24th INTERNATIONAL CONGRESS ON SOUND AND VIBRATION
23–27 July 2017, London

HIGH SPEED RAILWAY NOISE PREDICTION FOR THE HS2 LINE IN THE UNITED KINGDOM

Graham Parry, David Yates, Mike Ledbetter, Steve Summers & Becki Edwards
ACCON UK, Unit B, Fronds Park, Frouds Lane, Reading, Berkshire, UK
email: graham.parry@accon-uk.com

Proposals for a new high speed railway line in the UK (HS2) have resulted in new noise prediction methods being advocated for a new high speed train. This paper provides a further examination of the methodology which has been utilised and compares the prediction method with measurements of high speed trains both within the UK, France and Germany. In particular the paper considers the many assumptions made for different source contributions and the extent to which predictions of L_{Amax} can be relied upon without providing an uncertainty budget.

Keywords: LAmax, high speed, railway

1. Introduction

This paper assesses the prediction methodology put forward in the HS2 Environmental Statement (ES) by comparing the predicted maximum noise levels (L_{max}) of high speed train pass-bys with the maximum noise levels measured on the existing TGV-Atlantique (TGV-A) line in France. Addditionally, a further noise measurement study has been carried out for ICE trains in Germany during 2017.

2. Noise prediction methods

2.1 Calculation of Rail Noise (1995) (Supplement 1)

Supplement 1 to the Calculation of Rail Noise (1995) produced by the Department of Transport (Department for Transport, 1995) [1] describes the methodology that should be utilised to determine $L_{Aeq,16hr}$ and $L_{Aeq,8hr}$ from high speed Eurostar trains.

The methodology determines two SEL values, one for the rolling noise (SEL_{Tr}) and one for the noise of the fans utilised to cool excess heat produced from rheostatic braking (SEL_{Tf}). These values are then specifically corrected for the Eurostar Class 373 trains which consist of 2 powered cars separated by 18 or 14 coaches. Further corrections are then made for propagation and they are described in the technical memorandum. These SELs are then converted to L_{Aeq} values for the daytime and night-time periods at which point they are combined to provide the predicted daytime and night-time noise levels at the receptor location.

The methodology is unsuitable without augmentation to determine the noise levels of the proposed HS2 line for several reasons including:

- The calculations are specifically tailored to the train types utilised on Eurostar lines and would therefore not be compatible with the more modern trains proposed for HS2; and
- Aerodynamic noise is not included in the prediction methodology.

2.2 Ashdown Report (HS1 Methodology)

Ashdown Environmental Limited (AEL) produced a methodology for predicting the noise levels emanating from the then proposed HS1 line in England (Ashdown Environmental Limited, 1990) [2]. This methodology was shown to over- predict SEL noise levels and predict maximum noise levels relatively well. The HS1 methodology assumes that all of the noise sources originate at a height of 0.5m above the rail head. It does not take aerodynamic noise into account. The methodology was utilised and augmented for the HS2 noise prediction methodology.

2.3 CNOSSOS - EU

Common Noise Assessment Methods in EU (CNOSSOS – EU) (Joint Research Centre of the European Commission, 2012) [3], is the methodology designed to be utilised by EU member states for strategic noise mapping. The assessment of rail noise analyses multiple sources including rolling noise, traction noise, aerodynamic noise, impact noise, squeal noise, braking noise and additional effects. The methodology is not currently utilised by any member states of the EU.

2.4 Schall 03 2006

The German standard for predicting rail noise (SCHALL 03 2006, 2006) [4] identifies four types of high speed units. For each of these units, four types of noise source are identified with a total of nine individual sources. Each individual source is assumed to be at a height of either 0m, 4m or 5m above the rail head. The noise levels at each of these heights are then energetically summed. The types of vehicles and sources considered in the methodology are displayed in Table 1.

Table 1: Vehicle and Source Types.

Type of Vehicle	Type of Noise Source	Individual Sources
High Speed Traction	Rolling Noise	Rail Roughness
High Speed Coach	Aerodynamic Noise	Wheel Roughness
High speed Train-set	Equipment Noise	Structure-borne sound of tank wagons
High Speed tilting tech	Propulsion Noise	Pantograph
		Grills of cooling systems
		Bogies
		Ventilators
		Exhaust Gas System
		Engine

2.5 HS2 Methodology – Environmental Statement (ES)

The methodology utilised to determine noise from high speed trains within the HS2 ES (High Speed 2 Limited, 2013) [5] en built upon the methodology utilised for HS1. Assessment procedures from newer prediction methods, including the assessment of aerodynamic noise and utilising a multi-source concept rather than a single source 0.5m above the rail head have been added.

Due to the trains not yet being acquired for the HS2 line, the methodology has based worst case source terms on the Technical Specification for Interoperability (TSI) (Comission Decision of 21 February 2008 Concerning Technical Specifications for Interoperability Relating to the Rolling Stock sub-system of the Trans-European High-Speed Rail System Notified under Document C (2008) 648., 2008) [6]. It has also been assumed that the HS2 trains are likely to be quieter than the TSI compliant trains due to new “noise mitigation at source” technologies that are likely to be implemented. The methodology has produced source terms for rolling noise, body aerodynamic noise, starting sound and pantograph noise for TSI-compliant trains at 25m. The source terms are displayed in Table 2 below.

Table 2 – TSI compliant train source terms.

Noise Source	Acronym	Source terms
Rolling Sound	$R_{LpAF,max}$	16.6 dB
Body Aerodynamic Sound	$D_{LpAF,max}$	-85.5 dB
Starting Sound	$S_{LpAF,max}$	76.0 dB
Pantograph and Pantograph recess Sound	$P_{LpAF,max}$	92.3 dB

The methodology utilises the source terms given in Table 2 with the relationship for L_{pAFmax} in relation to velocity provided in Table 3 to determine the maximum noise levels generated by each component. The individual values are then energetically summed to determine the overall. Figure 1 provides a graphical representation of the speed (km/hr) against the noise levels for the individual source terms.

Table 3 – TSI compliant train velocity relationships.

Noise Source	Relationship with Velocity
Rolling Sound	$R_{LpAF,max}$ +30log10V
Body Aerodynamic Sound	$D_{LpAF,max}$ +70log10V
Starting Sound	$S_{LpAF,max}$
Pantograph and Pantograph recess Sound	$P_{LpAF,max}$ +70log10V

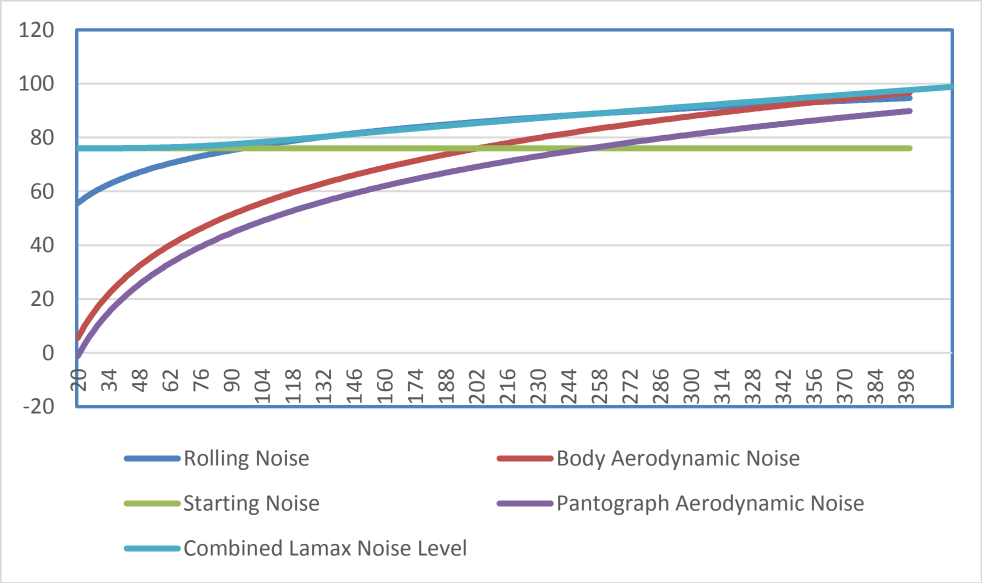


Figure 1: HS2 Methodology Noise Source Levels.

3. Noise Measurements

A previous study, conducted by Technica in 1990, to determine a calculation procedure for prediction of noise levels from the international rail link (Technica, 1990) [7] (now HS1) utilised measurements of the TGV-Atlantique line. This line has seen an increase in the number of trains operating during the daytime and therefore was a good candidate for measuring the noise from a relatively large number of high speed trains.

Simultaneous noise and speed measurements of the existing TGV-Atlantique line between Paris and Le Mans as well as the line between Paris and Tours have been carried out by ACCON Personnel on 14th and 15th April 2016. The TGV-Atlantique line runs southwest from Paris for approximately 125km before splitting, one split heading towards Le Mans and the other heading towards Tours.

3.1 Measurement Locations

A desktop study and a further site reconnaissance exercise were conducted in order to ascertain suitable locations to safely measure noise from high speed trains pass-bys in France. From this, five measurement positions were found to be suitable. Where possible the sound level meters were placed at intervals of approximately 25m, 50m and 100m from the rail head. Distances were checked after the measurement survey and where the distances differ from those specified above, a standard distance correction was applied. Figure 2 below identifies the approximate measurement locations along with the location of the rail and where it splits.

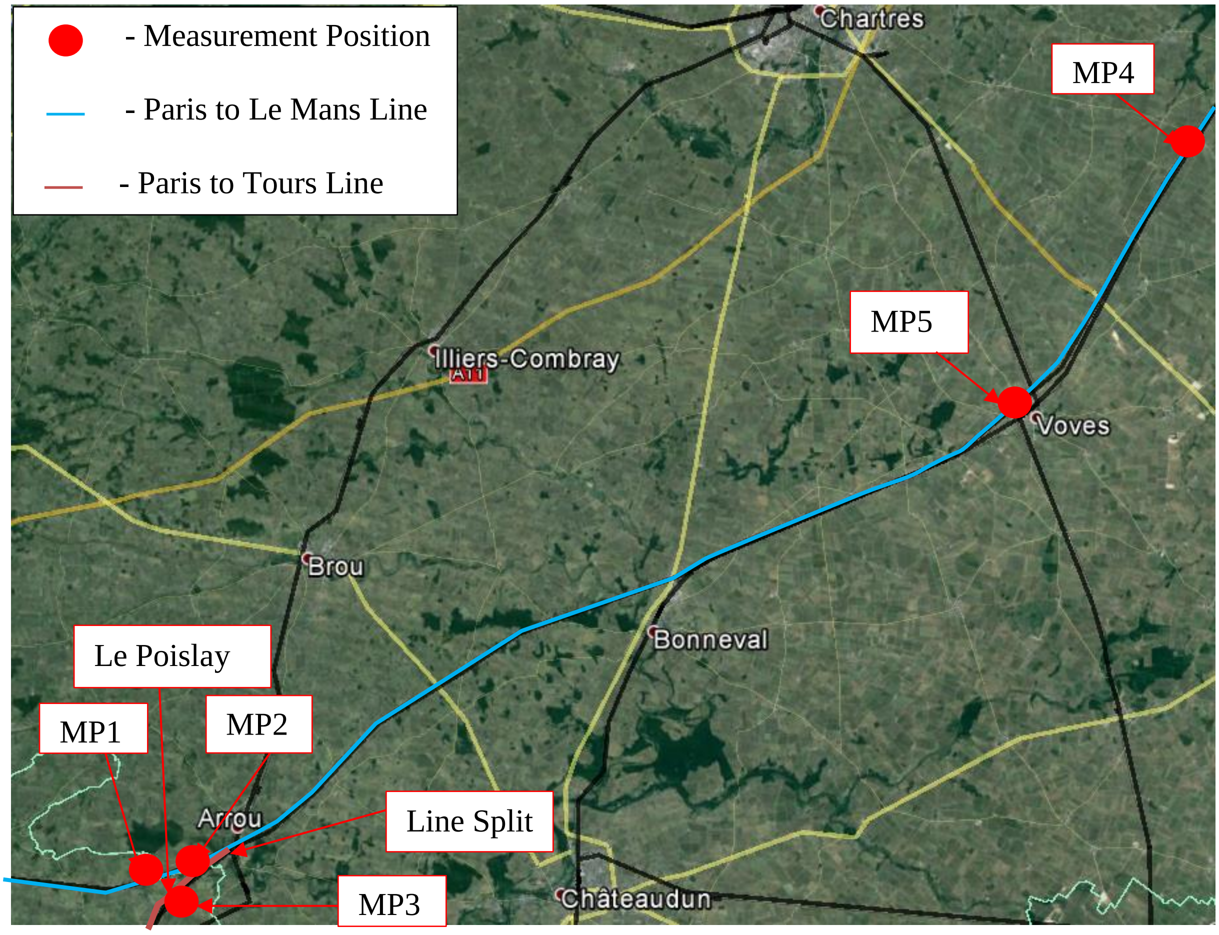


Figure 2: Noise Measurement Locations.

3.2 Measurement Locations in France

Further details relating to the noise measurement study can be found in ICSV23 Paper, Parry, G et al [8].

4. Comparison of Results for TGV trains

The results of the noise measurement survey are shown in graphical format in Figure 3 below. Measurements can be seen at each distance (25m, 50m and 100m) for the corresponding speed and maximum noise levels. The results for 25m, 50m and 100m have been identified individually in Figures 3, 4 and 5 respectively. The graph also shows the predicted L_{Amax} at each of the distances utilising the HS2 ES methodology. The HS2 ES methodology predicts noise levels at 25m. For 50m and 100m the predicted noise levels have been corrected using the distance attenuation formulae stated within the methodology.

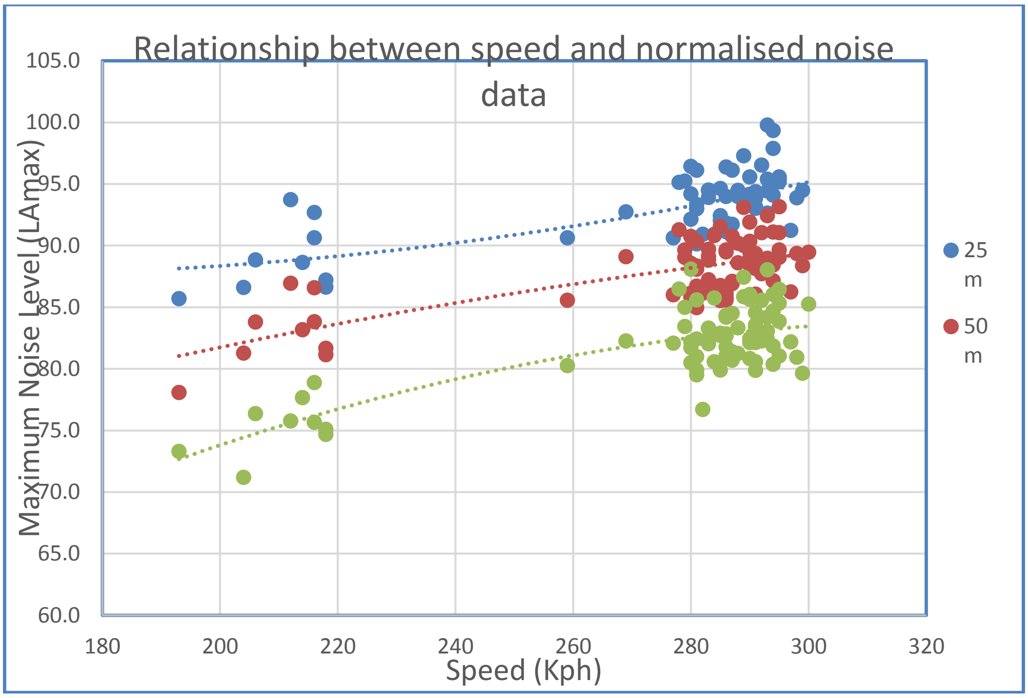


Figure 3: TGV-A Train Noise Levels.

It can be identified from the data presented in Figure 3, that there is a wide spread of LAmax levels for pass-by events at similar speeds. The spread increases with increasing distance from the rail head. The deviation in noise level from the attributed trend line is shown to be:

± 4 – 5 dB when measuring at 25m;
± 5 – 6 dB when measuring at 50m;
± 7 – 8 dB when measuring at 100m.

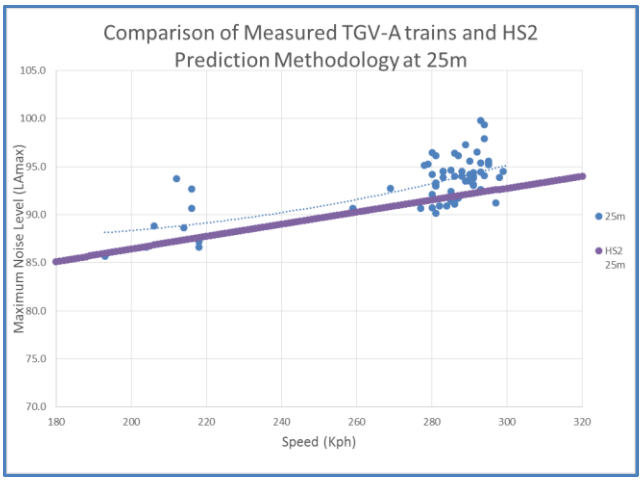
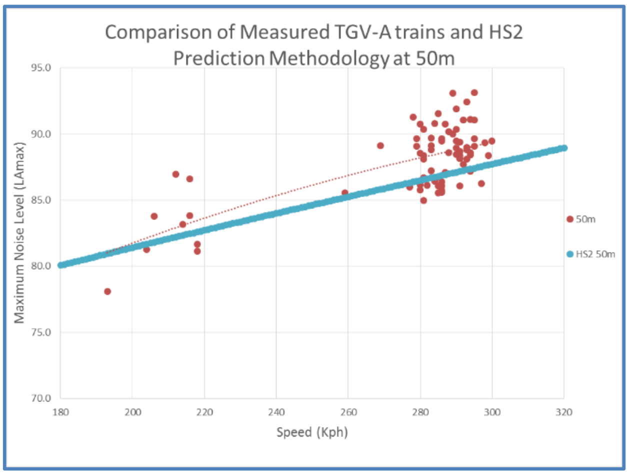


Figure 4 : Comparison of Measured TGV-A trains and HS2 Prediction Methodology at 25m.

The data shown in Figure 4 identifies that the measured data varies from the predicted noise level by up to 5 dB. It can be seen that the noise levels predicted utilising the HS2 methodology have a relatively good correlation with the measured noise levels, however the predictions of the HS2 methodology tends to under predict the L_{Amax} noise levels.



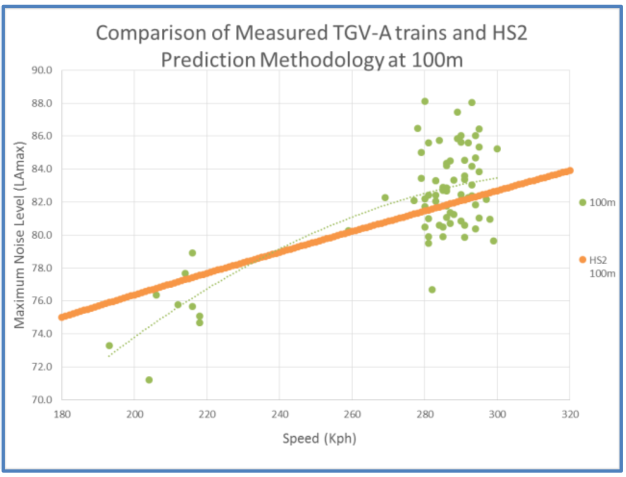


Figure 5 (left): Comparison of Measured TGV-A trains and HS2 Prediction Methodology at 50m.

Figure 6 (right): Comparison of Measured TGV-A trains and HS2 Prediction Methodology at 100m.

It can be identified from the data shown in Figure 5 that the measured data varies from the predicted noise level by up to 6 dB. It can be seen that the noise levels predicted utilising the HS2 methodology have a reasonable correlation to the measured data. It can however be identified in the higher speed data that the HS2 methodology generally under predicts the noise levels.

It can be identified from the data shown in Figure 6 that the measured data varies from the predicted noise level by up to 7 dB. It can be seen that the noise levels predicted utilising the HS2 methodology have an average correlation with the measured data at 100m. The predictions of the HS2 methodology tend to under predict the noise levels.

5. Noise measurement study in Germany

A similar noise measurement study of L_{Amax} was carried out for a number of locations for ICE trains travelling on the German railway line between Munich and Nuremberg. On this line ICE2 trains operate up to 280kph and ICE3 trains operate up to 300kph.

6. Comparison of results for ICE trains

The results of the noise measurement survey are shown in graphical format in Figure 7 below. Measurements can be seen at each distance (25m, 50m and 100m) for the corresponding speed and maximum noise levels.

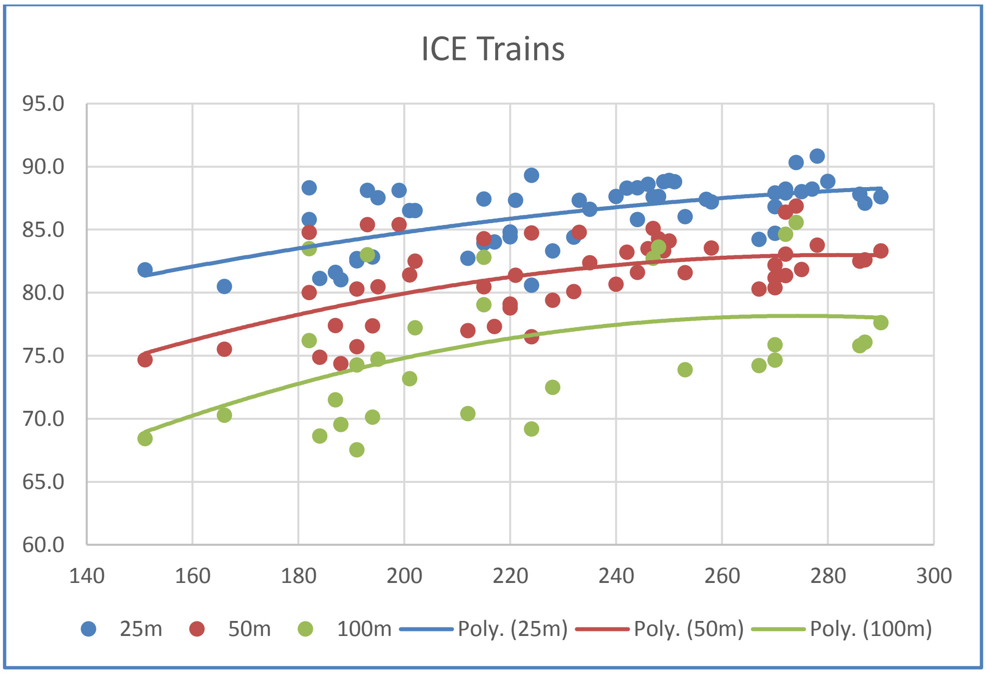


Figure 7: Comparison of Measured Noise Levels from ICE Trains at various rail offset distances.

At the same time as the noise measurements we also captured acoustic camera images of the train passages in order to identify the main sources of noise from the train pass-by.

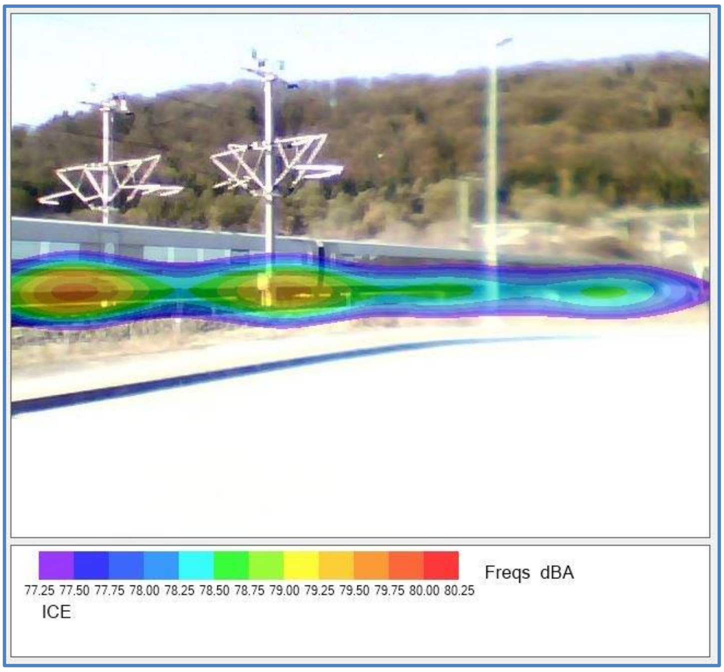


Figure 8: Acoustic camera image for ICE train pass-by.

Figure 8 above provides an image of the acoustic camera results where it can be seen that the principal source of noise generation is from the rail- wheel interaction.

7. Conclusions

It can be identified that the noise levels predicted utilising the HS2 methodology have a relatively good correlation with the measured noise levels at 25m and 50m. This correlation as would be expected worsens as the distance from the rail track increases. The spread of the data for both the studies carried out in Germany and France show that it would not be possible for the prediction methodology to accurately predict the maximum noise level to within ±5 dB which casts uncertainty on the determination of future noise impacts from the HS2 line. It has also been identified that the prediction methodology tends to under predict the noise levels generated by the railway.

It has therefore been demonstrated that extreme care should be taken when determining a model of the maximum noise levels emanating from any proposed high speed railway line. The variances in the L_{Amax} noise level from train movements will be primarily due to rail and wheel roughness which means in practice that some train passages will be higher and some lower than predicted noise levels.

REFERENCES

1 Calculation of Railway Noise., Department for Transport. London: HMSO. (1995).

2 Validation of the methodology for calculation of High Speed Train Noise. Ashdown Environmental Limited. (1990).

3 Joint Research Centre of the European Commission. Common Noise Assessment Methods in Europe (CNOSSOS-EU). Luxembourg: Publications Office of the Europen Union. (2012).

4 Richtlinie zur Berechnung der Schallimmissionen von Eisenbahnen und Straßenbahnen,. SCHALL 03 2006. (2006).

5 London-West Midlands Environmental Statement. High Speed 2 Limited. (2013).

6 Commission Decision of 21 February 2008 Concerning Technical Specifications for Interoperability Relating to the Rolling Stock sub-system of the Trans-European High-Speed Rail System Notified under Document C (2008) 648. (2008).

7 Evans, D. et al, International Rail Link Noise Prediction Procedure & TGV-A Measurement Survey. Technica. (1990).

8 Parry, G. et al, High Speed Railway Noise Prediction for the HS2 Line in the United Kingdom, #640, ICSV23, Athens, 2017