ARUP

Subject	Comments on Atkins Technical Note – Condition 19 vibration scheme of assessment – 18th February 2015		
Date	11 March 2015	Job No/Ref	237838-00/H01-OB

Oxford City Council (OCC) as a Local Planning Authority (LPA) is in receipt of two applications for the discharge of Condition 19 of the East West Rail Link Phase 1, in respect of a Vibration Scheme of Assessment (VSoA). The VSoA comprises a Plain Line Report, a S&C report and a covering letter, dated 16th may 2014[1,2]. Condition 19 requires that, when submitted, a VSoA must be accompanied by a report from an Independent Expert (IE) which comments on the robustness of the vibration aspects.

The IE for vibration, appointed by the applicant and approved by the LPA, has provided such a report and has concluded that the methods used in the VSoA are robust and may be relied upon. In doing so the IE took account of representations from local residents about detailed technical aspects of the VSoA and the work carried out to produce it.

The Council perceives a gap between on the one hand the position reached by the IE and Council officers and on the other hand, the public perception. The Council is seeking to close this gap by means of external expertise paid for at its own expense.

The Council has therefore appointed Arup as specialist consultant (the Review Expert) with sufficient knowledge, skills and experience:

1. To review the information made available to the IE, the responses he has made to Council officers and the conclusions he has reached, as published in his final report.

2. To advise Council officers of whether the conclusions reached may be relied upon.

On 29th of August 2014 we submitted a report (*R01-OB – 'Our Report'*) which detailed the findings of our review. The report concluded that there were some areas of the VSoA where a material change to the conclusions would occur if more cautious assumptions were adopted. We also highlighted that there were areas where cautious assumptions had been made. Overall, we advised that the applicant should be asked to provide additional evidence of the basis for several VSoA assumptions and therefore broadly how cautious the VSoA is before Arup could advise whether the IE's conclusions could be relied upon or not.

On 12th September a meeting was held between OCC, Network Rail NR (who are seeking discharge of Condition 19) and ERM (technical advisors to NR), Atkins (technical advisors to NR and authors of the VSoA) and Arup. In this meeting it was agreed that NR's technical advisors would respond to several of the recommendations made by Arup in Our Report.

In December 2014, Atkins issued a note which provided further information on the items raised at the September meeting. This technical note was made public in January 2015. On the 10th of February comments were received from the public which identified inconsistencies in the technical note and identified that Switches and Crossings (S&C) had not been considered. Arup made Atkins

[1] East-West Rail: Phase 1, Chiltern Railways Company Limited, Plain Line Vibration Assessment and Mitigation, reference 5114534-ATK-VIB-RPT-80001, revisions P07, 16 January 2014, prepared for Network Rail by Atkins.
[2] East-West Rail: Phase 1, Chiltern Railways Company Limited, Vibration from Switches and Crossings – Assessment and Mitigation. 5114534-ATK-VIB-80003, Revisions A01 28 January 2014.

aware these matters and advised that the S&C should be included in the technical note. The technical note was subsequently revised and re-issued to Oxford City Council 18th February 2015.

This document is our response to the final submission of the technical note (the Technical Note), and is structured as follows:

- Section 1 is concerned with whether the fact that the predictions presented in the VSoA over-predict the current levels of vibration at the Quadrangle may be used to confirm that the VSoA is robust.
- Section 2 discusses the VSoA assumption that vibration inside a property will be similar to the level measured outside and also discusses the alternative assumptions which are presented in the Technical Note.
- Section 3 discusses inter-train variability and whether it has been accounted for appropriately in the VSoA.
- Section 4 discusses the availability of information which could quantify how cautious the VSoA assumptions are relating to the track quality of the proposed scheme and train speed.
- Section 5 discusses predictions of vibration at properties close to S&C which were presented in the Technical Note.
- Section 6 summarises our recommendations to Council Officers (i.e. whether the conclusions reached by the IE, may be relied upon).

1 Discrepancy between EIA and VSoA in terms of vibration from the railway before the scheme was implemented

In Our Report we recommended that further details regarding the measurements presented in the EIA were sought. This was because the discrepancy between the EIA and the VSoA predictions for the levels of vibration from the railway operation before the scheme was implemented indicated that the VSoA assessment was conservative. This was also highlighted by the IE.

The Technical Note reinforces that the prediction method is conservative when compared to the vibration measured at the Quadrangle prior to the Permission being granted. However no further information is provided which could identify why the VSoA over-predicted existing levels of vibration at the Quadrangle.

Given this, the consideration of whether the conclusions reached by the IE may be relied upon is limited to the areas of uncertainty originally raised by us in Our Report. These are discussed further in the following sections.

2 Justification of amplification factor for external to internal vibration

In Our Report we stated that vibration on the first floor of a property may be four times the level of vibration measured on the ground outside of a property as a result of the amplification of vibration

by the building structure (termed the amplification factor hereafter). The application of a four times amplification factor to the VSoA would materially change its conclusions.

As previously reported, the four times amplification factor was derived for High Speed 1 using measurements made in properties close to the London Underground. The relationship has been used to predict the VDV throughout the design and implementation of HS1 and subsequently in the assessment of other railway schemes such as HS2. The relationship has since been further validated as a worst case amplification factor with vibration measurements from tunnelling activities and freight train vibration inside and outside of properties in London. We therefore believe it is a robust and precautionary factor to use in the absence of better information specific to the buildings in question.

The Technical Note addresses the point raised by reiterating that the assumption that vibration inside a building is likely to be the same as the vibration level outside based on the guidance given in Table 14.3 of the ANC *Guidelines on Measurement & Assessment of Groundborne Noise & Vibration*. Table 14.3 provides single value 'transfer functions' which may be used to estimate the transmission of vibration from the ground surface to a building's foundations, the transmission of vibration within a building, and the amplification of vibration within a building.

The Technical Note then provides a sensitivity analysis of the assumptions used in the VSoA by presenting two alternative derivations of an amplification factor. Both are informed by a visual inspection of the buildings in question by a qualified building surveyor:

- **Alternative 1** is a range of amplification factors for the three buildings: Quadrangle, 2B Bladon Close and 3 Bladon Close derived using a 'worst case' interpretation of the single value transfer functions presented in the ANC Guidelines.
- **Alternative 2** applies a range of amplification factors derived using:
    - the frequency dependent transfer functions provided in the references used to define the single value transfer functions in the ANC guidance[3,4]; together with
    - the ground vibration spectrum predicted at the three buildings in question from freight and stone trains measured on the original railway

Alternative 1 proposes 'worst case' amplification factors of 0 dB (vibration outside and inside are equal) at the Quadrangle, 10 dB (3.16 times) at 3 Bladon Close and 14 dB (five times) at 2B Bladon Close.

Alternative 2 proposes, when converted to equivalent single number amplification factors, 'worst case' amplification factors of 1.6 for the Quadrangle and 3 for the two properties on Bladon Close.

The Alternative 1 amplification factors are a reasonable interpretation of the data presented in Table 14.3 of the ANC Guidelines. However, as the Technical Note states, the ANC guidelines also advises *'...the response usually varies with frequency and hence an overall value for amplification and attenuation is difficult to identify*'. Alternative 2 responds appropriately to this by considering the frequency response of the building and the expected frequency content of the ground vibration level at each property.

[3] US Department of Transportation, Transit noise and vibration impact assessment, (2006) Report FTA-VA-90-1003-06. (Downloadable from www.fta.dot.gov)

[4] Transportation Noise Reference Book. Edited by Paul Nelson, Published by Butterworths, 1987. ISBN 0-408-01446.6

We believe that the Alternative 2 approach provides the best available estimate of the amplification factor for each building in that:

- they take into account the type of building structure and the mass of the building;
- in the absence of measured data specific to the buildings in question, they make a worst case estimate of the attenuation provided by the building foundations and the amplification of vibration due to the building structure taking account of visual inspections of the specific properties made by a competent person; and
- they take account of the frequency content of vibration expected on the ground outside the building.

The 'worst case' Alternative 2 'equivalent single number' amplification factors of three for 2B and 3 Bladon Close are in line with the factor of 4 typically used in Arup assessments in the absence of better information specific to the buildings in question. They also avoid the substantial over-estimation that could occur with Alternative 1. For the Quadrangle, Alternative 2 also takes into account that the larger mass of the building (relative to 2B and 3 Bladon Close) is likely to attenuate vibration.

It is important to note that the vibration criteria in Condition 19 are achieved at the Quadrangle, 2B and 3 Bladon Close using the 'worst case' Alternative 2 amplification factors.

3 Inter train variability

In Our Report we noted that freight train vibration on a line with a similar amount of traffic as is proposed for East West Rail may be more variable than demonstrated by the sample of freight train measurements presented in the VSoA. Data obtained from other locations (on other rail lines) suggests that there could be a few trains that generate levels of vibration much higher than the typical level.

Because of this, we felt that the assumption that the inter-train variability of the future freight operating on the line will be similar to the variability measured on the existing lines may not be a cautious assumption.

In the VSoA, the stone train[5] has been taken into account for day time operation of the scheme. It was therefore concluded that the inter-train variability has been dealt with robustly when predicting the daytime VDV. We therefore suggested that a reasonable estimate of upper bound VDV at night could be provided by also assuming that the stone train operates once at night in the vicinity of The Quadrangle and Bladon Close.

The Technical Note responds to this recommendation by stating that:

"*It is outside the remit of the Order Scheme to design and build the railway in a way to address inter-train variability from exceptional trains which do not currently form part of the Scheme*"; and

"*The known day-time operation of the stone train has been specifically taken into account*"; and

"*there is no indication that there would be an intensification in use of the stone train*"

[5] measured during operations prior to the scheme and which generated higher levels of vibration than other trains

The clarifications listed above provide a reasonable degree of confidence that there are no plans to operate stone trains or other trains which are known to generate exceptionally higher levels of vibration at night.

However, there are no safeguards or provisions that we are aware of which limits the type, timing or condition of trains which could operate on the scheme in the future nor obliges the operator to mitigate vibration generated by these trains if they are different from those assumed in the VSoA. Therefore there is a possibility that, in the future, trains could operate and there is a possibility such trains could generate vibration levels which exceed the numerical criteria contained in Condition 19.

4 Track quality and train speed assumptions

In Our Report we stated that the assumption that the current track system is representative of the new tracks and that trains would operate at the permitted line speed were likely to be cautious. We recommended that further information was sought to quantify the extent to which these assumptions could lead to an over-prediction of vibration levels.

Regarding track quality the Technical Note responds as follows:

"*it is considered that an enhanced level of detail on track roughness will not have a significant effect on the findings of VSoA. Although the new track (formation, ballast and rail) will result in a better track quality, and will be maintained to a higher standard than the existing, the difference is not expected to be overly significant when compared with the existing track, which is known already to be in a reasonable condition. This assumption therefore results in a robust assessment*."

On train speed the Technical Note responds as follows:

"*All new infrastructure from Oxford North Junction up to a point just west of Oxford Parkway Station is designed for a maximum line speed of 70mph."*

Passenger trains on leaving Oxford Station will accelerate to a maximum of 70mph at Oxford North Junction before they begin to decelerate to stop at Oxford Parkway Station. It is likely that in practice trains will not exceed 60mph due to defensive driver techniques on the curve and the limited time they could run at 70mph. Trains travelling in the opposite direction will generally follow the same principles.

The maximum speed of freight trains is limited by their type. For instance stone trains are typically limited to either 50 or 60mph depending on the type of wagon in use.

It is considered that the train speeds assumed as part of the VSoA are a conservative representation of the attainable line speeds through Wolvercote."

We concur that the assumptions used for the VSoA in terms of track design and likely train speeds are cautious.

5 Switches and Crossings (S&C)

In the VSoA vibration in properties in the vicinity of S&C was addressed in a separate report to the vibration in properties in the vicinity of plain line track.

Following the public circulation of the original December 2014 technical note, residents wrote to the Council to highlight that the S&C near Bladon Close had been omitted from the assessments presented in that document. Indeed the original technical note had only considered receptors presented in the 'plain line' VSoA report. Arup was asked by the Council's case officers to consider this omission and liaise with Atkins about the relevance of the technical note to the switches and crossings report.

The original Technical note was subsequently revised to include predictions of S&C vibration at 4 Bladon Close. These are referred to in Table 10 of the revised Technical Note. The levels include the effect of increased vibration as a result of the S&C.

The sensitivity analyses presented in the Technical Note – as discussed in the rest of these Comments - are also applicable to the properties identified in the VSoA adjacent to the S&C. We therefore consider it appropriate to combine the outcome of the sensitivity analyses with the amplification in vibration caused by trains traversing S&C when considering the robustness of the VSoA.

The Technical Note presents predictions for S&C vibration applying the "Alternative 2" amplification factors described in Section 2 of these Comments, above. Using these amplification factors the predicted daytime and Night-time VDVs at 4 Bladon Close are 0.48 and 0.24 respectively. On this basis, the Technical Note states that "*Using the worst-case transfer functions, there would be a marginal exceedance of the project limit at No. 4 Bladon Close*". This exceedence is equivalent to 20% above the limit.

The Technical Note goes on to suggest that the predictions for 4 Bladon Close using the Alternative 2 amplification factors are "overly conservative" because they combine conservative assumptions for building amplification with conservative assumptions for inter-train variability and S&C amplification:

"*S&C amplifications apply conservative assumptions in line with the rest of the assessments*";

"*the measured amplification factors [to account for S&C] are lower than the figures assumed in the assessments in 90% of the cases*";

"*it was shown as part of the plain line assessments that only 10% of the observed freight events are expected to exceed the assumed design curves*";

"*The assessments are based on conservative S&C amplification being applied to conservative plain line levels cumulatively*";

"*Considering that the assessments for vibration from plain line and S&Cs already incorporate conservative assumptions, the use of a 'worst-case' transfer function between the outside and the inside of properties would result in overly conservative estimates*"

The way that individual events within a series of events contribute to the total VDV[6] is complex. This makes it difficult to account for the variability on multiple input parameters in a VDV prediction. It is our view that the assumptions made about train source levels, the amplification of vibration that occurs at S&C and the combined cumulative effect of the two parameters are robust, but not over-cautious.

[6] The total VDV of a series of events is calculated as the fourth root of the sum of the fourth power of the VDVs of all the events that occurred. This means that the total VDV is 'weighted' by the highest events in a series of events.

It may be correct that the 'worst case' 'Alternative 2' building amplification factors do result in an over prediction of vibration, however, we would not recommend adopting less cautious assumptions unless further information could be provided to justify their use.

The Technical Note then discusses train speed in the context of the S&C predictions:

"*The assessments also assumed that the freight trains would travel at the design speed of 70mph through the area, when in reality this is likely to be lower (circa 50-60mph) due to the nature of freight rolling stock*"

The train speeds assumed in the assessment for conventional freight and the stone train were 70 mph and 60 mph respectively. If the stone train were to run at 50 mph rather than 60 mph, then the VSoA is over-predicting the daytime VDV by 20%[7] (Using the speed relationship proposed in the VSoA). If the conventional freight were also to run at 50 mph rather than 70 mph then the VSoA is over-predicting the night time VDV by 40%[8] (16% if the conventional freight were to run at 60 mph).

As reported in the Technical Note, both the day and night time VDV planning criteria are exceeded by 20% at one property. If the '*likely*' train speed s were applied to the future scheme the VDV would significantly reduce so that they only marginally exceed the planning criteria (by 4%) or, more likely, were below the planning criteria depending on the actual speed of the future line compared to the cautious assumptions discussed in Section 4.

Given the above we believe that that the Technical Note demonstrates that the VSoA predictions for vibration from S&C are robust when the 'Alternative 2' amplification factors are considered. Using the assumptions discussed in this document, the planning criteria are likely to be exceeded at 4 Bladon Close. However, as stated in the Technical Note, the assumptions for train speed are higher compared to the anticipated operational speeds on the line. If the likely lower speeds were incorporated as assumptions in the predictions it is likely that the planning criteria would be achieved.

6 Conclusions

Conclusions following consideration of the Technical Note

As Review Expert, we have come to the following conclusions after reviewing the clarifications provided in the technical note:

- The Technical Note reinforces that the prediction method is conservative when compared to the vibration measured at the Quadrangle at the time of the Environmental Statement. However no further information is provided which could identify why the VSoA over predicted the previous vibration at the Quadrangle.
- The Technical Note provides a sensitivity analysis of the assumptions made regarding the amplification of vibration inside a building by presenting two alternatives. We believe that the amplification factors derived from the frequency dependent transfer functions provide

[7] Assuming that the stone train was main contributor to the Daytime VDV in the S&C predictions as it was for predictions plain line predictions

[8] Assuming that the conventional freight was the main contributor to the night time VDV in the S&C predictions as it was for predictions plain line predictions

the best available estimate for the buildings in question. With these alternative frequency based amplification factors, we agree that the vibration criteria in Condition 19 are likely to be achieved at the Quadrangle, 2B and 3 Bladon Close.

- The clarifications given in the Technical Note provide a reasonable degree of confidence that there are no plans to operate the stone train or other trains which are known to generate exceptionally higher levels of vibration at night or to intensify the use of these trains further than has been assumed.
- We agree that the assumptions used for the VSoA in terms of track design and likely train speeds are cautious.
- With the application of the amplification factors derived from the frequency dependent transfer functions we consider the predictions for vibration from S&C to be robust. Using the assumptions discussed in this document, the planning criteria are likely to be exceeded at 4 Bladon Close, assuming that the trains run at the assumed line speeds. However, the assumptions for train speed are cautious compared to the anticipated operational speeds on the line. If these speeds we incorporated as assumptions for the scheme it may be possible to demonstrate that the planning criteria can also be achieved near S&C.

In Our Report we summarised our view on the robustness of the individual aspects of the VSoA prediction method. Following the clarifications provided in the Technical Note and our review documented here our revised view of the robustness of the prediction method is provided in the table below:

Aspect	**Impact on predicted VDVs**	**Estimated over or under prediction of VDV by VSoA**
Source data	Neutral	-
Track quality	Cautious	Cannot quantify
Inter train variability (Measured data)	Cautious	<1.3× for freight <1.5× for passenger stock
Inter train variability (Future situation)	Cautious	Cannot quantify
Speed correction	Neutral	-
Speed assumptions	Cautious	Up to 1.2 × daytime Up to 1.4 × night time
Ground vibration decay terms	Neutral	-
Vibration response of buildings using frequency dependent transfer functions	Cautious	Cannot quantify

Overall conclusions of Review Expert

We can conclude that we have reviewed the information made available to the IE, the responses he has made to Council officers and the conclusions he has reached as published in his final report.

As a result of our review we requested additional information on several matters relating to the VSoA, these were outlined in Our Report. The applicant has responded to these matters in two revisions of the Technical Note, the second revision was issued to the Council on the 20th February 2015.

Based on all of the information put in front of us and considering how the assessments have dealt with uncertainty throughout the prediction chain we consider the assessments presented in the VSoA, as clarified in the Technical Note, to be robust. This conclusion is based upon the assumption that the fleet mix, timing of trains and the condition of the trains will not differ significantly from those assumed in the VSoA. Accordingly, on balance, we consider that the conclusions reached by the IE may reasonably be relied upon for the plain line sections of the Order Scheme within the Oxford District.

For the S&C within Oxford District we do not believe that the conclusions reached by the IE may be relied upon. This is because we believe that it is likely that planning criteria will be exceeded at 4 Bladon Close with the current operational assumptions proposed by Network Rail.

For the case of S&C, further information provided by the applicant shows that compliance with planning Condition 19 is only likely if lower freight train speeds are considered. We note that the applicant has suggested that lower train speeds are likely compared to the higher design speed assumed in the VSoA. If these speeds were adopted as assumptions in the assessments it would provide more reassurance that compliance with the planning criteria at 4 Bladon close is likely.

Other matters

Since our appointment in August the residents have raised concerns on a number of additional matters relating to the VSoA.

As part of our remit to determine if the IE's conclusions may be relied upon we have focussed on matters which in our professional opinion are most likely to make a material change to the assessment.

We do however understand the importance of addressing other matters raised and we will therefore be responding further in separate correspondence.