HS2

Sound, Noise and Vibration

An explanation

Rupert Thornely-Taylor

March 2018

Outline of Presentation

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

Ways in which noise and vibration and their effects can be reduced

Government policy regarding assessment and decision making

HS2's application of government policy

Scope of sound and vibration issues

SURFACE CONSTRUCTION

TUNNEL CONSTRUCTION

SURFACE OPERATION - RAILWAY

SURFACE OPERATION - FIXED PLANT

UNDERGROUND OPERATION

Basics – what sound is

Sound is air oscillation that is propagated by wave motion

at frequencies between 20 cycles per second (called Hertz, abbreviated Hz) and 20,000 cycles per second (20kHz)

Basics – what sound is

Sound decays with distance –
It spreads out, is reduced by soft ground surfaces and by intervening obstacles
Sound decay is known as attenuation

Basics – what sound is

**Sound is measured in decibels, abbreviated as dB frequency-weighted to approximate the response of the human ear—
in units of dB(A)**

Basics – what sound is

Noise is unwanted sound

The human ear is much more complex than any sound level meter

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 when it spreads out, and is also attenuated by energy absorption in the soil and by obstacles and discontinuities

HOC/10001/0009

Basics – what vibration is

Vibration is mainly of interest in the frequency range 0.5Hz to 250Hz and is measured in units of acceleration, velocity or displacement, but it can give rise to audible sound which is then measured in decibels

Basics – what vibration is

Like sound, vibration needs to be frequency-weighted to match the response of the human tactile senses

Basics – what vibration is

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

Basics - sound

A 1 dB change is only perceptible under controlled conditions

Basics - sound

A 3 dB change is the minimum perceptible under normal conditions

Basics - sound

INDOOR	Noise Level, dB(A)	OUTDOOR
Rock Band	110	Underneath aircraft landing at 1km 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

Basics - sound

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)

Basics - sound

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

$L_{eq,T}$ (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 (0700-2300) and (2300-0700)

Basics - sound

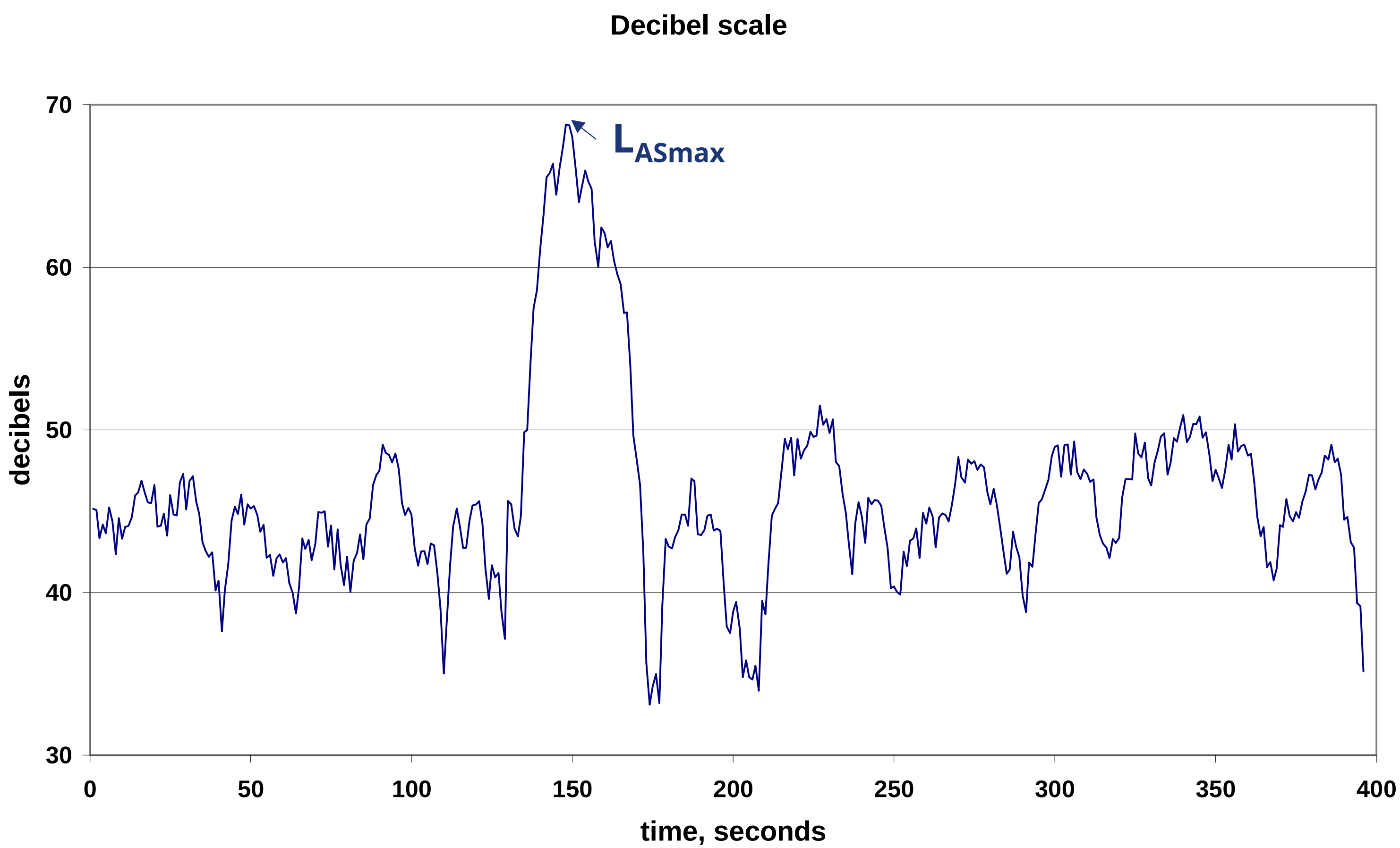
L_{Aeq} is ***not*** an average of sound levels.

It is an index that is an average of the energy content of sound levels.

A sound which is twice as loud as another contains ten times the amount of energy.
So averaging the energy gives a result dominated by the highest sounds in the averaging process.

e.g. five events of equal duration measuring 50 dB together with one of 70 dB gives an ordinary arithmetic average of 53 dB — but the L_{Aeq} value is 62 dB

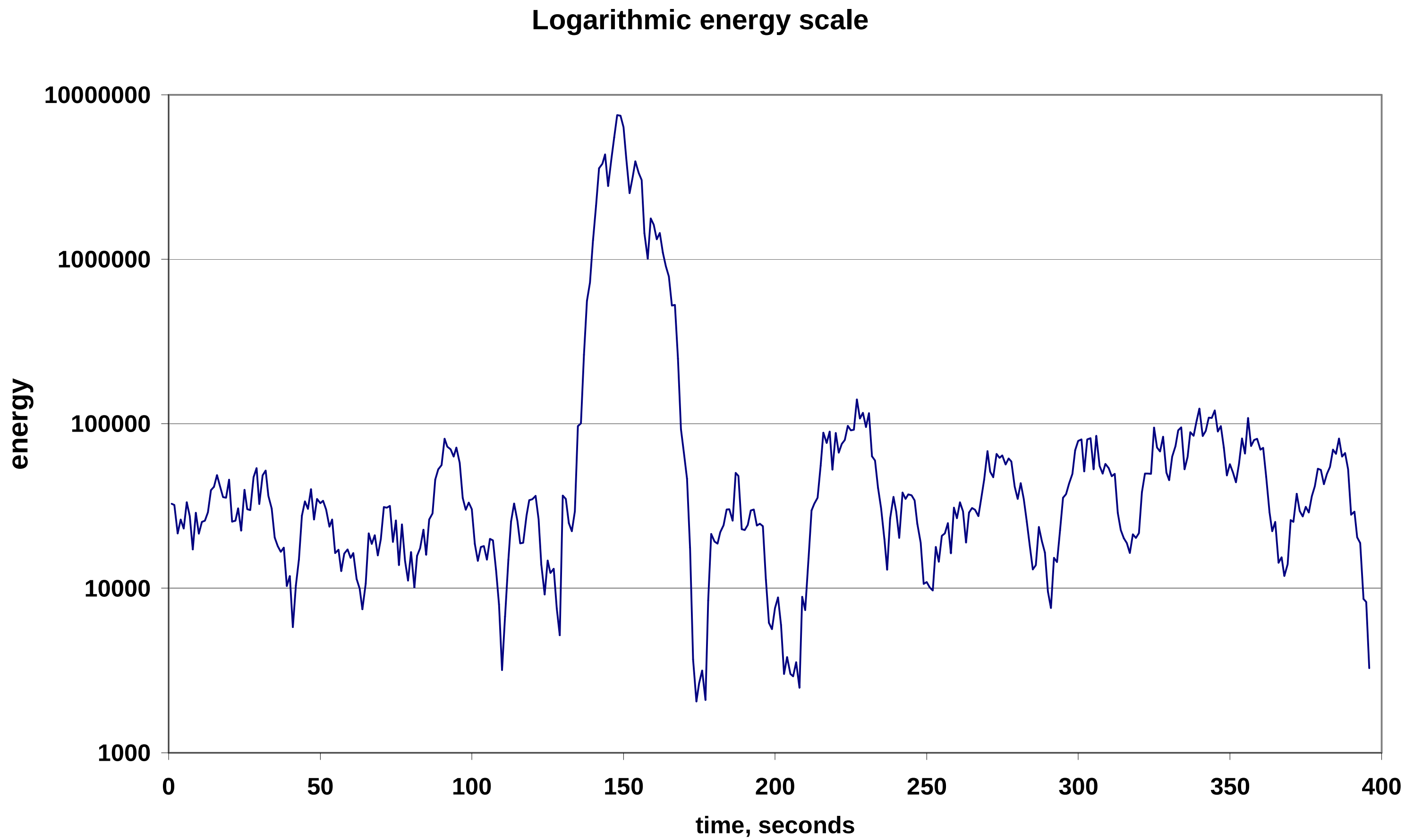
L_{Aeq} is no ordinary average...



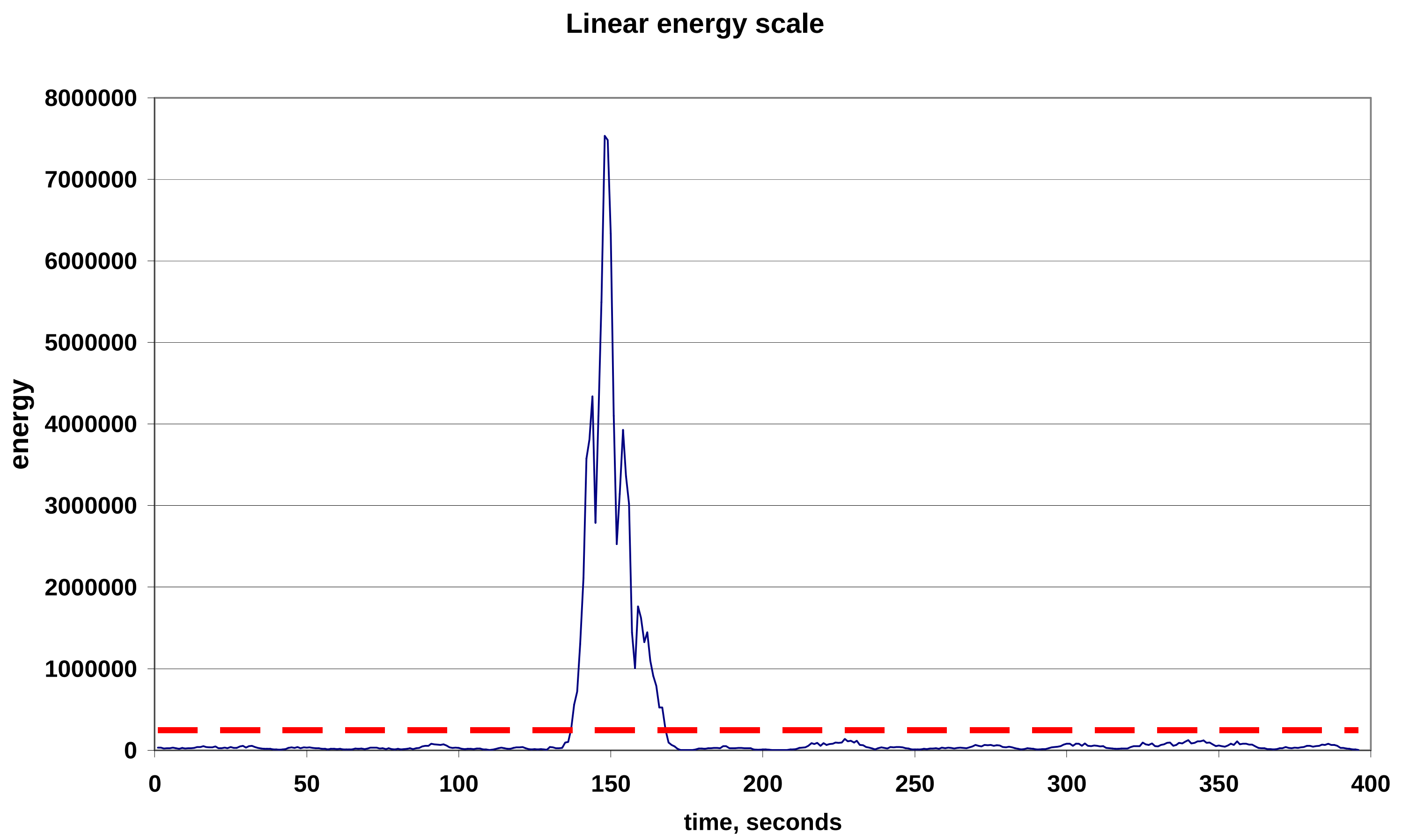
P4 (19)

HOC/10001/0020

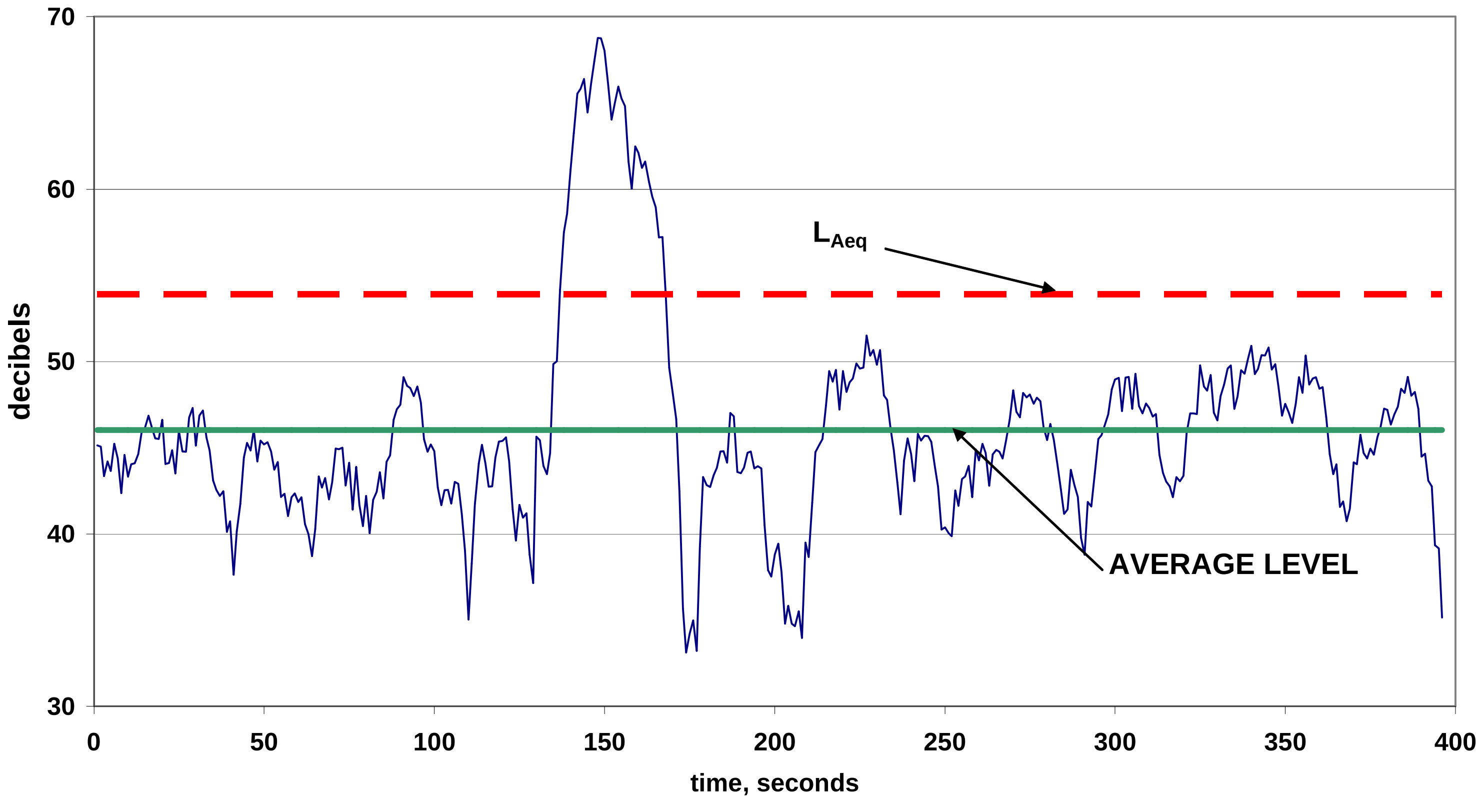
L_{Aeq} is no ordinary average…



L_{Aeq} is no ordinary average...



L_{Aeq} is no ordinary average…



Basics - sound

With L_{Aeq} :

doubling the energy in the sound,
doubling the number of sources,
doubling the duration of a sound event,
doubling the number of similar events

each give +3dB

Basics - sound

With L_{Aeq} :

ten times the energy in the sound,
ten times the number of sources,
ten times the duration of a sound event,
ten times the number of similar events

each give +10dB

HOC/10001/0025

Basics - sound

Environmental Indices based on L_{Aeq}

Noise in the day, evening and night periods has different effects, and for purposes such as noise mapping this is taken into account by calculating L_{Aeq} separately for the three periods as annual energy - average outdoor noise levels:

L_{day} 0700-1900
$L_{evening}$ 1900-2300
L_{night} 2300-0700

and combining these into one 24-hour long term index

Basics - sound

Day-Evening-Night Level L_{den}

Allowance is made for greater noise sensitivity at night, and to a lesser extent in the evening.

Night noise is treated as if it were 10 dB higher than the physical level

Evening noise is treated as if it were 5 dB higher than the physical level.

Basics - sound

Day-Evening-Night Level L_{den}

L_{day} is then combined with $L_{evening}$+5dB and L_{night}+10 dB to calculate L_{den}

The difference between L_{den} and $L_{Aeq(0700-2300)}$ depends on the relative amounts of day, evening and night noise.

For HS2 L_{den} is less than 1 dB greater in numerical level than L_{Aeq}, so for practical purposes, L_{Aeq} levels can be read as L_{den} levels

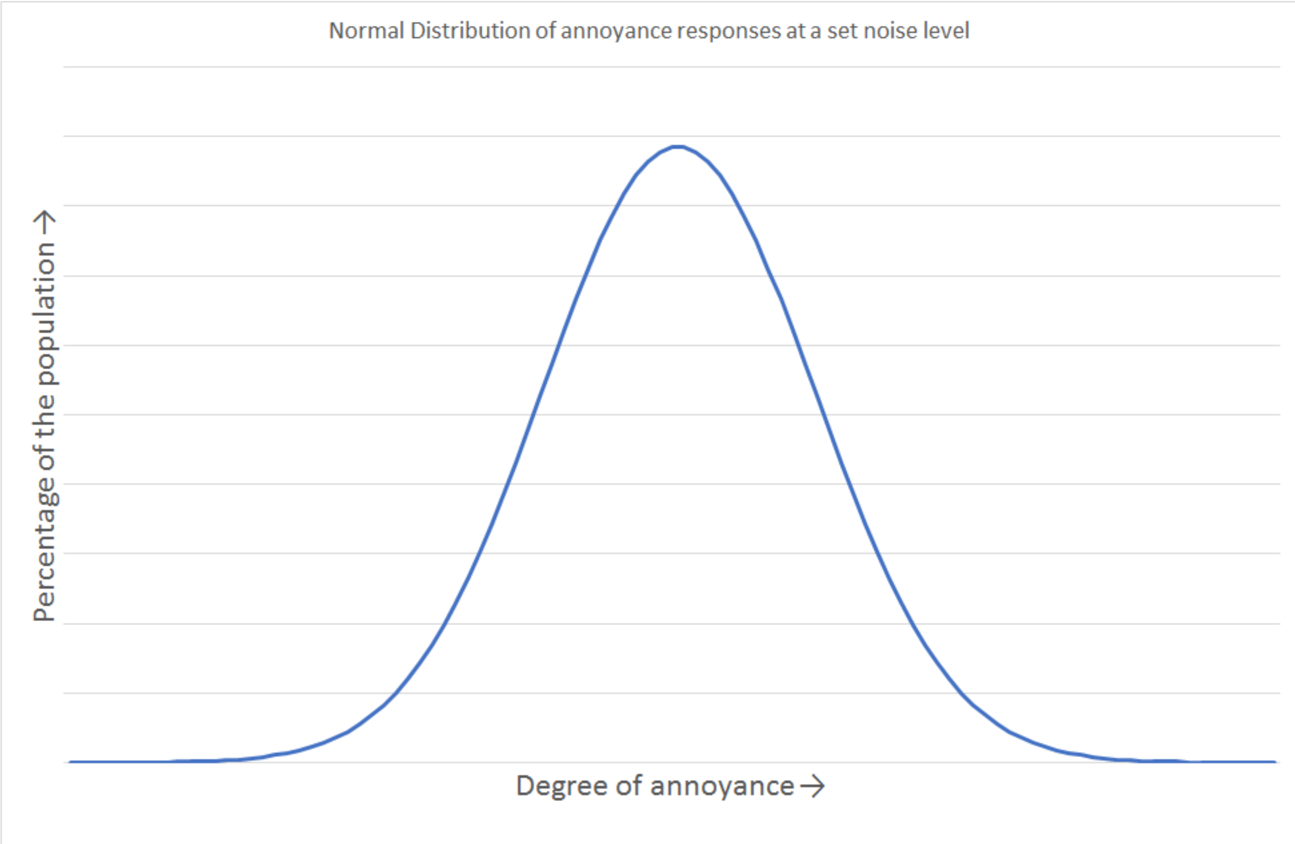
Basics – sound and vibration

In terms of human response at environmental sound levels:

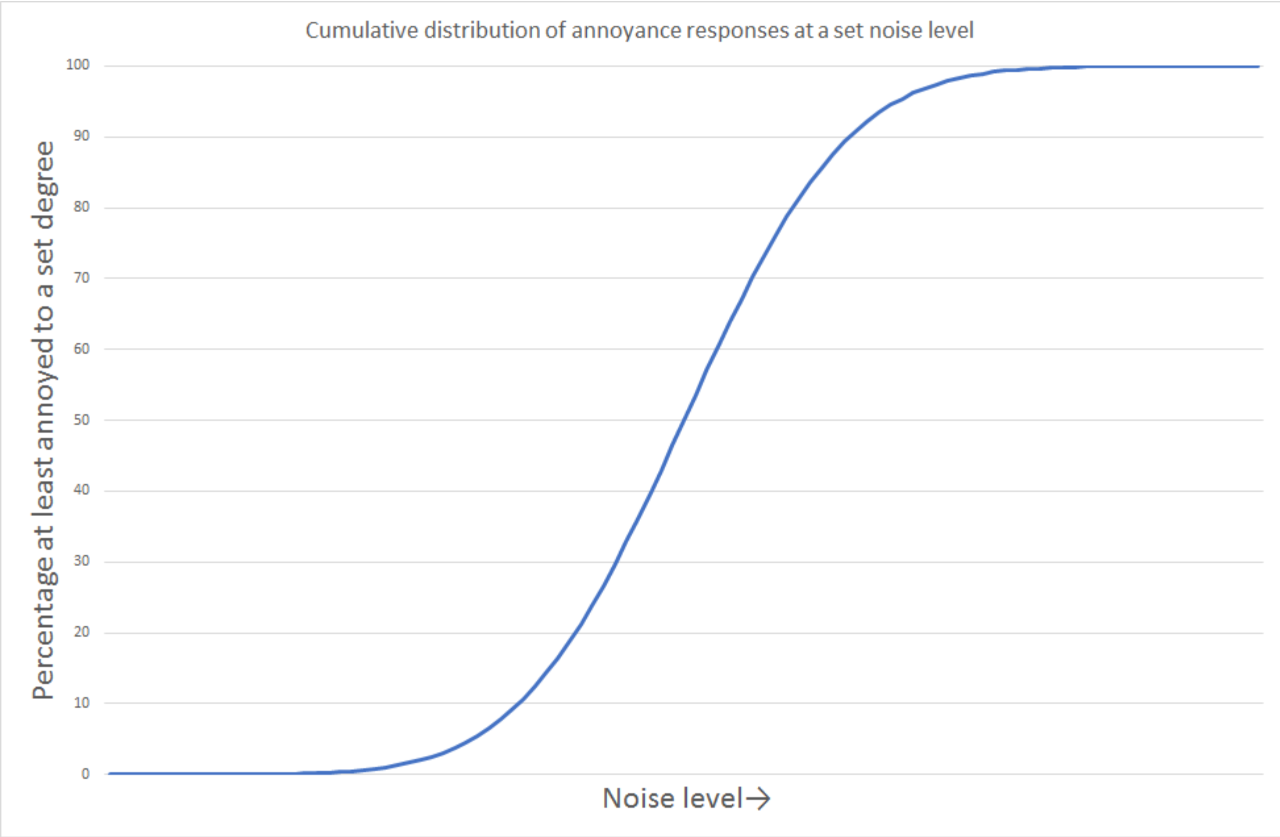
- Sound levels on their own mean nothing.
- Social surveys link sound levels with human response
- There is always a wide distribution of responses
- There is never a clear distinction between “acceptable” and “unacceptable” or “significant” and “not significant”

The same is true of vibration

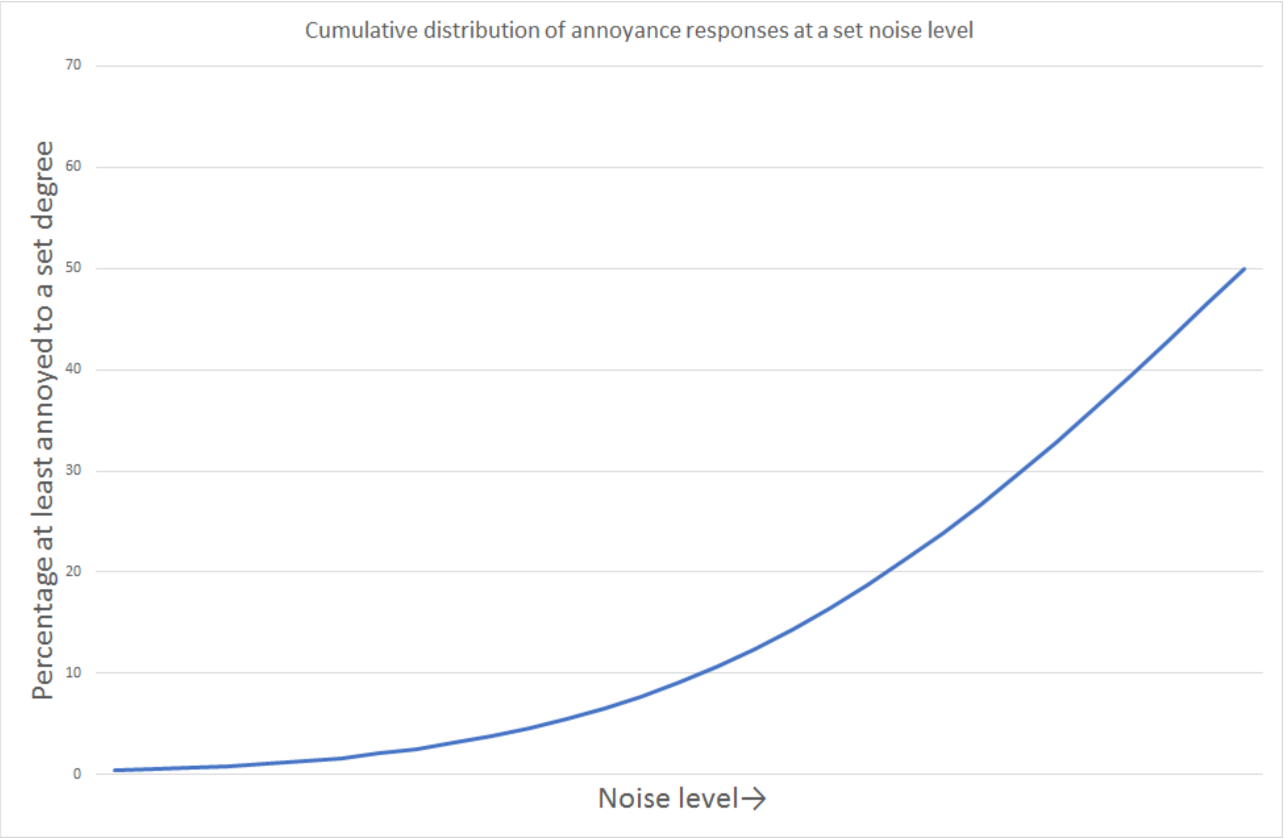
Basics - sound



Basics - sound



Basics - sound



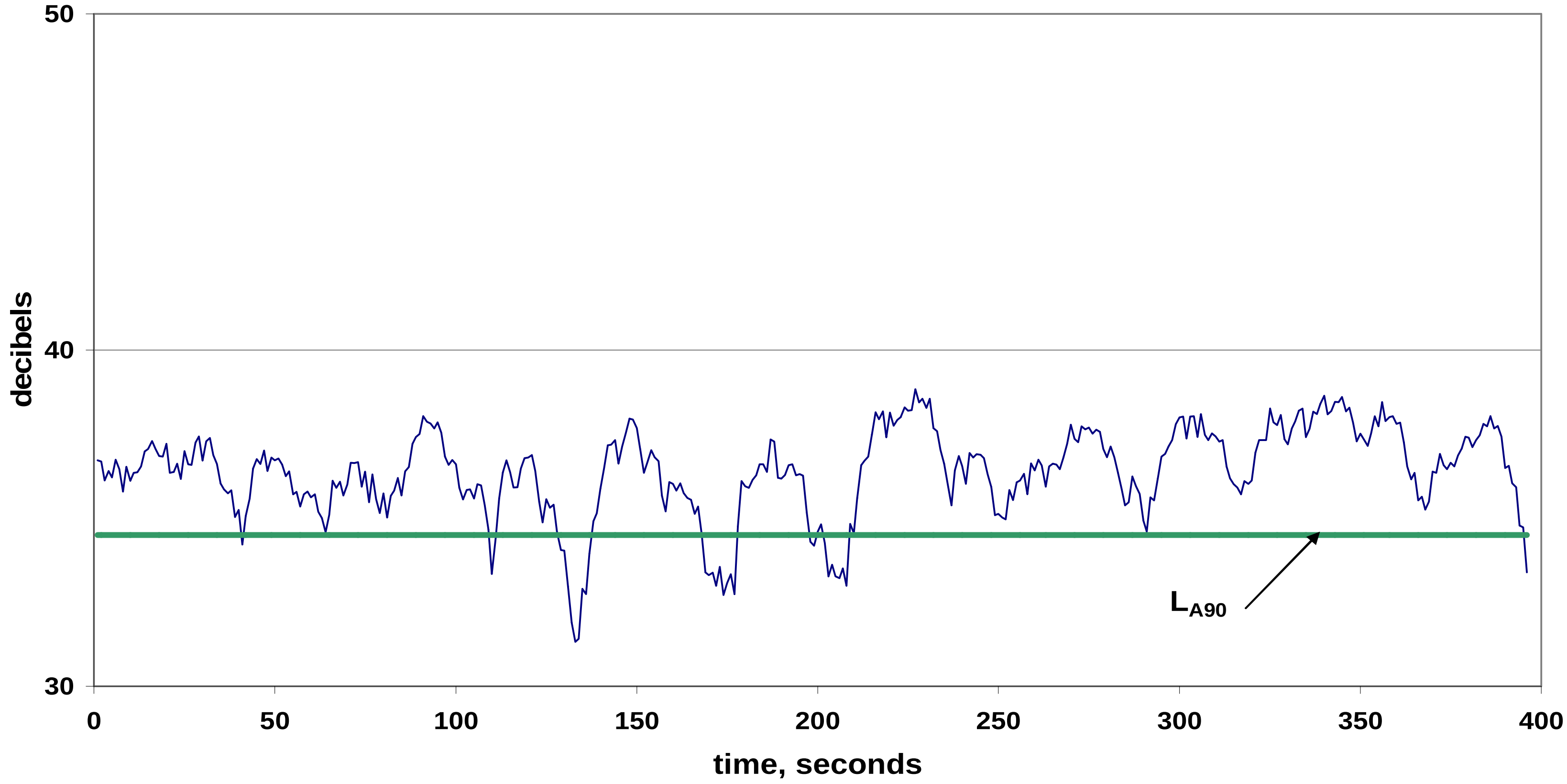
Basics - sound

Noise from fixed plant
is assessed by comparing the L_{Aeq}
with a penalty added unless the noise is characterless
against the background noise in L_{A90}.

L_{A90} measures quiet moments
e.g. between passing vehicles or aircraft.

P4 (32)

Basics - sound



Basics – vibration (affecting people)

Vibration felt by the sense of touch
is assessed using
Vibration Dose Value (VDV)

Basics – vibration (affecting buildings)

Vibration affecting buildings
is assessed using peak vibration velocity called
“Peak Particle Velocity” or PPV.

Basics – vibration (heard as noise)

Groundborne noise is assessed using

maximum sound level, $L_{Amax,S}$

where S is the "slow" time weighting (1 second)

Government Policy

Noise Policy Statement for England 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 effects on health and quality of life
Where possible, contribute to the improvement of health and quality of life

Government Policy

Noise Policy Statement for England Explanatory note:

- Avoid effects above Significant Observed Adverse Effect Level (SOAEL)
- Mitigate and minimise effects between Lowest Observed Adverse Effect Level (LOAEL) and SOAEL.
- Proactively manage noise taking account the guiding principles of sustainable development

Not focussing solely on the noise impact without taking into account other related factors

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.

Government Policy

Planning Practice Guidance:

- Neither the NPSE nor the National Planning Policy Framework expects noise to be considered in isolation, separately from the economic, social and other environmental dimensions of proposed development.
- 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).
- 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.
- Unacceptable effects should be prevented from occurring

HS2 implementation of government policy

- Achieve Noise Policy aims
- Set LOAEL and SOAEL values having due regard to
  - Established practice
  - Research results
  - Guidance in national and international standards
  - Guidance from national and international agencies
  - Independent review by academic, industry and government employees on the Acoustics Review Group

HS2 implementation of government policy

- DfT Transport analysis guidance: WebTAG
- Magnitude of railway noise effect (adverse or beneficial) is calculated using WebTAG
- WebTAG monetises the health effect cause by a change in noise (day and night)
- The WebTAG results are reported for the population in the health chapter of the EIA
- WebTAG has also been used at a local level to calculate the monetised value of noise control measures

Operational airborne noise effect levels

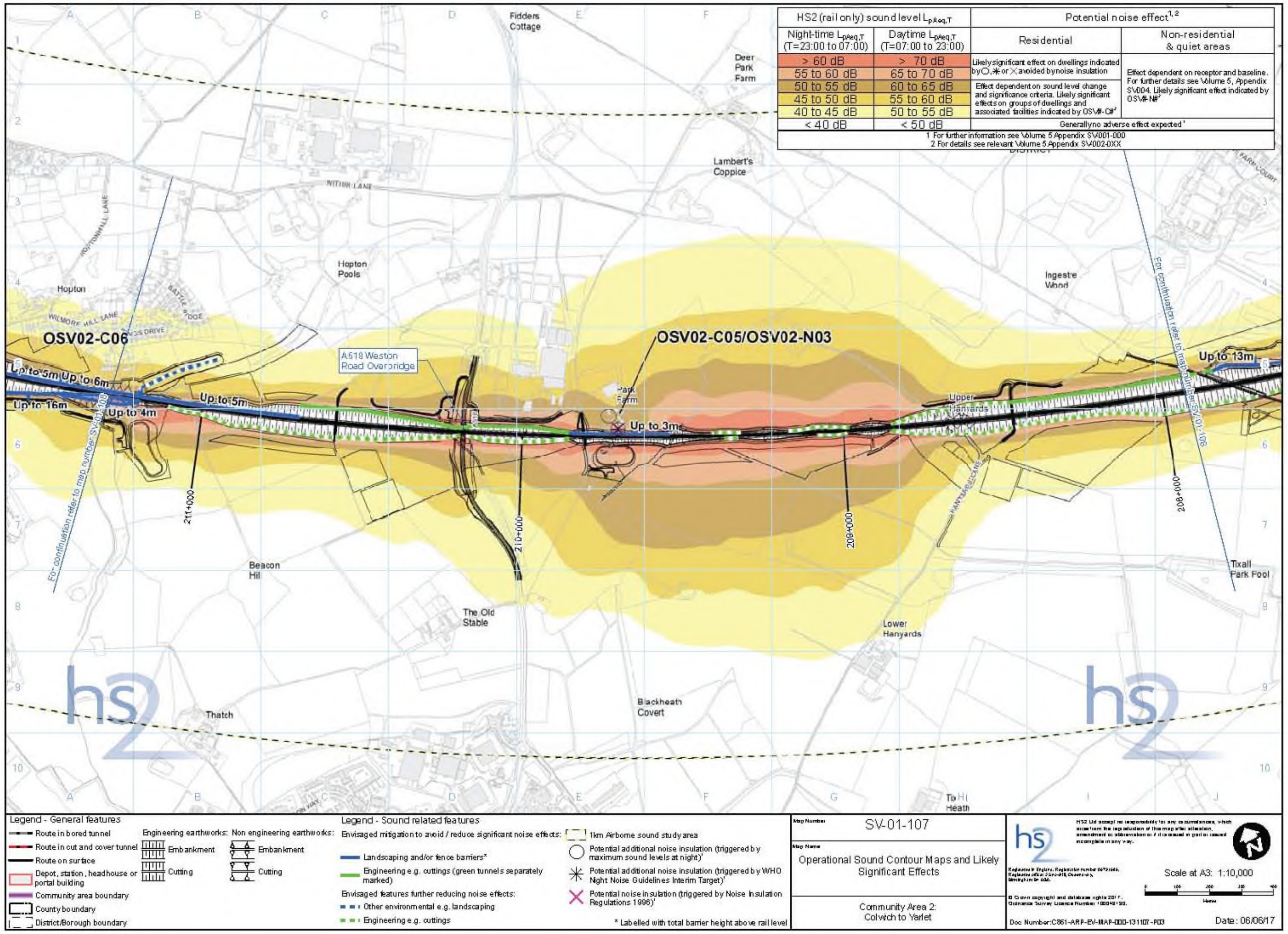
Time of day	Lowest Observed Adverse Effect Level (dB)	Significant Observed Adverse Effect Level (dB)
Day (0700 – 2300)	50 $L_{pAeq,\ 16hr}$	65 $L_{pAeq,\ 16hr}$
Night (2300 – 0700)	40 $L_{pAeq,\ 8hr}$	55 $L_{pAeq,\ 8hr}$
Night (2300 – 0700)	60 L_{pAFMax} (at the façade, from any nightly noise event)	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

Table 14: Explanatory notes for assessment results

Symbol	Explanation
	Where the significant effect column is marked, then a significant effect is identified at the referenced group of dwellings, or individual residential or non-residential receptor
	Yellow denotes a minor impact at a residential building – a change is of 3-5 dB
	Orange denotes a moderate impact at a residential building – a change is of 5-10 dB
	Red denotes a major impact at a residential building – a change is of >10 dB
*	Day - $L_{pAeq\,07:00-23:00}$
**	Night - $L_{pAeq\,23:00-07:00}$

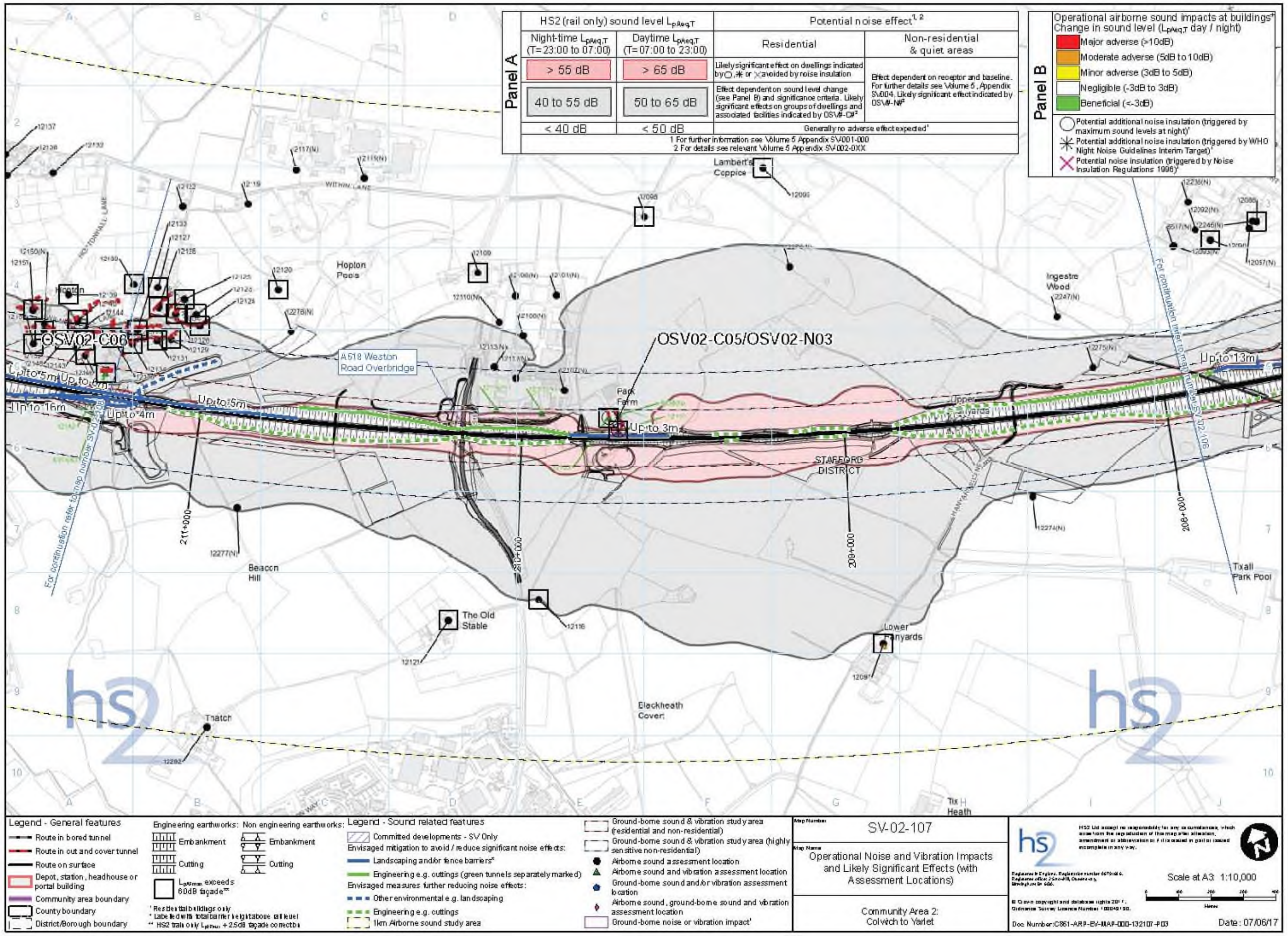
Operational airborne noise effect levels



P4 (44)

HOC/10001/0045

Operational airborne noise effect levels



Operational airborne noise effect levels

Assessment location		Impact criteria										Significance criteria									
Ref	Area represented	Proposed Scheme only (year 15 traffic)			Do nothing (opening year baseline)			Do something (opening year baseline +year 15 traffic) ****		Change		Type of effect	Number of impacts represented	Type of receptor	Receptor design	Existing environment	Unique feature	Combined impact	Mitigation effect	Significant effect
		Day *	Night **	Max ***	Day *	Night **	Max ***	Day *	Night **	Day *	Night **									
12135	Ravensbank Farm, Hopton	38	28	53/54	44	41	51	45	41	1	0	NA	1	R	T	-	-	-	-	
12136	Kings Drive, Hopton	52	42	66/68	40	35	47	52	43	12	8	A	5	R	T	-	-	-	-	OSV02-C06
12137	Within Lane, Hopton	41	31	55/56	44	41	51	46	41	2	0	NA	17	R	T	-	-	-	-	
12138	Within Lane, Hopton	42	32	55/56	44	41	51	46	42	2	1	NA	13	R	T	-	-	-	-	
12139	Hopton Hall Lane, Hopton	49	39	63/65	40	35	47	49	41	9	6	A	3	R	T	-	-	-	-	#
12140	Wilmore Hill Lane, Hopton	51	41	65/67	40	35	47	51	42	11	7	A	9	R	T	-	-	-	-	OSV02-C06
12141	Orchard Caravan Site, Hopton	40	30	55/56	44	41	51	45	41	1	0	NA	16	R	T	-	-	-	-	
12142	Lower Lane, Hopton	56	47	71/73	41	39	48	57	47	16	8	A	5	R	T	-	-	-	-	OSV02-C06
12143	Wilmore Hill Lane, Hopton	53	43	68/69	40	35	47	53	44	13	9	A	4	R	T	-	-	-	-	OSV02-C06
12144	Wilmore Hill Lane, Hopton	52	43	67/68	40	35	47	52	43	12	8	A	5	R	T	-	-	-	-	OSV02-C06
12145	Ravensbank Farm, Hopton	38	29	54/55	44	41	51	45	41	1	0	NA	5	R	T	-	-	-	-	
12146	Lower Lane, Hopton	55	45	70/72	40	35	47	55	46	15	11	A	1	R	T	-	-	-	-	OSV02-C06
12147	Within Lane, Hopton	43	33	56/57	44	41	51	46	42	2	1	NA	10	R	T	-	-	-	-	

Operational groundborne noise and vibration effect levels

(including temporary railways)

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

Construction noise effect levels

Day	Time (hours)	Averaging Period T	Lowest Observed Adverse Effect Level $L_{pAeq,T}$ (dB)	Significant Observed Adverse Effect Level $L_{pAeq,T}$ (dB)
Mondays to Fridays	0700 - 0800 0800 - 1800 1800 - 1900 1900 – 2200	1 hour 10 hours 1 hour 1 hour	60 65 60 55	70 75 70 65
Saturdays	0700 - 0800 0800 - 1300 1300 - 1400 1400 – 2200	1 hour 5 hours 1 hour 1 hour	60 65 60 55	70 75 70 65
Sundays & Public Holidays	0700 – 2200	1 hour	55	65
Any night	2200 – 0700	1 hour	45	55

Fixed plant noise control

Under BS 4142:
If the “rating level” (L_{Aeq} plus a penalty of up to 9dB for acoustic features such as tonality or impulsivity)
minus L_{A90}
is

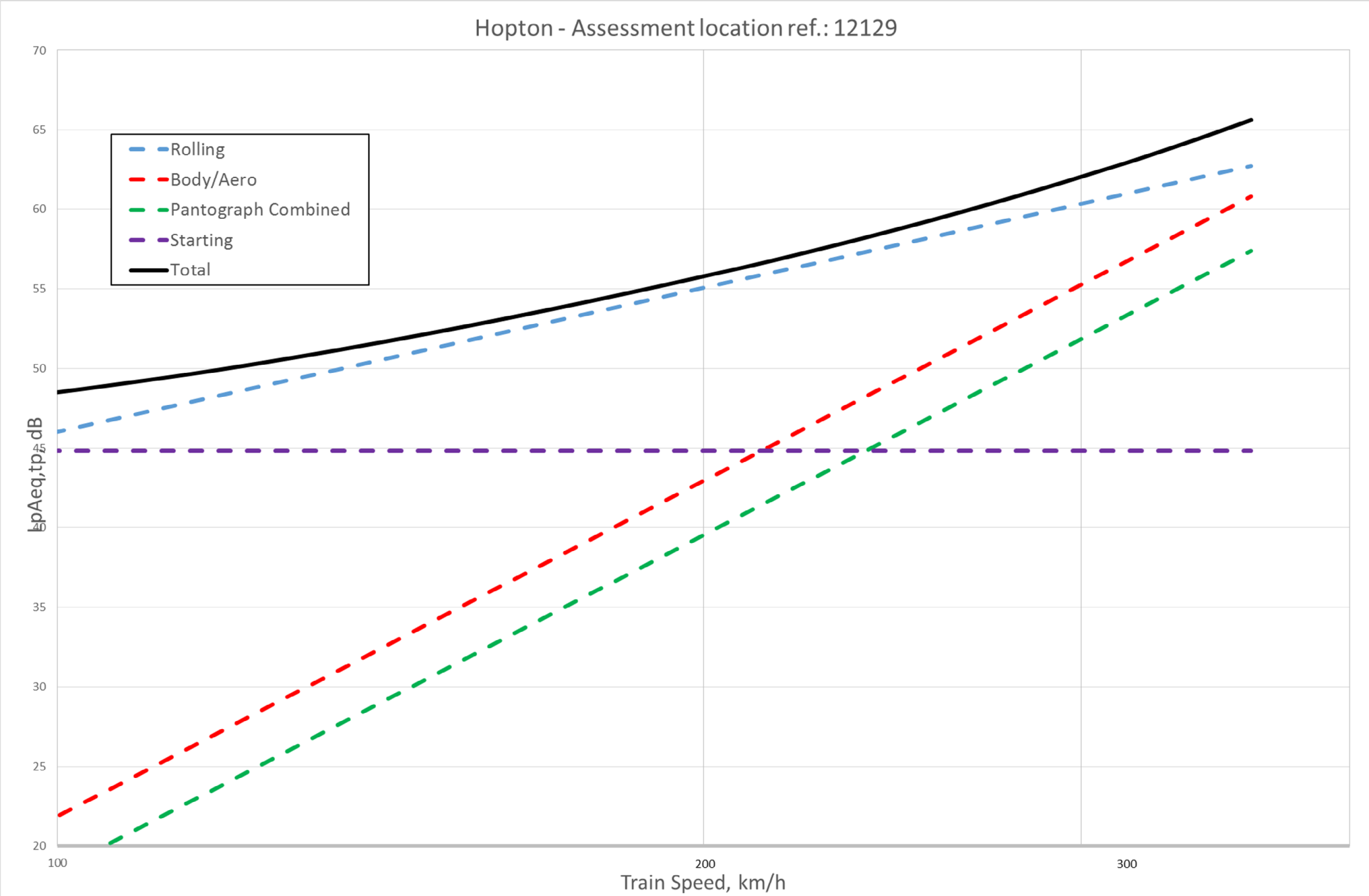
around +10 or more: likely to be an indication of a significant adverse impact
around +5: likely to be an indication of an adverse impact
0 or less: likely to be an indication of a low impact

Mitigation – Operational Noise

Operational noise mitigation measures will include:

- Train and track design
- Noise barriers
- Noise insulation where eligible

Operational Noise – mitigated railway



Mitigation – Train design

Current European TSI compliant trains do not have pantographs / wells designed to minimise aerodynamic noise
(TGV / Eurostar)

Current Asian HS trains do have pantographs / wells designed to minimise aerodynamic noise
(Shinkansen N700)

Mitigation – Noise barriers

Mitigation – Noise barriers

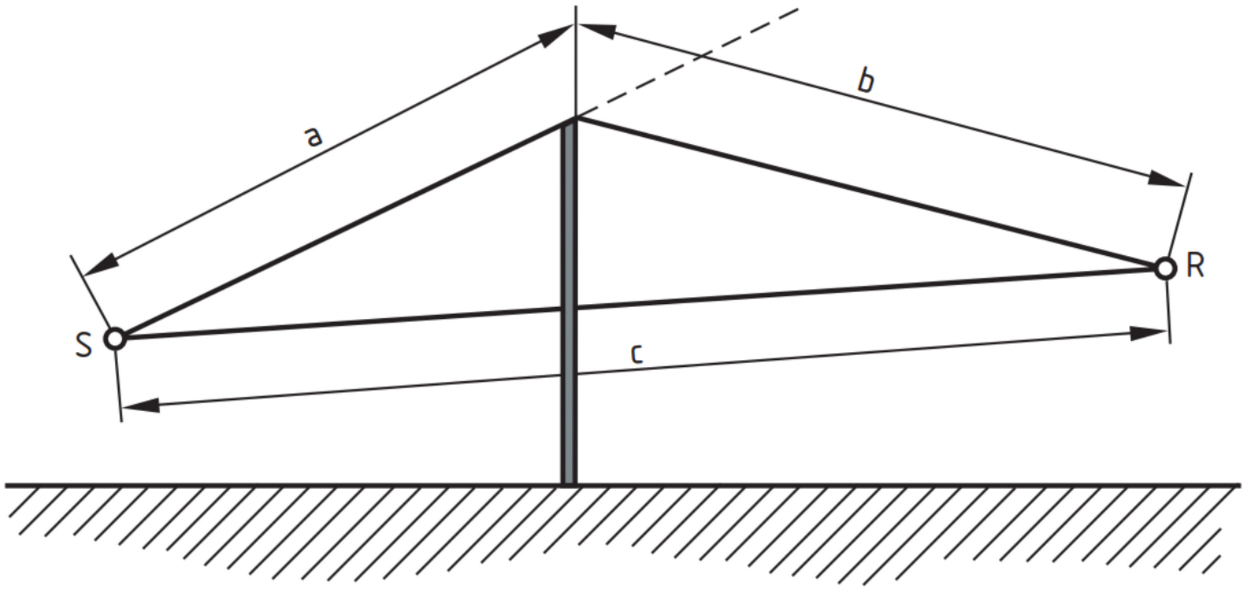


Illustration of path difference (a + b – c) introduced by a barrier

Mitigation – Micropressure waves

When a train enters a tunnel at high speed, there is a sudden rise in pressure like the effect of a piston in a tube.

A special kind of sound wave occurs, in which the compressed crest of the wave travels faster than the trough (because the compressed air is warmer) , causing a steep rise in pressure as the travelling wave passes any fixed point.

This wave travels ahead about three times faster then the train, and when it reaches the tunnel exit portal, some is reflected and some is emitted to the outside world as a boom-like sound.

Mitigation – Micropressure waves

The first wave arrives well before the train emerges, and is followed by smaller waves that have been reflected at both ends of the tunnel and also emerge as weakened copies of the first wave.

The prime means of mitigation is to make the initial rise in pressure on the train's entry to the tunnel smaller and less steep, and this is done by constructing a "porous portal", which does two things:

It is tapered so the entrance to it is considerably larger than the tunnel and it has progressively smaller openings in its sides to allow some air to escape before the train reaches the tunnel "eye".

Mitigation – Micropressure waves

Mitigation – Operational Vibration

Operational vibration will be mitigated by

- Train design and maintenance
- Track design and maintenance

Mitigation – Operational groundborne noise

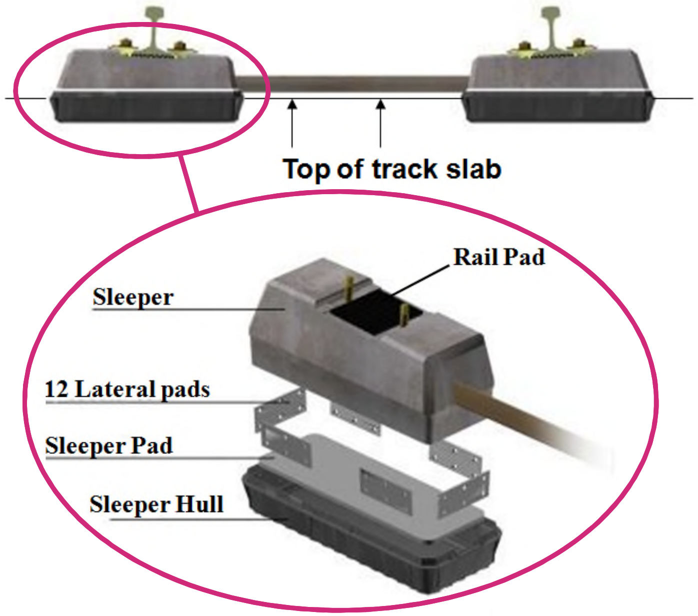
Operational groundborne noise will be mitigated by

- Track design and maintenance
- Continuous welded rail
- Resilient rail support

Standard Track design

Mitigation – Track design

Proven optimised track solutions



Mitigation – Construction Noise

Construction noise will be mitigated by

- Up-to-date methods of working
- Modern plant
- Noise barriers
- Noise enclosures
- Monitoring and management

All subject to Section 61 consent

- Noise insulation/temporary rehousing

Mitigation – Construction Vibration

Construction vibration will be mitigated by

- methods of working
- monitoring and management

All subject to Section 61 consent

HS2 Information Papers

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