MELBOURNE METRO RAIL PROJECT ENVIRONMENT EFFECTS STATEMENT INQUIRY AND ADVISORY COMMITTEE

MMRA TECHNICAL NOTE

TECHNICAL NOTE NUMBER:	064
DATE:	29 September 2016
PRECINCT:	All Precincts
EES/MAP BOOK REFERENCE:	EES Technical Appendix I: Noise and Vibration
SUBJECT:	Response to the 'Matters for further consideration and/or clarification' request dated 12 September 2016 (xiv) Vibration

NOTE:

1. The following queries were raised by the Inquiry and Advisory Committee (**"IAC"**) in respect of vibration as part of its 'Matters for further consideration and/or clarification' request dated 12 September 2016:

    a. *The basis for the use in NV9 of VDVs as the basis for setting threshold limits for human comfort in regard to continuous and impulsive vibration rather than just intermittent vibration.*

    b. *The reasons why PPVs (or some other criteria based upon RMS velocity/acceleration) either cannot, or should not, be adopted as the basis for these threshold limits especially for continuous construction activities.*

    c. *Whether the criteria identified in BS5228:2009 (PPV) or ISO 10137 (RMS acceleration) could or should be adopted as the basis for such threshold values, and if not why not.*

2. MMRA has instructed Dr John Heilig to prepare a written response which addresses these requests. Dr Heilig's response is provided to the IAC with this Technical Note (**Correspondence A**).

CORRESPONDENCE:

A. Letter from Dr John Heilig dated 27 September 2016

ATTACHMENTS:

No attachments.

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Tuesday, September 27, 2016

Ref:jhh:Response to panel

Mr. Tim Power
Herbert Smith Freehills
Level 42, 101 Collins Street
Melbourne, VIC 3000

RE: Response to Information Request: Vibration

Dear Tim,

1. I have been instructed to prepare a written response to the following three queries which I understand are contained in a request for information made by the Committee on 12 September 2016:

   a. *The basis for the use in NV9 of VDVs as the basis for setting threshold limits for human comfort in regard to continuous and impulsive vibration rather than just intermittent vibration.*

   b. *Reasons why PPVs (or some other criteria based upon RMS velocity/acceleration) either cannot, or should not, be adopted as the basis for these threshold limits especially for continuous construction activities.*

   c. *Whether the criteria identified in BS5228:2009 (PPV) or ISO 10137 (RMS acceleration) could or should be adopted as the basis for such threshold values, and if not why not.*

2. My response to each query is set out below.

Issue 1: ***The basis for the use in NV9 of VDVs as the basis for setting threshold limits for human comfort in regard to continuous and impulsive vibration rather than just intermittent vibration***

3. The use of VDV as the basis for setting threshold limits for human comfort in regard to all types of vibration (continuous, impulsive and intermittent) other than blasting is consistent with BS6472-1:2008.

4. As I explained in my evidence, I believe that this standard is the most appropriate standard to inform the preparation of EPRs concerning human comfort in respect of the Melbourne Metro:

   a. It is the most current of the British and ISO standards;

   b. It has been peer-reviewed and is accepted within the industry;

   c. It has not been superseded or replaced; and

   d. It is based on the most current research into the field of human response to vibration impacts.

5. BS6472-1:2008 presents a consistent methodology (based on the VDV metric) for evaluating vibration impacts on people in buildings for <u>all</u> types of vibration (constant, impulsive and intermittent).[1]

6. It presents guideline criteria that relate the probability of 'adverse comment' to VDV based on social surveys. These surveys show that the duration of exposure to vibration is an important determinant of the probability of adverse comment or annoyance (even for impulsive vibration). The VDV metric is the most suitable metric available to reflect this characteristic of exposure to vibration.

7. There are a number of substantial benefits in expressing the relevant criteria for different types of vibration in a common metric. In projects such as this, where different activities will generate different types of vibration

[1] See p.3 and part 3.5 of BS6472-1:2008.

(potentially concurrently), it would be entirely impractical to specify different metrics in respect of different types of vibration. It would require, for monitoring purposes, that certain activities be discounted from assessment depending on whether they were characterized as generating continuous, intermittent, or impulsive vibration.

8. The characterization of different types of vibration can prove difficult in circumstances where there is not a single source of vibration. It would be particularly difficult in circumstances where multiple sources of vibration operating concurrently generate different types of vibration (which would likely be the case during the construction of the Melbourne Metro).

9. The benefit in adopting a unifying metric is that there is scope to undertake a meaningful comparison between different types of vibration and formulate a response based on a common parameter. It also allows for the establishment of a single monitoring regime that does not need to distinguish between different types of vibration.

10. In saying this, I am aware that the NSW DEC document *Assessing Vibration: a technical guideline* (2006) (**The DEC Guideline**) includes guidelines levels for human comfort based on VDV for intermittent vibration and root square mean (**RMS**) for continuous and impulsive vibration.

11. This approach is outdated. It is based on the previous iteration of BS6472-1 published in 1992, and does not reflect the current research into the impacts of vibration on human comfort. As explained above, the British Standard was specifically amended in 2008 so that it adopts a unifying metric (VDV) in respect of all types of vibration. It does so because research demonstrated that the duration of impact is an important factor in evaluating human responses to all types of vibration (not just intermittent vibration).

12. I have been advised that it has been suggested in evidence that BS6472-1:2008 is not an appropriate standard to adopt for the Melbourne Metro on account of the following passage contained on page iv of the Standard:

> *BS 6472-1 advises use of the estimated vibration dose value only as an approximation to the vibration dose for vibration that is not time-varying in magnitude and has a crest factor which is below about six.*

13. I do not believe that this passage counts against the applicability of BS6472-1 to this project. Firstly and most importantly the relevant EPR does not propose the use of *estimated* VDV (or 'eVDV') but is instead framed in terms of actual or true VDV. The passage is accordingly not applicable in this context. Secondly, I do not accept that the crest factor of the applicable vibration dose will necessarily exceed six.

14. For the reasons set out above, I remain of the view that NV9 is worded appropriately.

Issue 2: ***Reasons why PPVs (or some other criteria based upon RMS velocity/acceleration) either cannot, or should not, be adopted as the basis for these threshold limits especially for continuous construction activities.***

15. As addressed above, I believe that VDV constitutes the appropriate metric to be adopted under EPR NV9, in determining whether the construction of Melbourne Metro will give rise to unacceptable impacts on human comfort (other than in respect of blasting).

16. There is potential for VDVs to be monitored in the field because:

    a. There are commercially available data loggers that record VDV; and

    b. Real-time monitoring and intervention can be achieved using VDV for constant or impulsive vibration sources by extrapolating a short-term measured VDV to predict an outcome for an assessment period, in the same way that an assessment would be made based on a short-term RMS or PPV vibration level.

17. That said, I remain of the view that there may be benefits (both from a monitoring and management perspective) in expressing the VDV criteria as equivalent short term PPV criteria (or even as RMS criteria depending on the preferences of the contractor).

18. This is because the monitoring of PPV is more widespread within the construction industry, and the notion of PPV is more readily understood than VDV. In this respect, I am satisfied that the potential conversion of the VDV criteria into PPV criteria is appropriately provided for in note 2 of NV9.

19. In the case of the Melbourne Metro, where the ultimate construction methodology is yet to be determined, I remain of the view that it is appropriate that any such conversion be documented as part of the Construction Noise and Vibration Management Plan.

20. This is because the derivation of a PPV or RMS value for the purpose of establishing an EPR requires an estimation to be made for the range of parameters that influence the dosage value. These parameters would include the range and relativity of the different vibration frequencies produced by the construction equipment, the differing crest factors,[2] and the proportion of any given unit of time in which a particular piece of equipment is utilised. These values are likely to vary for different equipment types, such as a TBM, road header, hydraulic hammer, and so on.[3]

21. While the contractor could reliably derive PPV or RMS criteria for its CNVMP based upon the construction equipment and schedule it proposes to use in developing the project, for the Committee to try and determine a PPV or RMS criterion now would require the Committee to estimate all of these matters.

22. Again, whilst this could potentially be done based on a series of assumptions, I do not see it as necessary at this stage in the process. The criterion would also need to be flexible enough to respond to any differences in the final construction program once equipment selection had been made.

23. This approach is not unique to this project. BS5228-2:2009 (discussed further below) specifically contemplates the possibility of administering VDV criteria as an equivalent in PPV for human comfort and amenity.[4]

24. In short, whilst it is possible to adopt either PPV or RMS as the basis of establishing criteria for the protection of human comfort, I am of the view that the criteria stated in NV9 (based on VDV) are appropriate.

Issue 3: Whether the criteria identified in BS5228:2009 (PPV) or ISO 10137 (RMS acceleration) could or should be adopted as the basis for such threshold values, and if not why not.

25. Either of these alternate criteria could be adopted in respect of Melbourne Metro. However, for the reasons outlined above, I am of the view that it is more appropriate at this stage in the process to base EPR NV9 on VDV criteria derived from BS6472-1:2008.

<u>BS5228-2:2009</u>

26. The British Standard BS5228-2:2009 provides guideline targets for the protection of amenity, infrastructure and sensitive equipment. The standard explains that the vibration levels at which minimum adverse comment from building occupants is likely to be provoked are aligned with BS6472-1:2008,[5] which is based on the use of VDV or weighted acceleration.

27. However, BS5228-2:2009 goes on to state that for construction it is more appropriate to provide guidance in terms of PPV, as 'this parameter is more likely to be routinely measured based upon the more usual concern over building damage.'[6] I generally agree with this statement for the reasons set out above.

28. BS5228-2:2009 does not provide vibration levels corresponding to the equivalent dosage values, but Table B.1 includes a brief list of vibration levels and their associated effect. Of the values listed in Table B.1, a PPV of 0.3mm/s is considered as just perceptible and a PPV of 1mm/s is considered to cause complaint

[2] The ratio of the peak value of a waveform to its RMS value

[3] See, for instance, TN42 at paragraph 4.

[4] RMS is contemplated for vibration sensitive equipment in Table B.3 (p.42)

[5] Section B.2, p.35

[6] Section B.2, p.36

without some prior notification. There are no other criteria that could be extracted from BS5228-2:2009 in respect of human comfort.

29. For the reasons set out below, I do not recommend that the limited criteria specified in BS5228-2:2008 should be specified in place of those contained in EPR NV9.

30. In particular, based on the PPV values specified in BS5528-2:2009, there is no basis to differentiate between the amenity effect of vibration:

    a. on different land uses in the same way as BS6472-1:2008;

    b. at different times of the day in the same way as BS6472-1:2008; and

    c. for different durations in the same way as BS6472-1:2008.

31. I consider these to be important aspects of the regime proposed under NV9.

32. Importantly, these are matters that could be addressed (as criterion expressed as PPV), as part of the CNVMP in the manner proposed under note 2 of EPR NV9.

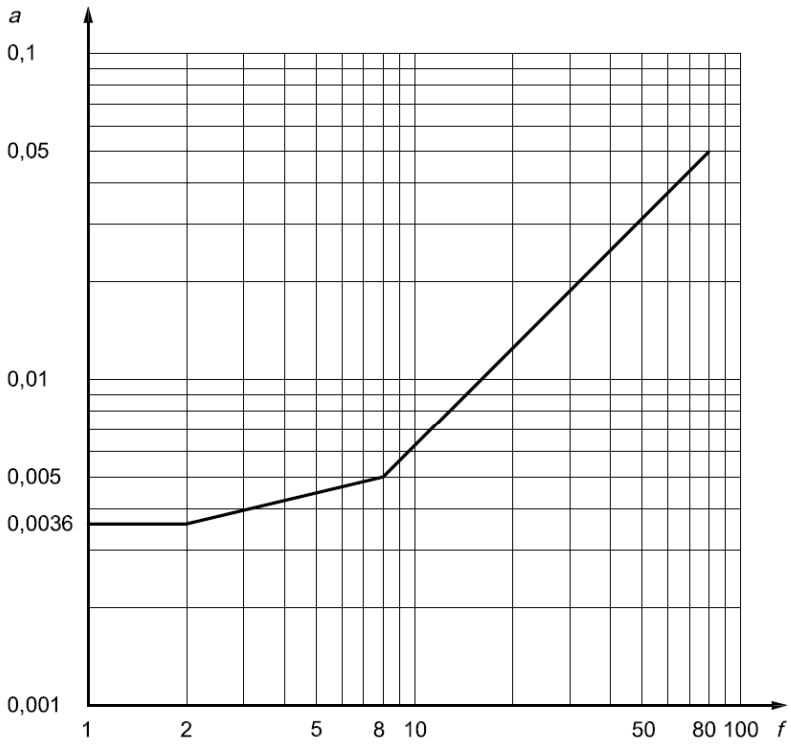
33. In short, the criteria specified in BS5528-1:2009 are not as sophisticated as those specified in BS6472-1:2008.

34. BS5528-2:2009 also provides quantitative information on building damage in accordance with the British Standard BS7385:1993, as well as guidance values for equipment consistent with the ASHRAE criteria. Values for both building damage and equipment protection are appropriately addressed in the proposed EPRs, and there is no need to further consider or apply the recommendations of the BS5228-2:2009 in these respects.

<u>ISO 10137</u>

35. ISO 10137 provides guidance for amenity criteria based upon dosage values which have been referenced to acceleration levels in terms of three charts, referred to as C1, C2 and C3.

36. The charts reference different measurement directions and of these C3, which is classed as a “combined direction” chart, would be most relevant to the construction impacts of Melbourne Metro. The chart is shown below:



Key

a acceleration (r.m.s.), m/s^2
f frequency, Hz

Figure C.3 — Building vibration combined direction (x-, y-, z- axis) acceleration base curve

37. The chart provides an RMS acceleration value per one third octave for acceleration frequencies up to 80Hz. The dosage criterion provides a value which equates to different levels of comment or reaction for a range of scenarios, and provides for permissible levels in terms of acceleration. However, it does not provide a single, easily measured numerical guideline value against which compliance can be measured.

38. If Chart C3 was to be adopted as a Performance Requirement, the whole chart would need to be included as the guideline criteria, as well as the relevant multiplying factors in Table C.1.

39. Compliance could be assessed directly against chart C3 (subject to the application of the relevant multiplication factors), although this would require a more sophisticated monitoring arrangement with one third octave capabilities. Also, because the curve is based on acceleration in the one-third octave range, a detailed assessment would need to be undertaken of the relevant equipment at different frequencies.

40. Alternatively, the curve could be used to form the basis for the contractor to establish PPV guideline values (measured as mm/s) in the CNVMP, once all of the different construction parameters (eg equipment type and vibration profile, duration of use, etc) are known. This type of conversion would be comparable to that described above in respect of the proposed VDV criteria.

41. Note 1 to Table C.1 is also important in assessing whether this approach should be adopted in respect of Melbourne Metro. That note provides that:

> *For evaluating the effects of a vibration signal containing two or more discrete frequency components, the root-mean-quad (r.m.q.) method can be employed.*

42. In the case of the construction of Melbourne Metro, there will be multiple discrete frequency components at any one time as is shown in the figure provided in paragraph 4 of Technical Note 42. This will make

assessment against the applicable base curve complicated and supports the adoption of VDV criteria (which is another name for the 'root-mean-quad' method).

Conclusion

43. Overall, I am satisfied that it is appropriate for EPR NV9 to contain a VDV guideline target, and for the EPR to allow the contractor the flexibility to convert these into PPV or RMS criteria in the CNVMP.

As always, you are most welcome to contact me at your convenience to discuss in further detail any of the issues raised in this letter.

Yours truly,

Dr. John Heilig
Principal - Heilig & Partners Pty Ltd