not considered a particularly serious health condition.

2.3 Sleep disturbance

2.3.1 Sleep is an essential and very active process that serves several vital physiological functions (Watson *et al.*, 2015). Undisturbed sleep of sufficient duration is essential for daytime alertness and performance, quality of life, and health (Banks and Dinges, 2007). In this regard, noise has been shown to fragment sleep, reduce sleep continuity, and reduce total sleep time (Muzet, 2007; Basner *et al.*, 2014).

2.3.2 A systematic review on environmental noise and the effects of sleep was undertaken by Basner and McGuire (2018). The review identified 74 studies conducted between 2000 and 2015 and conducted a meta-analysis of surveys linking road noise exposure to self-reports of sleep disturbance.

2.3.3 The results of the meta-analysis revealed the odds ratio for the percentage highly sleep disturbed (%HSD) for a 10 dB increase in L_{night} was significant at 2.13 (95% CI 1.82, 2.48) for studies where the question referred to noise, but non-significant (OR 1.09, 95% CI 0.94, 1.27) when the question did not refer to noise. This suggests that for self-reported %HSD it is attitude towards night-time noise that may drive the increase of HSD outcomes with night-time noise level. Nevertheless, the researchers involved in the systematic review considered the evidence for studies where subjects were asked whether road noise affected sleep were moderate quality because the dose-response relationships between L_{night} and %HSD were statistically significant and showed odds ratios >2 (Basner and McGuire, 2018).

2.3.4 A pooled analysis of sleep studies (polysomnographic) on the acute effects of road noise on adults’ sleep was also conducted and the unadjusted odds ratio for the probability of awakening for a 10 dBA increase in the indoor L_{max} was significant (OR 1.36; 95% CI 1.19, 1.55). The researchers of the systematic review considered the evidence from the pooled studies to be of moderate quality (Basner and McGuire, 2018).

2.3.5 The quality of evidence identified through systematic review for self-reported sleep disturbance where road noise as a source was not specified was rated very low and non-significant. Evidence for effects on motility measures of sleep (i.e. movement during sleep) was low, while evidence for road noise effects on sleep disturbance in children was low due to inconsistency in results (Basner and McGuire, 2018). The review identified a need for additional studies to determine the effect of noise on sleep in children.

2.3.6 A limitation in the evidence from the systematic review was that the reviewed studies only considered physically healthy individuals who were free of intrinsic sleep disorders. Therefore, the effect of transportation noise on sleep in those with pre-existing medical conditions is unknown and the results presented may underestimate the effect of noise on sleep in the general population.

2.3.7 The Environmental Noise Guidelines note that '*self-reported sleep disturbances are a very common problem in the general population*'. They '*affect quality of life directly and may also lead to subsequent health impediments. Effects on sleep may be in the causal pathway to cardiovascular disease. This measure is not a proxy for physiological sleep quality parameters but is an important outcome in its own right*' (WHO, 2018). The WHO applies a disability weighting of 0.07 for %HSD, suggesting it is considered slightly more serious in terms of health burden than annoyance.

2.4 Cardiovascular disease

2.4.1 Van Kempen *et al.* (2018) undertook a systematic review to evaluate the strength of evidence for associations between transport noise exposure and a range of cardiovascular effects and outcomes, including hypertension, ischaemic heart disease (IHD) and stroke.

2.4.2 For hypertension, they evaluated 40 studies, of which 38 were cross-sectional studies, which showed the strongest associations. A statistically significant association between road traffic noise and the prevalence of hypertension was found after aggregating the results of 26 studies (relative risk (RR) 1.05; 95% CI 1.02, 1.08) per 10 dB Lden for the association between road traffic noise and hypertension within the range of approximately 20 – 80 dB Lden. However, the researchers rated the evidence for hypertension as 'low' to 'very low' because of reasons such as low response rates (<60%) and use of self-reported measures for hypertension, which may bias the results.

2.4.3 The systematic review found evidence that road traffic noise is associated with increased risk of IHD. An increase in road traffic noise was associated with significant increases in the prevalence and the incidence of IHD, with the relationship between road traffic noise and incidence being more 'robust' (van Kempen *et al.*, 2018). The study found that after combining the results of three cohort studies and four case-control studies they found a relative risk of 1.08 (95% CI 1.01, 1.15) per 10 dB Lden. This was within the range of approximately 40 – 80 dB Lden. Van Kempen *et al.* (2018) rated the quality of evidence for these longitudinal studies into incidence as 'high'.

2.4.4 The systematic review found relatively few (nine) studies on the impact of traffic noise on stroke. The studies that investigated the impact of road traffic noise were not consistent. The only statistically significant result was for an association of road traffic noise and the incidence of stroke (RR 1.14; 95% CI 1.03, 1.25) per 10 dB Lden. This result was based on only one study (a cohort study with 51,485 participants and 1,881 incident cases of stroke). The review of cross-sectional and ecological studies into the association between road traffic noise and prevalence of stroke or mortality of stroke, observed no increase in risk of stroke due to road traffic noise. Overall, the researchers rated the quality of evidence supporting an association between road traffic noise and stroke to be 'low' (van Kempen *et al.*, 2018), indicating further research is required to improve confidence in the estimate of effect.

2.4.5 Based on the above, the strongest evidence is for an association between road traffic noise and incidence of IHD. IHD includes angina pectoris and myocardial infarctions (heart attacks).

2.5 Cognitive impairment

2.5.1 Clark and Paunovic (2018) undertook a systematic review to assess the quality of evidence on the effect of road traffic and other environmental noise on cognition. They identified 34 studies, all of child populations. Most of the studies were cross-sectional in design.

2.5.2 The review found no effect from road traffic noise on children's cognitive abilities of reading and oral comprehension, attention, and executive function in children. The researchers rated the quality of this evidence as 'very low' for the first two domains, and 'low' for executive function (working memory).

2.5.3 The review found evidence of a harmful effect of road traffic noise on standardised assessment tests (SATs) and long-term and short-term memory. Again, the researchers rated the quality of this evidence as 'very low'.

2.5.4 A key limitation in the evidence base is a lack of longitudinal and intervention studies across all of the cognitive outcomes. The low number of studies and the quality of the evidence across them does not necessarily mean that there are no noise effects in some cognitive domains, but rather, that more robust studies and a greater number of studies are required.

2.5.5 An updated systematic review and meta-analysis of recent evidence has been undertaken by Thompson *et al.* (2022). Some of the studies in this later systematic review evaluated total noise so it was not always possible to delineate all results by source of transport noise (i.e. if from road traffic noise or from other transport sources such as rail or aeroplane).

2.5.6 The researchers summarised that the '*study findings had a high degree of variation but tended to indicate some associations between the different exposures and cognitive outcomes. There was high quality evidence that residential noise is associated with cognitive impairment in 45+ year-olds, moderate quality evidence that noise exposure (especially aircraft noise) was associated with reading and related abilities in children, and moderate quality evidence that executive function was not associated with aircraft noise in children, but evidence for other noise associations is low or very low quality (poor quality research or insufficiently investigated)*' (Thompson *et al.*, 2022).

2.5.7 This more recent systematic review has not added greatly to the conclusions of the Clark and Paunovic (2018) systematic review.

2.6 Adverse birth outcomes

2.6.1 Nieuwenhuijsen *et al.* (2017) conducted a systematic review on environmental noise and adverse birth outcomes. They found five studies (two with more or less the same population) on road traffic noise and birth outcomes and three related studies on total ambient noise, likely to be mostly road traffic noise. There were too few studies on each birth outcome measure with which to undertaken meta-analysis. There was evidence of association between road traffic noise and low birth rates, but the estimates were imprecise and non-significant. The quality of evidence was rated low. There was evidence of no effect between road traffic noise and pre-term delivery, but there was a positive association between road traffic noise and small for gestational age (OR = 1.09, 95% CI 1.06, 1.12 per 6dB increase). The evidence for both these measures came from the same publications and was rated by the authors of the systematic review as low quality.

2.7 Metabolic outcomes

2.7.1 Van Kempen *et al.* (2018) undertook a systematic review to evaluate the strength of evidence for associations between transport noise exposure and metabolic outcomes of diabetes and obesity. One cohort study was identified which estimated the relative risk 1.08 (95% CI 1.02, 1.14) per 10dB Lden for an association between road traffic noise and incidence of diabetes in the range of approximately 40 – 80dB. The study was rated by the authors of the systematic review as moderate quality.

2.7.2 Two cross-sectional studies were identified which showed a harmful effect of noise on prevalence of diabetes, but the results were imprecise and with a serious risk of bias, and so were rated of very low quality.

2.7.3 Three cross-sectional studies were identified presenting evidence of association between road traffic noise and change in body mass index (BMI) and waist circumference. For each $_{10}$ dB increase in road traffic noise, there was a statistically non-significant increase in BMI of 0.03kg/m^2 (95% CI −0.10, 0.15 kg/m^2) and in waist circumference of 0.17cm (95% CI −0.06, 0.40cm). There was inconsistency in the results between the studies; therefore, for both associations, the evidence was rated by the authors of the systematic review as very low quality.

2.8 Summary of evidence for road traffic noise and health outcomes

2.8.1 Table 2.1 sets out the evidence for associations between road traffic noise and health outcomes.

Table 2.1 Summary of evidence for associations between road traffic noise and health outcomes

Health outcome	Association	Quality of evidence
Annoyance	Positive OR 2.7 (95% CI 1.9, 4.0) [significant]	Moderate to high quality
Sleep disturbance (self-reported Highly Sleep Disturbed) - When asked about effect of noise	Positive OR 2.13 (95% CI 1.82, 2.48) [significant]	Moderate quality
Sleep disturbance (self-reported Highly Sleep Disturbed) - When not asked about effect of noise	Positive OR 1.09 (95% CI 0.94, 1.27) [imprecise/non-significant]	Very low quality
Sleep disturbance – (polysomnographic sleep studies)	Positive OR 1.36 (95% CI 1.19, 1.55) [significant]	Moderate quality
Hypertension (high blood pressure)	Positive (i.e. harmful) (RR 1.05; 95% CI 1.02, 1.08) per $_{10}$ dB Lden within range of 20 – 80dB Lden [significant]	Low to very low quality
Ischaemic heart disease (angina and heart attacks) (Incidence)	Positive (i.e. harmful) RR 1.08 (95% CI 1.01, 1.15) per 10dB Lden [significant]	High quality
Stroke (incidence of stroke)	Positive (i.e. harmful) (relative risk 1.14; 95% CI 1.03, 1.25 per $_{10}$ dB Lden) [significant]	Low quality
Cognitive impairment – reading & oral comprehension (children)	No effect	Very low quality
Cognitive impairment – attention (children)	No effect	Very low quality
Cognitive impairment – SATs (children)	Harmful effect	Very low quality
Cognitive impairment – long-term memory (children)	Harmful effect	Very low quality
Cognitive impairment – working memory (children)	No effect	Low quality
Adverse birth outcome – low birth rates	Positive (i.e. harmful) [non-significant/imprecise]	Low quality

Health outcome	Association	Quality of evidence
Adverse birth outcome – pre-term delivery	No effect	Low quality
Adverse birth outcome – small for gestational age	Positive (i.e. harmful) (OR = 1.09, 95% CI 1.06, 1.12 per 6dB increase)	Low quality
Diabetes (incidence)	Positive (RR 1.08 (95% CI 1.02, 1.14) per 10 dB Lden) for the range of approximately 40 – 80dB	Moderate quality
Obesity - BMI	Positive (0.03kg/m^2 (95% CI −0.10, 0.15 kg/m^2) per 10dB increase) [non-significant]	Very low quality
Obesity – Waist circumference	Positive (0.17cm (95% CI −0.06, 0.40cm) per 10dB increase) [non-significant]	Very low quality

2.9 Interpretation of evidence for health assessment

2.9.1 Increases in noise levels are considered negative for health, while decreases are considered positive. It is noted that the WHO has considered the evidence sufficient to support a strong recommendation that road traffic noise should be reduced to below 53dB Lden. This guideline level is benchmarked at the level where $_{10}$% of a population are likely to be 'highly annoyed'. Noise of this level is relatively widespread in the UK, particularly in urban areas. Annoyance is regarded as a relatively mild health effect, as indicated by the disability weighting applied by the WHO. The more serious health outcome for which evidence is of a high quality, is IHD. This risk is linked to long-term exposure to higher levels of noise. However, it should be noted that the risk of IHD linked to noise is very small compared to other risk factors. Nevertheless, it is a public health issue of concern due to the widespread exposure of populations to traffic noise.

2.9.2 Health effects will be judged significant if the Scheme is expected to effect a large change in the noise environment or affect a large population.

3 Traffic-related vibration and related health effects

3.1 Introduction

3.1.1 There has been little research effort into links between traffic-related vibration and health outcomes. Traffic-related vibrations can be transmitted through two mechanisms, either through the ground or through air as low frequency sound. Low frequency airborne noise emissions (generally 50-100Hz) are generated by either the engine or exhaust of vehicles and can cause light flexible structures such as doors and windows to flex and generate secondary noise emissions which are perceived as vibrations. Commercial vehicles in congested, built-up areas are the main contributors to traffic-related vibration from airborne noise emissions. Traffic-related ground vibrations are not usually perceptible where vehicles are running on smooth surfaces. However, high levels have been recorded at building foundations where the underlying soil is soft and houses are close to surface irregularities (Boulter, 1991).

3.2 Sleep disturbance

3.2.1 Experimental evidence from a small scale study discussed by Arnberg *et al.* (1990) suggests that road traffic vibration can have synergistic effects with road traffic noise in terms of sleep disturbance, but acknowledges that further research is required to establish a dose-response relationship between vibration and sleep disturbance. No more recent research was identified through a literature review.

Interpretation of evidence for health assessment

3.2.2 On the above basis, traffic vibration has not been regarded as a likely significant health issue for the assessment and has not been considered as part of the scope of the assessment.

4 Traffic-related air pollution and related health effects

4.1 Introduction

4.1.1 Poor air quality is the largest environmental risk to public health in the UK (Public Health England, 2018). Air pollution has been associated with several health outcomes including asthma, chronic bronchitis, cardiovascular disease, cancer and adverse birth outcomes (Krzyżanowski *et al.*, 2005). This appendix presents recent evidence for associations between air pollution and health.

4.1.2 The key traffic related air pollutants of concern to public health in the UK are PM and oxides of nitrogen (NO_x), notably nitrogen dioxide (NO_2). NO_2 and PM are major components of urban air pollution. PM is classified by aerodynamic size and referred to as:

- Coarse particles (PM_{10}; particles that are less than 10 microns (μm) in diameter)
- Fine particles ($PM_{2.5}$; particles that are less than 2.5μm in diameter)
- Ultrafine particles ($PM_{0.1}$; particles that are less than 0.1μm in diameter)

4.1.3 This review of health evidence focuses on NO_x and PM. Air pollutants are emitted from a range of man-made and natural sources, including transport, industrial processes, farming, energy generation and domestic heating. Road transport is the dominant source of emissions for NO_x, but residential, commercial and public sector combustion sources provide a greater share of PM (see Table 4.1).

Table 4.1 Source emission contributions by sector, England 2019*

Source	PM_{10}	$PM_{2.5}$	NO_x
Transport sources	14.0%	15.2%	51.5%
Agriculture	8.8%	2.3%	0.3%
Energy industries	1.4%	1.8%	12.1%
Fugitive	0.5%	0.7%	0.0%
Industrial combustion	11.8%	18.1%	19.3%
Industrial processes	30.6%	12.2%	0.0%
Residential, commercial and public sector combustion	29.3%	45.5%	10.5%
Solvent processes	0.0%	0.0%	0.0%
Waste	1.2%	1.8%	0.0%
Other**	2.4%	2.6%	6.4%

Source: Defra (2021).

Notes:

*Whilst source emissions data for 2020 is now publicly available, due to the Covid-19 pandemic which took place during 2020 and stay-at-home orders implemented is it considered that 2019 data likely better reflects the current day source apportionment.

**The sector 'other' includes all other categories identified in the National Atmospheric Emissions Inventory and also a number of categories that are insignificant for a specific pollutant.

4.1.4 The WHO updated its global air quality guidelines in 2021 following a series of updated systematic reviews (WHO, 2021; Whaley, 2021).

4.2 Particulate matter and health

4.2.1 PM comprises various components and size fractions. PM_{10} has been the more routinely monitored fraction of PM, and hence until relatively recently, the majority of epidemiological studies have this fraction as the exposure indicator. More recently, $PM_{2.5}$ has become increasingly monitored.

4.2.2 Health effects of $PM_{2.5}$ and PM_{10} may differ because of different chemical composition and different penetration into the respiratory tract (Chen and Hoek, 2020). There is well documented evidence of health effects from both acute exposure to PM as well as chronic exposure. These health effects include:

- Morbidity from respiratory and cardiovascular diseases, such as increases in asthma, respiratory symptoms (e.g. irritation of the airways, coughing and breathing difficulties), and increases in hospital admissions (WHO, 2013; Pope and Dockery, 1999)
- Mortality due to respiratory and cardiovascular diseases, as well as lung cancer (WHO, 2013)

4.2.3 In 2019, the US Environmental Protection Agency's (EPA) Integrated Science Assessment (ISA) for PM concluded that short-term exposure and long-term exposure of $PM_{2.5}$ was 'causal' for cardiovascular effects, and 'likely to be causal' for respiratory effects (US EPA, 2019). The toxicological evidence for health effects of PM is not yet well understood and there are limited studies available. However, it is speculated that PM, such as black carbon, may act as a carrier of various substances with differing levels of toxicity into the human body (WHO, 2013).

Long-term exposure

4.2.4 A systematic review by Chen and Hoek (2020) has resulted in an update of the evidence base on health effects from long-term exposure to PM. The systematic review identified 107 studies for quantitative analysis, of which 104 were cohort studies. The majority of the studies were of North America and European contexts. The health outcomes for evidence evaluated in the review were:

- Natural-cause mortality
- Circulatory diseases (including specifically IHD and stroke)

- Respiratory diseases (including specifically chronic obstructive pulmonary disease (COPD) and acute lower respiratory infection (ALRI))
- Lung cancer

4.2.5 The combined risk ratio for $PM_{2.5}$ and natural cause mortality was RR 1.08 (95% CI 1.06, 1.09) per 10 µg/m^3 (Chen and Hoek, 2020). PM_{10} was significantly associated with natural cause mortality and most, but not all, causes of death. The quality of evidence was assessed as 'high' for all outcomes associated with $PM_{2.5}$, except for respiratory mortality which was assessed as 'moderate'. The evidence was rated as less certain for PM_{10} cause specific mortality ('moderate' for circulatory, IHD, COPD and 'low' for stroke mortality).

4.2.6 The relative risk for each health outcome and long-term exposure to PM_{10} and $PM_{2.5}$ is set out in Table 4.2.

Table 4.2 Pooled effect sizes on health outcomes for short-term exposure to PM

Outcome	PM_{10}	$PM_{2.5}$
Natural cause mortality	RR 1.04 (95% CI 1.03, 1.06)	RR 1.08 (95% CI 1.06, 1.09)
Circulatory mortality	RR 1.04 (95% CI 0.99, 1.10)	RR 1.11 (95% CI 1.09, 1.14)
IHD mortality	RR 1.06 (95% CI 1.01, 1.10)	RR 1.16 (95% CI 1.$_{10}$, 1.21)
Stroke mortality	RR 1.01 (95% CI 0.83, 1.21)	RR 1.11 (95% CI 1.04, 1.18)
Respiratory mortality	RR 1.12 (95% CI 1.06, 1.19)	RR 1.10 (95% CI 1.03, 1.18)
COPD	RR 1.19 (95% CI 0.95, 1.49)	RR 1.11 (95% CI 1.05, 1.17)
ALRI	-	RR 1.16 (95% CI 1.01, 1.34)
Lung cancer	RR 1.08 (95% CI 1.04, 1.13)	RR 1.12 (95% CI 1.07, 1.16)

Source: Chen and Hoek (2020)

RR = relative risk (per 10µg/m^3 increase in exposure)

4.2.7 In response to new evidence highlighted by this systematic review, the WHO has revised its guideline for long-term exposure to an annual mean of 5µg/m^3 for $PM_{2.5}$ and 15µg/m^3 for PM_{10} (WHO, 2021). These guideline values are substantially more conservative than the current UK Air Quality Objectives (AQOs) which are 25µg/m^3 for $PM_{2.5}$ and 40µg/m^3 for PM_{10}.

4.2.8 The above evidence is being interpreted for this assessment that while population health effects from PM are detectable at low levels of exposure, significant population health effects are currently a concern where the AQOs are exceeded.

Short-term exposure

4.2.9 A systematic review of short-term exposure to $PM_{2.5}$ and PM_{10} was undertaken by Orellano *et al.* (2020). The systematic review identified 96 studies for quantitative analysis. The health outcomes for evidence evaluated in the review were:

- All-cause mortality
- Cardiovascular mortality
- Respiratory mortality
- Stroke mortality

4.2.10 Significant positive associations were found between short-term exposure to PM_{10} and $PM_{2.5}$ and all-cause mortality as well as each specific cause of death. The level of evidence was judged to be 'high' (Orellano *et al.*, 2020). The relative risk for each health outcome and short-term exposure to PM_{10} and $PM_{2.5}$ is set out in Table 3.4.

Table 4.3 Pooled effect sizes on health outcomes for short-term exposure to PM

Outcome	PM_{10}	$PM_{2.5}$
All-cause mortality	RR 1.0041 (95% CI 1.0034, 1.0049)	RR 1.0065 (95% CI 1.0044, 1.0086)
Cardiovascular mortality	RR 1.0060 (95% CI 1.0044, 1.0077)	RR 1.0092 (95% CI 1.0061, 1.0123)
Respiratory mortality	RR 1.0091 (95% CI 1.0063, 1.0119)	RR 1.0073 (95% CI 1.0029, 1.0116)
Stroke mortality	RR 1.0044 (95% CI 1.0022, 1.0066)	RR 1.0072 (95% CI 1.0012, 1.0132)

Source: Orellano *et al.* (2020)

RR = relative risk (per 10µg/m^3 increase in exposure)

4.2.11 In response to new evidence highlighted by this systematic review, the WHO has revised its guidelines such that there should not be more than 3-4 exceedances per year of short term (24-hour) exposure of 15µg/m^3 for $PM_{2.5}$ and 45µg/m^3 for PM_{10} (WHO, 2021). These guideline values are substantially more conservative than the current UK AQOs which are that a 24-hour mean exposure to 50µg/m^3 for PM_{10} should not be exceeded more than 35 times a year and that a short-term exposure level for $PM_{2.5}$ has not been set.

Ultrafine particles

4.2.12 There is growing suggestion that ultrafine particles ($PM_{0.1}$) may contribute to the health effects associated with PM, since these particles are fine enough to reach the bloodstream and various organs of the body, although the evidence for this is still very limited (Kreyling *et al.*, 2004; Knol *et al.*, 2009) and this was not a fraction considered in the WHO Air Quality Guidelines (2021). Furthermore, monitoring data are not available to support assessment at this stage. Therefore, this fraction is not considered in the health assessment for the Scheme.

4.3 NO_x and health

4.3.1 Nitrogen oxide is not considered a particular health concern (Committee on the Medical Effects of Air Pollutants (COMEAP), 2011) and so is not considered further in this assessment. In high concentrations NO_2 is an irritant which can cause inflammation of the airways (COMEAP, 2011; WHO, 2013). It is difficult to disaggregate NO_2 from other roadside pollutants to understand its effects from long term exposure (COMEAP, 2011; WHO, 2013). However, there is some epidemiological evidence that long term exposure to NO_2 is associated with respiratory and cardiovascular deaths and with respiratory symptoms and lung function in children (WHO, 2013).

4.3.2 A systematic review and meta-analysis by Huangfu and Atkinson (2020) into the association between long-term exposure to NO_2 and all-cause and respiratory mortality identified a positive association for respiratory mortality (RR 1.03 per 10µg/m^3, 95% CI 1.00, 1.05), COPD (RR 1.03 per 10µg/m^3, 95% CI 1.01, 1.04) and ALRI (RR 1.06 per 10µg/m^3, 95% CI 1.02, 1.10) mortality. For all three outcomes there was a high level of heterogeneity between studies, however the certainty of evidence was considered ‘moderate’ for respiratory mortality and ALRI, and ‘high’ for COPD.

4.3.3 Zheng *et al.* (2021) conducted a systematic review and meta-analysis on short-term exposure to NO_2 and emergency department visits and hospital admissions due to asthma. The pooled results of their analysis was that the RR per 10 µg/m^3 increase of ambient concentrations was 1.014 (95% CI 1.008, 1.020) for average 24-hour NO_2. The researchers considered that the quality of evidence among the pooled studies was ‘high’. They also note that the analyses ‘*demonstrated that children and, to a lesser extent, the elderly were more susceptible to the adverse effects of air pollution (i.e. the magnitude of association was greater in these subgroups than in adults)…Moreover, the greater susceptibility among children and the elderly was consistent with the previous studies… The immature growth of airways and the defective host-defence in children and ageing of the respiratory system in the elderly population, might have underlay their greater susceptibility to asthma exacerbation following short-term exposure to air pollution*.’ (Zheng *et al.*, 2021).

4.3.4 The Orellano *et al.* (2020) systematic review of short-term exposure found positive associations between NO_2 (24-hour average) and all-cause mortality (RR 1.0072; 95% CI 1.0059, 1.0085 per 10µg/m^3 increase).

4.3.5 The Orellano *et al.* (2020) systematic review found evidence of a null effect between the 1-hour max NO_2 and all-cause mortality (moderate quality evidence), while the Huangfu and Atkinson (2020) systematic review found evidence of a null-effect of association between the 1-hour max NO_2 and hospital admissions due to asthma.

4.3.6 Based on the evidence from the systematic reviews, the WHO Air Quality Guidelines recommend an exposure guideline levels for NO_2 of 10µg/m^3 for average annual exposure limits and not more than 3-4 average 24-hour exposures per year of 25µg/m^3. These are much more conservative values than the current UK AQOs which are that an annual average exposure of 40µg/m^3 should not be exceeded. The AQOs do not set an objective for 24-hour exposure to NO_2 but instead set a 1-hour mean exposure of 200µg/m^3 not to be exceeded by more than 18 times per year.

4.4 Evidence for links between air pollution and specific health outcomes

4.4.1 This section provides further information on evidence for associations between air pollution and certain specific health outcomes. It includes evidence from some of the systematic reviews discussed above. No further evidence on stroke, COPD and ALRI than that reported above has been reviewed.

Asthma

4.4.2 A systematic review and meta-analysis by Khreis *et al.* (2017) found statistically significant associations between asthma onset in children and NO_2, $PM_{2.5}$ and PM_{10} exposure, although the authors acknowledge that there is a further need to improve exposure estimates and therefore consistency of cohort study findings.

4.4.3 A meta-analysis assessed the association between short-term increases in outdoor air pollutant levels and moderate or severe asthma exacerbations in children and adults, showing a statistically significant association between $_{NO2}$, $PM_{2.5}$, and PM_{10} with moderate or severe exacerbations of asthma when children and adults were considered as one group, and NO_2 and $PM_{2.5}$ when children were considered alone (Orellano *et al.*, 2017). However, the majority of observational studies included in the review by Orellano *et al.*, (2017) came from developing countries and the authors' caution that care is required in extrapolating these results to developed countries such as the UK.

4.4.4 As reported above under 'NO_x and health', the more recent systematic review and meta-analysis by Zheng *et al.* (2021) found statistically significant associations between short-term exposure to NO_2, and increased risk of asthma-related exacerbations, defined as emergency room visits and hospital admissions, although the authors acknowledge a number of limitations to the study including the difficulty associated with the documentation of milder forms of asthma exacerbations which are often underreported.

Cardiovascular disease

4.4.5 Air pollution both exacerbates existing heart conditions and also appears to have a role in the development of disease. Recent epidemiological and clinical evidence for associations between air pollution and cardiovascular disease suggests that exposure to fine particulate matter ($PM_{2.5}$ and below) air pollution contributes to the development of cardiovascular disease and the triggering of acute cardiac events (Franklin *et al.*, 2015). A systematic review by Orellano *et al.* (2020) found strong evidence of a positive association between short-term exposure to PM_{10} and $PM_{2.5}$, and cardiovascular mortality. Additionally, a systematic review by Newby *et al.* (2015) reports that the majority of cohort studies link long-term exposure to particulate matter air pollution with increased risk of incident fatal or non-fatal coronary artery disease, with positive associations observed below the current European recommended annual limit for $PM_{2.5}$ and PM_{10} (Cesaroni *et al.*, 2014).

Cancer

4.4.6 The International Agency for Research on Cancer (IARC) classified both outdoor air pollution and PM in outdoor air pollution as Group 1 human carcinogens for lung cancer in 2013 (IARC, 2015). Subsequent systematic and metanalytic reviews have found a strong and consistent statistically significant correlation between lung cancer incidence or mortality and $PM_{2.5}$ (Hamra *et al.*, 2014) and PM_{10} exposure (Hamra *et al.*, 2014; Pope *et al.*, 2020).

4.4.7 The recent systematic review and meta-analysis by Chen and Hoek (2020) reported above for PM, found evidence of a significant association between lung cancer mortality and long-term exposure to PM_{10} (RR 1.08, 95% CI 1.04, 1.13) and $PM_{2.5}$ (RR 1.12, 95% CI 1.07, 1.16). This evidence is consistent with several previous reviews but identifies slightly higher effect estimates than previously reported.

4.4.8 Research into links between NO_x exposure and lung cancer incidence or mortality have either found no significant association (Hvidtfeldt *et al.*, 2021), or that observed associations are not significant once confounding factors, such as individual smoking status, are taken into account (Hamra *et al.*, 2015; Atkinson *et al.*, 2018). It is also acknowledged that there are methodological difficulties with differentiating between effects associated with PM and those associated with NO_x.

4.4.9 Evidence for associations between $PM_{2.5}$ or NO_x exposure and incidence or mortality of other types of cancer including bladder cancer, breast cancer, brain tumours, cancers of the digestive system and urinary tract, leukaemia and lymphoma is mixed, with limited studies undertaken except for bladder and breast cancer (Turner *et al.*, 2020).

Adverse birth outcomes

4.4.10 Shah and Balkhair (2011) undertook a systematic review exploring associations between individual air pollutants and birth outcomes, finding that exposure to $PM_{2.5}$ is associated with low birthweight, pre-term births and 'small for gestational age' births, and exposure to PM_{10} is associated with 'small for gestational age' births only. Evidence for links between NO_x with adverse birth outcomes was inconclusive. A limitation of this study was that the impacts of other health determinants such as socioeconomic, lifestyle and behaviour-related factors, were not considered. A more recent systematic review investigating the associations between $PM_{2.5}$ and adverse birth outcomes (Yuan *et al.*, 2019) also found that, despite some inconsistencies, there is increasing evidence for associations between material $PM_{2.5}$ exposure and decreased birth weight, low birth weight, pre-term births and 'small for gestational age' births.

4.5 Interpretation of evidence for health assessment

4.5.1 There is good evidence that transport related air pollutants such as PM_{10}, $PM_{2.5}$ and NO_2 are associated with an increased risk of a range of health outcomes, including at levels of pollution substantially below the AQOs. However, it should be noted that the evidence from the systematic reviews which underpin the WHO Air Quality Guidelines are based on relatively small risk sizes and the WHO Air Quality Guidelines are designed to protect large populations from small increases in disease and mortality. For most individuals, the increase in risk posed by outdoor air pollution is extremely low compared to other risk factors.

4.5.2 It should also be noted that while road traffic contributes to pollution, it is one contributor among many other sources, and in the case of PM, sources such as residential, commercial and public sector combustion (which would include woodburning stoves, bonfires etc.) provide a greater share of the PM emissions.

4.5.3 Any increase in exposure to air pollution is negative for population health, while any decrease in exposure to air pollution is positive for population health. However, significant impacts on population health (i.e. where a notable change in the level of health outcomes) are only judged likely where the Scheme would cause an exceedance of the AQOs or where a substantial change in concentrations of pollutants are anticipated compared to the baseline (do minimum).

5 Traffic-related impacts on greenspace and blue space and related health effects

5.1 Introduction

5.1.1 The terms greenspace and blue space have no fixed definition; however, greenspace is most commonly considered to be areas of vegetated land within an urban area and blue space to be visible outdoor surface waters (e.g. rivers, lakes and ponds). Rivers, lakes and ponds are sometimes also considered within the definition of greenspace rather than as a separate entity.

5.1.2 Transport infrastructure has the potential to affect the availability and accessibility of green and blue infrastructure through the following key mechanisms:

- Direct loss of greenspace or blue space as a result of new construction
- Improvement or reduction in accessibility of greenspace or blue space through creation or loss of physical barriers
- Improvement or reduction in accessibility of greenspace or blue space through changes in traffic patterns or pedestrian/cyclist provision
- Changes in tranquillity or quality of greenspace or blue space

5.2 Mental health and well-being

5.2.1 Mental well-being is a fundamental component of health and quality of life. A recently published systematic review by Zhang *et al.* (2020) considered 14 studies from English-speaking developed nations and found evidence suggesting beneficial associations between greenspace exposure and reduced stress, positive mood, less depressive symptoms, better emotional well-being, improved mental health and behaviour and decreased psychological distress in adolescents (defined as ages 10-19). However, the number of available studies was limited and showed mixed results. Furthermore, the researchers were concerned about a risk of bias in the studies (Zhang *et al.*, 2020). A further systematic review by McCormick (2017) considered 12 studies from English-speaking nations and also found that access to green space was associated with improved mental well-being, overall health and cognitive development in children (ages 0-18).

5.2.2 A systematic review of associations between mental health in adults and green space by Houlden *et al.* (2018) considered 52 studies of predominantly European, UK, USA, Australian and Canadian populations, and found adequate evidence for positive associations between the amount of local area greenspace in urban environments and both mental well-being and life satisfaction, and limited evidence for positive associations between variety in greenspace types and frequency of visits to greenspace with mental well-being.

5.2.3 A systematic review on the mental health benefits of long-term exposure to residential green and blue spaces by Gascon *et al.* (2015) found limited evidence for a causal relationship between surrounding greenness and mental health in adults, whereas the evidence was inadequate in children. The evidence was also inadequate for the other exposures evaluated (access to green spaces, quality of green spaces, and blue spaces) in both adults and children. The main reason for the inadequate evidence was the limited number of studies, and the variability regarding how exposure to green and blue space was assessed in the studies by Gascon *et al.* (2015).

5.3 Physical health outcomes and mortality

5.3.1 A systematic review and meta-analysis of greenspace exposure and health outcomes conducted by Twohig-Bennett and Jones (2018) included 143 studies and found significant associations between exposure to greenspace and various health benefits. For populations in high greenspace areas compared to those in low greenspace areas there are statistically significant reductions in the incidences of type II diabetes 0.72 (95% CI 0.61, 0.85), all-cause mortality 0.69 (95% CI 0.55, 0.87), cardiovascular disease (CVD) mortality 0.84 (95% CI 0.76, 0.93), as well as pregnancy outcomes preterm birth 0.87 (95% CI 0.80, 0.94), and small size for gestational age 0.81 (95% CI 0.76, 0.86). Common limitations among the studies reviewed were the lack of information on the type of greenspace as well as a lack of information on how the use of greenspace was measured and included in the analysis.

5.3.2 In relation to obesity outcomes, two systematic reviews found that exposure to greenspace is generally associated with more favourable body weight and obesity-related health indicators but that the evidence is mixed and inconsistent (Lachowycz and Jones, 2011; Gascon *et al.*, 2017).

5.3.3 There is limited research available on the associations between green or blue space and cancer. A systematic review of associations between long-term exposure to residential greenspace and mortality (Gascon *et al.*, 2016) found no association between residential greenness and lung cancer mortality.

5.3.4 A systematic review of associations between long-term exposure to residential greenspace and mortality (Gascon *et al.*, 2016) found evidence of a reduction of the risk of CVD mortality in areas with higher residential greenness. However, evidence of a reduction of all-cause mortality was more limited and no benefits of residential greenness and lung cancer were observed. The systematic review supports the idea that living in areas with higher amounts of greenspaces reduces mortality, particularly from CVD. However, the researchers note that improved research is required to better account for the effect of other factors such as socioeconomic status, to provide more complete evidence (Gascon *et al.*, 2016).

5.3.5 A recent systematic review and meta-analysis by Zhan *et al.* (2020) considered the influence of residential greenness on adverse pregnancy outcomes. The review assessed the incidence of adverse birth outcomes between groups exposed to highest and lowest levels of residential greenness using data from 36 studies of populations within the US, Canada, New Zealand and Europe. The review supported an inverse association between residential greenness and adverse pregnancy outcomes. They found that residents exposed to highest levels of residential greenness had a statistically significant reduced odds of low birthweight (OR 0.86, 95% CI 0.75, 0.99 at 100m buffer) and being small for gestational age (OR 0.93, 95% CI 0.88, 1.00 at 100m buffer). The results also showed that maternal exposure to greenness was associated with increased head circumference and reduced risk of mental disorders. No significant associations were found on preterm birth, gestational age, gestational diabetes mellitus, gestational hypertension or preeclampsia.

5.3.6 The authors of the review do note several limitations of the study, including those measures of greenness exposure of most studies related to the maternal home address and do not take account of work addresses, activity routes and indoor exposure. Their findings are consistent with previous studies including the above-mentioned systematic review by Twohig-Bennett and Jones (2018), a systematic review by Banay *et al.* (2017) which found evidence of positive associations between exposure to greenspace and birthweight, and a meta-analysis study by Dzhambov *et al.* (2014) which found a weak positive association between neighbourhood greenspace and birthweight.

5.4 Interpretation of evidence for health assessment

5.4.1 The above suggests that there is substantial evidence supporting links between greenspace and several positive health outcomes. However, the methods on how exposure to greenspace is measured varies substantially, as does how researchers take the use of greenspace into account. Evidence is currently very mixed for some health outcomes, and the quality of studies is variable.

5.4.2 It is plausible that greenspace may help reduce exposure to air pollution and noise, and therefore reduce the impact of environmental factors on health. Furthermore, people who live near or have access to greenspace are more likely to be physically active and have better mental health, and therefore be healthier overall. A review on access to greenspace by Public Health England (2020) identified pathways through which greenspace can promote positive health and wellbeing outcomes such as encouraging greater physical activity, recreational activities, connection with nature, and community and social cohesion.

5.4.3 Improved access to greenspace is judged to be positive to health based on the results of the studies, however the significance in terms of improving health outcomes is not clear while the mechanisms for the better health outcomes associated with exposure to greenspace are not yet clear from the research. For the assessment, health impacts associated with access to greenspace are judged to be significant if the Scheme makes a substantial long-term change in access to greenspace that would affect a notable proportion of a community.

6 Road traffic, physical activity and health

6.1 Introduction

6.1.1 Traffic infrastructure and patterns can have direct and indirect effects on mental and physical health by acting as a physical or psychological barrier to access places of employment and study, community and recreational facilities or public transport access points for pedestrians and cyclists.

6.1.2 Physical inactivity is associated with one in six UK deaths, and is estimated to cost the UK £7.4 billion annually (including £0.9 billion to the National Health Service (NHS) alone) (Public Health England, 2020 (and references therein)).

6.2 Cancer

6.2.1 An umbrella review by de Rezende *et al.* (2018) found a negative and statistically significant association between physical activity levels and incidence, mortality or incidence and mortality of seven cancer types (colon, breast, endometrial, lung, oesophageal, pancreas and meningioma) as well as all cancer mortality. However, only the associations with breast cancer, colon cancer and all cancer mortality were considered to have strong or highly suggestive evidence, and when only recreational physical activity was considered then only breast cancer and colon cancer were considered to have strong or highly suggestive evidence. A previous meta-analysis by Liu *et al.* (2016) also found statistically significant associations between leisure time physical activity rates and incidence of colon cancer and breast cancer, with no relationship identified between other cancer types considered (prostate, lung, pancreatic, endometrial, ovarian and lymphoid neoplasms). In contrast, Moore *et al.* (2016) identified statistically significant negative associations between leisure time physical activity levels and oesophageal, liver, lung, gastric, endometrial, colon, head and neck, bladder and breast cancer as well as myeloid leukaemia and myeloma.

6.2.2 A recent UK cohort study (Patterson *et al.*, 2020) used data from the Office for National Statistics Longitudinal Study (linking UK census data from 1991, 2001 and 2011 to mortality and cancer registrations) to investigate the relationship between commuting mode, and cancer incidence and mortality. Compared with commuting by private vehicle, bicycle commuting was associated with a 16% lower rate of cancer mortality and 11% reduced rate of cancer incidence, and a walking commute with a 7% lower rate of cancer incidence. Results did not differ significantly in magnitude between socioeconomic groups or by gender. These findings are partially consistent with a previous meta-analysis using a wide range of cohort studies of populations based across the UK, US, Europe, China and Japan (Dinu *et al.*, 2019). These identified a statistically significant association between cycle commuting and reduced cancer mortality, but no association with walk commuting. A UK-based prospective cohort study found negative associations between cycle commuting and mixed mode commuting including cycling and cancer incidence and mortality, but not between walk commuting and cancer incidence and mortality.

6.3 Cardiovascular disease

6.3.1 A recent umbrella review by Kraus *et al.* (2019) reports the strong negative association between physical activity levels and CVD incidence and mortality (coronary heart disease, ischemic stroke and heart failure), although they note that most studies have focussed on moderate to vigorous physical activity and limited understanding of the relationship between light physical activity and CVD incidence and mortality.

6.3.2 Of specific relevance to the role of transport infrastructure and active travel, Dinu *et al.* (2019) and Patterson *et al.* (2020) found statistically significant negative associations between active (bicycle or walking) commuting and CVD incidence and between cycle commuting and CVD incidence and mortality respectively.

6.4 Cognitive abilities and dementia

6.4.1 A recent umbrella review by Barbosa *et al.* (2020) concluded that physical activity levels have a small-medium positive to null association with academic achievement in school age children and adolescents, depending on the type and duration of activity. Increased allocation of physical education time and chronic physical activity levels were found to have a small positive effect, however no association between active commuting and academic achievement was identified although it is suggested that methodological factors may confound this result. Overall, the authors conclude that physical activity may be beneficial to academic achievement, with most benefit gained from long term programmes of physical exercise.

6.4.2 Evidence regarding the association between physical activity levels and onset of dementia is mixed, however the most recent large scale meta-analysis by Kivimäki *et al.* (2019) found that in analyses that addressed bias due to reversed causation, there was no association between physical activity levels and incidence of all-cause dementia or Alzheimer’s disease, except where a dementia diagnosis was preceded by cardiometabolic disease.

6.5 Diabetes

6.5.1 A meta-analysis by Raza *et al.* (2020) based on 59 cohort studies from across Europe, Canada, USA, Australia, China, Japan and South Korea found an inverse dose-response relationship between active travel commuting and leisure time physical activity levels and incidence of type 2 diabetes. Regular active commuters, and those who undertook leisure time physical activity of an equivalent duration, were found to have a 22% reduced risk of type 2 diabetes. Dinu *et al.* (2019) also reported a negative but not statistically significant relationship between active commuting and incidence of diabetes.

6.6 Obesity

6.6.1 A systematic review by Xu *et al.* (2020) found that there is some evidence for an inverse association between active travel and obesity in school aged children, however, further study is needed to confirm these findings.

6.7 All-cause mortality

6.7.1 A large scale UK based cohort study by Patterson *et al.* (2020) found that bicycle commuting was associated with a 20% reduced rate of all-cause mortality compared with private motorised vehicle commuting, with rail commuters having a 10% lower rate. There was no statistically significant difference between the all-cause mortality of walk commuters and those that commuted by private motorised vehicle. Associations between commute mode and health were consistent across occupation based socioeconomic groups. These results were broadly consistent with a previous systematic review by Kelly *et al.* (2014) which found that walking and cycling were associated with a reduced risk of all-cause mortality independent of physical activity levels associated with other activity types. They were also consistent with a second large scale UK cohort study by Panter *et al.* (2018) which found that more active travel patterns for non-commuting purposes were associated with an 8% reduced risk of all-cause mortality in those who were not regular commuters.

6.8 Mental health

6.8.1 Limited studies into associations between physical activity and mental health in adults were identified in this literature review. Evidence in studies is mostly based on self-reported physical activity and mental health measures.

6.8.2 A recent systematic review by Marques *et al.* (2020) into whether there is an association between active commuting and depression symptoms in adults found only seven studies which met the inclusion criteria, and of those, two presented a significant relationship between active commuting and depression symptoms, while five found no significant association between active travel or active commuting and depression. In the studies where an association was found, switching to active travel modes and walking long distances were negatively associated to the likelihood of developing new depressive symptoms. The researchers conclude that based on the results of the systematic review the ‘relationship between active commuting and depression symptoms in adults is not clear.’ (Marques *et al.*, 2020).

6.8.3 A systematic review into cardiorespiratory fitness and the incidence of common mental health disorders by Kandola *et al.* (2019) identified only four studies eligible for inclusion. From a synthesis of those studies they found that low and medium levels of cardiorespiratory fitness were associated with a 47% and 23% greater risk of a common mental health disorders respectively, compared with groups that have high cardiorespiratory fitness. Their findings suggest there is a long-term relationship between cardiorespiratory fitness and the risk of a common mental health disorder.

6.8.4 A recent systematic review and meta-analysis by Rodriguez-Ayllon *et al.* (2019) found that significant associations between physical activity and both lower levels psychological ill-being and greater levels of psychological wellbeing in children and adolescents.

6.8.5 A meta-analysis by White *et al.* (2017) which considered domain specific associations between physical activity levels and mental health in adults and children found that both leisure time physical activity and transport related physical activity had a positive association with mental health, and leisure time physical activity and school sport had an inverse relationship with mental ill-health.

6.9 Interpretation of health evidence for assessment

6.9.1 The above evidence varies in terms of whether it has researched the association of active travel specifically, or physical activity generally, on health. Nevertheless, the two are interlinked with active travel providing an opportunity to build in regular physical exercise into lifestyles.

6.9.2 One of the questions that can be asked is whether people are healthier because they undertake active travel, or whether people undertake active travel because they are healthier? Another issue is that house prices within walking distances of places of work can often be higher than those of a greater distance away from employment centres, suggesting that those within walking distance may be socioeconomically better off. While some of the above research will have accounted for these issues, they illustrate some of the difficulties with gaining a true measurement of the health effects of active travel.

6.9.3 It should also be noted that driving a car supports sedentary behaviour and so people who use this mode would need to build alternative forms of physical activity into their lives to accrue the benefits of physical exercise on health.

6.9.4 For the health assessment, increases in opportunities for active travel have been considered positive for health on account of health benefits associated with physical exercise, as well as benefits in terms of reducing pollution and other negative aspects of motor vehicles. However, significant impacts on population health outcomes are only predicted where a substantial modal shift to active modes of travel is anticipated.

7 Road traffic collisions

7.1 Introduction

7.1.1 The WHO predicts that road traffic collisions will become the fifth leading cause of death globally by 2030 (WHO, no date a) and that they are currently the leading cause of death for children and young adults (aged 5-29 years) (WHO, no date b). It is estimated that road traffic collisions cost nations an average of 3% of their gross domestic product (GDP) as a result of costs associated with treatment of those injured and loss of productivity by individuals killed or disabled by their injuries and of family members required to take time off work or school to care for the injured (WHO, no date). The Department for Transport (DfT) estimates the prevention value of road traffic fatalities and casualties in England in 2019 exceeds £33 billion once both casualty (e.g. productivity losses, medical costs and human costs) and accident (police, insurance and admin, damage to property) costs are taken into account.

7.2 Physical health and mortality

7.2.1 In the UK in 2022, 1,760 people (including 57 children) were killed in a road traffic accident and a further c. 137,013 (including 13,405 children) reported an injury (DfT, 2022). Whilst the majority of fatalities were car occupants, travel by motorcycle has the highest fatality rate per mile, followed by pedestrian travel and travel by pedal cycle (see Table 7.1). In 2019 the majority (57%) of fatalities occur on rural roads, whereas the majority of casualties occur in urban roads (DfT, 2019). Road traffic accident casualty data by road type or by injury type was not yet publicly available for 2022 at the time of preparation of this review, and therefore 2019 data has been presented as the 2020 and 2021 COVID-19 lockdowns mean that these data for these years may not be representative of typical conditions.

7.2.2 It should be noted that there is no obligation for people to report personal injury accidents to the police except under specific circumstances, and therefore DfT road traffic accident statistics do not reflect the full range of collisions and casualties.

Table 7.1 Road traffic collision fatalities by mode

Mode	% of total fatalities (DfT, 2022)	Fatality rate per billion miles (Dft, 2019)
Car	45	1.6
Motorcycle	20	104.6
Pedal cycle	6	29.0
Pedestrian	24	35.4
Other (including bus, coach and goods vehicle)	5	0.6-1.1 depending on vehicle type

Transport mode and casualty rate

7.2.3 In contrast to the road traffic fatality data presented above, car occupants have one of the lower casualty rates of all modes, with motorcycle, pedal cycles and pedestrian modes having casualty rates more than 10-fold higher (see Table 7.2).

Table 7.2 Road traffic accident casualties by mode (DfT, 2019)

Mode	Casualty rate per billion miles
Car	195
Motorcycle	5,051
Pedal cycle	4,981
Pedestrian	1,640
Other (including bus, coach and goods vehicle)	45-141 depending on vehicle type

Physical injuries

7.2.4 Whiplash and minor cuts and bruises are the most common types of injury sustained during road traffic collisions, reported by 51% and 43% of individuals involved in road traffic collisions in England between 2017 and 2019 respectively (DfT, 2019). Of those individuals who experienced serious injuries, 12% reported fractured or broken bones and between 6% and 8% reported one or more of severe shock, concussions, severe cuts and internal injuries. Around a third of individuals involved in road traffic collisions attended an Accident and Emergency centre, and 10% required in patient treatment (DfT, 2019).

7.3 Mental health

7.3.1 Road traffic collisions are the leading cause of post-traumatic stress disorder (PTSD) in the general population, with prevalence in road traffic survivors ranging from 6% to 45% depending on time frame and socioeconomic factors (summarised in Kovacevic *et al.*, 2020). A recent meta-analysis found that women, individuals with low education level and black, Asian and minority ethnic individuals were more likely to experience PTSD following involvement in a road traffic accident (Lin *et al.*, 2018). Studies show that the rate of PTSD in child and adolescent road traffic collision survivors has been found to be around 20% (Mehta and Ameratunga, 2012; Dai *et al.*, 2018). The prevalence of depressive disorders in adult road traffic collision survivors ranges from 7.8% to 63% and for anxiety disorders from 19.4% to 60.0% (summarised in Kovacevic *et al.*, 2020).

7.4 Long term impacts on quality of life

7.4.1 Recent research into the longer term impacts of road traffic collisions has shown that both minor and severe injuries resulting from road traffic collisions can have long term negative effects on health related quality of life (HRQOL), with women and younger people experiencing greatest reductions in HRQOL (Nhac-Vu *et al.*, 2014; Hasselberg *et al.*, 2019; Rissanen *et al.*, 2020).

7.5 Health inequalities

7.5.1 Unintentional injuries (including road traffic collisions) are a major health inequality in the UK, with the social class gradient in child injury steeper than for any other cause of child injury of death (Marmot and Bell, 2012).

7.5.2 A review of associations between road traffic incidents and deprivation by Laflamme *et al.* (2010) found that in the UK:

- Children in deprived areas have a four times higher risk of pedestrian injury than children in the least deprived
- Children in families with low socioeconomic positions are at greater risk of bicycle injuries
- Children in the most deprived areas have a significantly higher risk of injury as a car occupant than in the least deprived areas
- Young people in the most disadvantaged families have an increased risk of injuries as a car driver compared to children in the most advantaged families

7.6 Interpretation of health evidence for assessment

7.6.1 Road traffic collisions are a direct cause of mortality, injuries and disability, and also damage mental health and have life-long health implications for individuals affected.

7.6.2 While the greater proportion of road collision fatalities are among car drivers, the fatality rate among motorcyclists, pedestrians and cyclists is substantially higher, indicating the greater vulnerability for these types of travellers. In most cases, fatalities among these types of travellers involve a collision with a car or other motor vehicles. Measures which help separate vulnerable travellers from motor vehicles are likely to be positive for health.

7.6.3 The results of traffic collision analysis have informed the assessment. Significant positive health outcomes are judged likely if there is a substantial reduction in risk of serious injury and fatalities from collisions, particularly for motorcyclists, pedestrians and cyclists, whilst accessibility for these modes of travel is maintained or improved.

8 Community severance

8.1 Introduction

8.1.1 The Design Manual for Roads and Bridges (DMRB) LA 112 (Highways England, 2020) defines ‘severance’ as *‘the extent to which members of communities are able (or not able) to move around their community and access services/facilities’*. However, within transport and health literature, community severance may be applied to any one of, or a combination of, the following impacts: reduction in pedestrian access due to high traffic flows, barrier effect of physical infrastructure, changes in mobility and accessibility, reductions in social contacts, and psychological separation of neighbourhoods. The various definitions of community severance make comparisons of research difficult (Mindell and Karlsen, 2012).

8.1.2 An influential piece of research in this area was that by Appleyard and Lintell (1972) which compared three residential streets in San Francisco which did not differ on much except for levels of traffic. The 2,000 vehicles per day street was considered ‘Light Street’, the 8,000 vehicles per day street was ‘Medium Street’ and 16,000 vehicles per day passed down ‘Heavy Street’. The research showed that residents of Light Street had three times more friends and twice as many acquaintances as the people on Heavy Street. Furthermore, as traffic volume increased, the size of area people considered to be their neighbourhood reduced. Appleyard suggested that these results were related, indicating that residents on Heavy Street had fewer friends and acquaintances because people felt they had a smaller neighbourhood in which to interact socially.

8.1.3 There are various more recent studies which provide evidence that traffic speed and volume reduces levels of physical activity, social contacts, children’s play and access to goods and services. Anciaes *et al.* (2016) identify that:

- High levels and speeds of motorised traffic discourage walking (see Section 6 of this appendix for a discussion of the health impacts associated with physical activity)
- High levels and speeds of motorised traffic limit social contact between residents living on the opposite sides of roads

8.1.4 However, the research into associations between community severance and mental or physical health outcomes is limited (Mindell and Karlsen, 2012).

8.1.5 Mindell and Karlsen (2012) undertook a systematic review on community severance and health. They identify that Appleyard and Lintell's study of San Francisco showed a reduction in social contacts due to increased traffic, and that there is research which shows an inverse association between social contacts and mortality risk. However, they could not identify any studies of mortality or morbidity which have examined reductions in social contacts as a result of new roads, increased traffic volumes or traffic speeds. They conclude that 'The chain of inference for the health effects of community severance does not currently extend to direct observation. It seems inherently likely that the effects of community severance do indeed impact on health, with adverse health consequences of reduced social contacts also occurring when this social disruption is due to road traffic. Given the scale of the effect on mortality of high social integration, which is of similar magnitude to stopping smoking (Holt-Lundstad *et al.*, 2010) it is of great public health importance that research is conducted to confirm the postulated links and to establish which are the important components of community severance for health and how they can be ameliorated.' (Mindell and Karlsen, 2012).

8.2 Interpretation of health evidence for assessment

8.2.1 There are still relatively few good quality studies into the health effects of community severance. However, it is considered that the pathway between new road infrastructure and increases in speed and volume of traffic to health outcomes is plausible, given evidence for the effect of reduced social contacts on health.

8.2.2 On this basis, large increases in traffic volume or speed, or creation of physical infrastructure which may act as a barrier to pedestrian movement or use of outdoor space for social interaction, will be considered as negative for health, while large reductions in traffic volume or speed, or removal of physical infrastructure which may act as a barrier to pedestrian movement or use of outdoor space for social interaction, will be considered as positive for health. Given the lack of research on size of effect, or thresholds at which severance may occur, significant effects on health outcomes are judged likely only if changes would be widespread across the human health study area.

Acronyms and initialisms

Abbreviation	Term
µm	Micron
%HA	Percentage of the population highly annoyed
%HSD	Percentage highly sleep disturbed
ALRI	Acute Lower Respiratory Infection
AQO	Air Quality Objective
BAME	Black, Asian, and minority ethnic
BMI	Body mass index
CI	Confidence interval
COMEAP	Committee on the Medical Effects of Air Pollutants
COPD	Chronic Obstructive Pulmonary Disease
CVD	Cardiovascular disease
dB	Decibels
DMRB	Design Manual for Roads and Bridges
DfT	Department for Transport
EPA	Environmental Protection Agency
GDP	Gross Domestic Product
HRQOL	Health-Related Quality of Life
IARC	The International Agency for Research on Cancer
IHD	Ischaemic heart disease
ISA	Integrated Science Assessment
L_{den}	Day-evening-night noise level
L_{max}	Maximum noise level
L_{night}	Night noise level
NHS	National Health Service
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
OR	Odds ratio
PE	Physical education

Abbreviation	Term
PHE	Public Health England
PM	Particulate matter
PM_{10}	Particles that are less than 10 µm in diameter
$PM_{2.5}$	Particles that are less than 2.5 µm in diameter
$PM_{0.1}$	Particles that are less than 0.1 µm in diameter
PTSD	Post-traumatic stress disorder
RR	Risk ratio / relative risk
SAT	Standardised assessment tests
WHO	World Health Organization

Glossary

Term	Definition
Absolute risk	The likelihood of an event occurring under specific conditions.
Angina pectoris	Chest pain caused by reduced blood flow to the heart muscles.
Black carbon	A component of fine particulate matter (PM ≤ 2.5 µm in aerodynamic diameter). It is formed through the incomplete combustion of fossil fuels, biofuel, and biomass, and is one of the main types of particle in both human-made and naturally occurring soot.
Cross-sectional study	A type of research design where data are collected from a sample at a single point in time. It is an observational study (i.e. does not influence the variables under research).
Epidemiological	Relating to epidemiology. Epidemiology is the study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to the control of health problems.
Gestational diabetes mellitus	A condition which develops during pregnancy in which a hormone made by the placenta prevents the body from using insulin effectively.
Health related quality of life (HRQOL)	HRQOL is a measure used to summarise impacts on health from multiple domains including physical health, psychological state, level of independence and social relationships.
Lymphoid neoplasms	Types of cancer that affect the lymph and lymphatic system (part of the circulatory system and immune system).
Lymphoma	Types of blood tumour that develops from a type of white blood cell. The term is usually applied to cancerous tumours.

Term	Definition
Meta-analysis	A research process used to systematically synthesise or merge the findings of single, independent studies.
Myeloid leukaemia	An aggressive form of cancer of a type of white blood cells known as myeloid cells.
Myeloma	A type of blood cancer that develops from cells in the bone marrow.
Odds ratio (OR)	A measure of association between exposure and an outcome. The OR represents the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure.
Polysomnographic	Describing a comprehensive test process to diagnose sleep disorders. Polysomnography records brain waves, blood oxygen levels, heart rate, breathing, eye and leg movements during sleep.
Preeclampsia	A pregnancy complication characterised by high blood pressure and signs of damage to organs such as the liver and kidneys.
Relative risk / risk ratio (RR)	A measure of association between exposure and an outcome. The RR is the ratio of the probability of an outcome in an exposed group to the probability of an outcome in an unexposed group.
Synergistic effect	The result of two or more processes or substances interacting together to produce an effect that is greater than the cumulative effect that those processes or substances produce when used individually.
Systematic review	A systematic review is a summary of all of the literature on a particular topic, that meets pre-defined eligibility criteria.
Umbrella review	A review of systematic reviews or meta-analyses.

References

Anciaes, P. R. *et al.* (2016). Urban transport and community severance: Linking research and policy to link people and places. Journal of Transport and Health, 3(3), pp. 268–277. doi: 10.1016/j.jth.2016.07.006.

Appleyard D, Lintell M (1972). The environmental quality of city streets: the residents' viewpoint. Am Inst Plan J, 38(3): 84–101.

Arnberg, P. W., Bennerhult, O. and Eberhardt, J. L. (1990). Sleep disturbances caused by vibr tions from heavy road traffic. Journal of the Acoustical Society of America, 88(3).

Atkinson, Richard W. *et al.* (2018). Long-term concentrations of nitrogen dioxide and mortality. Epidemiology, 29(4), pp. 460–472. doi: 10.1097/EDE.0000000000000847.

Banay, R. F. *et al.* (2017). Residential greenness: Current perspectives on its impact on maternal health and pregnancy outcomes. International Journal of Women's Health, 9, pp. 133–144. doi: 10.2147/IJWH.S125358.

Banks, S.; Dinges, D.F. (2007). Behavioral and physiological consequences of sleep restriction. J. Clin. Sleep Med, 2007, 3, 519–528.

Barbosa, A. *et al.* (2020). Physical activity and academic achievement: An umbrella review. International Journal of Environmental Research and Public Health, 17(16), pp. 1–29. doi: 10.3390/ijerph17165972.

Basner, M. *et al.* (2014). Auditory and non-auditory effects of noise on health. The lancet, 383(9925), pp. 1325–1332.

Basner, M. and McGuire, S. (2018). WHO environmental noise guidelines for the european region: A systematic review on environmental noise and effects on sleep. International Journal of Environmental Research and Public Health, 15(3). doi: 10.3390/ijerph15030519.

Boulter, P. G. (1991). The perceived environmental impacts of traffic management schemes (a literature review). TRL report.

Cesaroni, G. *et al.* (2014). Long term exposure to ambient air pollution and incidence of acute coronary events: Prospective cohort study and meta-analysis in 11 European cohorts from the escape project. BMJ (Online), 348(January), pp. 1–16. doi: 10.1136/bmj.f7412.

Chen J., and Hoek G. (2020). Long-term exposure to PM and all-cause and cause-specific mortality: a systematic review and meta-analysis. Environ Int, 143. 105974. doi: 10.1016/j.envint.2020.105974.

Clark, C. and Paunovic, K. (2018). WHO environmental noise guidelines for the european region: A systematic review on environmental noise and cognition. International Journal of Environmental Research and Public Health, 15(2). doi: 10.3390/ijerph15020285.

Committee on the Medical Effects of Air Pollutants (2011). Review of the UK Air Quality Index. Accessed July 2023. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/304633/COMEAP_review_of_the_uk_air_quality_index.pdf.

Dai, W. *et al.* (2018). Prevalence of Posttraumatic Stress Disorder among Children and Adolescents following Road Traffic Accidents: A Meta-Analysis. Canadian Journal of Psychiatry, 63(12), pp. 798–808. doi: 10.1177/0706743718792194.

Department for Environment, Food and Rural Affairs (2021). Air Pollutant Inventories for England, Scotland, Wales, and Northern Ireland: 2005-2019. Accessed July 2023. https://naei.beis.gov.uk/reports/reports?report_id=1030.

Department for Transport (2019). Reported road casualties in Great Britain: 2019 annual report, Reported road casualties Great Britain, annual report: 2019. Accessed July 2023. https://www.gov.uk/government/statistics/reported-road-casualties-great-britain-annual-report-2019.

Department for Transport (2022). Reported road casualties in Great Britain, provisional estimates: year ending 2022. Accessed July 2023. https://www.gov.uk/government/statistics/reported-road-casualties-in-great-britain-provisional-estimates-year-ending-june-2022/reported-road-casualties-in-great-britain-provisional-estimates-year-ending-june-2022#casualties-by-road-user-type.

Dinu, M. *et al.* (2019). Active commuting and multiple health outcomes: a systematic review and meta-analysis. Sports medicine, 49(3), pp. 437–452.

Dzhambov, A. M., Dimitrova, D. D., and Dimitrakova, E. D. (2014). Association between residential greenness and birth weight: Systematic review and meta-analysis. Urban Forestry and Urban Greening, 13(4), pp. 621–629. Doi: 10.1016/j.ufug.2014.09.004.

European Commission (2017). Environmental Impact Assessment of Projects. Guidance on Scoping (Directive 2011/92/EU as amended by 2014/52/EU). Luxembourg: European Union.

European Environment Agency (2014). Noise in Europe 2014. EEA Report No. 10/2014. EEA Luxemburg. doi:10.2800/763331.

Franklin, B. A., Brook, R. and Arden Pope, C. (2015). Air Pollution and Cardiovascular Disease. Current Problems in Cardiology, 40(5), pp. 207–238. doi: https://doi.org/10.1016/j.cpcardiol.2015.01.003.

Gascon, M., Triguero-Mas, M., Martinez D., Dadvand P., Forns, J., Plasencia, A., Nieuwenhuijsen, M.J. (2015). Mental health benefits of long-term exposure to residential green and blue spaces: A sytematic review. Int. J. Environ. Res. Public Health 2015, 12, 4354-4379; doi:10.3390/ijerph120404354.

Gascon, M. *et al.* (2016). Residential green spaces and mortality: A systematic review. Environment International, 86, pp. 60–67. doi: 10.1016/j.envint.2016.10.013.

Gascon, M. *et al.* (2017). Outdoor blue spaces, human health and well-being: A systematic review of quantitative studies. International Journal of Hygiene and Environmental Health, 220(8), pp. 1207–1221. doi: 10.1016/j.ijheh.2017.08.004.

Guski, R., Schreckenberg, D. and Schuemer, R. (2017). WHO environmental noise guidelines for the European region: A systematic review on environmental noise and annoyance. International Journal of Environmental Research and Public Health, 14(12), pp. 1–39. doi: 10.3390/ijerph14121539.

Hamra, G. B. *et al.* (2014). Outdoor particulate matter exposure and lung cancer: A systematic review and meta-analysis. Environmental Health Perspectives, 122(9), pp. 906–911. doi: 10.1289/ehp.1408092.

Hamra, G. B. *et al.* (2015). Lung cancer and exposure to nitrogen dioxide and traffic: A systematic review and meta-analysis. Environmental Health Perspectives, 123(11), pp. 1107–1112. doi: 10.1289/ehp.1408882.

Hasselberg, M. *et al.* (2019). I did NOT feel like this at all before the accident: do men and women report different health and life consequences of a road traffic injury?. Injury prevention : journal of the International Society for Child and Adolescent Injury Prevention, 25(4), pp. 307–312. doi: 10.1136/injuryprev-2017-042673.

Highways England (2020). Design Manual for Roads and Bridges, LA 112 Population and human health. Revision 1.

Holt-Lunstad J, Smith TB, Layton JB (2010). Social relationships and mortality risk: a meta-analytic review. PLoS Med. 2010; 7(7): e1000316.

Houlden, V. *et al.* (2018). The relationship between greenspace and the mental wellbeing of adults: A systematic review. PLoS ONE, 13(9), p. e0203000. doi: 10.1371/journal.pone.0203000.

Huangfu, P. and Atkinson, R. (2020). Long-term exposure to NO2 and O3 and all-cause and respiratory mortality: A systematic review and meta-analysis. Environmental International, 144(October), p. 105998. doi: 10.1016/j.envint.2020.105998.

Hvidtfeldt, U. A. *et al.* (2021). Long-term low-level ambient air pollution exposure and risk of lung cancer – A pooled analysis of 7 European cohorts. Environment International, 146, p. 106249. doi: https://doi.org/10.1016/j.envint.2020.106249.

The International Agency for Research on Cancer (2015). Outdoor Air Pollution (109), IARC monographs.

Kandola, A., Ashdown-Franks, G., Stubbs, B., Osborn, D.P.J., and Hayes, J.F. (2019). The association between cardiorespiratory fitness and the incidence of common mental health disorders: A systematic review and meta-analysis. J Affect Disord. 257:748-757, 2019 10 01

Kelly, P. *et al.* (2014). Systematic review and meta-analysis of reduction in all-cause mortality from walking and cycling and shape of dose response relationship. International Journal of Behavioral Nutrition and Physical Activity, 11(1), p. 132. doi: 10.5167/uzh-102567.

van Kempen, E. *et al.* (2018). WHO environmental noise guidelines for the European region: A systematic review on environmental noise and cardiovascular and metabolic effects: A summary. International Journal of Environmental Research and Public Health, 15(2), pp. 1–59. doi: 10.3390/ijerph15020379.

Khreis, H. *et al.* (2017). Exposure to traffic-related air pollution and risk of development of childhood asthma: A systematic review and meta-analysis. Environment International, 100, pp. 1–31. doi: 10.1016/j.envint.2016.11.012.

Kivimäki, M. *et al.* (2019). Physical inactivity, cardiometabolic disease, and risk of dementia: an individual-participant meta-analysis. bmj, 365.

Knol, A. B. *et al.* (2009). Expert elicitation on ultrafine particles: likelihood of health effects and causal pathways. Particle and fibre toxicology 6(1), pp. 19-19. doi: 10.1186/1743-8977-6-19.

Kovacevic, J. *et al.* (2020). Predictors of Mental Health Outcomes in Road Traffic Accident Survivors. Journal of Clinical Medicine, 9(2), p. 309. doi: 10.3390/jcm9020309.

Kraus, W. E. *et al.* (2019). Physical activity, all-cause and cardiovascular mortality, and cardiovascular disease. Medicine and science in sports and exercise, 51(6), p. 1270.

Kreyling, W.G., Semmler, M., and Moller, W. (2004). Dosimetry and toxicology of ultrafine particles. J Aerosol Med 2004, 17:140-52.

Krzyżanowski, M., Kuna-Dibbert, B. and Schneider, J. (2005). Health effects of transport-related air pollution. WHO Regional Office Europe.

Lachowycz, K. and Jones, A. P. (2011). Greenspace and obesity: A systematic review of the evidence. Obesity Reviews, 12(5), pp. 183–189. Doi: 10.1111/j.1467-789X.2010.00827.x.

Laflamme, L., Hasselberg, M. and Burrows, S. (2010). 20 Years of Research on Socioeconomic Inequality and Children's—Unintentional Injuries Understanding the Cause-Specific Evidence at Hand. International Journal of Pediatrics. Edited by M. D. Dowd, 2010, p. 819687. Doi: 10.1155/2010/819687.

Lin, W. *et al.* (2018). Prevalence of posttraumatic stress disorder among road traffic accident survivors. Medicine (United States), 97(3), pp. 1–7. doi: 10.1097/MD.0000000000009693.

Liu, L. *et al.* (2016). Leisure time physical activity and cancer risk: Evaluation of the WHO' s recommendation based on 126 high-quality epidemiological studies. British Journal of Sports Medicine, 50(6), pp. 372–378. doi: 10.1136/bjsports-2015-094728.

Marmot, M. and Bell, R. (2012). Fair society, healthy lives (Full report). Public Health, 126(SUPPL.1), pp. S4–S10.

Marques, A., Peralta, M., Henriques-Neto, D., Frasquilho, D., Rubio Gouveira, E.,

Gomez-Baya, D. (2020). Active Commuting and Depression Symptoms in Adults: A Systematic Review. Int J Environ Res Public Health. 17(3), 2020 02 06.

McCormick, R. (2017). Does Access to Green Space Impact the Mental Well-being of Children: A Systematic Review. Journal of Pediatric Nursing, 37, pp. 3–7. doi: https://doi.org/10.1016/j.pedn.2017.08.027.

Mehta, S. and Ameratunga, S. N. (2012). Prevalence of post-traumatic stress disorder among children and adolescents who survive road traffic crashes: A systematic review of the international literature. Journal of Paediatrics and Child Health, 48(10), pp. 876–885. doi: 10.1111/j.1440-1754.2011.02076.x.

Mindell J S and Karlsen S (2012). Community Severance and Health: What Do We Actually Know? Journal of Urban Health: Bulletin of the New York Academy of Medicine, Vol. 89, No. 2. doi:10.1007/s11524-011-9637-7.

Moore, S. C. *et al.* (2016). Association of Leisure-Time Physical Activity With Risk of 26 Types of Cancer in 1.44 Million Adults. 20850(6), pp. 816–825. doi: 10.1001/jamainternmed.2016.1548.

Muzet, A. (2007). Environmental noise, sleep and health. Sleep Medicine Reviews, 11(2), pp. 135–142. doi: 10.1016/j.smrv.2006.09.001.

Newby, D. E. *et al.* (2015). Expert position paper on air pollution and cardiovascular disease. European Heart Journal, 36(2), pp. 83–93. doi: 10.1093/eurheartj/ehu458.

Nhac-Vu, H. T. *et al.* (2014). Prognosis of Outcome in Adult Survivors of Road Accidents in France: One-Year Follow-Up in the ESPARR Cohort. Traffic Injury Prevention, 15(2), pp. 138–147. doi: 10.1080/15389588.2013.804180.

Nieuwenhuijsen, M.J., Ristovska, G., and Dadvand, P. (2017). WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Adverse Birth Outcomes. Int J Environ Res Public Health. 2017 Oct 19;14(10):1252. doi: 10.3390/ijerph14101252. PMID: 29048350; PMCID: PMC5664753.

Orellano, P., Reynoso, R., Quaranta, N., Bardach, A., and Ciapponi, A. (2020). Short-term exposure to particulate matter (PM10 and PM2.5), nitrogen dioxide (NO2), and ozone (O3) and all-cause and cause-specific mortality: Systematic review and meta-analysis, Environment International, Volume 142, 2020, 105876, ISSN 0160-4120, https://doi.org/10.1016/j.envint.2020.105876.

Orellano, P. *et al.* (2017). Effect of outdoor air pollution on asthma exacerbations in children and adults: Systematic review and multilevel meta-analysis. PLOS ONE, 12(3), p. e0174050.

Ouis, D. (2001). Annoyance from road traffic noise: a review. J Environ Psychol. 21:101–20. Referenced in WHO, (2018).

Panter, J. *et al.* (2018). Using alternatives to the car and risk of all-cause, cardiovascular and cancer mortality. Heart, 104(21), pp. 1749–1755. doi: 10.1136/heartjnl-2017-312699.

Patterson, R. *et al.* (2020). Associations between commute mode and cardiovascular disease, cancer, and all-cause mortality, and cancer incidence, using linked Census data over 25 years in England and Wales: a cohort study. The Lancet Planetary Health, 4(5), pp. e186–e194. doi: 10.1016/S2542-5196(20)30079-6.

Pope CA III, Dockery DW. (1999). Epidemiology of particle effects. In: Air Pollution and Health (Holgate ST, McConnell R, Koren HS, Maynard RL, eds). San Diego, CA:Academic Press, 673–706

Pope, C. A. *et al.* (2020). Fine particulate air pollution and human mortality: 25+ years of cohort studies', Environmental Research, 183, p. 108924. doi: https://doi.org/10.1016/j.envres.2019.108924.

Public Health England (2018). Health matters: air pollution. Accessed July 2023. https://www.gov.uk/government/publications/health-matters-air-pollution/health-matters-air-pollution.

Public Health England (2020). Improving access to greenspace. A new review for 2020. p. 112. Accessed July 2023. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/904439/Improving_access_to_greenspace_2020_review.pdf.

Raza, W. *et al.* (2020). Health benefits of leisure time and commuting physical activity: A meta-analysis of effects on morbidity. Journal of Transport and Health, 18(June), p. 100873. doi: 10.1016/j.jth.2020.100873.

de Rezende, L. F. M. *et al.* (2018). Physical activity and cancer: an umbrella review of the literature including 22 major anatomical sites and 770 000 cancer cases. British journal of sports medicine, 52(13), pp. 826–833.

Rissanen, R. *et al.* (2020). Quality of life following road traffic injury: the impact of age and gender. Quality of Life Research, 29(6), pp. 1587–1596. doi: 10.1007/s11136-020-02427-3.

Rodriguez-Ayllon, M. *et al.* (2019). Role of Physical Activity and Sedentary Behavior in the Mental Health of Preschoolers, Children and Adolescents: A Systematic Review and Meta-Analysis. Sports Medicine, 49(9), pp. 1383–1410. doi: 10.1007/s40279-019-01099-5.

Shah, P. S. and Balkhair, T. (2011). Air pollution and birth outcomes: A systematic review. Environment International, 37(2), pp. 498–516. doi: 10.1016/j.envint.2010.10.009.

Thompson, R., Smith, R.B., Bou Karim, Y., Shen, C., Drummond, K., Teng, C., and Toledano, M.B. (2022). Noise pollution and human cognition: An updated systematic review and meta-analysis of recent evidence. Environ Int. 2022 Jan;158:106905. doi: 10.1016/j.envint.2021.106905. Epub 2021 Oct 12. PMID: 34649047.

Turner, M. C. *et al.* (2020). Outdoor air pollution and cancer: An overview of the current evidence and public health recommendations. CA: A Cancer Journal for Clinicians, 0(0), pp. 1–20. doi: 10.3322/caac.21632.

Twohig-Bennett, C. and Jones, A. (2018). The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. Environmental Research, 166 (February), pp. 628–637. doi: 10.1016/j.envres.2018.06.030.

United States Environmental Protection Agency (2019). Integrated Science Assessment (ISA) for Particulate Matter (Final Report, Dec 2019). United States Environmental Protection Agency, Washington, DC, EPA/600/R-19/188, 2019.

Watson, N.F. *et al.* (2015). Joint consensus statement of the American Academy of Sleep Medicine and Sleep Research Society on the recommended amount of sleep for a healthy adult: Methodology and discussion. Sleep 2015, 38, 1161–1183.

Whaley, P., Nieuwenhuijsen, M., Burns, J., and editors (2021). Update of the WHO global air quality guidelines: systematic reviews. Environ Int. 142. Special issue.

White, R. L. *et al.* (2017). Domain-Specific Physical Activity and Mental Health: A Meta-analysis. American Journal of Preventive Medicine, 52(5), pp. 653–666. doi: https://doi.org/10.1016/j.amepre.2016.12.008.

World Health Organization (2013). Review of evidence on health aspects of air pollution – REVIHAAP Project. Technical Report. WHO Regional Office for Europe. DK-2100 Copenhagen Ø, Denmark. Accessed July 2023. https://apps.who.int/iris/handle/10665/341712.

World Health Organization (2018). Environmental Noise Guidelines for the European Region. WHO Regional Office for Europe. Copenhagen, Denmark. Accessed July 2023. https://www.who.int/europe/publications/i/item/9789289053563.

World Health Organization (no date). Injury deaths rise in rank.

World Health Organization (no date). Road traffic injuries. Accessed July 2023. https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries.

World Health Organization (2021). WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization. Accessed July 2023. https://apps.who.int/iris/handle/10665/345329.

Xu, F. *et al.* (2020). Access to public transport and childhood obesity : A systematic review. (November 2019), pp. 1–10. doi: 10.1111/obr.12987.

Yuan, L. *et al.* (2019). Maternal fine particulate matter (PM 2.5) exposure and adverse birth outcomes: an updated systematic review based on cohort studies. Environmental Science and Pollution Research, pp. 13963–13983. doi: 10.1007/s11356-019-04644-x.

Zhan, Y. *et al.* (2020). Influence of residential greenness on adverse pregnancy outcomes: A systematic review and dose-response meta-analysis. Science of the Total Environment, 718, p. 137420. doi: 10.1016/j.scitotenv.2020.137420.

Zhang, Y. *et al.* (2020). The Association between Green Space and Adolescents' Mental Well-Being: A Systematic Review. International journal of environmental research and public health, 17(18). doi: 10.3390/ijerph17186640.

Zheng, X., Orellano, P., Lin, H., Jiang, M., and Guan, W. (2021). Short-term exposure to ozone, nitrogen dioxide, and sulphur dioxide and emergency department visits and hospital admissions due to asthma: A systematic review and meta-analysis. Environment International, Volume 150, 2021, 106435, ISSN 0160-4120, https://doi.org/10.1016/j.envint.2021.106435.