Railway noise mitigation factsheet 01: Overview of railway noise

1.1 Noise sources and indicative noise levels

Exterior noise sources on high-speed trains can be broadly categorised as follows and are illustrated in Figure 1.

- **Rolling noise:** Noise generated at the wheel/rail interface; this is affected by wheel roughness, rail roughness and the decay rates of energy in the rail

- **Traction (propulsion) noise:** Sources include traction motors, cooling fans, gears and auxiliary equipment;

- **Aerodynamic noise:** Sources include vortex shedding from wheels (particularly around the first bogies) and pantographs, the train nose and tail, and edges/cavities e.g. gaps between adjoining carriages.

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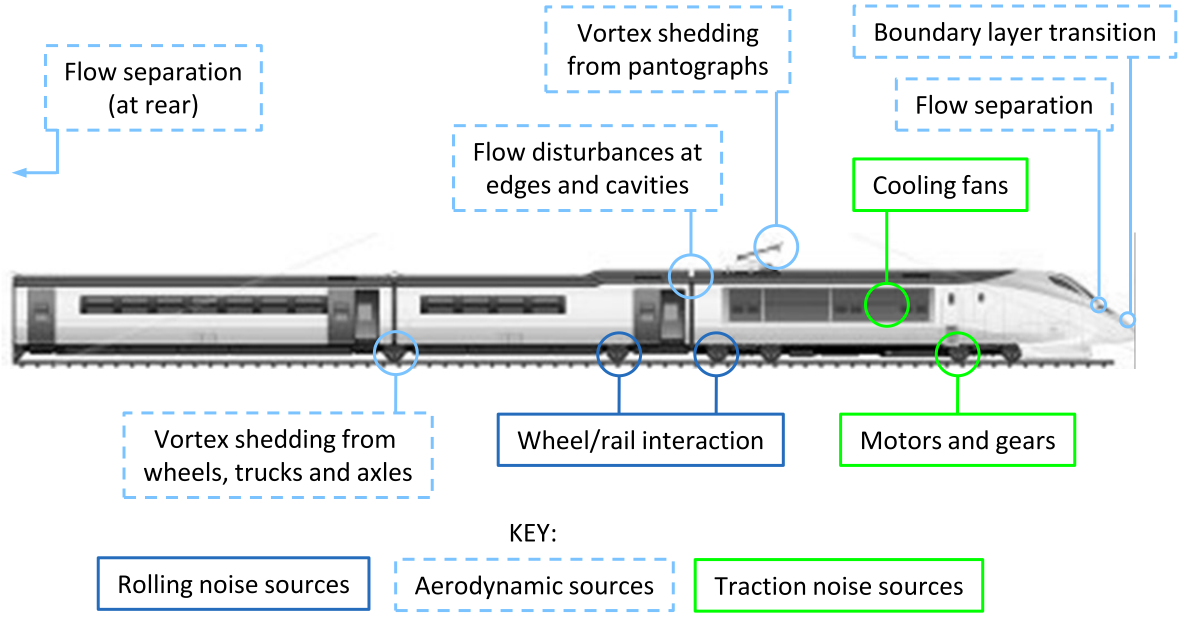

Figure 1: Exterior noise sources on high-speed trains

Other noise sources may also be present, e.g. brake squeal generated by friction brakes at low speeds, wheel rail squeal generated on small radius curves, switches and track equipment

As the Figure shows, these noise sources are distributed over the height of the train. When modelling high-speed train noise for the purposes of noise mitigation, it will therefore be necessary to use models that are capable of taking these different sources into account (see Section 1.1 of this Factsheet)

The noise sources shown in Figure 1 are speed dependent and Figure 2 shows an example of the typical speed dependency. Poisson (2009) reports that traction noise is the dominant noise source at speeds below 80 km/h, rolling noise is the main source from 80-340 km/h (noise levels for this source increase with train speed *V* at a rate of ~30 $\log_{10}V$) and aerodynamic noise is important at speeds above 340 km/h (noise levels for this noise source type increase with train speed *V* at a rate between 60-80 $\log_{10}V$).

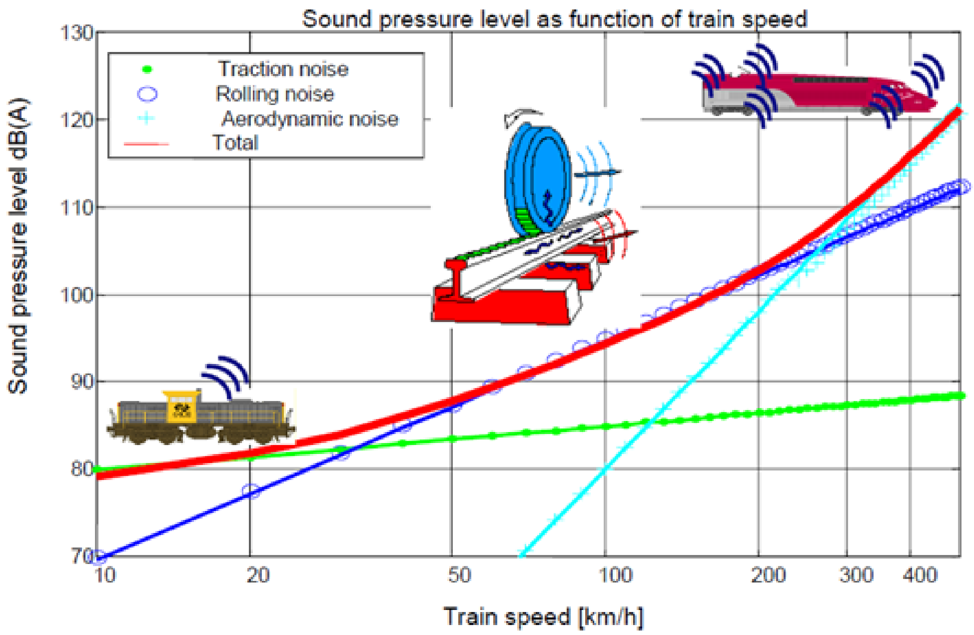

Figure 2: Exterior railway noise sources and their associated speed dependency (from European Commission, 2003)

At the speeds at which HS2 is expected to operate, i.e. 360 km/h for initial technologies and trains, with route alignment designed for 400 km/h (HS2 Ltd, n.d.), the graph shows that aerodynamic noise sources will be the primary source of noise disturbance. Any mitigation measures that are implemented along the route must therefore be capable of addressing these sources.

Based on pass-by measurements taken during a range of studies, over a number of years, at 25m from the track, Table 1 presents indicative pass-by noise levels for different high-speed trains across Europe (Gautier et al, 2007).

It is noted that the proposed operational speeds for HS2 will be greater than anything currently running on existing high-speed rail lines. Assuming that similar technologies are used on HS2, the Table indicates that noise levels in excess of 90 dB(A) will be likely at 25m from the line.

For comparison purposes, the noise levels at a distance of 25m from a motorway generated by the pass-by of individual vehicles travelling at or close to the speed limit will be of the order of 75 dB(A) in the absence of any noise mitigation.

1.2 Modelling and overview of possible noise mitigation options

As noted from the noise sources shown in Figure 1, care will need to be taken in the design and modelling of noise mitigation measures for high-speed rail since not all railway noise prediction models will take account of aerodynamic noise sources. As such, the level of noise mitigation predicted could be overestimated.

Table 1: Pass-by noise levels, dB(A) for high-speed trains measured at 25m

Train (all TSI+ tracks except Belgium)	Test site	Speed (km/h)			
		250	300	320	350
TGV Thalys	Belgium	88.5	92.0	93.0	
	France	85.5	90.0	92.0	
	Germany	85.5			
TGV Duplex	France	87.0	91.0	92.0	95.0
TGV Atlantique	France		90.5		94.7
TGV Réseau	France	89.0	91.5	94.0 (330 km/h)	97.0
ICE3	France	87.5	90.0	91.5	
	Germany	85.5	89.0	92.0	
AVE	Spain	86.0	90.0	91.0	
ETR480	Italy	90.5			
ETR500	Italy	88.0	90.5		
TSI* Limits	TSI+		92.0	94.0	

* TSI: Technical Specification for Interoperability

The standard UK prediction model for railway noise is 'Calculation of Railway Noise 1995' (Department of Transport, 1995a). Even taking into account Supplement 1 of the method which was developed to take account of noise levels from Eurostar trains (Department of Transport, 1995b), the source modelling with CRN may not be appropriate for modelling noise from HS2.

Examples of models which allow for the inclusion of aerodynamic noise sources include the German prediction method Schall 03 (Moehler et al, 2007) and the forthcoming CNOSSOS-EU noise prediction model (Joint Research Centre, 2010).

The Factsheets that accompany this document have addressed noise mitigation measures that can be applied either at/in very close proximity to the source or which affect the propagation path of the radiated noise. Mitigation at the receiver using sound insulation measures (e.g. secondary glazing) have not been addressed. The following paragraphs provide a very short overview of these different measures:

Mitigation of noise at/close to the source:

- **Rail fasteners and slab tracks:** Used to reduce vibration generated noise, particularly on bridges and viaducts (See Factsheet 06, 'Bridges and Viaducts');

Mitigation of noise along the propagation path:

- **Noise barriers:** One of the most common forms of noise mitigation measure used on railways. These may be installed at the trackside, generally no closer to the track than fixtures such as signal posts and electrification masts, or located in close proximity to the sleeper ends (approximately 1.7m from the centre of the track); the latter barriers are generally no more than 1m in height. (See Factsheet 02, 'Full-height noise barriers' and Factsheet 03, 'Low-height noise barriers).

In terms of use for mitigating high-speed rail noise, based on the dominant aerodynamic noise sources, low-height barriers as the sole mitigation measure will be of limited benefit; barriers in excess of 4m in height will be required to screen all of the sources associated with high-speed rail lines.

Careful structural design may be required when used on high-speed rail lines in order to take account of the cyclic dynamic loading caused by the repeated aerodynamic pressure and suction of passing trains;

- **Cuttings/earth berms:** The use of cuttings may be necessary due to the profile of the local terrain through which a railway line is required to pass. However, they may also be implemented specifically for the purposes of noise mitigation; in such instances, this may be a more costly approach than using conventional noise barriers. Screening of receivers through the use of earth berms (mounds) is an alternative option to conventional noise barriers although it is noted that they require a much larger physical footprint (See Factsheet 05, 'Cuttings and earth berms');

- **Tunnels:** The use of tunnels may be necessary due to the local terrain through which a railway line is required to pass. However, they may also be implemented specifically for the purposes of noise mitigation. Secondary noise effects resulting from the passage of trains through the tunnels will result, particularly for high-speed trains. These include sonic boom effects at tunnel portals when high-speed trains enter tunnels and noise emission from ventilation shafts. These secondary noise sources will in turn require mitigation through the use of tunnel hoods/portal design, absorptive claddings and baffles, as appropriate (See Factsheet 04, 'Tunnels').

Any cost information presented within those Factsheets is for illustrative purposes only. Where no cost information is presented this is because no such information has been identified or because there will be too many influencing factors to allow generalised costs to be derived.

1.3 Noise indices and subjective perceptibility

Within the Factsheets that accompany this document, the following noise indices are referred to.

- Sound Pressure Level, SPL, in decibels: This is the standard index for reporting absolute noise levels and is defined as the logarithmic measure of the root mean square (RMS) sound pressure relative to a reference pressure;

- Maximum Noise Level L_{max}, in decibels: This is the standard index used for pass-by noise measurements and is defined as the maximum RMS (root mean squared) noise level occurring in the time period T.

- Sound Exposure Level (SEL): This describes the *cumulative noise exposure* from a single event and is represented by the total sound energy during the event normalised to a one second time interval.

- Peak Noise Level (L_{Peak}): This describes the maximum (instantaneous) level of the noise source.

Other noise indices may also be used, including Leq which is defined as the equivalent noise level for the period, T, i.e. the continuous level that contains the same sound energy as the actual (varying) sound over the time period.

All of these indices will be weighted to adjust the levels to correlate better with what might be heard by the human ear. Two different weighting scales are referred to in the Factsheets: A-weighting, dB(A), is the main way of adjusting measured sound pressure levels to take account of human hearing; C-weighting, dB(C), is another method of weighting data, but is a relatively small correction, sometimes applied to very loud noise sources.

With regard to the subjective perceptibility of changes in noise level, a 1 dB increase is just detectable under the most favourable of laboratory conditions; an increase of 3 dB(A) will be just noticeable to the majority of people; an increase in level of 10 dB(A) is a perceived doubling of loudness.

1.4 References

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