Technical Paper

SURFACE RAILWAY NOISE AND VIBRATION Draft 4, 17 September 2007

1. Introduction

1.1 This Technical Paper provides an explanation of the nature of the assessment of surface railway noise associated with the operation of Crossrail. It explains how people living along the Crossrail route may perceive changes in noise as a result of changes to the rail service. It explains the measures that will be put in place to control the effects of surface noise and vibration from the operation of Crossrail trains. It does not apply to fixed installations which are covered by the Information Paper on fixed installations.

2. The Effect of Different Time Periods on the Measurement and Prediction of Railway Noise

2.1 Railway noise is conventionally measured and assessed using the L_{Aeq} index. The L_{Aeq} is a measure of the mean square sound pressure during a period of time, in dB (A weighted). The "Period" used varies slightly between the various guidance documents as follows:

- Planning Policy Guidance (PPG) 24, Planning and Noise, indicates day and night periods consisting of 07:00 to 23:00 hours for the day and 23:00 to 07:00 hours for the night.
- Calculation of Railway Noise (CRN), 1995 and the subsequent Noise Insulation (Railways and Other Guided Transport Systems) Regulations 1996 (NIR), indicate a longer daytime period of 06:00 to 24:00 hours and shorter night-time period of 00:00 to 06:00 hours.

2.2 In addition to the above, other assessments of major railway projects, such as the Channel Tunnel Rail Link where the assessment was based on the change in the $L_{Aeq, 24\ hr}$, have adopted other periods. Conventionally, separate assessments of noise change for the day and night periods are required, but there is no convention or specific historic precedent to consider impacts over shorter time periods.

2.3 For Crossrail, the noise assessment has addressed two different but related aspects:

- The assessment of impact based upon noise change over the daytime (07:00 to 23:00 hours) and night-time (23:00 to 07:00 hours) periods; a significant impact was deemed to occur if a change of 3 dB(A) or more was predicted.
- The assessment of potential eligibility for noise insulation (NI) under the Regulations mentioned above, where various criteria are assessed for the daytime (06:00 to 24:00 hours) and the night-time (00:00 to 06:00 hours) periods.

2.4 Based upon the above, the measurement and prediction of noise levels from the surface railway has been undertaken for the periods described in

paragraph 2.3 above and no consideration has been given to effects that may occur if shorter periods are considered. This is because values of a noise index such as L_{Aeq} are most helpful if they are associated with social survey results, and no social surveys have been published that relate L_{Aeq} levels for periods shorter than a day or a night to public response. In addition, there is no statutory nor perceived requirement to do this based upon experience and the precedent set by other major rail projects. Notwithstanding this, the perceived change in noise during shorter time periods, such as one hour, may be greater than that for longer periods. Thus, for example, it is possible that a change of greater than 3 dB(A) may occur over a single hour despite the level of noise changing by less than 3dB(A) for the longer assessment periods described in section 2.3 above. This is because there might be relatively larger changes during specific hours of the day or night which are noticed, but which, when the overall impact is averaged over the 16- or 8-hour period, become less than 3 dB(A).

2.5 With regard to measurement or prediction, the daytime period, during which the majority of the services would operate, would be subject to variations in service patterns to accommodate the peak and off peak service requirements. Therefore, noise levels would vary throughout the day but, on the basis that if services double or halve, only a 3 dB change would result (assuming the same vehicle type), quite a large change in services, i.e. greater than a doubling/halving, is required for a significant noise change, as defined in paragraph 2.3, to occur. This is due to the logarithmic nature of the decibel; noise when expressed in terms of the LAeq index is relatively insensitive to changes in the numbers of train movements.

2.6 For the night-time period, services, as already mentioned, are reduced to reflect the lower demand and there would be less hourly variation and it is most unlikely that a 3 dB(A) change would occur within the night-time period if, for example, hourly periods with and without Crossrail were compared.

2.7 With regard to the day and night periods advocated under PPG 24 and CRN/the NIR, the former includes a shorter day/longer night (16/8 hour) and the latter, a longer day and a shorter night (18/6 hour). Therefore, the Crossrail assessment using the PPG 24 periods would include more services in the night-time period than using CRN/the NIR and hence there would be less of a difference between the L_{Aeq} levels forecast for these two periods.

2.8 Hourly noise changes and corresponding day and night-time period noise changes are considered for a number of sections of the railway line in the three following examples. In these three examples the same service pattern assumptions adopted for the ES have been used; the without Crossrail service is based on the winter 2003/4 timetables. The modelling with Crossrail operating was based on the same timetables but adjusted, either by addition or substitution, to take account of Crossrail operating. The only

areas where known service enhancements were included in the modelling were where they were affected by future development of the Docklands Light Railway (DLR). Consequently, the 'Do-Minimum' service pattern scenario for each of the following examples is actually the same service pattern as was operating in winter 2003/4. The following examples are level 2 calculations as defined in Para 5.67 of Volume 1 of the Crossrail Noise & Vibration Technical Report, February 2005.

Example 1: Pudding Mill Lane area

Daytime Period

The maximum hourly change in daytime train flow is between 16:00 and 17:00 hours (13 additional movements over a Do-Minimum flow of 50). An assessment of these changes in flows, taking account of changes in speeds and train types predicts an average noise increase of 1.2 dB(A). The hour with the lowest flow is between 21:00 and 22:00 hours when there are no additional train movements (over a Do-Minimum flow of 36). Assessment of the noise level increase taking account of changes in speeds and train types gives an average noise increase of 0.9 dB(A) for this hour. Therefore, for this section of line, the maximum effect of Crossrail is only an additional 1.2 dB(A) during the worst hour.

The predicted noise change for the period 07:00 to 23:00 hours taking full account of the train types and speeds is calculated to be an increase of 0.9 dB(A). This is not a level of difference that is significant.

Night-time Period

The maximum hourly night-time noise increase that would occur is between 00:00 and 01:00 hours due to a change in train flow of 3 additional movements over a Do-Minimum flow of 23. An assessment of these changes in flows, taking account of changes in speeds and train types predicts a corresponding noise increase of approximately 0.4 dB(A). Between the hours of 01:00 and 05:00 no changes in the numbers of train movements would occur and hence there would be no change in the hourly railway noise levels for these periods. For the hour between 05:00 and 06:00 hours the number of train movements would decreases by 3 (over a Do-Minimum flow of 23), giving a corresponding noise increase of approximately 0.1 dB(A).

The predicted noise change for the period 23:00 to 07:00 hours taking full account of the train types and speeds is calculated to be an increase of 0.7 dB(A). This is not a level of difference that is significant.

Example 2: Romford area

Daytime Period

The approximate maximum hourly daytime noise increase of 1.6 dB(A) would occur between 11:00 and 12:00 hours (4 additional movements over a Do-

Minimum flows of 34). The hour with the lowest increase in noise level (approximately 0.8 dB(A)) is between 17:00 and 18:00 hours when number of train movements would increase by 10 (over a Do-Minimum flow of 52).

The predicted noise change for the period 07:00 to 23:00 hours taking full account of the train types and speeds is calculated to be an increase of 1.1 dB(A). This is not a level of difference that is significant.

Night-time Period

The maximum hourly night-time noise change would occur between 23:00 and 00:00 hours. This change is due to 6 additional movements over a Do-Minimum flow of 22 which gives a corresponding average noise increase of 2.0 dB(A).

The predicted noise increase for the period 23:00 to 07:00 hours taking full account of the train types and speeds is calculated to be 0.9 dB(A). This is not a level of difference that is significant.

Example 3: Plumstead to Abbey Wood section

Daytime Period

The maximum hourly change in daytime train flow is between 17:00 and 18:00 hours (24 additional movements over a Do-Minimum flow of 14). A detailed assessment of these change in flows, taking account of,changes in speeds and train types, indicates an average noise increase of 4.5 dB(A). The hour with the lowest noise increase is between 19:00 and 20:00 hours when there would be 17 additional train movements (over a Do-Minimum flow of 19) and this gives an average noise increase of 2.8 dB(A).

The predicted noise change for the period 07:00 to 23:00 hours taking full account of the train types and speeds, is calculated to be +3.9 dB(A). This represents a significant increase. Significant increases were identified for properties along this section of line in the ES and mitigation measures such as noise insulation and noise barriers were identified.

Night-time Period

The maximum hourly night-time noise change would occur between 00:00 and 01:00 hours due to a change in train flow of 6 additional movements over a Do-Minimum flow of 2. A detailed assessment of these change in flows, taking account changes in speeds and train types, indicates an average noise change of 5.9 dB(A). Between the hours of 01:00 and 05:00 no trains would operate and therefore there would be no changes in the numbers of train movements or in the hourly railway noise levels for these periods. For the hour between 05:00 and 06:00 hours the number of train movements would double (over a Do-Minimum flow of 4) and giving a corresponding average noise increase of 2.9 dB(A).

The predicted noise change for the period 23:00 to 07:00 hours taking full account of the train types and speeds is calculated to be an increase of 4.0 dB(A). This represents a significant increase.

Significant increases were identified for properties along this section of line in the ES and mitigation measures were proposed as indicated above.

2.9 With regard to annoyance, there is evidence that railway noise compared to road traffic and aircraft noise is the least annoying (Transportation Noise Reference Book, Edited by P.M. Nelson, Butterworths, 1987) of these three sources.

2.10 Based upon the above, the following conclusions can be drawn:

- The assessment time periods adopted in assessing the impact of Crossrail reflect those that are defined in national guidance and Regulations and are appropriate.
- There is no national requirement or specific precedent that indicates that assessments should consider shorter time periods.
- The effect of additional services associated with Crossrail, as the services would mostly use existing lines where on the surface, is relatively small. This is true whether the full day or night period or shorter periods are considered. The relatively small difference between peak hour noise changes and whole day noise changes is also a function of the relative lack of sensitivity of the LAeq noise index to changes in traffic numbers.
- With regard to the effects on the population exposed to railway noise, there is evidence that it is the least annoying of all the transportation sources.

3. Predicting Railway Noise

3.1 The predicted change in railway noise at any given location depends upon a number of factors including whether trains have been brought closer to a noise sensitive location (e.g. residential property), the speed of the rolling stock, the size and type of rolling stock, and the number of train passes in any given period.

3.2 As noted in paragraph 2.3, the assessment of operational rail noise for Crossrail considers a significant impact to occur if there is a predicted change of 3dB or greater at a noise sensitive location. In order to assess the nature of the change it is necessary to predict a noise level for both the existing and future situation and compare the difference between the two. It is also apparent that a significant change is more likely where there are presently a low number of train movements because the addition of a new service, even if it is only a few trains would lead to a relatively larger noise impact compared to a situation where there are currently a high number of train movements.

3.3 This point is well illustrated by the predicted noise levels on the southeast section of Crossrail, for example route window SE7 of the ES where the number of trains between Plumstead Portal and Abbey Wood Station would increase from a typical existing peak hour of 16 to 40 once Crossrail is in service. At Custom House there would be a change to the existing situation before Crossrail in that the North London Line is expected to close in early 2007 creating a lull in the noise environment before Crossrail begins operating. This factor was taken into account when the modelling of the impacts of Crossrail was undertaken. Without the North London Line running, the only train noise would come from the Docklands Light Railway. Taking into account the existing background noise, the total predicted noise level at a noise sensitive location with the DLR alone was 68.9 $L_{Aeq,16hr}$ and 62.3 $L_{Aeq, 8hr}$. This rises to predicted levels of 69.3 $L_{Aeq, 16hr}$ and 63.0 $L_{Aeq, 8hr}$ with Crossrail, changes of 0.4 dB and 0.7 dB and no significant impact is predicted.

3.4 A series of 3 drawings are included as part of this Technical Paper illustrating in summary form where changes to track are proposed and the changes in peak hour and off-peak hour train services would occur pre- and post-Crossrail.

4. Surface Railway Noise

4.1 As noted in section 3.1 of this Technical Paper, the predicted change in railway noise at any given location depends upon a number of factors including whether trains have been brought closer to a noise sensitive receptor (e.g. residential property), the speed of the rolling stock, the size and type of rolling stock, and the number of train passes in any given period. For the purposes of this Technical Paper, sensitive receptors are defined in Table 1, below.

Table 1: Sensitive Receptors

Building
Dwellings and other buildings used for residential purposes[1]
Offices
Hotels
Theatres
Auditoria/Concert Halls
Sound recording studios
Places of religious worship
Courts
Lecture theatres
Schools and Colleges
Hospitals
Laboratories
Libraries
Cemeteries
Public open space including recreational areas and sports grounds

Notes

As defined in The Noise Insulation (Railways and Other Guided Transport Systems) Regulations 1996.

4.2 The implementation of Crossrail may result in changes to the existing noise levels at sensitive receptors. In circumstances prescribed by the Noise Insulation (Railways and other Guided Transport Systems) Regulations 1996, those changes may, in the case of dwellings and other buildings used for residential purposes, lead to mitigation in the form of the provision of noise insulation.

4.3 The nominated undertaker will be required to design and construct the new surface sections of the railway using continuously welded rail to the greatest extent practicable with the objective of reducing noise and vibration due to the operation of the surface railway.

4.4 At the detailed design stage, the nominated undertaker will be required to endeavour to design sections of the initial[1] (new), additional[1] or altered[1] surface railway (including the consideration of mitigation measures such as noise

[1] As defined under The Noise Insulation (Railways and Other Guided Transport Systems) Regulations 1996.

barriers) such that in all reasonably foreseeable circumstances the predicted[2] operational noise level increase is restricted to less than 3 dB $L_{Aeq,T}$ at the nearest sensitive receptor, as identified in the ES, when calculated in relation to the periods of a day (07:00 to 23:00) and of a night (23:00 to 07:00), although as mentioned in example 3 above there will be cases where noise will exceed this.

4.5 In addition, during detailed design, the nominated undertaker will be required to endeavour to design sections of the initial (new), additional or altered surface railway (including the consideration of mitigation measures such as noise barriers) such that in all reasonably foreseeable circumstances the predicted operational maximum night-time (23:00 to 07:00) noise level, arising from the initial (new), additional or altered surface railway, due to Crossrail trains, does not exceed 85 dB $L_{Amax,F}$ at the nearest sensitive receptor, as identified in the ES, where existing noise levels due to trains are below that figure, although as mentioned in example 3 above there will be cases where noise will exceed this.

4.6 The nominated undertaker will be required to comply with the Noise Insulation (Railways and other Guided Transport Systems) Regulations 1996, as amended, which set out a requirement to carry out or make a grant toward the provision of insulation works in eligible buildings, where noise levels from initial (new) or additional railway works exceed the predefined limits.

4.7 The Regulations, summarised below, require the nominated undertaker to carry out or make a grant in respect of insulation works in eligible buildings, where noise levels from initial (new) or additional railway works exceed the following triggers:

- the noise levels at the dwelling façade would be above 68 dB L_{Aeq} daytime (06:00 - 24:00) or 63 dB L_{Aeq} night-time (24:00 - 06:00);
- the relevant noise level would exceed the prevailing noise level by 1 dB (A); and
- the noise levels from trains operating on the initial (new) or additional tracks would be at least 1 dB(A) higher than those generated from the trains operating on the unaltered tracks.

For full details see regulation 4 of the Noise Insulation (Railways and Other Guided Transport Systems) Regulations 1996 (SI 1996 No. 428).

4.8 The Regulations, and hence this technical paper, do not apply to stationary trains, station activities, shunting or groundborne noise.

[2] Predictions of operational railway noise will be carried out using the calculation procedure set out in Calculation of Railway Noise (1995) or whichever is the latest edition of that work at the time of modelling.

5. Vibration from the Surface Railway

5.1 At the detailed design stage, the nominated undertaker will be required to endeavour to design sections of the initial (new), additional or altered surface railway in accordance with the guidance set out in British Standard 6472:1992 "Guide to evaluation of human exposure to vibration in buildings (1 Hz to 80 Hz)" such that in all reasonably foreseeable circumstances the predicted operational vibration arising from the initial (new), additional or altered surface railway, expressed as vibration dose value (VDV) at sensitive receptors identified in the ES is no greater than the levels presented in Table 2.

Table 2: Operational Surface Railway Vibration Criteria

In the Absence of Appreciable Existing Levels of Vibration		Appreciable Existing Levels of Vibration[1, 2]
VDV $ms^{-1.75}$ Daytime (07:00 – 23:00)	VDV $ms^{-1.75}$ Night-time (23:00 – 07:00)	% Increase in VDV
0.31	0.18	40

Notes:

1. Highest impact category used, daytime or night-time.

2. There is an appreciable existing level of vibration where daytime and night-time vibration dose values (VDVs) exceed 0.22 $ms^{-1.75}$ and 0.13 $ms^{-1.75}$ respectively.

5.2 Where, when carrying out that design work, vibration at sensitive receptors identified in the ES, arising from any section of initial (new) additional or altered surface railway, is predicted to exceed the levels set out in Table 2, the nominated undertaker will be required to endeavour to include mitigation measures in the design, such as under-ballast mats, which are predicted to ensure compliance with the levels in Table 2 in all reasonably foreseeable circumstances.

6. Maintenance of the Surface Railway and Rolling Stock Wheels

6.1 For those parts of the surface railway that are part of the National Rail network that will be modified by Crossrail, maintenance of them will remain the responsibility of Network Rail. For any parts of the surface railway for the maintenance of which a person other than Network Rail is the nominated undertaker, the nominated undertaker will be required to maintain them in accordance with Railway Group and Network Rail Company Standards. With regard to the generation of vibration and groundborne noise at the wheel/rail interface, the wheels of the Crossrail rolling stock will be maintained, as a minimum, at the level defined by the maintenance requirements necessary to meet the undertaking on this issue set out in Information Paper D10, Groundborne Noise and Vibration.