High Speed Rail: Consultation on the route from the West Midlands to Manchester, Leeds and beyond

Sustainability Statement

Appendix E6 – Noise and Vibration

A report by Temple-ERM for HS2 Ltd

TEMPLE ERM

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CONTENTS

1. INTRODUCTION

1.1.1. This report has been prepared to support the HS2 Phase Two proposed scheme for consultation Sustainability Statement (the Sustainability Statement, Volume 1), a report which describes the extent to which the Government's Proposed Scheme for HS2 Phase Two supports objectives for sustainable development. This document is a technical appendix which summarises the method for the Noise and Vibration assessment, informing the Sustainability Statement main report. The Sustainability Statement places emphasis on the key impacts only. This technical report summarises all the conclusions relating to the Noise and Vibration assessment.

1.1.2. This technical report presents the noise and vibration appraisal that has been carried out. The current strategic appraisal has primarily concentrated on operational airborne noise at residential areas. Airborne noise at other sensitive locations, construction noise, vibration and ground-borne noise have been appraised on either a qualitative basis or at commentary level. All of these matters will be considered in greater detail at the Environmental Impact Assessment (EIA) stage of the project.

2. SCOPE AND METHOD

2.1. How railway noise is assessed

2.1.1. There are a number of indices that can be used to measure noise from the operation of a railway and it is therefore important to identify which most closely correlate with people's response when exposed to that noise. The consensus of many worldwide studies, reflected in legislation, standards and guidance, is that annoyance correlates best with the measure of equivalent continuous sound level L_{Aeq}. This is the sound level, which, if kept constant over the assessment period, would give the same noise energy as is received from the fluctuating noise of, for example, a new railway.

2.1.2. Its use is widespread; for example in the assessment of eligibility for sound insulation[1] and as the basis for noise mapping under "The Environmental Noise (England) Regulations 2006".

2.1.3. In order to predict L_{Aeq} from a railway service it is necessary to sum the received noise energy from each train event in the assessment period. Therefore, to determine the total noise energy from a railway, one needs to know the type of train, type of track, train length, train speed and the number of trains over the assessment period. Also, to predict railway noise at a particular location, one also needs to take account of the distance, any screening, surrounding topography and type of ground absorption (i.e. soft or hard ground), between the receiver and the railway.

2.1.4. Appendix B (AoS Method and Alternatives) provides an explanation of the methodology used for the AoS and the rationale behind it.

2.2. Key drivers for noise standards and assessment

Noise Action Plans in England

2.2.1. The Government's (Defra) Noise Mapping in England for aircraft, road, rail and industrial noise sources was produced to help fulfil the requirements of The Environmental Noise

[1] The Noise Insulation (Railways and Other Guided Transport Systems) Regulations 1996

(England) Regulations 2006 that themselves respond to the requirements of the EU Environmental Noise Directive.

2.2.2. From the results of the mapping it was a requirement that Action Plans be drawn up to determine locations which should be a focus for improved noise management.

2.2.3. In England, Defra concluded that for railways, these "Important Areas" were those where 1% of the population are affected by the highest noise from major railways, with principal consideration given to those where the mapped noise level exceeded 73 dB L_{Aeq} for the period 06.00 – 24.00 ($L_{Aeq,18hr}$). Consistent with the mapping requirements, this was a free field noise level (no reflection effect from the building façade) for a receiver 4m above the ground.

Noise Policy Statement for England (NPSE) March 2010

2.2.4. The NPSE sets out the following Noise Policy Aims :

Through the effective management and control of environmental, neighbour and neighbourhood noise within the context of Government policy on sustainable development:

- avoid significant adverse impacts on health and quality of life;
- mitigate and minimise adverse impacts on health and quality of life; and
- where possible, contribute to the improvement of health and quality of life.

2.2.5. These Policy Aims are consistent with the AoS evaluation objectives and criteria.

National Planning Policy Framework (NPPF) March 2012

2.2.6. The NPPF sets out the Government's planning policies for England and how these are expected to be applied. It is consistent with the NPSE Policy Aims, requiring that "The planning system should contribute to and enhance the natural and local environment by ….preventing both new and existing development from contributing to ….noise pollution". It sets out a number of aims that seek to ensure noise impacts are minimised, which are also consistent with the AoS noise criteria.

2.2.7. The WebTAG noise sub-objective (see below) states that tranquillity is to be taken into account in the assessment of impact under the Landscape sub-objective and is not repeated in this noise appraisal.

Department of Transport WebTAG

2.2.8. The Department for Transport (DfT) has produced a method for a common assessment of different transport proposals ("Transport Analysis Guidance") which is particularly valuable in the context of route optioneering and selection. The noise sub-objective was updated in August 2012.

2.2.9. This method identifies notional costs against proposals based on residents "perceived willingness to pay", relative to impacts. In the case of noise this places a value on changes in noise levels in terms of a value people would be willing to pay to avoid that noise. The guidance contains tables of annoyance vs. noise level, including a table of monetary valuation, per household, for a 1 dB change in noise level as a function of base noise level. Again, this assessment uses the noise indicator L_{Aeq} measured over an 18 hour day 0600 – 2400.

3. TYPES OF TRAIN NOISE

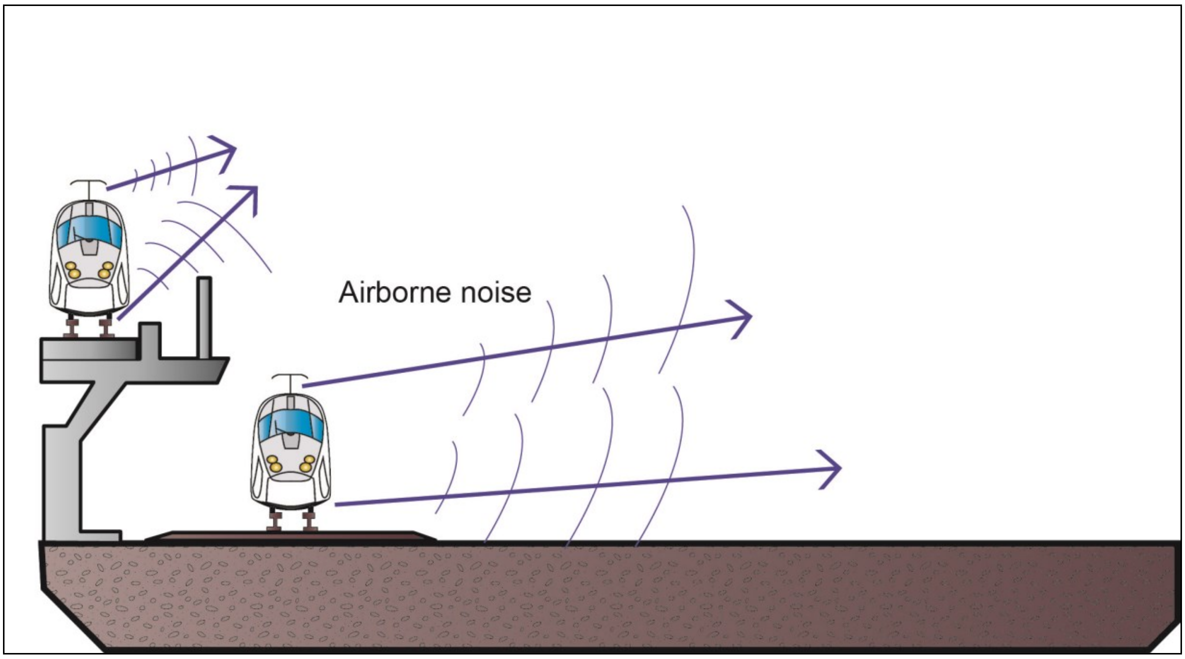
3.1. Direct airborne noise

3.1.1. Direct airborne noise includes the following:

- mechanical noise from motors, fans and ancillary equipment on the train; which tends to be the dominant source at low speeds;
- 'rolling' noise from wheels passing along the rails, which is predominant at higher speeds; and
- aerodynamic noise from general air flow around the train body and the air flow around the pantograph and wheel areas, which starts to become prevalent at the highest speeds, over 300kph

3.1.2. **Figure 3.1** illustrates typical propagation paths of airborne noise associated with railway operation as described above.

Figure 3.1 – Environmental airborne noise from railways



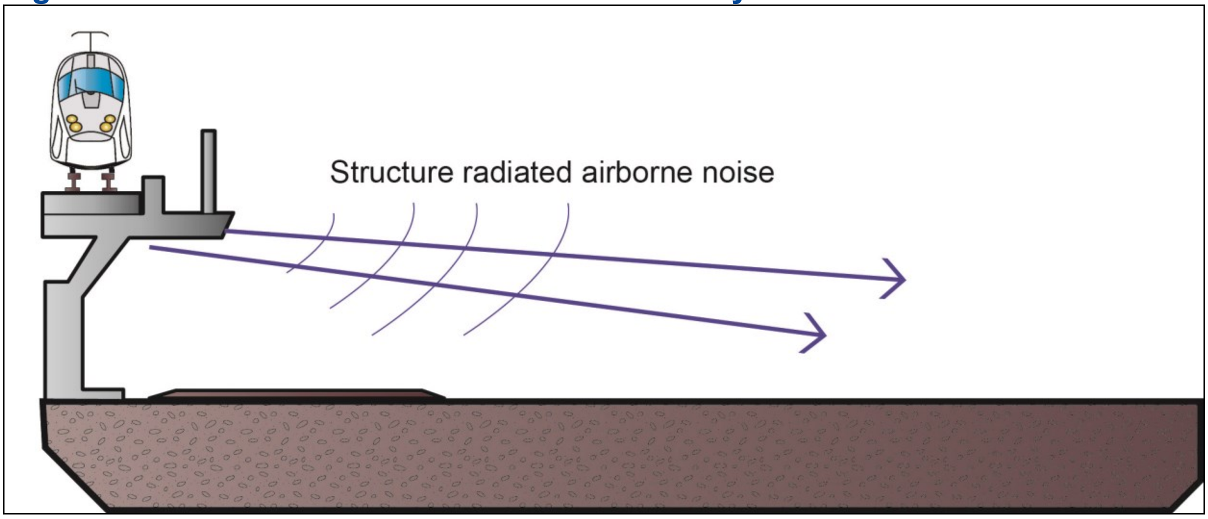
3.1.3. Airborne noise from railways can be mitigated in the following ways:

- at the source, through advanced rolling stock and track design,
- at the propagation pathway, by using barriers and earth bunds; and
- at the receptor by using noise insulation.

3.2. Structure-radiated airborne noise

3.2.1. Airborne noise also includes structure radiated noise, for example from viaducts. **Figure 3.2** illustrates typical propagation paths of structure radiated noise associated with railway operation as described above.

Figure 3.2 - Structure radiated noise from railways



3.2.2. Structure radiated noise from railways can be mitigated by damping the track structure, using resilient baseplates or resiliently supported ties.

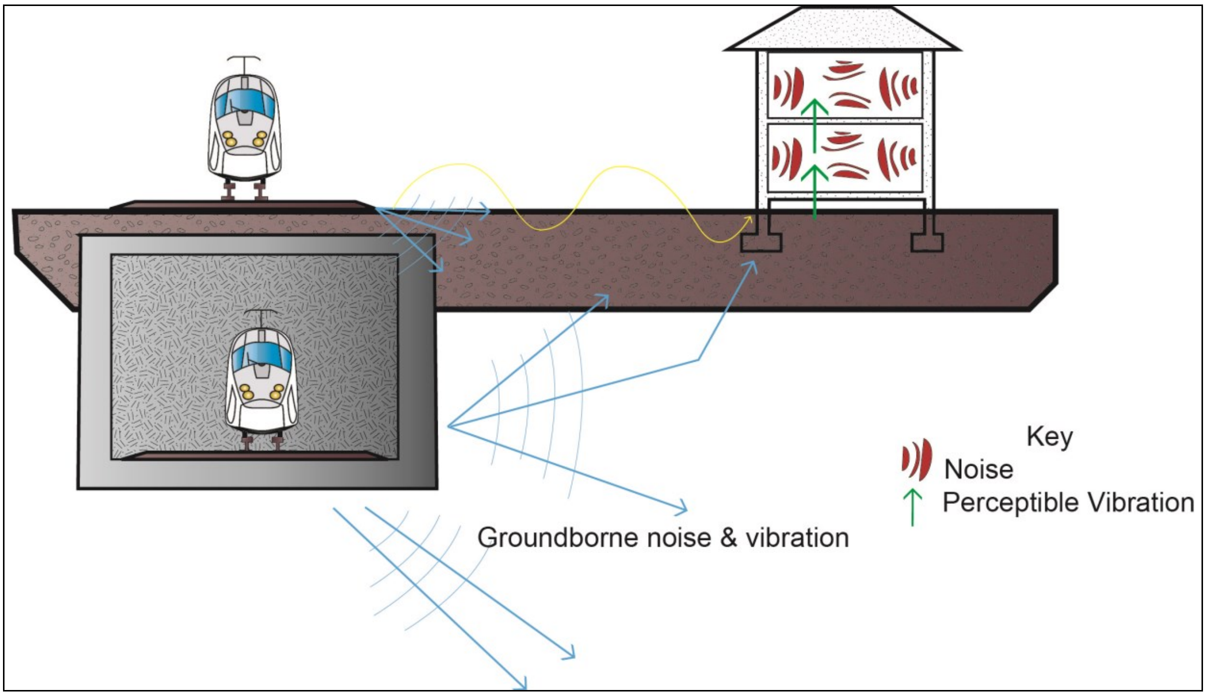
3.3. Ground-borne noise and vibration

3.3.1. Ground-borne noise and vibration consists of:

- Ground-borne vibration (tactile vibration); and
- Ground-borne noise (audible low frequency 'rumbling' sound generated inside rooms by low amplitude vibration on walls, floors and ceilings).

3.3.2. **Figure 3.3** illustrates typical propagation paths of ground-borne noise and vibration associated with railway operation as described above.

Figure 3.3- Ground-borne noise and vibration from railways



3.3.3. Ground-borne noise and vibration from railways can be mitigated by incorporating vibration isolating track forms, for example booted sleepers.

4. NOISE APPRAISAL AND THE AOS

4.1. Background

4.1.1. The approach to noise appraisal for the AoS of Phase Two followed the approach used on Phase One. This method was developed and endorsed by the HS2 noise and vibration working group, which included specialists from outside the AoS team. The working group was established to provide scrutiny, advice and direction on the application and relevance of emerging noise and vibration legislation and guidance, as well as on new research findings.

4.1.2. The noise appraisal method that was used for option development and selection was based on DfT's guidance provided in WebTAG noise sub-objective Unit 3.3.2 August 2012. In addition, a WebTAG appraisal was carried out for the proposed scheme for consultation (the proposed scheme), which is presented in Section 5.2.

4.1.3. Once the proposed scheme emerged, the appraisal criteria described in Section 4.9 were used to help inform the design process and identify the potential noise impacts at a community level. The effect of indicative additional mitigation was also appraised and this is discussed in Section 5.

4.2. Assumptions and limitations

4.2.1. Operational noise at non-residential noise sensitive receivers has not been appraised to a similar level of detail at this stage.

4.2.2. Construction noise has not been appraised as it is not appropriate at this stage of the project. However, such matters would be addressed as part of the HS2 Code of Construction Practice (CoCP).

4.2.3. Ground-borne noise and vibration have been appraised at a strategically high level to determine the potential impacts to sensitive properties (residential and non-residential) and indicative mitigation measures have been considered.

4.2.4. All potential noise and vibration impacts including construction noise, operational noise at non-residential receivers, ground-borne noise and vibration will be fully assessed at EIA stage.

4.2.5. A more detailed set of assumptions and limitations is provided at the end of this document

4.3. Computer Noise Model

4.3.1. The approach developed to perform the airborne noise appraisal of the proposed scheme includes predicting noise levels at receivers and undertaking statistical calculations of the results such as calculating the numbers of dwellings which meet the appraisal criteria.

4.3.2. The HS2 Noise Model has been developed using the CadnaA[2] noise prediction software which involves modelling a three dimensional approximation of the study area and implements the railway noise calculation methodology (Calculation of Railway Noise 1995). ArcView GIS (geographic information system) software[3] has been used to perform the statistical calculations on the resulting receiver noise levels.

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[2] CadnaA (Computer Aided Noise Abatement) software version 4.3.143 (64bit) - DataKustik GmbH.

[3] Esri ArcMap 10.1 Build 3035

4.4. Study areas

4.4.1. A study area 3km either side of the proposed scheme has been used as it is considered sufficient to encompass all areas subject to potential HS2 residential airborne noise impacts.

4.5. Modelled scenarios

4.5.1. Noise levels were predicted for both with-scheme and without-scheme scenarios.

4.5.2. The predictions of ‘with scheme’ noise impacts were carried out by calculating noise levels at receiver points representative of residential dwellings using the HS2 Noise Model. Noise sources ‘with scheme’ consisted of the proposed railway as well as existing railways.

4.5.3. The prediction of ‘without scheme’ noise impacts was carried out calculating noise levels at receiver points representative of residential dwellings using the HS2 Noise Model. Noise sources ‘without scheme’ consisted of the existing railways only.

4.6. Existing noise

4.6.1. The perception and potential effect of mixed noise (noise which contains contributions from more than one type of noise source, e.g. rail and road noise) is not easily predicted and genuine uncertainties remain on how best to assess mixed noise. This is due to the changes in the perception and potential effect of different noise sources related not only to the noise level (or ‘volume’) of the source, but also its characteristics (tonality, intermittency, etc.)

4.6.2. No baseline noise surveys have been undertaken for the AoS. Baseline noise monitoring will be undertaken as part of the EIA. However, in the absence of measured ambient noise data and due to the uncertainty described above with assessing mixed noise, predicted potential impacts have been identified based on a comparison of HS2 and other existing rail noise only, subject to a minimum value of 45dB $L_{Aeq,18hr}$ [4]. As a result the calculation of HS2 noise impacts at this stage is likely to be an over-estimate.

4.6.3. The existing rail noise levels at dwellings have been calculated within the HS2 CadnaA Noise Model. Existing railway source noise levels have been based on published Defra railway noise contour maps[5]. The Defra railway noise maps are strategic in nature, and therefore do not give accurate noise levels at specific locations. However, this was considered sufficient for the strategic level appraisal.

4.6.4. The location of existing railways within the vicinity of the study area was input to the model. The source noise level attributed to these railways was calibrated so that the noise levels they produced were reasonably consistent with those provided in the Defra railway noise contour maps.

4.6.5. Where predicted rail noise levels are low, a minimum value of 45dB $L_{Aeq,18hr}$ has been chosen and this has also been taken as the assumed level in areas where railway noise is not present.

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[4] This level is used as the cut-off for both annoyance and valuation calculations in WebTAG

[5] Department for Environment, Food and Rural Affairs: London. Noise Mapping England. [Online] Accessed on 29 June 2009 http://www.Defra.gov.uk/environment/quality/noise/mapping/index.htm

4.7. Factors affecting train noise

Overview

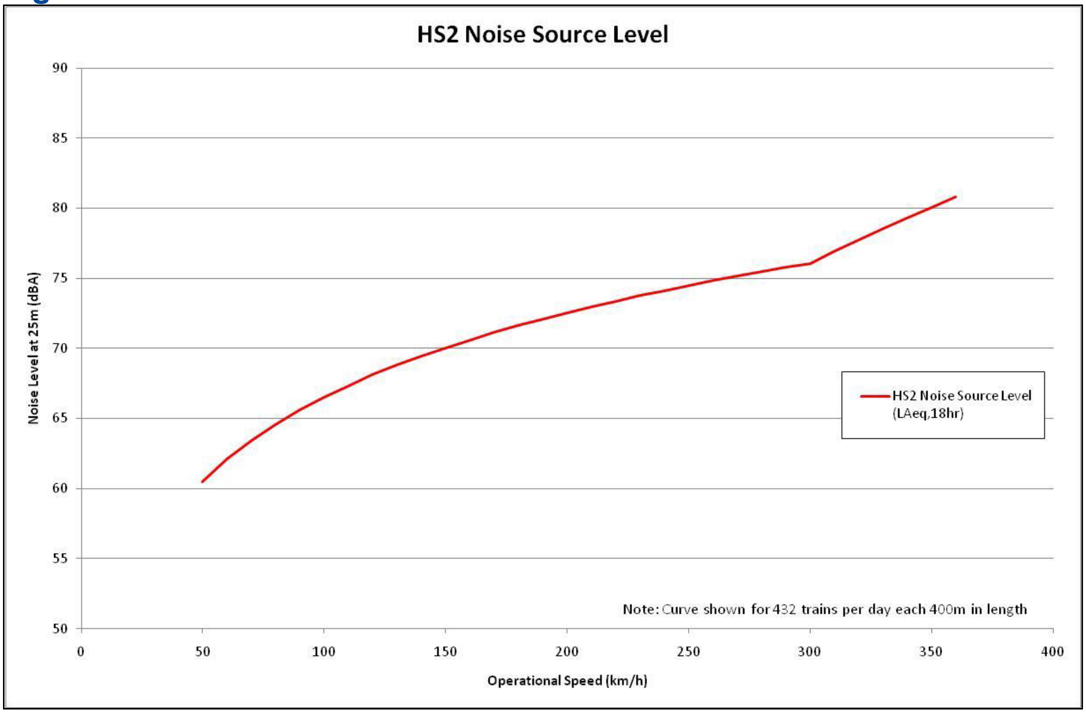
4.7.1. The HS2 source noise level used in the Noise Model relies upon:

- assumed noise levels of HS2 trains are based on the noise levels of currently operating high speed trains[6] together with noise level requirements for new trains from European specifications[7] (Technical Specification for Interoperability [TSI]);
- operating speeds for different sections of the route, as supplied by HS2 Ltd;
- the number and length of the trains;
- details on the proposed scheme alignment, including proposed embankments, cuttings, tunnels and viaducts, within the context of the surrounding landscape; and
- a defined time period.

Source noise level

4.7.2. HS2 source levels were derived using both 2008 measurement data of TGV trains at 350 km/h and high speed TSI requirements. Figure 4.1 below shows the $L_{Aeq,18hr}$[8] HS2 source noise level at 25m for various operational speeds; for a specific number of trains with no mitigation and hard flat ground.

Figure 4.1 - HS2 noise source level



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6 Gautier, P.-E., Létourneaux, F., & Poisson, F. (2007). High Speed Trains External Noise: A Review of Measurements and Source Models for the TGV Case up to 360km/h. SNCF, Innovation and Research Department, France.

7 COMMISSION DECISION of 21 February 2008 concerning a technical specification for interoperability relating to the „rolling stock" sub-system of the trans-European high-speed rail system (notified under document number C(2008) 648) (2008/232/CE).

8 The LAeq is the A-weighted sound level, which, if kept constant over the assessment period (06:00-24:00), would give the same noise energy as is received from the fluctuating noise (in this case noise from the new railway)

Operational speeds

4.7.3. Operational speed data within the HS2 Noise Model is the design speed provided by HS2 Ltd in the HS2 geospatial data (shapefiles); where design speeds are over 360km/h, a maximum of 360 km/h is used as listed in the HS2 Project Specification.

Operational service patterns

4.7.4. Operational characteristics have been provided by HS2 Ltd including the number of trains and length of trains on each route segment, and track speeds. These are provided in Table 4.1 below.

Table 4.1 – HS2 Phase Two indicative train movements

Phase Two Western Leg		Operational Year 15 (trains per period)		
Section number	**Route description**	**Total trains per direction per hour**	**Total for both directions per hour**	**Total for both directions per 18 hours**
1	Streethay Junction to Crewe Junction	11	22	396
2	Crewe Junction to South Mancunian Junction	9	18	324
3	South Mancunian Junction to Manchester Station	6	12	216
4	South Mancunian Junction to Golborne North Junction	3	6	108
5	Crewe South Junction to Crewe Junction	2	4	72
Phase Two Eastern Leg		**Operational Year 15 (trains per period)**		
Section number	**Route description**	**Total trains per direction per hour**	**Total for both directions per hour**	**Total for both directions per 18 hours**
1	Hams Hall Junction to East Midlands Interchange	10	20	360
2	East Midlands Interchange to Meadowhall Interchange	10	20	360
3	Meadowhall Station to West Riding Junction	10	20	360
4	West Riding Junction to York	4	8	144
5	West Riding Junction to Leeds	6	12	216

Route alignment

4.7.5. The HS2 proposed scheme alignment was provided as a three dimensional shapefile, the height of which is the rail head height. Only a single centreline was modelled, which was considered reasonable for the strategic level appraisal.

Noise source height of High Speed trains

4.7.6. HS2 noise predictions have used the UK modelling methodology Calculation of Railway Noise 1995 (CRN). This is the official model for assessing eligibility for sound insulation under England and Wales Noise Insulation Regulations for Railways and the model used for the HS2 Phase One AoS.

4.7.7. In its general form, this model assumes there are three possible noise source heights:

1. At the head of the nearest rail (of the relevant track); to model rolling noise and
2. At 2m or 4m above rail head:

- To model diesel locomotive power noise, the source is located 4m above the head of the nearest rail (of the relevant track); or
- For fan noise from Eurostar high speed train locomotives the source is located 2m above the head of the nearest rail (of the relevant track).

4.7.8. For very high speed rail, i.e. above 300km/h it is likely that CRN would need to be adapted to have sources at two or more heights above rail: for example rolling noise and the second for aerodynamic noise. However, the research basis for this change in calculation methodology is not currently available.

4.7.9. It was decided that some modification to the base CRN calculation should be included to account for aerodynamic noise. The best option at this stage was to retain a single noise source but alter the source height.

4.7.10. A source located 1m above the head of the near rail was used as a series of comparative calculations indicated that this gave the most consistent results when compared with SNCF[9] data for speeds in excess of 300km/h. For train speeds less than 300km/h the rolling noise source location of CRN was used (rail head height).

4.7.11. Following a review of 3m high barriers, the acoustic barrier effect, for these or higher barriers, expected from high speed rail at above 300km/h was simulated for modelling purposes by reducing the actual barrier height by 1m for calculation purposes only and retaining a source 1m above the head of the rail.

Time period of assessment

4.7.12. For consistency with WebTAG and Noise Action Plans in England, the noise from the operation of HS2 has been appraised, for the purpose of the AoS, in terms of the equivalent continuous sound level L_{Aeq} for the 18hr period from 0600 to 2400. This approach is considered appropriate due to the predominantly daytime operation of HS2[10]. Night-time noise has been qualitatively appraised in section 6.2.

4.8. Modelling the receiving environment

4.8.1. The following inputs were included in the HS2 CadnaA Noise Model to provide an adequate level of precision in the calculated noise levels.

9 Experimental study of noise barriers for high-speed trains; P. Belingard, F. Poisson, S. Bellaj (2010); IWRN10; SNCF
10 HS2 likely operating hours are 0500 to 2400

Digital terrain model

4.8.2. The existing digital terrain model is based on 5m interval contour lines extracted from ordnance survey data provided by HS2 Ltd.

4.8.3. To model the terrain changes due to the alignment of the HS2 proposed scheme, the three dimensional shapefile lines provided by HS2 Ltd (i.e. embankments, cuttings and viaducts for example) were converted to contour lines to define the ground terrain.

Built up areas

4.8.4. The effect of acoustic shielding from buildings has been approximated by calculating the noise attenuation at dwellings located in areas of densely populated buildings. The attenuation of built-up areas is based on the guidance within the ISO 9613-2 standard[11] for noise propagation with a relative height of 8m above ground level assigned to all built up areas. Other detailed built-up areas have not been incorporated into the HS2 Noise Model.

Ground absorption

4.8.5. The calculations have been carried out with a default ground absorption assuming hard ground in built up areas and soft ground elsewhere.

Receivers

4.8.6. Calculations of noise exposure have been completed at receiver locations which represent either individual dwelling address points close to the route or clusters of dwellings further from the route. All receivers are represented in the HS2 Noise Model as points located 4m above the existing ground height.

4.8.7. Within 300m of the route centreline (i.e. 600m corridor), individual address points from the postal address points data[12] provided by HS2 Ltd (this can represent more than one dwelling) were used. This was done to provide a higher level of detail to receivers near the line of route which are more noise sensitive to the precise geometry of the source-to-receiver sound propagation path.

4.8.8. To represent dwellings further than 300m from the route centreline, point receivers have been used, each representing a group of all the dwellings located in the postal address point data in a 50m square surrounding the point.

4.8.9. All airborne noise levels calculated and reported are free field (see glossary for further explanation) with the exception of those used to represent noise insulation criteria. In this case, a facade correction of 3 dB has been used to convert free field noise levels to facade noise levels.

4.8.10. Calculations have been carried out using the noise exposure results at receiver points calculated in the HS2 Noise Model, using GIS software.

Barriers

4.8.11. Barriers are included in the HS2 Noise Model as part of the calculation of the predicted noise levels due to the HS2 proposed scheme with indicative additional mitigation. Barriers have been included where an area has been identified as a Preliminary Candidate Area for Mitigation (PCAM - based on the ‘without additional mitigation’ Noise Model results) although barriers may not necessarily be employed in the final form of mitigation in any

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[11] ISO 9613-2: 1996 Attenuation of sound during propagation outdoors – Part 2 General method of calculation

[12] Dwellings extracted from 2009 ordnance survey data provided by HS2 Ltd. Dwellings likely to be demolished have been removed from all results. However, the data does not consider any future dwelling developments.

given location. Further information regarding the selection of PCAM's and barrier height is discussed below in Section 7.

4.9. Appraisal criteria

High noise levels

4.9.1. To indicate potential noise impacts associated with the proposed scheme, the number of dwellings that could potentially experience high HS2 noise levels have been reported. The proposed criterion for a high noise level exposure is defined as a free field noise level greater than or equal to 73 dB $L_{Aeq,18hr}$[13].

Noise insulation

4.9.2. The Noise Insulation (Railway) Regulations (NIRR 1996) are England and Wales legislation that applies to works on new, altered or additional railway systems such as HS2. The regulations set the daytime criterion for noise insulation of residential buildings at:

greater than or equal to 68 dB $L_{Aeq,18hr}$ at the building façade (i.e. a facade noise level);

the new altered or additional railway must make a contribution of at least 1 dB $L_{Aeq,18hr}$ to the total railway noise;

at least 1dB $L_{Aeq,18hr}$ increase in total railway noise level; and

within 300m of the new, altered or additional railway.

Noticeable noise increase

4.9.3. The noise level criteria above, i.e. High HS2 Noise Levels and Noise Insulation levels, have been identified at National level. However, neither represents an acceptable design level and should be viewed as an upper limit when no further reduction of noise is possible having regard to all reasonably practicable mitigation measures.

4.9.4. It follows that other design criteria need to be developed to inform the appraisal process and design of the railway in order to minimise the noise impacts on the local community. There is no universally accepted approach but there is general acceptance that it is appropriate to evaluate rail noise impact in terms of noise change, as evidenced by noise impact assessments on recent railway schemes e.g. HS2 Phase One, HS1 Channel Tunnel Rail Link (CTRL), West Coast Main Line (WCML) and Crossrail. This is also the approach for roads as set out in the Design Manual for Roads and Bridges. Additional criteria (referred to as "assessment criteria") will be developed at the EIA stage should the scheme be progressed, to provide further guidance on the community impacts and to inform the design process.

4.9.5. In terms of a railway noise change, 3 dB L_{Aeq} or more is generally considered a noticeable change. For the AoS, this has been taken as the difference in railway noise, with and without the presence of HS2 Phase Two; this approach is consistent with the approach taken for HS2 Phase One, HS1 (CTRL), Crossrail and WCML.

4.9.6. The World Health Organisation, in its 1999 Noise Guidelines[14] report in 2000 states "to protect the majority of people from being moderately annoyed during the daytime, the outdoor sound level should not exceed 50 dB L_{Aeq}".

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[13] This criterion for railway noise exposure has been used in the past by Defra, to identify First Priority Locations for Noise Action Planning as part of The Environmental Noise (England) Regulations 2006.

14 World Health Organisation 1999 Guidelines for Community Noise

4.9.7. This been taken as an indicator of the onset of annoyance and, therefore, a Noticeable Noise Increase for HS2 AoS purposes is defined as having a total rail noise level of greater than or equal to 50 dB L_{Aeq} 06:00 – 24:00 with an increase in rail noise of at least 3 dB L_{Aeq} 06:00 – 24:00. At receiver locations where predicted existing rail noise levels are low or there is no rail traffic (assumed at 45 dB $L_{Aeq,18hr}$), a predicted HS2 noise level of 50 dB $L_{Aeq,18hr}$ or above would result in a Noticeable Noise Increase as per this definition.

4.10. Mitigation

Preliminary mitigation

4.10.1. The development of proposed scheme has resulted in a number of changes to the route alignment to reduce environmental and community impacts. These have already been described in appendix B (AoS Process and Alternatives), but they include green bridges and new or deeper cuttings, as well as re-alignments away from certain settlements.

4.10.2. In addition, other locations were identified as candidate areas for additional mitigation (PCAM). The general approach taken has been to locate the PCAM where they would have the greatest benefit to reducing overall numbers of noise impacts and involved the following:

PCAM were typically located adjacent to 'clusters' of dwellings shown to be potentially impacted by the unmitigated noise modelling results. A cluster would normally be five or more dwellings potentially qualifying for noise insulation within 250m of the route. This is consistent with the approach taken in the Phase One AoS and for earlier schemes such as HS1.

A rigid rule for selecting clusters could miss out or include situations where mitigation could respectively be beneficial or not required. Roundtable meetings were therefore held between HS2 Ltd, Temple ERM and the engineers to review the PCAM locations in terms of feasibility and acoustic performance. The following was further considered when reviewing the PCAM:

- Additional locations may have been selected as a PCAM if there were more than five Noticeable Noise Increase (NNI) properties identified within 500m.
- An area may also have been identified as a PCAM if in the opinion of the acoustic and engineering teams, the intervening topography may not offer particularly effective noise attenuation. For example where there is little screening from built up areas, or over a valley or gravel works where there may be little ground attenuation.
- It is assumed that barriers can be installed to PCAM; i.e. that there is sufficient space alongside the route.

4.10.3. These locations have been highlighted on the Residential Airborne Noise Appraisal Maps (see **Volume 2: maps for the Appraisal of Sustainability**). Due to the strategic nature of this study, these locations should be considered as preliminary at this stage. There are likely to be a number of more detailed options that will be considered with the evolving design.

Further mitigation options

4.10.4. The consideration of mitigation at this stage of the scheme's development is necessarily strategic. The airborne noise mitigation hierarchy consists of mitigation at the source, including the rolling stock and track, before mitigation of the propagation pathway, including barriers and earth bunds. Mitigation at the receiver, including noise insulation, should only be considered for residual effects, and as a last resort.

4.10.5. To mitigate potential impacts in areas of high operating speeds, there is a need to control aerodynamic noise through advanced rolling stock design. Without first mitigating the source of aerodynamic noise, wayside noise barriers are not likely be as effective or feasible, due to the required increase in barrier height, to provide shielding to the entire train.

4.10.6. The assumptions used in the additional indicative mitigation scenario drew on the knowledge and experience of the engineers and acoustic specialists.

4.10.7. The principal assumptions used to model this scenario are set out below.

- At operation, there would be a 3 dB reduction in noise emissions at source based on the anticipated noise control improvements in the next generation of high speed rolling stock.
- Noise reduction would be equivalent to that achieved by use of 3m high[15] noise barriers (or bund) at all the preliminary candidate areas for mitigation or, at viaducts, by 2m high barriers; noise-absorbent materials would be used throughout. For the western and eastern leg respectively, approximately 70km and 100km of noise barriers have been broadly applied in the Noise Model at preliminary candidate areas for mitigation. The actual mitigation technique employed at each location may not be a barrier; and may take the form of earth bunds, barriers, building structure, or some other technical innovation and local conditions would be considered to decide which technology would be most appropriate at a later stage.

4.10.8. The way in which noise would eventually be mitigated would depend on various considerations, such as engineering feasibility and effectiveness, and may use any of the techniques set out, either independently or in combination, and these will be developed further as part of the EIA.

5. AIRBORNE NOISE APPRAISAL FINDINGS

5.1. HS2 proposed scheme airborne noise appraisal

5.1.1. **Table 5.1** shows the estimated number of dwellings potentially impacted by operational noise from the proposed scheme according to the HS2 appraisal criteria with and without additional indicative mitigation. This table should be read in conjunction with the residential airborne noise appraisal maps (Volume 2: maps for the Appraisal of Sustainability). These results are based on indicative operational service patterns for Phase Two.

[15] Barrier height quoted is the height above ground level; suitable barrier locations within the preliminary candidate areas for mitigation were chosen to give the greatest screening effect; based on the location.

Table 5.1 – HS2 Phase Two proposed scheme airborne noise appraisal findings

HS2 Phase Two proposed scheme airborne noise appraisal findings						
	High noise levels[1]		Noise Insulation Regulations[2]		Noticeable Noise Increase[3]	
	Including Additional Indicative Mitigation	Without Additional Mitigation	Including Additional Indicative Mitigation	Without Additional Mitigation	Including Additional Indicative Mitigation	Without Additional Mitigation
Western Leg	**<5**	<15	**<30**	100	**1,100**	5,800
Eastern Leg	**<15**	<70	**200**	450	**7,800**	28,100
Total*	**<20**	<85	**250**	550	**8,900**	33,900

1 Dwellings potentially exposed to high HS2 noise levels, greater than 73dB$L_{Aeq18hr}$
2 Dwellings potentially qualifying for noise insulation under the Noise Insulation Regulations
3 Dwellings potentially exposed to a Noticeable Noise Increase
*Numbers may not add up due to rounding
Estimated numbers exclude dwellings likely to be demolished.

5.2. WebTAG

5.2.1. WebTAG results for the proposed scheme with the additional indicative mitigation applied are reported in the AoS framework tables and summarised in **Table 5.2** below.

5.2.2. Given the strategic nature of the study, reported numbers have been rounded[16].

[16] See Section 11 for details of rounding methodology

Table 5.2 - HS2 Phase Two Airborne Noise Impacts from Webtag Appraisal

WebTAG appraisal of HS2 Phase Two proposed scheme							
Criteria	Description of Criteria	HS2 Phase Two Proposed scheme					
		Western Leg		Eastern Leg		Total*	
		Including Additional Indicative Mitigation	Without Additional Mitigation	Including Additional Indicative Mitigation	Without Additional Mitigation	Including Additional Indicative Mitigation	Without Additional Mitigation
WebTAG Annoyance	Change in Annoyance	**~250**	~900	**~1400**	~4400	**~1600***	~5300
WebTAG Monetary Cost	Residents "willingness to pay" for the change in noise	**£10m**	£42.5m	**£62m**	£203m	**£72m**	£245.5m
Non – Residential noise sensitive properties	Number of non-residential noise sensitive properties within 300m either side of the line of route (No. schools in brackets)	**N/A**	20 (7)	**N/A**	74 (12)	**N/A**	94 (19)

*Numbers may not add up due to rounding
Estimated numbers exclude dwellings likely to be demolished.

5.2.3. The 'change in noise annoyance' figure is assessed in WebTAG by calculating the difference in the population who would be annoyed by the predicted noise levels, comparing the 'with scheme' and 'without scheme' scenarios.

5.2.4. The monetary values are national average values per household per year at 2010 prices. These are increased in line with forecasts of GDP per household and discounted over the appraisal period to give a present value of noise, representing peoples' expected willingness to pay to avoid such effects.

5.2.5. The number of potentially impacted non-residential noise sensitive receivers has been identified by counting the number of educational, health, community and recreational properties located within 300 metres of the route centreline, which are considered to be those potentially at risk of airborne operational noise impacts. These results are also presented in **Table 5.2.**

5.2.6. The WebTAG noise sub-objective includes a methodology for the assessment of Social and Distributional Impacts (SDI) of Noise. This current assessment provides the airborne noise appraisal that can be used to input to an SDI assessment.

5.2.7. Locations identified by the WebTAG appraisal with a higher risk of HS2 operational noise impacts include[17]:

- **Western Leg**: Great Haywood, Chorlton, Lostock Green, Lostock Gralam, Hollins Green; and

[17] Further locations of residual noise impact may be identified on the noise maps; however these are predicted to receive a relatively higher change in annoyance by the WebTAG appraisal.

- **Eastern Leg**: Kingsbury, Measham, Long Eaton, Sandiacre, Stapleford, Nuthall, Poolsbrook, Netherthorpe, Woodthorpe, Mastin Moor, Renishaw, Killamarsh, Beighton, Swallownest, Woodhouse, Treeton, Tinsley, Wincobank, Blackburn, Shiregreen, Worsbrough, West Green, Cudworth, Royston, Crofton, Woodlesford.

5.2.8. With ambient noise from existing roads (motorways and A roads) also taken into account, noise impacts from HS2 would be expected to be moderately less in terms of overall change in noise level and/or the overall number of people affected.

6. OTHER POTENTIAL NOISE IMPACTS

6.1. Introduction

6.1.1. Due to the strategic nature of this appraisal, not all potential noise issues have been addressed quantitatively. This section identifies these further issues at commentary level. These issues will be assessed in detail at the EIA stage.

6.2. Night-time noise

6.2.1. The noise appraisal has identified preliminary candidate areas for mitigation. The application of this mitigation would also benefit those who may experience night noise effects since:

- It is likely that all the properties which would be identified as eligible for noise insulation under the night time noise insulation criteria within the Noise Insulation Regulations have already been identified in the AoS as being eligible under the daytime noise insulation criteria; and
- It is unlikely that any further candidate areas for mitigation would arise as a result of a night time noise assessment using a high maximum noise level (e.g. 85 dB L_{Amax}).

6.3. Stations and depots

6.3.1. The following sources of noise from HS2 stations and depots have the potential to cause impacts at sensitive locations in proximity to the proposed stations and depots:

- Passenger and maintenance trains accessing stations or depots;
- Potential wheel squeal issues at curved track;
- Fixed plant installations at stations or depots e.g. wheel lathes, CET (Controlled Emissions Tanking) units, wash plant etc;
- Mobile plant and maintenance activities not considered a constant noise source e.g. forklift trucks, hand tools etc;
- Local road traffic accessing stations and depots, and changes to local road infrastructure; and
- Public Address (PA) systems.

6.3.2. However, past experience has shown that the majority of these impacts can be avoided or minimised to a large degree through the use of effective planning/design and other noise mitigation measures.

6.3.3. During construction there could be potential for construction noise impacts depending on proximity to residential receptors as some of the work may need to be carried out during night-time and weekend possessions.

6.3.4. A qualitative assessment of potential noise impacts has been made of the proposed locations for stations and depots The findings are as follows:

Western leg

- **Manchester Piccadilly Station & Manchester Airport High Speed Station**: The potential for noise impacts is considered to be moderate. There are a number of dwellings in the vicinity; although they are exposed to existing noise sources which could reduce the impact of the new development.
- **Golborne depot & Crewe depot**: The potential for noise impacts is considered to be moderate to low as there are a limited number of dwellings in the vicinity.

Eastern leg

- **Leeds New Lane, Sheffield Meadowhall and East Midlands Hub (Toton) Stations**: The potential for noise impacts is considered to be moderate to low. There are a limited number of dwellings in the vicinity and they are exposed to existing noise sources.
- **New Crofton depot & Staveley depot**: The potential for noise impacts is considered to be moderate to low as there are a limited number of dwellings in the vicinity.

6.4. Tunnel ventilation shafts

6.4.1. Tunnel ventilation shafts (TVS) are required to provide:

- natural ventilation, which also acts as pressure relief;
- forced, mechanical ventilation, to operate during maintenance or emergency situations; and
- Access and egress for emergency services.

6.4.2. The forced ventilation system would not operate continuously but only in the event of severely disrupted operation, an emergency or testing. When the ventilation system is not operating, the main noise source from the tunnel would be associated with the passage of trains, that is pressure relief and train pass-by noise.

6.4.3. HS1 and the Jubilee Line Extension experience indicates that impacts can be avoided if vent shafts are built with appropriate mitigation. Crossrail will also feature noise-controlled vent shafts. The approach to HS2 TVS noise would adopt best practice for noise control. Past experience has shown that the majority of potential noise impacts can be avoided through the use of effective planning/design and other noise mitigation measures.

6.5. Tranquillity and Quiet Areas

6.5.1. The WebTAG noise sub-objective states that tranquillity is to be taken into account in the assessment of impact under the Landscape sub-objective. A tranquillity map has been produced by the CPRE (Campaign to Protect Rural England), and Northumbria University, where noise is one of a number of considerations. Identification of England’s Quiet Areas within agglomerations is currently under investigation by Defra.

6.5.2. A mitigation strategy that takes into account the relative importance of different factors affecting relative tranquillity, as identified in the CPRE/NU study and mapping, could help to reduce the potential impacts.

6.5.3. The Environmental Noise Regulations (England) 2006 must identify quiet areas for agglomerations. This requirement relates only to identifying Quiet Areas in large agglomerations (urban areas) and as such, do not provide any protection for quiet areas in open country or smaller populated areas.

6.6. Tunnel boom noise levels

6.6.1. For tunnelled route sections, pressure waves created as a high speed train enters a tunnel portal can result in micropressure waves that cause a boom or bursting noise at the exit of long tunnels comprising a slab track rail formation. If unmitigated, the boom noise associated with high speed rail in tunnels can create a significant environmental impact at the exit of the tunnel.

6.6.2. The Draft Environmental Statement for HS2 Phase 1 has said that *"The engineering design of tunnel portals … will … avoid any significant airborne noise effects caused by the tunnel portals."* Widening the tunnel entrance and providing a more aerodynamic noise profile of the train are the primary options for mitigation at the stage of pressure wave generation. Further ways to mitigate the propagation of the of the pressure waves within the tunnel include providing ballasted track, acoustic track absorbers, or pressure relief shafts along the length of the tunnel.

6.7. Modal shift

6.7.1. There may be the potential for some modal shift from road to rail on both HS2 and the existing rail network and the resultant shift could produce a small reduction in traffic numbers. However, it is unlikely that this effect would result in any perceived benefit in terms of reduced overall noise levels.

6.8. Secondary benefits

6.8.1. In some instances noise barriers or earth bunds may be implemented as part of a noise mitigation strategy. These also have the potential to provide acoustic screening of noise from existing roads and/or railways as has been the case with other schemes.

6.8.2. In these areas, some properties may experience a noticeable reduction in overall noise level (existing sources and HS2 combined), due to the attenuation effect of such noise barriers or bunds. The specific locations where this benefit may arise will be explored further as part of the EIA.

6.8.3. The implementation of noise insulation under the Noise Insulation Regulations at some properties may also benefit some residents who live near an existing transport corridor and are already exposed to high existing noise levels, and the implementation of such noise insulation could reduce internal noise levels from existing noise sources.

7. VIBRATION AND GROUND-BORNE NOISE

7.1. Introduction

7.1.1. Vibration and ground-borne noise is dependent upon numerous factors at the source, during ground propagation and at receivers. The design at this early stage of a development provides insufficient detail to undertake a quantitative assessment. However, substantial experience from other projects, particularly HS1, enables a robust qualitative assessment to be made.

7.1.2. Experience from HS1 and international guidance[18] suggests that, *without* any mitigation, ground-borne noise and vibration impacts from HS2 could occur up to 100m from the Manchester tunnel and up to 200m from all other tunnels, the difference reflecting the greater speed of these tunnels compared to the Manchester tunnel. However, HS1 and other international high speed rail experience suggest that potential vibration and ground-borne noise impacts could be avoided.

7.2. Approach

7.2.1. Whilst later, more detailed assessments would need to consider potential ground-borne noise and vibration impacts arising from all sections of the line, this strategic appraisal has been based on the overarching conclusion of HS1 and the majority of high-speed lines in Europe: that airborne noise is the dominant issue for surface sections of line; and ground-borne noise is the key issue for tunnelled sections.

7.2.2. Receivers considered for the vibration and ground-borne noise appraisal consisted of geo-referenced postal address point data. Both residential dwellings and a small number of non-residential noise sensitive receivers are included within this address point data.

7.2.3. Two buffer distances were used to screen potential ground-borne noise and vibration impacts. For the Manchester tunnel a buffer distance of 100m was used to assess properties potentially at risk. For all other tunnels, a buffer distance of 200m was used. The smaller buffer distance used to assess the Manchester tunnel was selected because train speeds are relatively slow in this tunnel (230km/h) compared to train speeds in all other tunnels (which run at 360km/h).

7.3. Vibration and ground-borne noise findings

7.3.1. The number of properties potentially at risk of vibration and re-radiated noise around the eastern leg tunnels is around 7,200 dwellings and 80 non-residential noise sensitive properties (including nine schools). The number of properties potentially at risk of vibration and reradiated noise around the western leg tunnels is around 980 dwellings and five non-residential noise sensitive properties (including one school).

7.3.2. An initial search has not identified any non-residential receivers considered particularly sensitive to noise and vibration, such as research and media facilities, around the proposed tunnel alignments. However, should any be identified, these locations would require further consideration as the project progresses.

7.3.3. Where properties may experience adverse effects based on the above, mitigation would first be assessed by further optimisation of the track design e.g. HS1 substantially extended the level of ground-borne noise and vibration mitigation possible for underground high speed train operations.

7.3.4. Such mitigation could avoid potential adverse effects over the tunnels. HS2 Ltd is committed to ensuring that no significant effects arise.

[18] U. S. Department of Transportation Federal Railroad Administration HMMH Report No. 293630-4:High-Speed Ground Transportation Noise and Vibration Impact Assessment (Harris Miller Miller & Hanson Inc., October 2005)

8. ASSUMPTIONS AND LIMITATIONS

8.1.1. Tables 8.1-4 set out key assumptions and limitations for the airborne noise appraisal, and should be read in conjunction with those already discussed in this chapter.

Table 8.1 - Assumptions - WebTAG airborne noise appraisal

The limited strategic level data available on 'with scheme' and 'without scheme' scenarios is sufficient to provide a plan level WebTAG appraisal of route.
Annoyance levels and monetary valuation provided in WebTAG can be used to assess noise from high speed railways.
Only Daytime 18hr (06:00-24:00 hrs) operational noise levels ($L_{Aeq,18hr}$) between 45 dB $L_{Aeq,18hr}$ and 81 dB $L_{Aeq,18hr}$ are appropriate for the WebTAG appraisal.
Change in annoyance has been based on the 'with scheme' and 'without scheme' noise levels during operational year 15.
The difference between the 'with scheme' and 'without scheme' noise levels is considered to be constant throughout the life of the 60 year appraisal period.
Dwellings located in areas with noise levels over 81 dB $L_{Aeq,18hr}$ have been considered to be relocated to an area experiencing the same noise level as the predicted existing noise level.
Monetary values have been based on 2010 data with no adjustment for income levels, property values, deprivation or demographic.
Monetary values based on operational year 15 noise levels with GDP growth and discounting applied as per WebTAG supplementary guidance.
Habituation to noise has not been considered in annoyance or monetary value calculations.
Population has been calculated as a national average of 2.36 people per dwelling.
Reported numbers of dwellings have been rounded. Generally, those in the hundreds have all been rounded to the nearest fifty, in the thousands to the nearest hundred and less than 100 have been reported as "less than". Reported monetary costs have all been rounded to the nearest half a million.

Table 8.2 - Assumptions - airborne noise source level

Existing aircraft noise has not been considered in calculations
Existing road traffic noise has not been considered in calculations
Noise levels 'without scheme' are considered to be existing railway noise levels only, subject to a minimum 45 dB(A).
Existing railway source levels have been calculated using the HS2 CadnaA Noise Model. Published Defra railway noise contour maps have been used to calibrate existing railway source noise levels for use in the model.
Noise levels 'with scheme' are considered to be existing railway noise levels combined logarithmically with future HS2 noise levels
HS2 source levels have been based on TGV measured data up to 360 km/h and further extrapolated to higher speeds.
Aerodynamic noise contribution starts to influence overall levels at 300 km/h
Maximum operational speed for HS2 is 360 km/h.
Operational characteristics such as service patterns, train length and design speed were provided by HS2 Ltd. with peak periods considered to be 07:00 to 10:00 and 16:00 to 19:00.
Speed used to calculate HS2 sources noise level is 360 km/h where design speed is above 360 km/h and design speed where design speed is below 360 km/h
3dB reduction in HS2 source noise level for the mitigated scenario irrespective of speed or numbers of trains*

*this assumption is only valid for the proposed scheme with additional indicative mitigation

TEMPLE ERM

Table 8.3 - Assumptions - Airborne Noise Model

HS2 and existing rail receiver noise levels have been calculated using CRN prediction methods combined with ISO 9613-2 prediction methods for shielding from buildings
Shielding from residential and commercial buildings has been approximated by built up areas (8m relative height at edges) using ISO 9613-2 prediction methods with an attenuation of 15dB per 100m.
Receiver heights have been set at 4m relative to ground.
Dwellings within 300m of route centreline have been spatially located from postal address point data.
All dwellings outside of 300m from route centreline have been spatially located from postal address point data and grouped to 50m x 50m grid squares.
Estimated numbers exclude dwellings likely to be demolished.
3D route alignment shapefile provided has been modelled as 3D
3D earthworks shapefile (cuttings and embankments) provided has been modelled as 3D
Existing Digital terrain model is based on 5m ground contours.
Built up areas assumed to be hard ground; elsewhere assumed to be soft ground.
Barrier locations within the model based on preliminary candidate areas for mitigation. These are groups of 5 or more dwellings which experience HS2 noise levels over 45 dB(A) within 300m of route centreline; additional areas were introduced following discussion and professional judgment.*
Indicative barriers applied as 2m barriers at the top of cuttings and embankments where speed is over 300km/h; 3m barriers where speed is below 300km/h and 2m on all viaducts. *
Source height has been assumed as 1m above rail head for speeds over 300km/ and Rail head height for speeds below 300km/h
Attenuation from barriers has been calculated using CRN method, except, where speeds are above 300kph, and barrier height is 3m, barrier height has been reduced by 1m. *

*this assumption is only valid for the proposed scheme with additional indicative mitigation

Table 8.4 - Limitations - airborne noise

Noise model accurate as a community level appraisal.
'With scheme' and 'without scheme' noise levels do not consider released capacity or future changes to traffic volumes of road or rail.
Noise levels do not consider stationary environmental noise sources (eg, industrial, commercial sources).
Noise bands or intermediate WebTAG tabulation have been prepared. Calculations have been applied directly to receiver noise levels using GIS software.
The influence of detailed variations in ground attenuation and meteorological conditions are not considered in sound propagation.
The feasibility of additional indicative mitigation options has only been examined at a strategic level.
Limited research available on dose response relationship of high speed rail noise. The appraisal, therefore has assumed a traditional railway dose response.
No site surveys or baseline surveys have been carried out at the time of the noise appraisal.

Glossary

Aerodynamic Noise	Acoustic noise caused by turbulent airflow over the surface of the train body, pantograph and bogie areas..
Defra Noise Maps	Noise maps produced by Defra to meet the requirements of the Environmental Noise (England) Regulations 2006, and are intended to inform the production of noise action plans for large urban areas, major transport sources, and significant industrial sites in England.
dB	Decibel. The unit used to describe the magnitude of sound. The decibel scale is logarithmic and it ascribes equal values to proportional changes in sound pressure.
dBA	The unit of sound pressure level, weighted according to the A scale, which takes into account the increased sensitivity of the human ear at some frequencies.
Free Field	An environment in which there are no sound reflections other than from the ground. A façade correction of 3 dB is commonly used to convert free field noise levels to façade noise levels.
HGV	Heavy Goods Vehicle (a lorry/ truck weighing more than 3.5 tonnes)
$L_{Aeq,18h}$	The A-weighted equivalent continuous sounds pressure level over the 18 hour daytime period (06:00 to 24:00).
$L_{Aeq,Tp}$	The A-weighted equivalent continuous sounds pressure level of a train passbynormalised to the passby duration (buffer to buffer).
L_{den}	The day, evening, night level, L_{den} is a logarithmic composite of the L_{day}, $L_{evening}$, and L_{night} levels but with 5 dBA being added to the $L_{evening}$ value and 10 dBA being added to the L_{night} value
PCAM	Preliminary Candidate Area for Mitigation. Areas where additional mitigation, such as noise barriers or earth bunds, would potentially have the greatest benefit to reducing the overall number of noise impacts. For the purposes of modelling the scheme 'including additional indicative mitigation' it has been assumed that mitigation at these locations would achieve a noise reduction equivalent to that achieved by use of 3m high noise barriers (or bund) or, at viaducts, by 2m high barriers with noise-absorbent materials used throughout.