Noise Demonstration Report - West Ruislip Portal S2

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Contents

1 Introduction

1.1.1 This report describes the design of the proposed noise mitigation and presents the results of the operational noise predictions assessment for High Speed 2 railway in the London Borough of Hillingdon for the section of railway between the new West Ruislip Portal and Harvil Road.

1.1.2 While the scope of the West Ruislip Portal Schedule 17 application only covers the area from the very western edge of the Northolt Tunnels (West Ruislip Portal) through to a point just before the proposed River Pinn Bridge, it is necessary, in calculation and modelling, to consider operational noise over a longer section of the route to better understand the cumulative effects. Therefore, assumptions about the broader geographical area (up to Harvil Road) have been made for the operational noise assessment, including rail alignment and landscapes.

1.1.3 The purpose of this report is to demonstrate that noise from operational railway has been reduced 'as far as reasonably practicable' and that the assurances relating to railway noise have been satisfied.

1.1.4 Several options have been evaluated against a range of criteria including the acoustic effects; landscape and visual effects; engineering practicability and value for money. The options assessed can be found in the table in 3.1.11, while the results are summarised in Section 6. The preferred option has been selected on the basis that it reduces noise as far as reasonably practicable and represents the optimum balance between maximising the acoustic benefits, whilst minimising visual impacts.

1.1.5 An assessment has also been made for the ground-borne vibration, and noise emissions from stationary systems.

2 Policy, requirements and standards

2.1.1 Paragraph 7.5.2 of the Planning Memorandum states that when submitting designs for approval under Schedule 17 the nominated undertaker:

2.1.2 *'shall, where reasonably necessary for the proper consideration of the design proposed, provide an indication or outline of the appropriate mitigation measures (if any) which it intends to submit subsequently under paragraphs 9 or 12 of the Planning Conditions Schedule. Where works for approval will have a mitigating effect in relation to the operational noise from the railway or new roads, the nominated undertaker will provide information to show, so far as is reasonably practicable at that stage in the design process, how the noise mitigation performs and the expected conditions. While not material to approvals under paragraph 2 or 3 this information will provide re-assurance in advance of the request for approval under paragraph 9 that the mitigation is appropriate and will present an opportunity to raise concerns.'*

2.1.3 This report provides assurances of the requirements in Planning Forum Note 10. Sections 3.1.5 to 3.1.11 provide information on the requirements and performance of noise barriers as described in Planning Forum Notes 10 and 14. They are included as part of a request for approval of plans & specifications of West Ruislip Portal under Schedule 17 to the HS2 Act design for the West Ruislip Portal.

2.1.4 The report demonstrates how the proposed noise mitigation design performs against the HS2 Environmental Minimum Requirements (specifically Information papers E20, E21 and E22).

2.1.5 When seeking Bringing Into Use approvals in relation to the relevant scheduled works under Schedule 17(9), an update to this report will be provided to the Local Planning Authority in order to assist it in determining whether there are any reasonably practicable measures which need to be taken for the purposes of mitigating the effect of the work or its operation on the local environment or local amenity.

2.2 Information Papers

2.2.1 Information Paper E20 "Control of airborne noise from altered roads and the operational railway" explains the assurances relating to airborne railway noise.

2.2.2 E20 states that:

"The nominated undertaker will take all reasonable steps to design and construct altered roads, and to design, construct, operate and maintain the operational railway so that the combined airborne noise from these sources, predicted in all reasonably foreseeable circumstances, does not exceed the lowest observed adverse effect levels.

Where it is not reasonably practicable to achieve this objective, the nominated undertaker will reduce airborne noise from the altered roads and the operational railway as far as is reasonably practicable.

Noise insulation will be offered with the aim that airborne noise from altered roads and the operational railway does not give rise to significant adverse effects on health and quality of life that would otherwise be expected when airborne noise exceeds the significant observed adverse effect levels.

Where possible, the nominated undertaker will also contribute to the improvement of health and quality of life through the control of airborne noise.

Effects on health and quality of life are primarily avoided and minimised through the control of airborne noise at residential dwellings. It is recognised that effects can also occur when people are engaged in noise sensitive activities away from their home. To deliver the Policy aims, reasonable steps will be taken to control airborne noise from altered roads and the operational railway to the levels for noise sensitive non-residential buildings and external amenity spaces."

2.2.3 E20 lists the following control measures:

- *"reduce noise generation at source;*

- *reduce noise generation through the design, specification, construction and maintenance of noise fence barriers and/or landscape earthworks; and*
- *reduce the amount of noise entering eligible properties through the offer of noise insulation."*

2.2.4 This report also demonstrates how the design in this area has been developed in consideration of the HS2 Environmental Minimum Requirements (EMRs) to ensure that the effects assessed in the Environmental Statement (as amended) will not be exceeded and that reasonable endeavours have been taken to adopt mitigation measures that further reduce any adverse impacts with regards to operational noise.

2.2.5 *Information Paper E21: Control of ground-borne noise and vibration from the operation of temporary and permanent railways* describes undertakings and the application of the aims set out in the Noise Policy Statement for England that relate to ground-borne noise and vibration from the operation of both the temporary and permanent railways.

2.2.6 *Information Paper E22: Control of noise from the operation of stationary systems* describes the application of the undertakings and how they relate to noise emissions from stationary systems and plant.

2.3 Surrounding Receptors

2.3.1 When assessed using the latest source terms, the Supplementary Environmental Statement (SES) and Additional Provisions 4 (AP4) ES Appendix SV-004-006 identified a significant community operational airborne effect (OSV06-C01) at approximately 70 dwellings in Ickenham at The Greenway and Hoylake Crescent.

2.3.2 SES and AP4 also identified that the research facility at Ickenham is also sensitive to airborne operational noise from railway. However, it has (August 2018) been confirmed that the research facility (MSD) will be relocated to Milton Keynes because of MSD's concerns that dust and vibration would impact their vaccination production and that HS2 requires the demolition of some of MSD's buildings. MSD's most sensitive operations have already been shut down at the Breakspear Road South site and will not return. While the Department for Transport owns the entire MSD site at the moment, there is provision for MSD to take back ownership of some of the site following completion of construction, but their sensitive operations will not return to the site. No vibration sensitive uses are expected to return to the site.

3 Description of the works

3.1.1 The surface rail section of the HS2 alignment in the West Ruislip area forms part of the western end of the S2 package of works, between the proposed Northolt Tunnels and the edge of the Colne Valley Viaduct. The works include all the surface elements from the very western end of the Northolt Tunnels (West Ruislip Portal) through to a point just before the proposed River Pinn Bridge. All the remaining S2 works from this point westwards, including the River Pinn Bridge, Breakspear Road Bridge, Gatemead Embankment and Copthall Tunnel through to Harvil Road (including the three proposed new bridges over the Chiltern Line, HS2 tracks and Newyears Green Bourne) will be the subject of a separate submission for approval under Schedule 17 of the HS2 Act.

3.1.2 The principal design elements relating to the proposed railway in the West Ruislip area for approval are illustrated in the schematic plans below.

Figure 1 - Schematic Plan of the Main Elements within the Red Line Application Boundary

3.1.3 The ES (as amended) reported a likely significant noise effect because of 19 moderate and 51 minor noise impacts due to the proposed scheme. Absorbent, vertical fence noise barriers varying in height between 3m and 5m above rail level were assumed mitigation in the ES (as amended).

3.1.4 Landscaped earth bunds were considered to mitigate noise impacts, but due to constrained site areas it was not possible to achieve the required performance. Therefore, noise barriers have been adopted as the optimal solution.

3.1.5 The noise barriers to protect Ickenham are placed immediately south of the HS2 alignment and north of the Chiltern Main Line.

3.1.6 The proposed locations and extents of the proposed noise barriers are similar to those assumed in the ES (as amended), and are as shown in Figure D1 in Appendix D.

3.1.7 Cranked noise barriers (as shown in Figures 2 and 3) are proposed for environmental reasons. The two main benefits are that:

- The cranked noise barrier helps to soften the visual appearance of the barrier at wayside receptor locations; and
- The diffracting edge of the barrier can be moved closer to the track thereby increasing the acoustic performance of the barrier by reducing the transmission of noise (E20).

3.1.8 A tall vertical face, often presented by conventional noise barriers, may seem abrupt in the context of the contours of a natural landscape and the strong horizontal of the railway corridor. By sloping the upper section of the noise barrier backwards (cranking the barrier) and creating a receding visual form, the barrier design achieves an efficient acoustic solution which is more sympathetic to its surroundings.

3.1.9 This cranked solution can be applied to noise barriers of different heights so that they share a recognisable family resemblance, whilst responding to the acoustic requirements in each location.

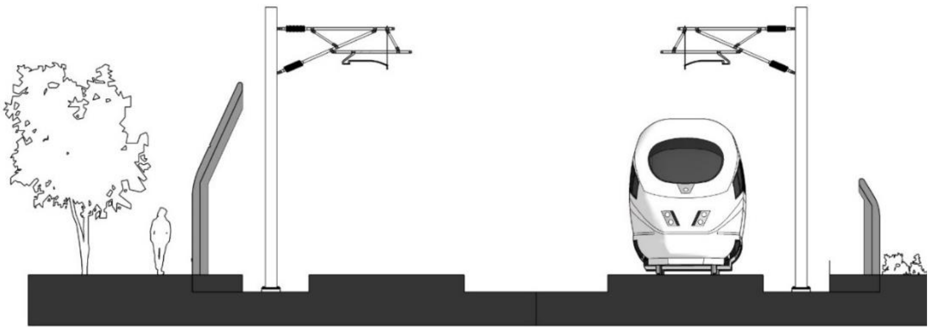


Figure 2: Cranked noise barriers showing tall barrier to the south (L) and low barrier to the north (R).

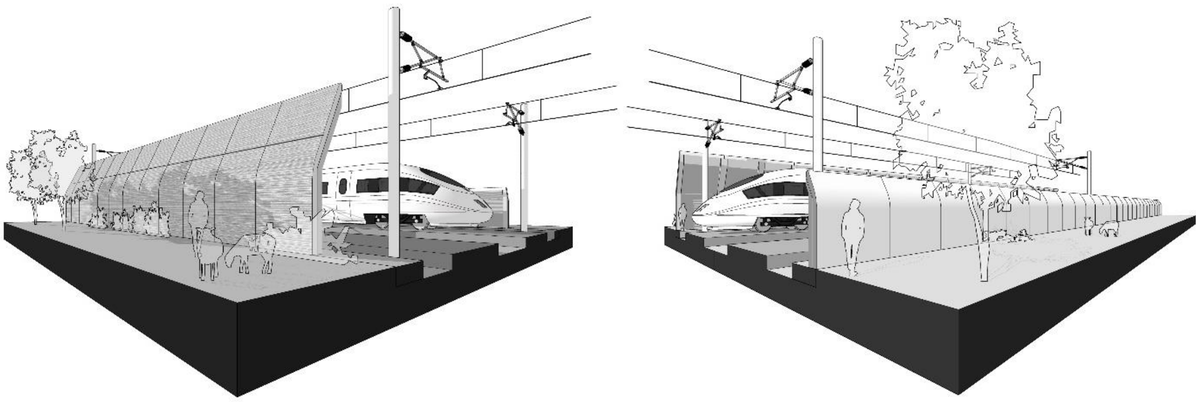


Figure 3: Views of cranked noise barriers from the south (L) and north (R).

3.1.10 The table below summarises the barrier options considered, leading to the selection of the proposed design. The proposed design is highlighted in green, and hereafter is referred to as "The Design". The change in acoustic performance, visual impact and value for money compared to the baseline ES (as amended) design and assumptions have been considered for each option. Operational practicability eliminated options with cranked barriers lower than 2.5 metres, as this would obstruct the safe walkway. Options with continuous barrier heights would ease the construction process. Stakeholder engagement and preference throughout the Schedule 17 submission will also be taken into account to ensure the "as far as reasonably practicable" criteria are met.

3.1.11 The value for money is calculated using WebTAG and the cost of barriers. The Design value for money is shown as better (B), worse (W) or neutral (N), compared to the ES.

Case	Description	Acoustic	Visual	Value for money
ES Noise Barriers **[Comparison Design]**	*S side barrier heights: 5m embankment, 4m on bridges, 3m W end. N side barrier heights: 3m. Nov 18 Assumptions.*	-	-	-
A - SCS Scheme Design	*ES design (Case c)) with changed offsets. 4m on bridges. N side: 5.2m, S side: 6.3m.*	✔✔	-	-
B - Close-In Cranked Barriers	*Cranked barriers, same heights as ES - offset from rail effectively reduced to 3.76m S side and 4.86m N side*	✔✔	✔✔	N
C - Lowered Close-In Cranked Barriers	*Cranked barriers, 0.5m reduction in barrier height on both sides from ES barrier heights (N: 2.5m, S: 4.5m).*	✖	✔✔	B
D - Raised Close-In Cranked Barriers (+1m)	*Cranked barriers, 1m increase in barrier height on both sides from ES barrier heights (N: 4m, S: 6m).*	✔✔	✖	W
E - Raised Close-In Cranked Barriers (+2m)	*Cranked barriers, 2m increase in barrier height on both sides from ES barrier heights (N: 5m, S: 7m).*	✔✔	✖✖	W
F - Lowered South Side West End Barrier	*Same heights as ES but with cranked barriers, S side barrier W end segment (~100m long) lowered from 5m to 3m.*	✔✔	-	B
G - Shortened North Side Barrier	*Same as ES design, with N side barrier W extent ending at River Pinn.*	✔	✔	N
H - Close-in Cranked South Side Barrier and lowered North Side Barrier (-0.5m), steeper crank	*Cranked barriers, N side barrier lowered to 2.5m (-0.5m), S side barrier 5m high. Offset 3.76m. Crank at steeper 29° angle.*	✔✔	✔✔	B
I - Close-in Cranked South Side Barrier and lowered North Side Barrier (-0.5m), lower crease	*Cranked barriers, N side barrier lowered to 2.5m (-0.5m), S side barrier 5m high. Offset 3.76. Crank crease lowered to 1.28m.*	✔✔	✔✔	B
J - Close-in Cranked South Side Barrier and lowered North Side Barrier (-0.5m) Offset increased for coordination with trackside walkway access. **[The Design]**	*Cranked barriers, N side barrier lowered to 2.5m (-0.5m), S side barrier 5m high. Northern offset 5.2m, Southern offset 4.01m. This option is more cost effective than H and I.*	✔✔	✔✔	B
K - Lowered North Side Barrier (-1m) **Impractical – walkway compromised**	*Cranked barriers, N side barrier lowered to 2m (-1m).*	✔✔	✔✔	B
L - Lowered North Side Barrier (-1.5m) **Impractical – walkway compromised**	*Cranked barriers, N side barrier lowered to 1.5m (-1.5m).*	✔	✔✔	B

✖✖ Materially worse *(Using EIA methodologies)*
✖ Worse
\- Neutral, N/A – no change or not applicable
✔ Beneficial
✔✔ Materially beneficial *(Using EIA methodologies)*
Value for money compared to the ES:

Case		Description	Acoustic	Visual	Value for money
B	Better				
W	Worse				
N	Neutral				

Table 1: West Ruislip Acoustic Mitigation Options Appraisal

4 Methodology

4.1 Calculation methodology

4.1.1 Appendix A sets out the technical methodology for the prediction of airborne noise from operational trains in detail.

4.1.2 The HS2 methodology requires predictions of noise emission from five discrete sources at different heights above the top of the rail to represent the sources of noise associated with High Speed Rail. The total noise emission from the train is calculated from the sum of contribution of these sources, individually corrected for propagation to the assessment location. The methodology includes corrections to account for future rolling stock being quieter than current TSI-compliant trains and to allow representation of an individual track to better allow for divergence of the up and down tracks. Two tracks have been accounted for in the calculations. The coefficients used can be found in Appendix B2.

4.2 Assessment methodology

4.2.1 In accordance with the information paper (E20) and the EIA methodology, the impact of The Design is assessed against:

- The number of residential properties exceeding the Lowest Observed Adverse Effect Level (LOAEL);
- The number of residential properties exceeding the Significant Observed Adverse Effect Level (SOAEL);
- The number of residential properties with noise impacts;
- The number of properties eligible for noise insulation; and
- The number of non-residential properties with noise impacts, although none of these are considered sensitive.

5 Assumptions

5.1.1 The assumptions for the operational airborne and ground-borne noise assessments can be seen in Appendix B of this report. These include the assumed train service patterns, track form, rolling stock noise sources and planned operational train speeds used in the assessment.

5.1.2 Passenger services will start at or after 05:00 from the terminal stations and in this area will progressively increase to the number of trains per hour in each direction on the main lines set out in Appendix B. This number of services is assumed to operate every hour from 07:00 to 21:00. The number of services will progressively decrease after 21:00 and the last service will arrive at terminal stations by 24:00.

5.1.3 Appendix B2 shows HS2 trains will be quieter than the relevant current European Union specifications. This will include reduction of aerodynamic noise from the trains that otherwise would occur above 300kph (186mph). Overall these measures would reduce noise emissions compared to a current European high speed train. These reductions are approximately 3dB at 360kph considering a TSI (current European high speed train) compliant train vs Captive train and approximately 2 dB at 360 kph considering a TSI compliant train vs Conventional Compatible train.

5.1.4 The validation of the methodology is described in Appendix A.

5.1.5 A detailed description of source terms and HS2 airborne noise prediction can be found in Appendix A.

6 Results

6.1.1 A summary of the results is presented in the tables of Appendix C. The results are also summarised below.

6.2 Airborne noise barriers (The Design)

6.2.1 The Design consists of close-in cranked barriers, where predicted levels above the LOAEL have been reduced as far as reasonably practicable, following the optioneering process in 3.1.11. These results take into account the latest track alignment and portal arrangement.

6.2.2 Summary of results for The Design:

	Observed Adverse Effect Level	Total Day	Total Night
The Design	*Number of dwellings exceeding lowest adverse effect level (LOAEL)*	102	127
ES		148	156

Table 2: Number of dwellings exceeding the LOAEL in The Design and ES.

	Major Impacts	Moderate Impacts	Minor Impacts
The Design	0	16	25
ES	0	19	51

Table 3: Number of major, moderate and minor community impacts due to The Design and ES.

6.2.3 Compared to the ES (as amended), the results of The Design indicate a reduction in the number of residential properties exceeding the day time LOAEL (46 fewer), night time LOAEL (29 fewer) and a reduction in moderate and minor impacts (3 and 26 fewer, respectively). Reductions in the number of residential properties exceeding LOAEL and impacts are mainly attributed to the cranked barrier design. Therefore, The Design will provide a material reduction in the adverse noise impacts (using EIA methodologies).

6.2.4 Tabulated predictions at all ALIDs where the LOAEL is likely to be exceeded with The Design:

ALID	Area Represented	No. of Dwellings	LAeq (dB)		LOAEL Day	LOAEL Night
			Day	Night		
401424	Harvil Road, Harefield	1	52	42	Y	Y
408811	Harvil Road, Ickenham	1	42	33	Y	Y
410569	The Greenway, Ickenham	11	55	46	Y	Y
410650	The Greenway, Ickenham	16	52	43	Y	Y
412058	Hoylake Crescent, Ickenham	11	50	40	Y	Y
413146	Bushey Road, Ickenham	17	49	40	N	Y
419116	Breakspear Road South, Ickenham	3	53	44	Y	Y
419154	Hoylake Crescent, Ickenham	25	50	41	Y	Y
419186	Hoylake Crescent, Ickenham	8	49	40	N	Y
419214	Hoylake Crescent, Ickenham	10	51	42	Y	Y
419263	Hoylake Crescent, Ickenham	11	50	41	Y	Y
419323	Breakspear Road South, Harefield	8	54	44	Y	Y
700377	The Greenway, Ickenham	5	57	48	Y	Y

Table 4: The scheme levels at each dwelling which exceeds the LOAEL in The Design.

6.2.5 While the significant community operational airborne effect OSV06-C01 remains, the scale of it has been reduced due to the cranked barrier design.

6.2.6 This report demonstrates that noise from operational railway has been reduced 'as far as reasonably practicable' and that the assurances relating to railway noise have been satisfied.

6.3 Ground-borne vibration and stationary systems

6.3.1 HS2 assurances relating to railway vibration and stationary systems will ensure that vibration from trains and stationary systems will be reduced as far as is reasonably practicable.

6.3.2 Modern railway systems are far more effective at controlling the level of vibration transmitted into the ground compared to older conventional systems. In addition, vibration will decay rapidly with increasing distance from the railway. Having regard to these various factors vibration levels arriving at nearby receptors would not be expected to give rise to any adverse effects. This is consistent with the findings of the Environmental Statement. As such, no combined railway noise and vibration effects are predicted. In other words, the predicted adverse effects from the operation of trains in this location will be dominated by airborne railway noise. For the civils works, as they relate to stationary systems, particular consideration has been given in the design to: space provision for attenuators on air-moving plant; positioning of terminations and openings to reduce sound transfer to nearby sensitive premises; sizing of systems to run at peak efficiency; massing of buildings to attenuate noise from headhouses and spatial provision for vibration isolation. These measures will help to ensure that there will be no adverse impacts from stationary systems noise.

7 Conclusion

7.1.1 This report describes the design of the proposed noise barriers and presents the results of the operational noise predictions assessment.

7.1.2 The Design has been developed using an optioneering process, where several options have been evaluated against a range of criteria including the acoustic effects; landscape and visual effects; engineering practicality and costs. This process has been used to optimise the design of the barriers and reduce the noise impacts as far as reasonably practicable.

7.1.3 All reasonable steps have been taken to minimise the predicted airborne noise from the railway, in all reasonably foreseeable circumstances. Due to The Design, the airborne railway noise exceeds the LOAEL at 102 dwellings during the day and 127 dwellings during the night. Compared to the ES, this represents an improvement of 46 dwellings exceeding the LOAEL during the day, and 29 during the night. There are no exceedances of the SOAEL.

7.1.4 The Design (close-in cranked barriers, retained at 5 metres above top-of-rail on the south side and lowered to 2.5 metres on the north side) will provide a material reduction in the adverse noise impacts compared to the ES.

7.1.5 Assessments of groundborne vibration and stationary systems noise indicate no impact.

8 Appendices

Appendix No.	Title
Appendix A	Technical Methodology
Appendix B	Assumptions for Operational Airborne Noise Assessment
Appendix C	Results of Acoustic Calculations
Appendix D	Figures

Appendix A - Technical Methodology

1 Purpose

1.1.1 This Appendix sets out the methodology to be used for the prediction of airborne noise from operational trains for HS2 S1 & S2 by the SCS Design House. Following the methodology will enable a consistent approach across HS2 Ph1.

2 Prediction of Noise from High Speed Rail

2.1.1 Between 1990 and 1994 CTRL (now HS1) had to develop a calculation methodology for the ES that was submitted in support of the project's hybrid Bill (submitted November 1994).

2.1.2 Evidence at that time, and since, showed that calculating maximum noise levels was key to the assessment of sleep disturbance for high speed rail (HSR) as well as the calculation of L_{pAeq} levels to assess changes in annoyance etc.

2.1.3 The calculation method developed for HS1 therefore calculates L_{pAFmax} as well as L_{pAeq} values. L_{pAFmax} is the maximum A-weighted sound pressure level using a sound level meter's fast time weighting, usually used to represent the peak noise level of an event, such as a passing train.

2.1.4 In 1995 the Department for Transport published the draft Calculation of Railway Noise (CRN). This presents an empirically-based method to predict noise from conventional railways to determine eligibility under the Noise Insulation (Railways and Other Guided Transport Systems) Regulations 1996. CRN was compared with the HS1 method, in terms of L_{pAeq}, and found to provide broadly similar values. HS1 therefore carried on using only its method given that firstly it was developed specifically for HSR (where as CRN is for conventional rail – albeit it with an HSR supplement) and secondly because it calculates L_{pAFmax} whereas CRN does not.

2.1.5 Noise measurements undertaken after HS1 came into operation showed that the HS1 method was appropriately precautionary. Measurements of L_{pAFmax} recorded on behalf of HS2 for latest European HSR trains further verified the HS1 method for calculating L_{pAFmax} (for an unmitigated railway at 320 km/h) out to distances of over 1km from a line (reference HS2 Phase One ES, Volume 5, Technical Appendix SV-001-000).

2.1.6

2.1.7 Research into the noise generating mechanisms of high speed trains suggests that at speeds above around 250kph the aerodynamic noise contributes significantly to the total trackside noise levels. To account for this, the methodology developed for CTRL was expanded to include these additional high speed noise sources for the assessment of HS2 Phase One. This expanded method forms the basis of the HS2 Prediction Method (reference HS2 Phase One ES, Volume 5, Technical Appendix SV-001-000).

2.2 High Speed One Prediction Method Overview

2.2.1 The Train Noise Prediction Method was originally validated against a large number high speed train noise measurements covering a broad range of scenarios, including propagation over flat ground up to distances of 800m from the railway, effects of screening (including reflective and absorptive barriers) and varying angles of view. The overall regression analyses gave a standard error, for the goodness of fit between predicated and measured levels, of approximately 3dB(A) for SEL and L_{pAFmax}. This means that the difference between predicted and measured sound levels is typically within ±3dB(A). Consistent with the Hybrid Bill Scheme the mean values levels are presented in this report.

2.2.2 A description of the methodology, which predicts $L_{Aeq,T}$ and L_{AFmax} noise levels, a presentation of the measurement results and the conclusions of the validation exercise are presented in the AEL report 'Validation of the Methodology for Calculation of High Speed Train Noise – Final Report, July 1991'. For the purpose of this Technical Note, the methodology presented in this report will be referred to as the 'HS1 method' and the report as the 'AEL report'.

2.2.3 The source measurements for the HS1 Method were made at 25m from the centre of the nearest track to determine a Sound Exposure Level (SEL) and maximum noise levels for a high speed trains at varying speed. Thousands of measurements were also made at lower speeds, increasing distances from the track (out to 800m from the line with up and down wind conditions) and in the presence of barriers to determine how speed, distance and screening affect the propagation of noise from high speed trains.

2.2.4 Flowcharts showing the application of the HS1 Method are presented in Figure A2 and A3. These flowcharts are based upon Table 17 and Table 18 of the AEL report.

2.2.5 The flowcharts illustrate that a source noise level, which has been derived from the empirical relationship between train speed and noise level at 25m from the centre of the track, is adjusted by a series of propagation corrections that depend upon the topography and distance between the source and the receptor location.

HS1 Source Level and SEL

2.2.6 The source noise level for the $L_{Aeq,T}$ calculations is a function of the sum of the SELs of all trains using the segment of railway under investigation, where each SEL is unique to each train type and speed. Similarly for L_{AmaxF} calculations, the single, highest train SEL is taken, although this L_{Amax} SEL has a different speed / level relationship to that of the $L_{Aeq,T}$ calculations. In both cases, the two tracks are modelled as a single line source at a height of 0.5m above the ground.

HS1 Sound Propagation Corrections

2.2.7 The following corrections are applied to the source noise level to account for how the noise propagates to the receptor location.

- Geometric spreading.
- Air absorption.
- Ground attenuation.

- Barriers and other screening objects.
- Terrain profile.
- Meteorological conditions.
- Visible angle of view of the railway.

2.2.8 Where barriers or other screening objects are present, the barrier attenuation and ground attenuation corrections are compared, with the higher of the two used in the calculation.

2.2.9 Meteorological conditions have been taken into account in the derivation of the propagation model. The model represents propagation under moderate, downwind (from the source to the receptor) conditions.

2.2.10 The method predicts free-field noise levels. Where an assessment location represents a façade noise level, a correction of +1.5dB for $L_{Aeq,T}$ and +2.5dB for $L_{Amax,F}$ is applied. These corrections are based on measurements.

2.3 High Speed 2 Prediction Method Overview

2.3.1 The empirical HS1 Method was based upon the measurements of high speed trains current at the time of the HS1 project. Train design, aerodynamics and top speeds have all developed significantly since then. Consequently, the HS1 Method has been updated in order to predict the noise emission of high speed trains current at the time of HS2.

2.3.2 The HS1 method was adopted for HS2 Phase One because a) the method was developed for and verified against HSR noise; and b) the method calculated L_{pAFmax} as well as L_{pAeq} values and the HS2 assessment methodologies require both indicators.

HS2 Source Level

2.3.3 Research into noise emission from high speed rolling stock indicates that the sources of noise emission change at high speed. At lower speeds up to around 250kph the total noise level is clearly dominated by noise from the wheel / rail interface ('rolling noise').

2.3.4 At speeds greater than 250kph an increasingly significant aerodynamic noise component contributes to the total emission level. To account for these aerodynamic components, a further three discrete aerodynamic noise sources ('body aerodynamic', 'pantograph well' and 'pantograph') require consideration in the HS2 Method, each with a unique SEL relationship with speed.

2.3.5 At slow speeds below 180kph, for example when a stopping service is arriving or departing from a station, the overall noise emission will include a significant contribution from the power, traction and auxiliary systems distributed across the trainset. To account for this additional source of noise at low speed the HS2 Method includes a fifth source with a negative SEL relationship with speed.

2.3.6 The HS2 Method therefore considers a total of five continuous line sources at representative heights above the ground:

- Roll noise at 0.0m (top of rail height).

- Body Aerodynamic noise at 0.5m.
- Start-up / Power noise at 2m.
- Pantograph Well noise at 4m.
- Raised Pantograph noise at 5m.

2.3.7 For each of these five sources the HS2 Method presents an SEL and L_{pAFmax} noise level relationship with speed considered representative of the rolling stock likely to be used on HS2. This method of representing rolling stock with five discrete sources is the main difference between the HS1 Method and the HS2 Method.

HS2 Sound Propagation Corrections

2.3.8 The propagation corrections in the HS1 Method were validated against measurements and are independent of the advances in rolling stock design. These well-established propagation corrections will be adopted in the HS2 method with only the source terms changing to reflect the current and future high speed rolling stock.

2.4 Sound Modelling Methods

HS1 Method Software Implementation

2.4.1 NoiseMap Ltd is presently the only supplier of environmental acoustic modelling software that implements the HS1 Method and where the implementation has been verified (first by CTRL and then by Arup).

3 The HS2 Prediction Methodology

3.1 Source Location & SEL

3.1.1 As described in Section 2.3.6, the HS2 Method requires predictions of noise emission from five discrete sources at different heights above the top of rail. Figure A1 illustrates the locations of these five sources assuming that the assessment point is away to the right of the figure.

3.1.2 The five sources represented in Figure A1 in decreasing height above top of rail are:

- Raised Pantograph
- Pantograph Well
- Start-Up / Power
- Body Aerodynamic
- Roll

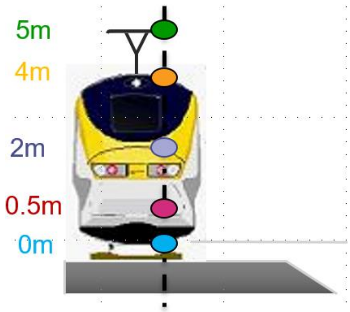


Figure A1: Location of the five sound sources of the HS2 Method relative to the nearside top of rail height

3.1.3 The HS2 Method assumes a 200m long trainset, two of which could form a 400m long trainset.

SEL Source Term Relationship with Speed

3.1.4 The following list describes the relationship of the SEL of a single TSI-compliant high speed train with speed for each of the noise sources identified in Section 2.3.6. These relationships are for a single, 200m trainset on the nearside track and represent a reasonably foreseeable worst- case scenario, where sound levels are the maximum permitted by statutory guidance. The SEL coefficients (the first number in the equation, in bold font) for HS2 trains can be found in Appendix B2.

- Raised Pantograph: **-69.3** + 60.0 $Log_{10}(V)$.
- Pantograph Well: **-69.3** + 60.0 $Log_{10}(V)$.
- Start-up / Power: **101.7** – 10.0 $Log_{10}(V)$.
- Body Aerodynamic: **-56.9** + 60.0 $Log_{10}(V)$.
- Roll: **45.1** + 20.0 $Log_{10}(V)$.

3.1.5 The equation for the Roll term above inherently assumes a ballasted track system. The form of the speed to SEL relationship is similar to the determination of SEL proposed in the HS1 Method. Notably however, the other equations all have a different $Log_{10}(V)$ gradient, with the Start-up / Power term being negative.

3.1.6 The total noise emission from the train is calculated from the sum of contribution of these sources, individually corrected for propagation (described further in Section 3.2) to the assessment location.

L_{pAFmax} Source Term Relationship with Speed

3.1.7 The list below describes the relationship between the speed and the maximum noise level for each noise source identified in Section 3.1.2. These relationships are for a single TSI-compliant trainset on the nearside track. The Roll term assumes a ballasted track system. The L_{pAFmax}

coefficients (the first number in the equation, in bold font) for HS2 trains can be found in Appendix B2.

- Raised Pantograph: **-92.3** + 70.0 Log_{10}(V).
- Pantograph Well: **-92.3** + 70.0 Log_{10}(V).
- Start-up / Power: **76.0**.
- Body Aerodynamic: **-85.5** + 70.0 Log_{10}(V).
- Roll: **16.6** + 30.0 Log_{10}(V).

3.1.8 The resultant maximum noise level from a train pass-by is calculated by comparing the sum of the Roll term, Body Aerodynamic term and Start-up term with the sum of the Roll term, Pantograph terms and Start-up term. The larger of these represents the maximum noise level.

$$L_{pAFmax} = MAX\ [\ (L_{pAFmax,\ rolling} + L_{pAFmax,\ body\ aero} + L_{pAFmax,starting})\ ,\ (L_{pAFmax,\ rolling} + L_{pAFmax\ pantograph} + L_{pAFmax,\ starting})]$$

3.1.9 This calculation is based on the assumption that the pantograph and pantograph recess are not on the leading and trailing coaches, and hence the L_{pAFmax} body aerodynamic, which normally occurs at the front of the train (nose and leading bogie) does not occur at the same time as L_{pAFmax} pantograph, which is a robust assumption for modern distributed power trains.

3.1.10 This calculation is determined at the assessment location and thus includes the corrections for propagation (described further in Section 3.2) individually for each source.

3.2 Propagation

3.2.1 The HS2 Method propagation terms are detailed in the decision trees illustrated in Figures A2 and A3.

3.2.2 For unobstructed propagation, the HS2 Method includes similar corrections to CRN, for:

- Geometric spreading.
- Air absorption.
- Ground attenuation.
- Angle of view.
- Façade correction.

3.2.3 For obstructed propagation an additional correction to evaluate the barrier performance is calculated and compared to the ground attenuation correction. The larger of the two corrections is selected to combine with the other corrections to evaluate the final noise level.

3.2.4 The majority of the above propagation terms evaluate the correction for both HS2 Method and CRN from the same geometric properties; 'mean propagation height', 'slant distance', etc. However, there are notable differences with the ground attenuation term and the angle of view.

3.2.5 In addition, in the HS2 Method, the path difference in the presence of a barrier or screening object refers to both positive and negative path differences rather than separately stating the 'zone', like in CRN.

3.3 Train Type and Future Mitigation

3.3.1 The source terms presented in Section 3.1.4 and 3.1.7 are based upon a reasonably foreseeable worst-case scenario, where sound levels are the maximum permitted by statutory guidance. The future rolling stock used for HS2 will be quieter than this worst-case assumption through improvements in aerodynamics, bogie and track design. To reflect this, further corrections are applied to the source terms to correspond to new, HS2 rolling stock and older, 'just TSI compliant' rolling stock which represents the maximum permitted by European standards. These corrections can be found in Section 3.3.4, and the HS2 SEL and L_{pAFmax} coefficients can be found in Appendix B2.

Classic Compatible ('Just TSI Compliant') Train Types

3.3.2 For trainsets that just comply with the TSI requirements the relationships established in Sections 3.1.4 and 3.1.7 apply.

3.3.3 For route sections proposed with slab track a correction of 0 dB should be applied to any terms.

Mitigated HS2 Train Assumptions

3.3.4 For future, new HS2 trainsets the following additional corrections are applied to both the SEL and L_{pAFmax} source terms:

- Raised Pantograph: - 5 dB.
- Pantograph Well: - 10 dB.
- Start-up (Power): - 3 dB.
- Body Aerodynamic: - 3 dB.
- Roll: - 3 dB.

3.3.5 For route sections proposed with slab track a correction of +2 dB should be applied to the Roll term and +4 dB to Body Aerodynamic term.

4 Modelling Individual Tracks

4.1 HS1 Dual Track Assumption

4.1.1 The AEL report noted that there was a consistent difference of 2.5dB between the measured noise levels of a train pass-by on the near side track compared to that of a far side pass-by. The AEL report offered no derivation of this phenomenon, suggesting only that the difference is significantly higher than the theory suggests and stating that further work would be required to investigate the causes of this higher than anticipated difference.

4.1.2 The measured difference of 2.5dB between the near side and far side tracks could not be reproduced accurately with a two source (separate up-line and down-line) model. Instead, the difference was accounted for by moving the source position between the up and down lines, to the alignment centreline, and creating a new source level that represents the average of the near side contribution and the near side contribution minus 2.5dB (to represent the far side track). The HS1 Method therefore adjusts the measured SEL of a train pass-by to arise from a single source line in the centre of the alignment used for predicting noise emission from both near and far side tracks at the same time.

4.2 HS2 Track Separations

4.2.1 The 2.5dB difference between the near side and far side pass-bys observed during the measurements of the HS1 Method occurred when each track was separated by a distance of 4.2m.

4.2.2 For aerodynamic reasons, the normal track separation for HS2 has increased to 5m, with only a small percent of the proposed route alignment comparable to the 4.2m separation assumption inherent in the source derivation of the HS1 Method.

4.2.3 Significantly higher proportions of the proposed alignment have track separation distances greater than 5m, including sections where the tracks separate in both the horizontal and vertical planes.

4.3 Using a Dual Track Assumption to Represent a Single Track

Adjustment to SEL

4.3.1 As the HS1 Method for $L_{Aeq,T}$ predictions has a fixed relationship between the location of the source line, the individual track positions and the near and far side sound contribution, it is straightforward to apply a correction to the HS1, 'dual source' level to represent an HS2 'single source' SEL. This correction can be applied to the HS1 source level so that the source location assumption can be effectively relocated from the centre of the alignment to the centre of the track, thus allowing the method to represent each of the parallel tracks separately.

4.3.2 The correction can be derived by comparing the theoretical SEL of an individual train type to the HS1 'dual source' SEL assumption, with the difference between these two forming the correction. For example, an SEL of 100 dB would result in a HS1 'dual source' level of 99.3 dB (comprising the average of 100.4 dB near side contribution and 97.9 dB far side contribution).

So to accurately represent a single train pass-by with SEL of 100 dB from a HS1 source line located in the centre of a single track the source noise level needs to be increased by +0.7 dB.

Adjustment to Maximum Sound Levels

4.3.3 The calculation of the maximum sound level in the HS1 Method includes an additional adjustment to account for the offset in the source line position relative to the centre of the near-side track, which is assumed to be where the highest sound level will occur.

4.3.4 As with the $L_{Aeq,T}$ source level derivation, the track separation in the HS1 maximum sound level calculation is assumed to be fixed at 4.2m. Consequently, the correction to the L_{pAFmax} used in the HS1 method will always be +0.5dB. Therefore, to assume the position of the source line will be in the centre of the nearest rail will require an additional correction of -0.5dB to the maximum noise level calculated to factor out this adjustment already inherent in the HS1 method.

4.4 Track segmentation procedure

4.4.1 To reflect the current best-practises and ensure on-going consistency with other HS2 noise predictions, the track geometry is divided down to 10m long segments.

5 Figures

Where:

T	Time period in seconds
D	Perpendicular distance to the extended track segment
d	Distance from the centre of the track segment
d'	Distance from the closes part of the track segment
H	Mean propagation height
δ	Path difference

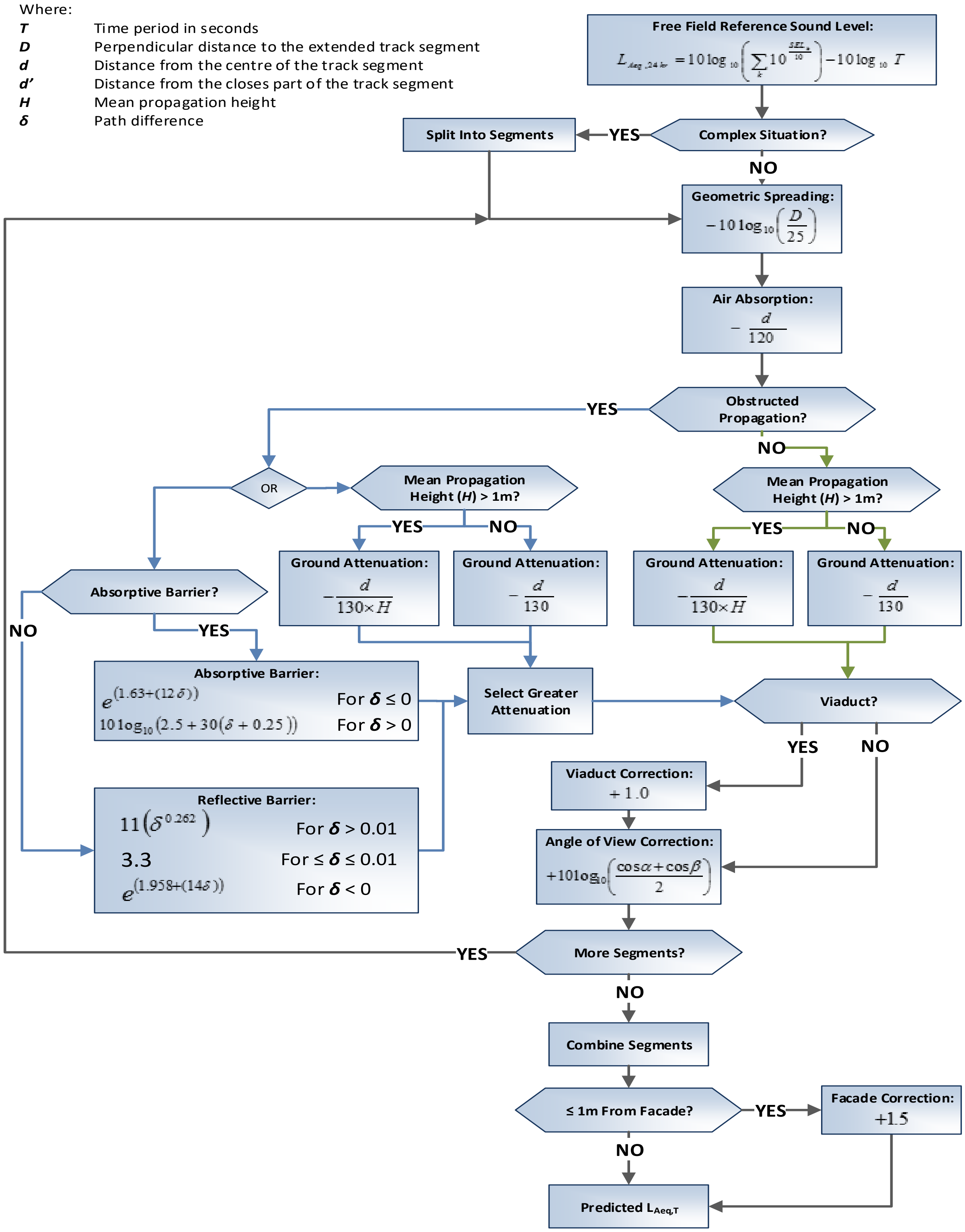


Figure A2 HS 1 Method $L_{Aeq,T}$ Sound Level Prediction Method

Where:

T	Time period in seconds
D	Perpendicular distance to the extended track segment
d	Distance from the centre of the track segment
d'	Distance from the closes part of the track segment
H	Mean propagation height
δ	Path difference

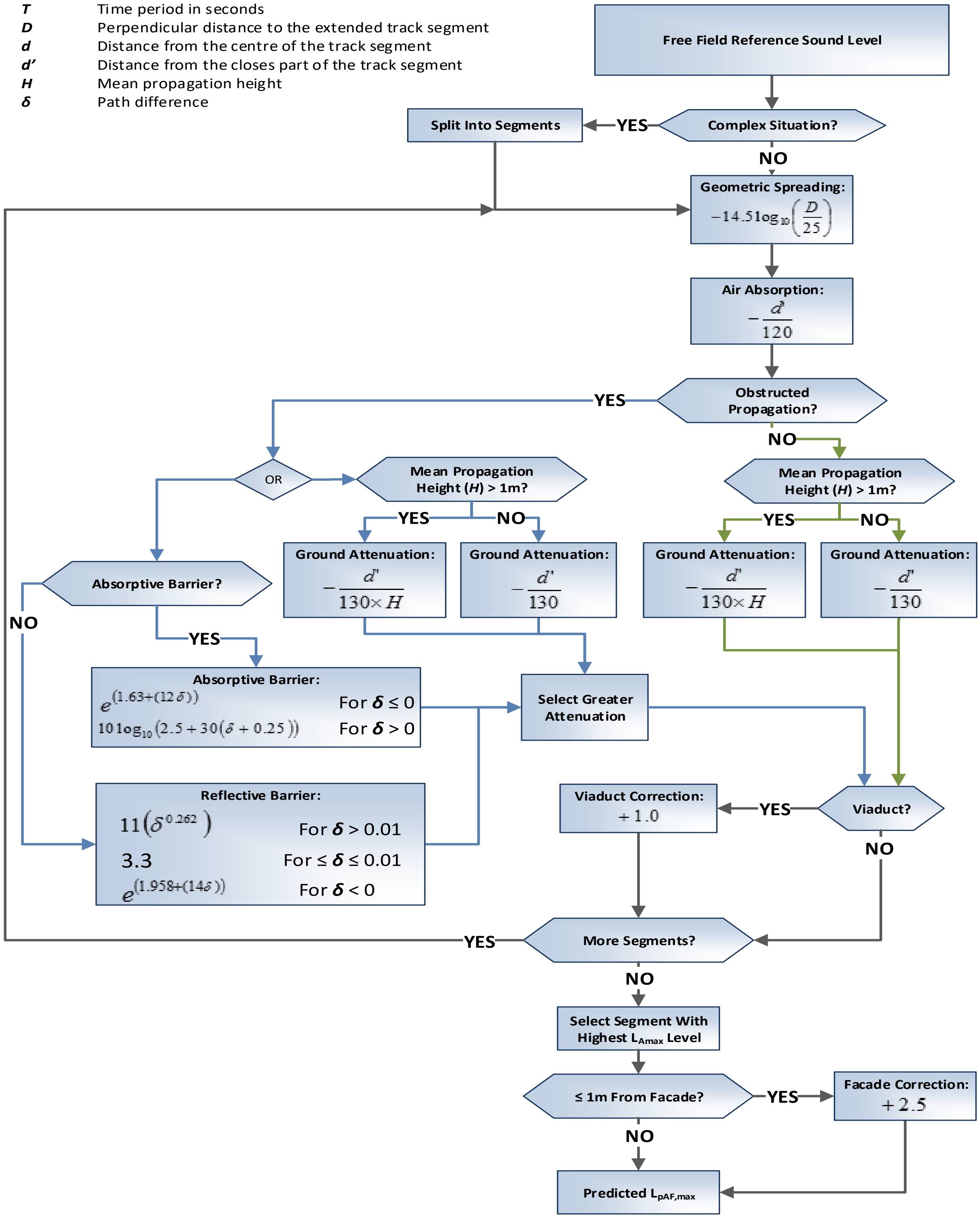


Figure A3 HS 1 Method L_{pAFmax} Sound Level Prediction Method

Appendix B - Assumptions for Operational Airborne Noise Assessment

1 Introduction

1.1.1 As part of the Scheme Design of Phase 1 Areas S1 and S2 for Skanska Costain Strabag, the operational noise and vibration assessments need to make various assumptions about the operational train flows, speeds, track form and train types across the study area.

1.1.2 The assumptions have been established having regard to the likely application of existing technology with reference to the probability of the noise occurring. This includes reference to sensitivity tests and regression analysis between predicted and measured levels set out in Appendix A of this report. Assumptions in all reasonably foreseeable circumstances are taken on a reasonable worst case. As such, under the majority of operating conditions, lower noise levels than those predicted in this assessment would be expected.

1.1.3 This document describes the input assumptions for the operational airborne noise assessment, hereby referred to as the "November 2018 assumptions".

2 Train Service Patterns

2.1.1 The effects of sound, noise and vibration are assessed for the highest train flows occurring within the first 15 years of operation. In most areas across the route this is found to occur at Operation Year 15.

2.1.2 The assumed flow variation over the day for the November 2018 assumptions can be seen in Appendix B1.

2.1.3 The mix of 200m and 400m long trains set out in Appendix B1, is based on the Train Service Specification. The two right-most columns contain the total number of daytime and night time 200m-long-equivalent trains for use in the noise modelling.

2.1.4 The flows presented are one-way flows. These flows would be assumed to apply in each direction.

3 Source terms for rolling stock and track

3.1.1 Since the ES, new source terms have been instructed by HS2 to reflect the further development work that has been carried out on the rolling stock and the track. The new train service pattern includes two train types and the "Just TSI" train has been removed from the train service pattern:

- *"Phase 1 fleet made up of Conventional Compatible (CC) train and*
- *Phase 2B fleet made up of Captive (CP) train"*

3.1.2 The assumptions related to the noise source levels of the rolling stock taken from the November 2018 Assumptions are set out in Appendix B2 of this document.

4 Train speeds

4.1.1 Speed profiles provided by the rail systems engineers during the ES – rounded up to the nearest 10 km/h – were used in the noise modelling. The speed profile with the maximum speed out of the various services using that section of line was used for noise modelling. These speeds were provided by HS2 and were also used for a calibration exercise, which was deemed acceptable.

4.1.2 No change to the train speed assumptions have been received for the "November 2018 assumptions"

5 Design Drawings

5.1.1 Input assumptions for rail alignment, barrier and all other relevant design information has been drawn from the information submitted as part of the Schedule 17 application, in particular the below, which will be added once all the submissions have been finalised:

- Track Alignment 1MC04-SCJ-RT-DM3-S002-000003
- GIS Plan 1MCO4-SCJ-RT-DMR-S002-114010-C01
- Long Sections 1MC04-SCJ-AR-DSE-SS05_SL07-122152
- Site Plan 1MC04-SCJ-AR-DGA-SS05_SL07-120121
- Cross sections 1MC04-SCJ-AR-DSE-SS05_SL07-122153

6 Modelling of porous portals

6.1.1 Porous portals (provided for the mitigation of micro-pressure waves) include portions with holes (air vents which provide pressure relief). Some airborne noise from the trains is therefore emitted from these openings – albeit at a much-reduced noise level compared to an open section of track.

6.1.2 The assumptions used for the modelling of porous portal sections in the acoustic modelling software Noisemap are set out below. These are consistent with the system-wide approach taken on Phase One. More detail will be added in the modelling of the detailed design based upon acoustics principles and working in consort with the engineers and aerodynamicists

- A -10 dB correction is applied to the track sections that fall within the portal.
- An absorptive barrier (5m above rail) is built around the porous portal openings i.e. around the top of the portal slab.
- A small gap is created between the segments of the track that fall into the porous portal and segments that are just outside the porous portal.

7 Assessment Locations

7.1.1 To undertake the Scheme Design Noise Assessment, every residential and sensitive non-residential receptor will be assessed individually. The assessment locations approach also ensures that:

- All sensitive receptors within the study areas are considered.
- All sensitive receptors are assessed on a reasonably worst-case basis.
- Sufficient calculation points are defined to appropriately account for changes in both proposed scheme noise/vibration levels and baseline sound levels.

7.1.2 Each Assessment Location is placed to represent either:

- One or a group (multi-storey building) of residential dwellings, or
- One or a group of non-residential receptors.

7.1.3 Assessment location reference numbering will be different compared to the Phase 1 ES and the number will range from 1 – 100000.

7.1.4 The study area for the operational airborne noise assessment is 1 kilometre from the Scheme alignment in rural areas and 500 metres from the scheme alignment for urban areas.

7.2 Residential Assessment Locations

7.2.1 Each assessment location shall be chosen to predict the worst-case impact for each building. The broad principles are:

7.2.2 Assessment locations shall be placed with likely variation in both HS2 scheme levels and baseline levels in mind.

7.2.3 As well as distance, sound levels drop off more rapidly when they hit dense collections of buildings. Therefore, at these locations, assessment location density may need to be higher on the 'front few rows' of buildings (where sound levels are changing more rapidly), then less dense further back.

7.3 Non-residential Assessment Locations

7.3.1 Individual assessment locations for non-residential receptors are placed individually, because receptor sensitivity is specific to each.

7.3.2 Where a building affected by noise has more than one noise sensitive receptor (e.g. dual or multiple use buildings), only the most sensitive of these will be assessed.

8 Baseline

8.1.1 The Baseline Scheme assessment will take the baseline from the Phase 1 ES, in the case that no better-quality data is received during the assessment process. Arup will apply professional judgement to assign the existing background noise levels from existing assessment location reference from the Phase 1 ES to the new Assessment Locations that surrounds them.

8.1.2 The ES baseline data was obtained from the Technical Appendices SV-002-006[1].

8.1.3 Arup are undertaking a review of existing baseline data.

1 HS2 Ltd, "London – West Midlands Environmental Statement – Volume 5 – Technical Appendices – CFA6 – Euston – South Ruislip to Ickenham – Baseline (SV-002-006) – Sound, noise and vibration" November 2013. [Online]. Available: http://webarchive.nationalarchives.gov.uk/20140613014546/http://assets.dft.gov.uk/hs2-environmental-statement/volume-5/sound/Vol5_CFA6_Sound_noise_and_vibration_Baseline_report_SV-002-006.pdf . [Accessed 23 May 2018].

9 Coordinate system

9.1.1 The SnakeGrid coordinate system was used during the modelling process.

Appendix B1 – Assumed train service pattern

November 2018 assumptions

HS2 Phase One – Year 15

The following data has been extracted from PH1-HS2-EV-MOD-000-000002 P01 – 'Phase 1 Flow Information for Acoustics Modelling' as referred to in the

November 2018 assumptions document.

NB. These train flows form the basis of the detailed sound, noise and vibration assessment only and do not represent a timetable for the Proposed Scheme	**Route Section**	**200m trains per section**	**400m trains per section**	**Total rains per section**	**Equivalent 200m trains per section**	**One-way train flow assumptions (equivalent 200m trains)** 05.30-06.00	06-07.00	Standard hour	21-22.00	22-23.00	23-00.00	Total (24hr)	**Total Day (16hr)**	**Total Night (8hr)**
London to Birmingham / The North	3	6.0	12.0	**18.0**	30.0	5	20	30	25	15	5	490	460	30
└--> Conventional Compatible (Catch-Up)	3A	1.5	0.0	**1.5**	1.5	0	1	2	1	0	0	23	22	1
└--> Conventional Compatible (330)	3B	4.5	4.0	**8.5**	12.5	2	8	13	10	6	2	203	191	12
└--> Captive (Catch-Up)	3C	0.0	0.8	**0.8**	1.5	0	1	2	1	0	0	23	22	1
└--> Captive (330)	3D	0.0	7.3	**7.3**	14.5	2	9	15	12	7	2	235	222	13

Appendix B2 – Assumed rolling noise sources

November 2018 assumptions

The following data has been extracted from the November 2018 Assumptions.

Track correction included in the rolling noise term.

Captive (CP) train on slab track

Source term	CP on slab Sound Exposure Level Coefficients *(dB)* Values for CP trains at 25m
R (Rolling)	42.1
B (Body Aerodynamic)	-59.9
S (Starting)	98.7
P (Pantograph recess)	N/A
P (Pantograph)	-74.3

Speed *(km/h)*	Equivalent A-weighted Sound Level of a Train Pass Values for 200m long CP trains at 25m $L_{Aeq,Tp}$ *(dB)*
320	90.0
350	91.9
360	92.5

Conventional Compatible (CC) train on slab track

Source term	CC on slab Sound Exposure Level Coefficients *(dB)* Values for CC trains at 25m
R (Rolling)	42.1
B (Body Aerodynamic)	-57.9
S (Starting)	98.7
P (Pantograph recess)	N/A
P (Pantograph)	-74.3

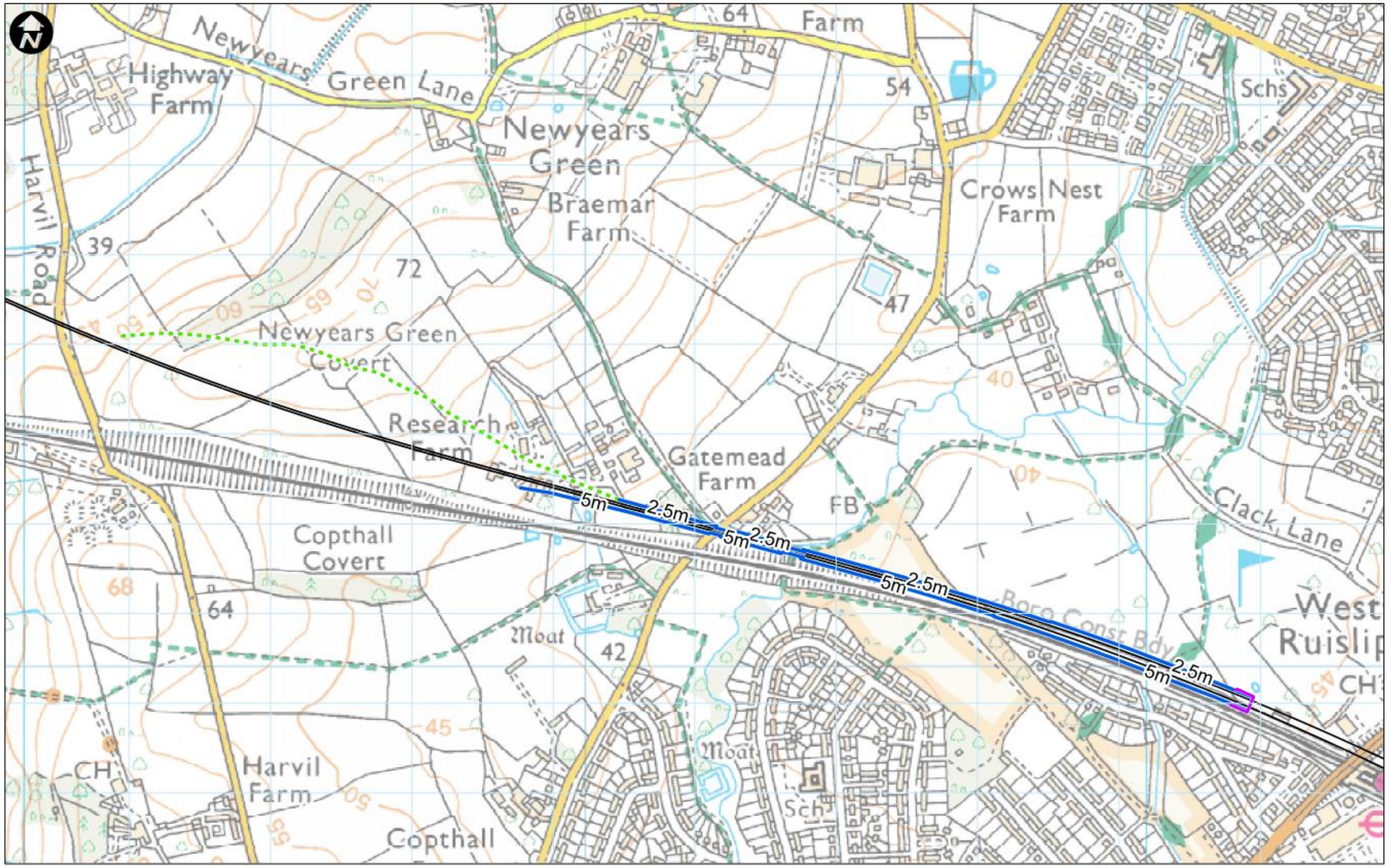
Speed *(km/h)*	**Equivalent A-weighted Sound Level of a Train Pass Values for 200m long CC trains at 25m** $L_{Aeq,Tp}$ *(dB)*
320	90.9
350	92.9
360	93.6

Appendix C: Results of Acoustic Calculations

	Number of residential properties		
	ES Mitigation and November 2018 Assumptions	**The Design***	**Comparison: ES versus The Design**
Major Impacts	0	0	0
Moderate Impacts	19	16	-3
Minor Impacts	51	25	-26
Above LOAEL DAY	148	102	-46
Above LOAEL NIGHT	156	127	-29
Above SOAEL DAY	0	0	0
Above SOAEL NIGHT	0	0	0
Noise Insulation Qualifier	0	0	0

Table 5 Comparison of total number of impacts, number of residential properties exceeding the LOAEL and SOAEL and number of insulation qualifiers at receptors.

Appendix D – Route



Noise Mitigation	The Design	Scale at A3: 1:6,001
Portal Opening Noise barrier Open Cut Alignment	The Design Close-In Cranked Barrier 5m high on South side, 2.5m high on North side CFA6 South Ruislip to Ickenham	Figure D1 Date: 14/03/19