HS2

Phase 2b (Crewe – Manchester) – Sound, Noise and Vibration

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Expert Sound, Noise and Vibration Witness for the Promoter

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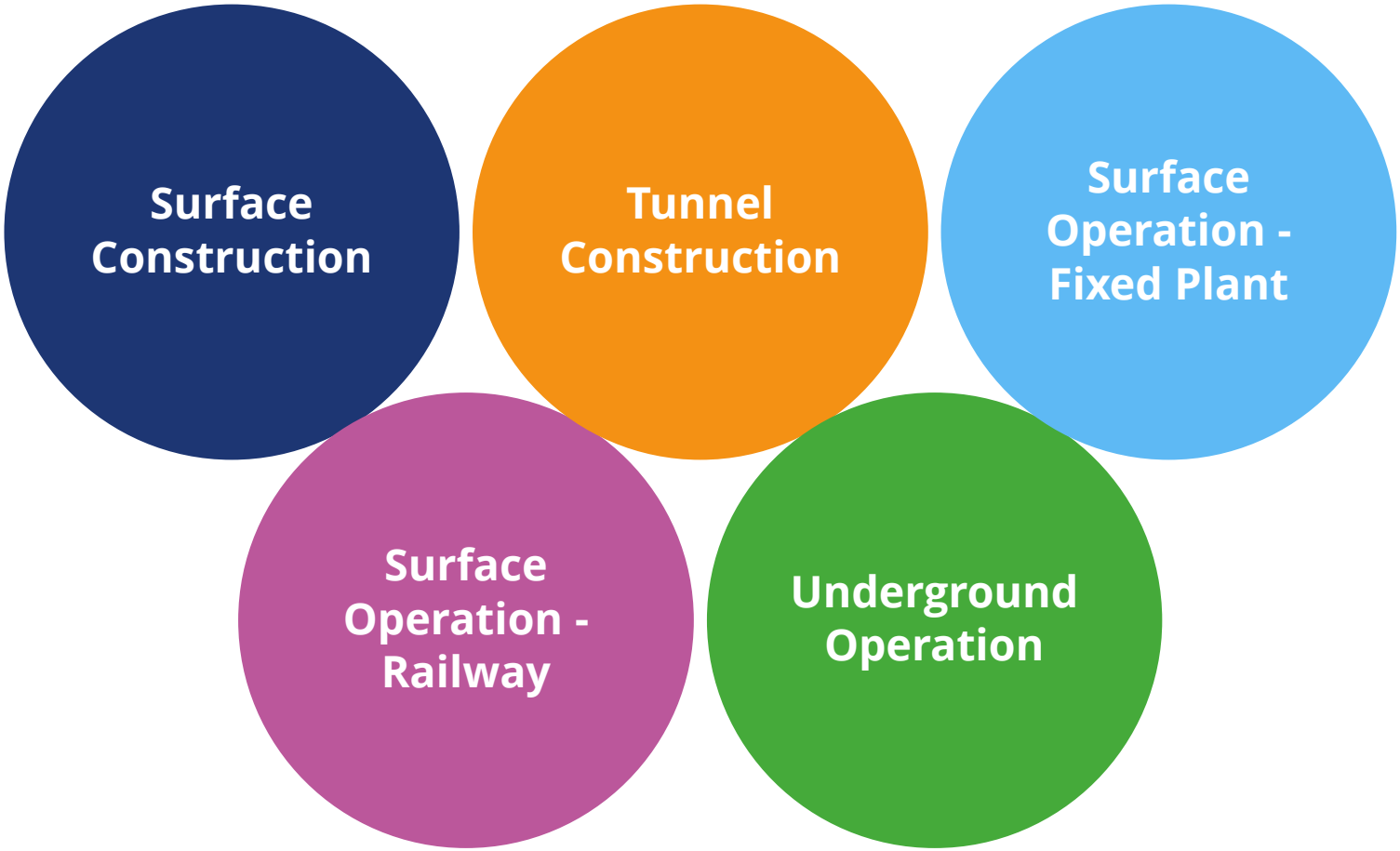
Outline of Presentation

- **Scope of Sound and Vibration Issues**
- **What sound is** - sources, and ways in which is it transmitted from source to receiver
- **What vibration is** - sources, and ways in which is it transmitted from source to receiver
- **Human perception of sound and vibration**
- **Measurement scales and indices**
- **Assessment approaches** - relationship between noise and vibration and human response to them
- **Government policy** regarding assessment and decision making
- **HS2's application of government policy**
- **Ways in which noise and vibration and their effects can be reduced**

Scope of Sound and Vibration Issues



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Basics – What Sound Is

- Sound is air oscillation that is propagated by wave motion at frequencies between 20 cycles/per second (Hertz, abbreviated Hz) and 20,000 cycles/second (20kHz).
- Sound is measured in frequency–weighted decibels (dBA) approximating the response of the human ear.
- Sound decays with distance – it spreads out, is reduced (attenuated) by soft ground surfaces and by intervening obstacles.
- Noise is unwanted sound.
- The human ear is much more complex than any sound level meter and human beings are more complex still – there is no simple relationship between noise measurements and human response to the noise.

Basics – What Vibration Is

- Vibration is oscillation of solids that can be propagated through wave motion.
- Vibration in soil decays with distance and is also attenuated by energy absorption in the soil and by obstacles and discontinuities.
- Vibration is mainly of interest in the frequency range 0.5Hz to 250Hz and is measured in units of acceleration, velocity or displacement.
- Vibration can give rise to audible sound which is then measured in decibels.
- Like sound, vibration needs to be frequency-weighted to match the response of the human tactile senses.
- As with sound, human response to vibration is much more complex than can be measured with a meter.

Basics - Sound

- Every 10 dB ***increase*** is about ***double*** the subjective loudness.
- Every 10 dB ***decrease*** is about a ***halving*** of subjective loudness.
- A 1 dB change is only perceptible under controlled conditions.
- A 3 dB change is the minimum perceptible under normal conditions.

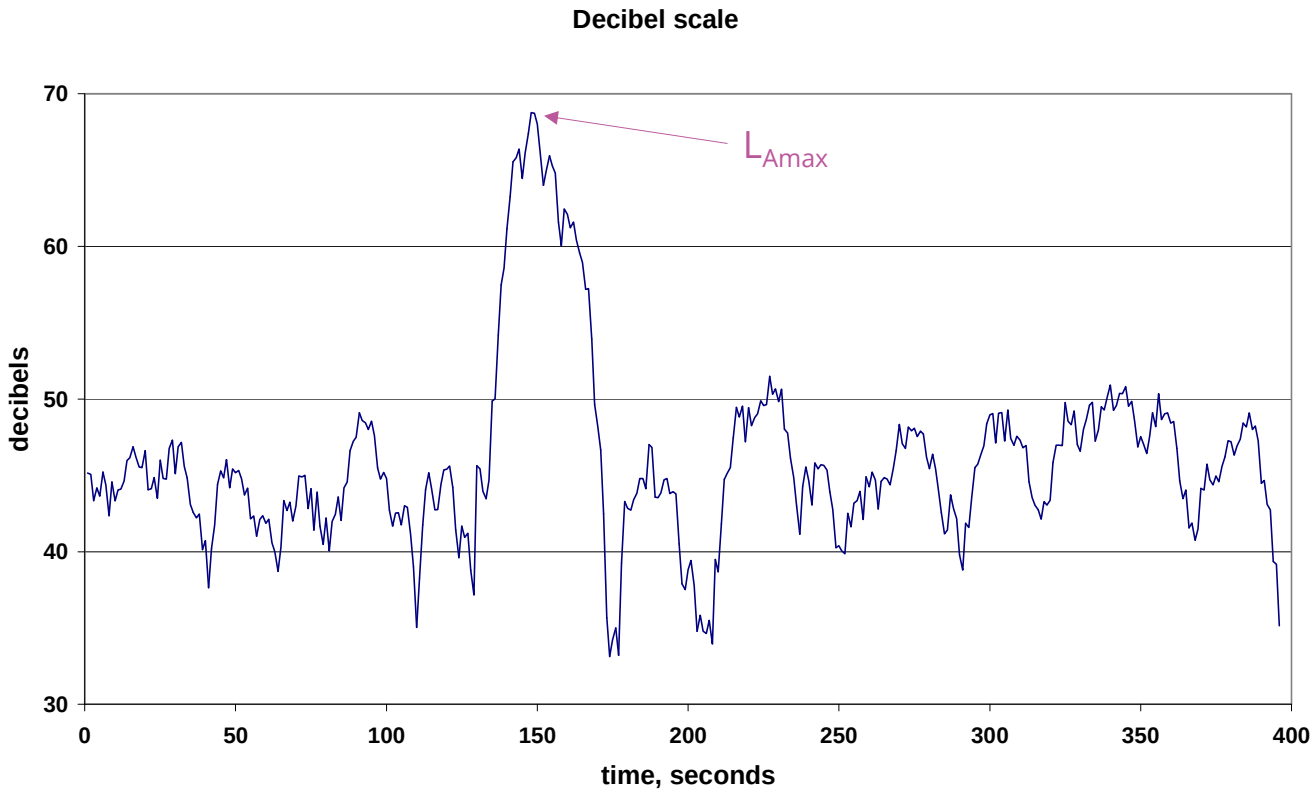
INDOOR	NOISE LEVEL, dB(A)	OUTDOOR
Rock Band	110	Underneath aircraft landing at 1km (0.6 miles) from runway
Night club	100	1m from pneumatic road breaker
Food blender at 1m	90	1m from petrol lawnmower
Vacuum cleaner at 1m	80	Pavement of city street
Loud voice at 1m	70	Aircraft at height of 200m
Normal voice at 1m	60	30m from petrol lawnmower
Open plan office	50	Lorry at 100m, heavy rainfall
Refrigerator at 1m	40	Suburban area at night, no local traffic
Concert hall background noise	30	Country area at night, no local traffic
Extremely quiet room	20	Very remote rural area no wind
Nearly Silent	10	Wilderness at night with no wind
Threshold of audibility	0	Threshold of audibility

L_{Amax} Measurement

- Sounds in the environment normally vary in level, for example due to the passage of vehicles, or trains.

- The sound level therefore varies with time, showing highs and lows. The highs are measured with an index called L_{Amax} .

- L_{Amax} levels are presented in the tables in Volume 5 of the Environmental Statement. These are L_{AFmax} levels where F is the "fast" time weighting (0.125 second).



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$L_{Aeq,T}$ Measurement

- Because many noise events are more annoying than a few noise events, an index is needed to take account of both level and number (and duration) of events.

- Sounds that vary in level are therefore measured in *equivalent continuous sound level*, used internationally.

$$L_{eq,T} \text{ (or } L_{Aeq,T})$$

T = time period

- $L_{Aeq,T}$ levels are presented both in the tables in Volume 5 of the Environmental Statement and also plotted as contours for the time periods day (07:00–23:00) and night (23:00–07:00).

$L_{Aeq,T}$ Measurement

- L_{Aeq} is *not* an average of sound levels but an index. The index averages the energy and gives a result dominated by the highest sounds in the averaging process.

With L_{Aeq} :

- **Doubling:** the energy in the sound, the number of sources, the duration of sound event, the number of similar events.

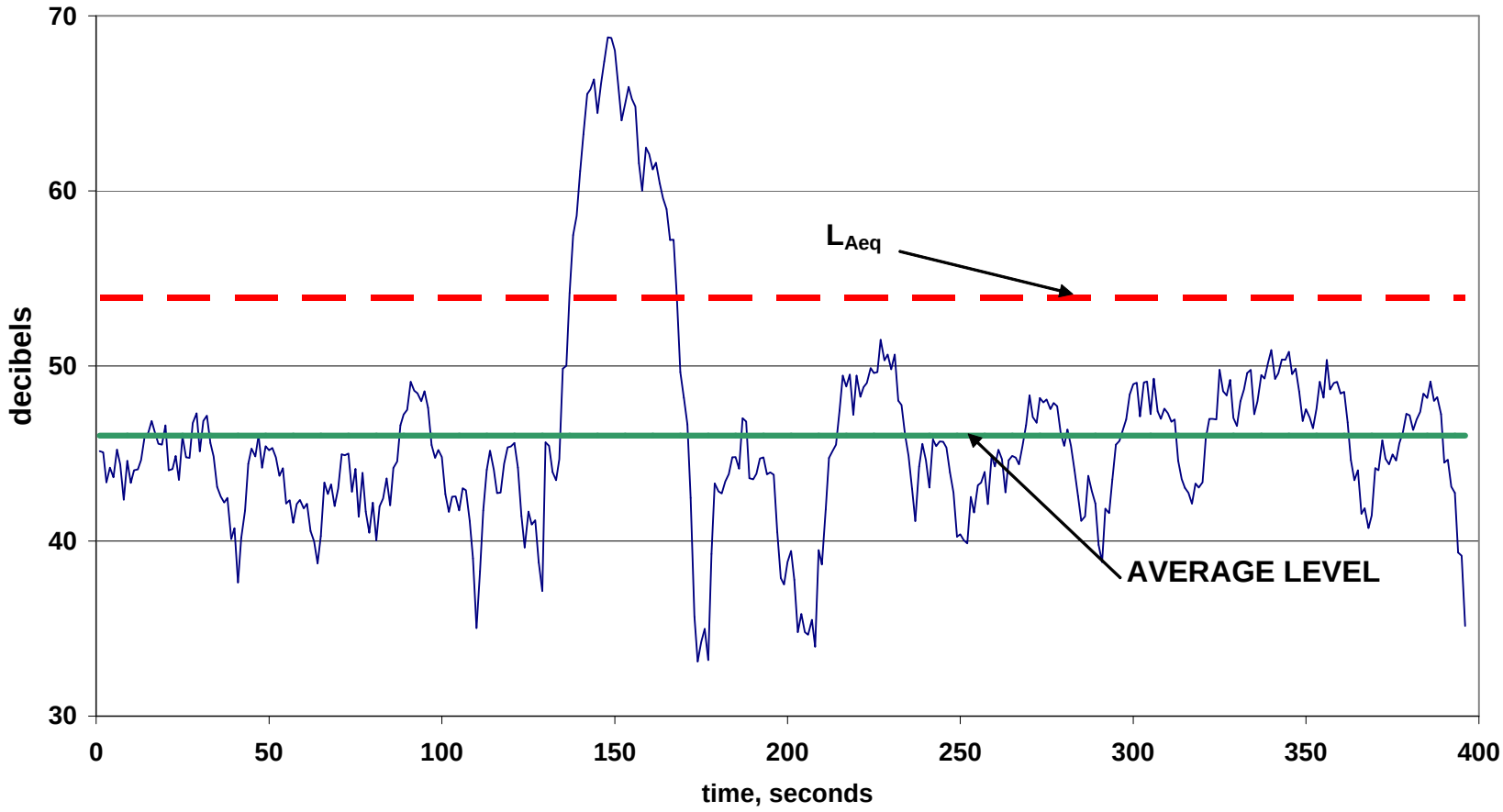
  each give +3dB

With L_{Aeq} :

- **Ten times:** the energy in the sound, the number of sources, the duration of a sound event, the number of similar events.

  each give +10dB

$L_{Aeq,T}$ Measurement



Measurement of Vibration & Ground-borne Sound

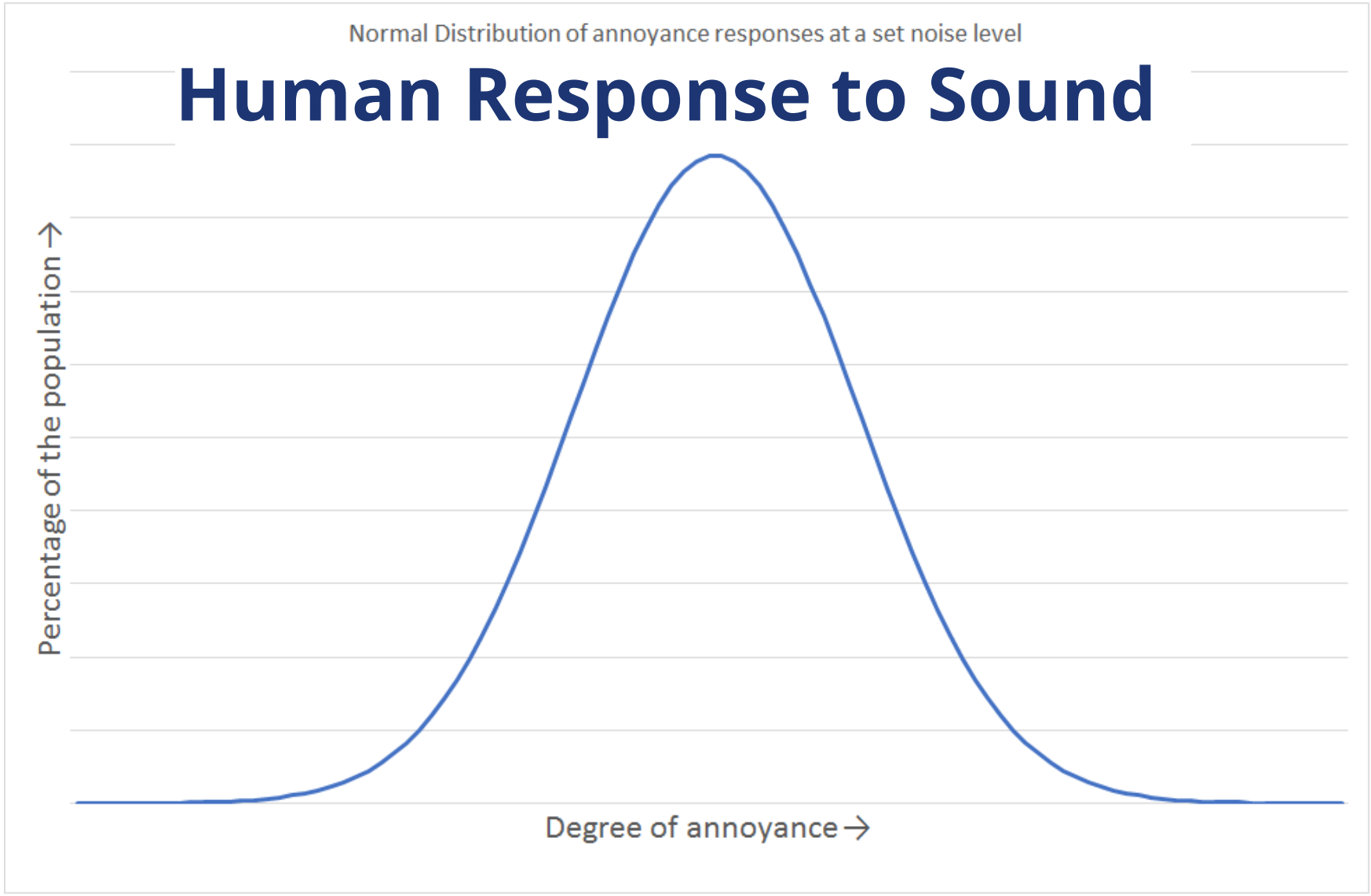
- Vibration felt by touch is assessed using Vibration Dose Value (**VDV**).
- Vibration affecting buildings is assessed using peak vibration velocity called “Peak Particle Velocity” or **PPV**.
- Ground-borne sound is assessed using maximum sound level, $\mathbf{L_{Amax,S}}$ where S is the “slow” time weighting (1 second).

Human Response to Sound and Vibration

In terms of human response to environmental sound levels:

- Sound levels on their own mean nothing.
- Social surveys link sound levels with human response.
- There is always a wide distribution of responses.
- There is never a clear distinction between “acceptable” and “unacceptable” or “significant” and “not significant”.

The same is true of vibration.


Normal Distribution of annoyance responses at a set noise level
Human Response to Sound
Percentage of the population →
Degree of annoyance →

Government Policy

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.**

Noise Policy Statement for England

Introduces the concept of effect levels used by World Health Organization (WHO) in toxicology

LOAEL – Lowest Observed Adverse Effect Level

Level above which adverse effects on health and quality of life can be detected.

LOAEL

SOAEL – Significant Observed Adverse Effect Level

Level above which significant adverse effects on health and quality of life occur.

SOAEL

Government Policy

- Above SOAEL, the planning process should be used to avoid this effect occurring, by use of appropriate mitigation such as by altering the design and layout. Such decisions should be made taking account of the economic and social benefit of the activity causing the noise, but it is undesirable for such exposure to be caused.

- Above LOAEL, consideration needs to be given to mitigating and minimising those effects (taking account of the economic and social benefits being derived from the activity causing the noise).

- Government policy does not expect noise to be considered in isolation, separately from the economic, social and other environmental dimensions of proposed development.

HS2 Implementation of Government Policy

Not possible to have a single objective noise-based measure that defines SOAEL that is applicable to all sources of noise in all situations. SOAEL is likely to be different for different noise sources, for different receptors and at different times.

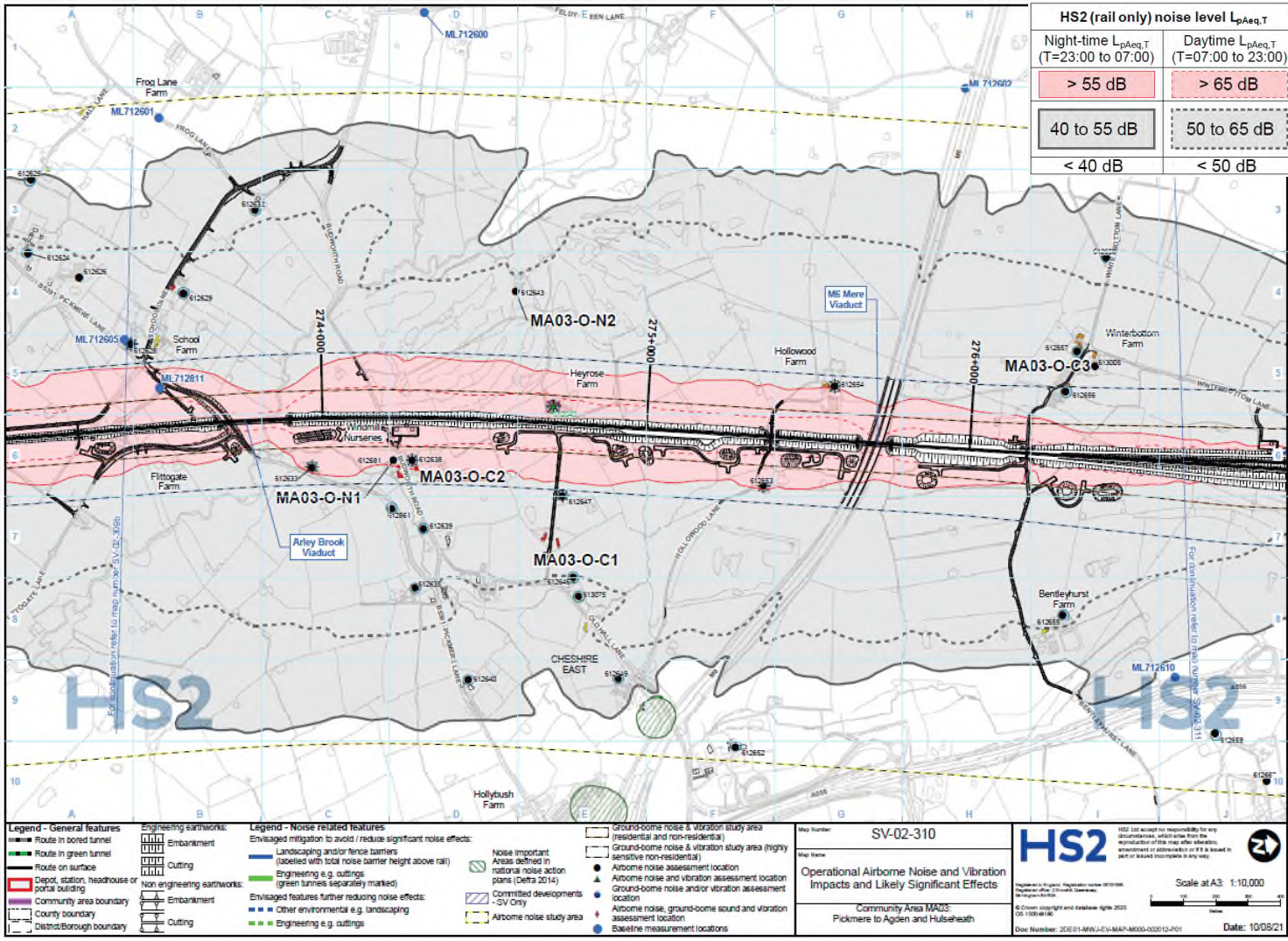
To set LOAEL and SOAEL values having due regard to:

- Established practice
- Research results
- Guidance in national and international standards
- World Health Organization Guidelines for Community Noise 1999
- World Health Organization 2009 Night Noise Guidelines for Europe
- World Health Organization 2018 Environmental Noise Guidelines for the European Region
- Independent review by academic, industry and government employees on Acoustics Review Group
- Use DfT Transport Analysis Guidance: WebTAG to assess impact on health of populations and at a local level to calculate the monetised value of noise control measures

Operational Airborne Noise Effect Levels

Time of day	Lowest Observed Adverse Effect Level (dB)	Significant Observed Adverse Effect Level (dB)
Day (07:00–23:00)	50 $L_{pAeq, 16hr}$	65 $L_{pAeq, 16hr}$
Night (23:00–07:00)	40 $L_{pAeq, 8hr}$	55 $L_{pAeq, 8hr}$
Night (23:00–07:00)	60 L_{pAFMax} (at the façade, from any nightly noise event)	80 L_{pAFMax} (at the façade, from more than 20 nightly train passbys), or 85 L_{pAFMax} (at the façade, from 20 or fewer nightly train passbys)

Operational Airborne Noise Effect Levels



HS2 (rail only) noise level $L_{pAeq,T}$		Potential noise effect[1, 2]	
Night-time $L_{pAeq,T}$ (T=23:00 to 07:00)	Daytime $L_{pAeq,T}$ (T=07:00 to 23:00)	Residential	Non-residential & quiet areas
> 55 dB	> 65 dB	Likely significant effect on dwellings indicated by ○, ✳ or ✕ avoided by noise insulation	Effect dependent on receptor and baseline. For further details see Volume 5, Appendix SV-003-0MA0X. Likely significant effect indicated by MA0X-O-N#[2]
40 to 55 dB	50 to 65 dB	Effect dependent on noise level change and significance criteria. Likely significant effects on groups of dwellings and any shared community open areas indicated by MA0X-O-C#[2]	
< 40 dB	< 50 dB	Generally no adverse effect expected[1]	

Operational airborne noise impacts at residential buildings[1]

- Major adverse
- Moderate adverse
- Minor adverse
- Negligible
- Beneficial

- ○ Potential additional noise insulation (triggered by maximum noise levels at night)[1]
- ✳ Potential additional noise insulation (triggered by WHO Night Noise Guidelines Interim Target)[1]
- ✕ Potential noise insulation (triggered by Noise Insulation Regulations 1996)[1]
- ○ L_{pAFmax} exceeds 60dB façade HS2 train only L_{pAFmax} +2.5dB façade correction

Ground-borne noise or vibration impact at residential buildings

[1] For further information see Volume 5 Appendix SV-001-00000
[2] For details see relevant Volume 5 Appendix SV-003-0MA0X

Operational Airborne Noise Effect Levels

Assessment location		Impact criteria										Significance criteria								Significant effect
Reference	Area represented	Proposed Scheme only (year 15)			Without Proposed Scheme (opening year baseline)			With Proposed Scheme (opening year baseline + year 15 traffic) ****		Change		Type of effect	Number of impacts represented	Type of receptor	Receptor design	Existing environment	Unique features	Combined impact	Mitigation effect	
		Day *	Night **	Max ***	Day *	Night **	Max ***	Day *	Night **	Day *	Night **									
612638	Budworth Road, Tabley	64	58	79/--	49	45	50	64	58	15	13	S	5	R	T	-	-	-	NI	MA03-O-C2
612645	Heyrose Lane, Over Tabley	69	63	88/--	47	42	47	69	63	22	21	S	2	R	T	-	-	-	NI	MA03-O-C1
612646	Old Hall Lane, Over Tabley	55	49	69/--	52	47	52	56	51	5	4	A	3	R	T	-	-	-	-	MA03-O-C1
612647	Heyrose Lane, Over Tabley	60	55	75/--	46	41	46	60	55	14	13	S	3	R	T	-	-	-	NI[4]	MA03-O-C1
612656	Winterbottom Farm, Winterbottom Lane, Mere	58	52	77/--	49	44	49	58	52	9	8	A	1	R	T	-	-	-	-	MA03-O-C3
612657	Winterbottom Lane, Mere	55	49	73/--	51	46	51	56	50	5	4	A	4	R	T	-	-	-	-	MA03-O-C3
613075	Old Hall Lane, Over Tabley	53	48	67/--	52	47	52	56	50	4	3	A	4	R	T	-	-	-	-	MA03-O-C1
612643	Heyrose Golf Club (Wedding Venue), Budworth Road, Knutsford	56	50	71/--	45	40	45	56	50	11	10	B	1	A2	T	-	-	-	-	MA03-O-N2
612681	Tabley Brook Kennels and Cattery (Lower Sensitivity Office), Budworth Road, Tabley	62	56	78/--	51	46	51	62	56	11	10	B	1	A4	T	-	-	-	-	MA03-O-N1

Table presents a selection of receptors from the previous maps that form part of the significant effects noted.

Significance Criteria

As set out in the Scope and Methodology Report, the significance criteria set for airborne noise effects considers:

- The number and grouping of adversely affected dwellings and shared community open areas
- The magnitude of the adverse effects identified (based on noise change)
- The overall level of noise exposure once the scheme is in operation
- The level and character of the existing sound environment
- Any unique features of the source or receiving environment in the local area
- Combined exposure to noise and vibration
- The duration of the adverse effect (for construction)
- The effectiveness of mitigation measures that could avoid or reduce the adverse effects

Operational Ground-borne Noise and Vibration Effect Levels

Ground-borne noise	Lowest Observed Adverse Effect Level	L_{pASMax} [dB]	35
	Significant Observed Adverse Effect Level	L_{pASMax} [dB]	45
Vibration	Lowest Observed Adverse Effect Level	VDVday [$m/s^{1.75}$]	0.2
		VDVnight [$m/s^{1.75}$]	0.1
	Significant Observed Adverse Effect Level	VDVday [$m/s^{1.75}$]	0.8
		VDVnight [$m/s^{1.75}$]	0.4

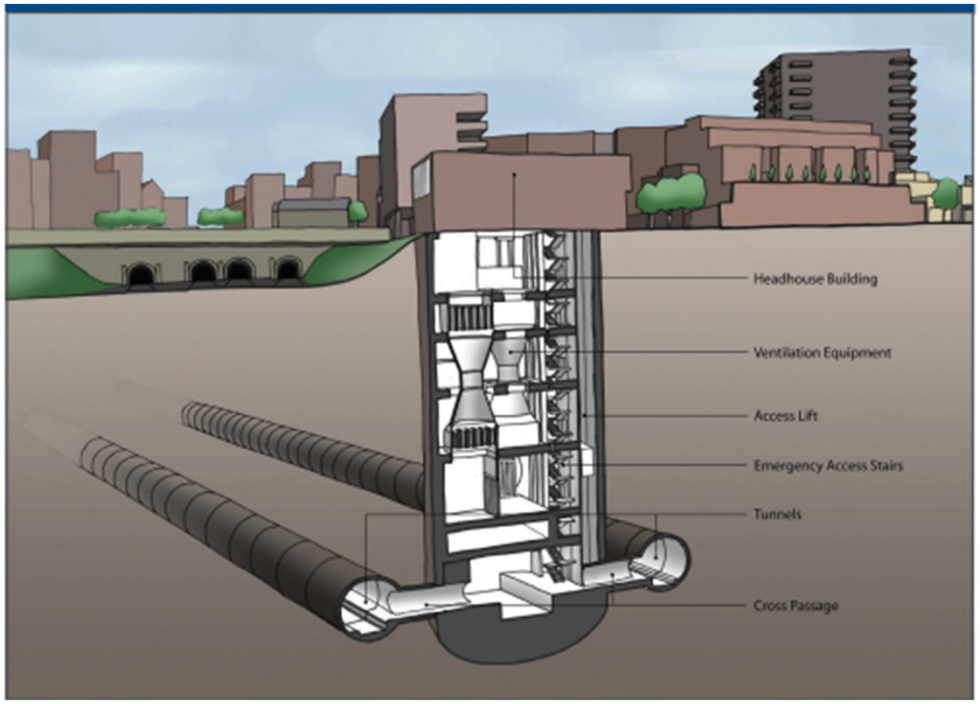
Stationary systems noise

For HS2 there are a number of types of stationary system that require consideration from a noise perspective.

These include:

- Mechanical ventilation at tunnel shafts and portals
- Trackside plant compounds
- Fixed plant located at stations and within depots

Noise from stationary systems such as fixed plant is assessed in accordance with BS4142:2014.

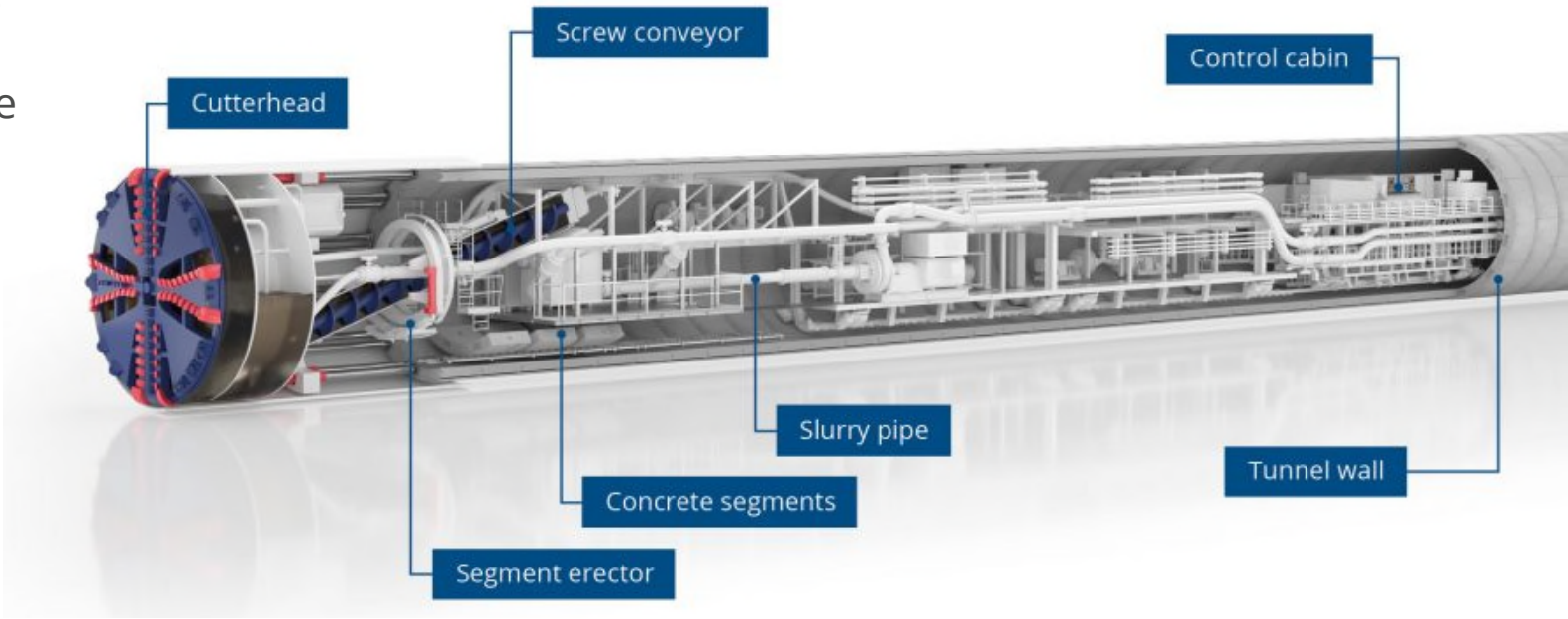


Construction Noise Effect Levels

Day	Time (hours)	Averaging Period T	Lowest Observed Adverse Level Effect $L_{pAeq,T}$ [dB]	Significant Observed Adverse Effect Level $L_{pAeq,T}$ [dB]
Mondays to Fridays	07:00–08:00	1 hour	60	70
	08:00–18:00	10 hours	65	75
	18:00–19:00	1 hour	60	70
	19:00–22:00	1 hour	55	65
Saturdays	07:00–08:00	1 hour	60	70
	08:00–13:00	5 hours	65	75
	13:00–14:00	1 hour	60	70
	14:00–22:00	1 hour	55	65
Sundays & Public Holidays	07:00–22:00	1 hour	55	65
Any night	22:00–07:00	1 hour	45	55

Ground-borne Sound and Vibration from Tunnelling

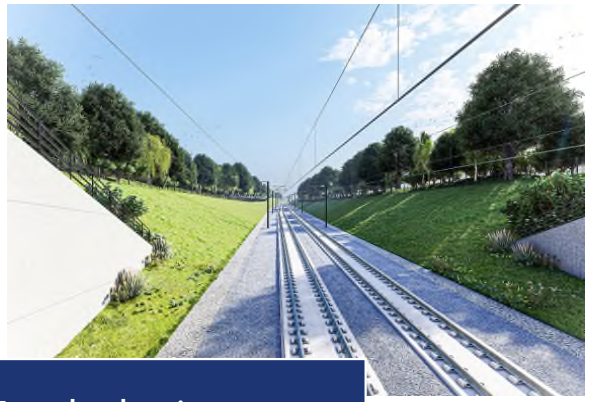
- To excavate the tunnels Tunnel Boring Machines (TBMs) will be used, which can generate ground-borne sound and vibration as the rotating head of the TBM 'cuts' through the ground.
- TBMs can therefore give rise to ground-borne sound and vibration impacts, albeit only for short periods of time (generally a matter of days) at any individual property. Given the limited duration of the impact, the passage of the TBM is not assessed generally to give rise to significant effects.
- Vibration is predicted to be substantially lower than criteria for building damage in the Scope and Methodology Report.



Mitigation – Operational Noise

Operational noise mitigation measures will include:

Train design

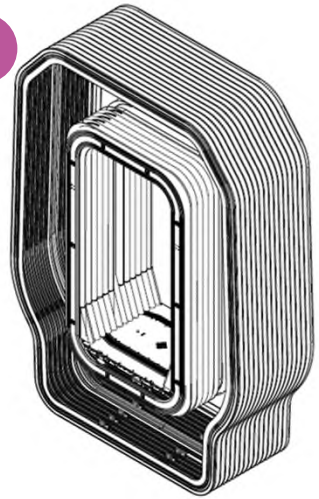


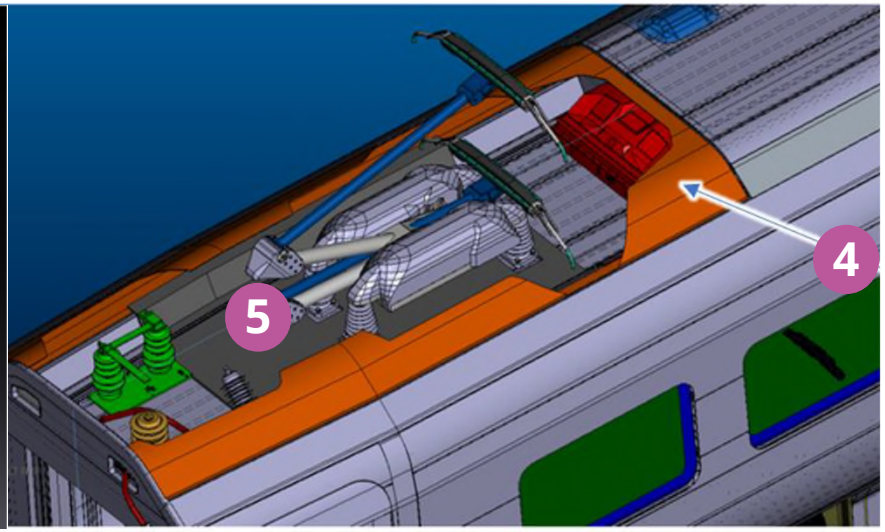
Track design

Noise barriers

Noise insulation where eligible

Mitigation – Train Design





1
- Partially shrouded bogies
- Underframe equipment will be enclosed by covers on the sides and below
- Wheel-mounted brake discs

2 Aerodynamic design of the train body

3 Gangways have smooth outer-fairing to reduce noise

4 Pantograph wells have covers / shrouds

5
- Aerodynamically-optimised pantographs
- Pantographs located on the 3rd and 6th vehicles of the 8-vehicle formation

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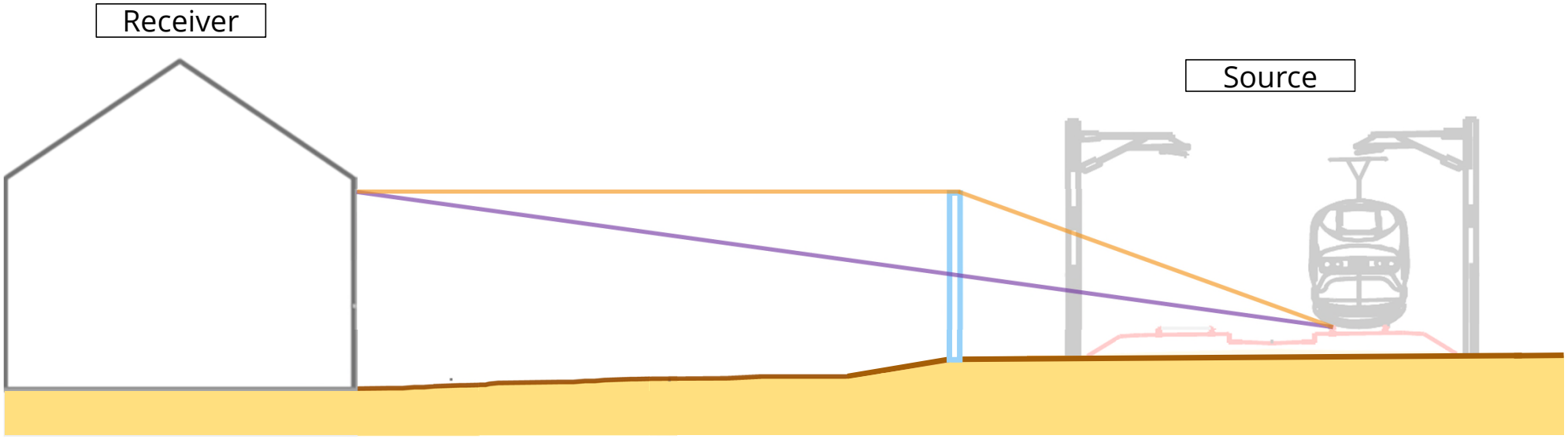
Mitigation – Noise Barriers


Colne Valley Viaduct noise barriers


Colne Valley Viaduct partially transparent noise barrier

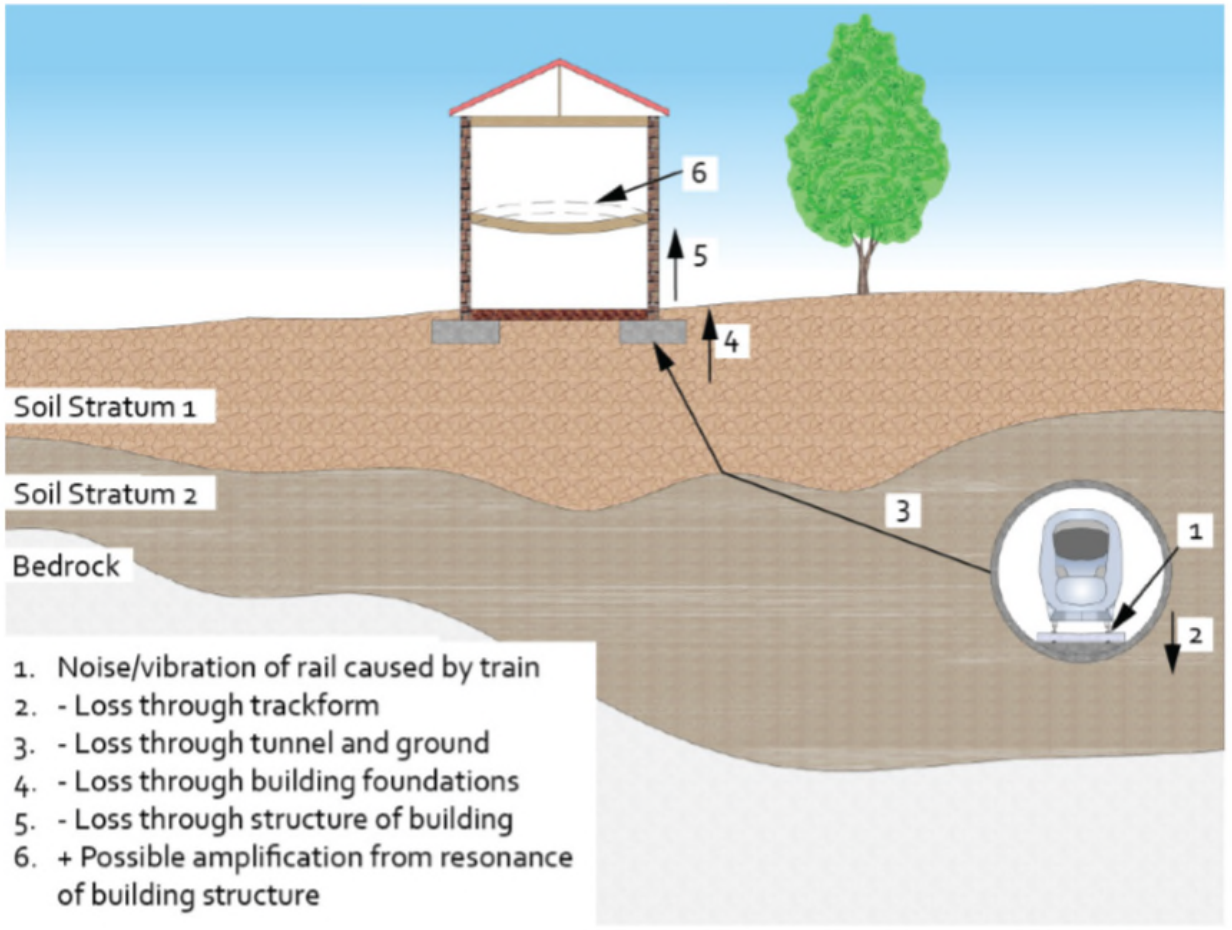
West Ruislip noise barrier design

Mitigation – Noise Barriers



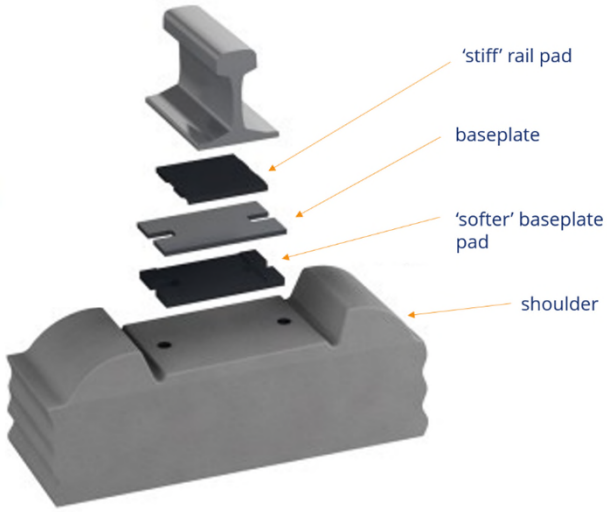
- The effectiveness of a noise barrier depends on how much longer the orange lines are than the purple line (the path difference).
- The path difference is longer the closer the barrier is to the source, therefore greater barrier height brings diminishing returns.

Operational Ground-borne Sound and Vibration



Mitigation – Operational Vibration & Ground-borne Noise

- Improving quality of the track
- Straightening rail alignments
- Smoothing running surfaces on the rails
- Fewer rail joints, which reduces the dynamic loads and consequently the wear and tear on the rolling stock
- Better suspension on the trains, improving passenger comfort and reducing the impact forces on the track
- Resilient rail support



Example track system only – HS2 tracks are part of an active procurement process.

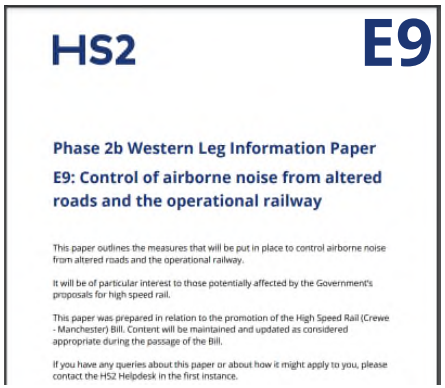
Mitigation – Construction Noise & Vibration

- Construction noise & vibration will be mitigated by:
  - Up-to-date methods of working
  - Modern plant
  - Noise barriers
  - Noise enclosures
  - Monitoring and management

  } Subject to Section 60 and 61 of the Control of Pollution Act 1974 consent

  - Noise insulation/temporary rehousing/prolonged disruption compensation scheme where applicable

HS2 Information and Technical Papers


HS2 E9

Phase 2b Western Leg Information Paper

E9: Control of airborne noise from altered roads and the operational railway

This paper outlines the measures that will be put in place to control airborne noise from altered roads and the operational railway.

It will be of particular interest to those potentially affected by the Government's proposals for high speed rail.

This paper was prepared in relation to the promotion of the High Speed Rail (Crewe - Manchester) Bill. Content will be maintained and updated as considered appropriate during the passage of the Bill.

If you have any queries about this paper or about how it might apply to you, please contact the HS2 Helpdesk in the first instance.


HS2 E10

Phase 2b Western Leg Information Paper

E10: Control of ground noise and vibration from the operation of temporary and permanent railways

This paper outlines the measures that will be put in place to control ground-borne noise and vibration from the operation of the Proposed Scheme's temporary and permanent railways.

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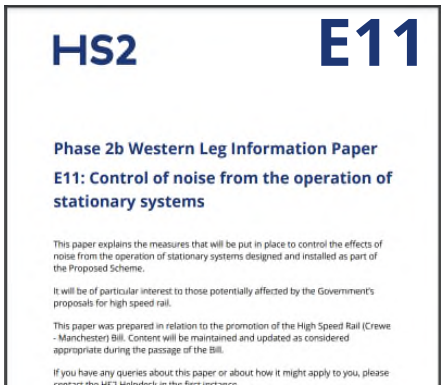
HS2 E11

Phase 2b Western Leg Information Paper

E11: Control of noise from the operation of stationary systems

This paper explains the measures that will be put in place to control the effects of noise from the operation of stationary systems designed and installed as part of the Proposed Scheme.

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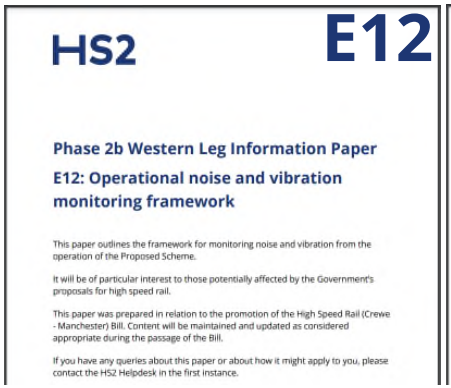
HS2 E12

Phase 2b Western Leg Information Paper

E12: Operational noise and vibration monitoring framework

This paper outlines the framework for monitoring noise and vibration from the operation of the Proposed Scheme.

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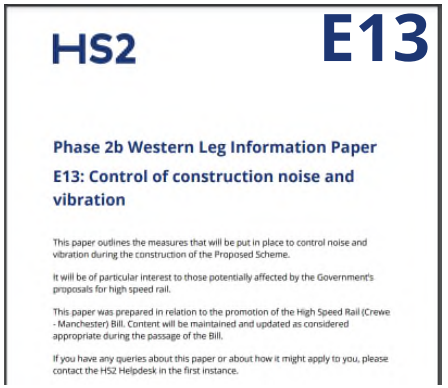
HS2 E13

Phase 2b Western Leg Information Paper

E13: Control of construction noise and vibration

This paper outlines the measures that will be put in place to control noise and vibration during the construction of the Proposed Scheme.

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- **E9** Control of airborne noise
- **E10** Control of ground-borne noise and vibration from the operation of temporary and permanent railways
- **E11** Control of noise from the operation of stationary systems
- **E12** Operational Noise and Vibration Monitoring Framework
- **E13** Control of construction noise and vibration
- Environmental Statement Volume 5: Sound, Noise and Vibration methodology, assumptions and assessment (Appendix SV-001-00000)

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