Appendix G. Peer Review

MELBOURNE METRO RAIL PROJECT

PEER REVIEW OF NOISE AND VIBRATION IMPACT ASSESSMENT

Issued

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1 Introduction

1.1 Scope

Acoustic Studio was commissioned by Herbert Smith Freehills, on behalf of Melbourne Metro Rail Authority, to peer review the noise and vibration impact assessment within the Environment Effects Statement (EES) for the Melbourne Metro Rail Project.

The noise and vibration impact assessment (referred to as the NVIA in this report) was carried out by the AJM Joint Venture.

The intent of this peer review was to assess the NVIA, identify issues for consideration prior to the NVIA being finalized, and to provide recommendations for further consideration through the EES process. The scope of the peer review covers the following aspects of the NVIA:

- The noise and vibration standards and criteria,
- The noise and vibration prediction methodologies used, and the prediction results,
- The proposed noise and vibration mitigation and the assessment of residual impacts.

1.2 Experience

This peer review was carried out by Dave Anderson and Sav Shimada of Acoustic Studio. CVs for both staff are attached at Appendix A.

Sav and Dave have, between them, over 35 years' experience in all aspects of operational rail noise and vibration management, as well as in the preparation and peer review of impact assessments and mitigation designs for new rail infrastructure projects.

Recent rail project experience includes:

- Western Port Rail Freight Line, Victoria – feasibility study, expert witness statement and presentation to panel hearing (2014). Client: Department of Economic Development, Jobs, Transport and Resources, Victoria.
- Sydney Metro NorthWest – Technical Advisor, acoustics, noise and vibration (ongoing). This involves the peer review and technical review of specialist design reports from multiple contractors and consultants. Client: Transport for NSW.

- Sydney Metro City & South West – Peer review and technical review of noise and vibration chapters and reports forming part of the draft Environmental Impact Statement (EIS). Client: Transport for NSW.
- Singapore Circle Line rail fastener replacement – noise and vibration assessment (ongoing). Client: Delkor Rail
- 85 Harrington Street, Sydney – residential development adjacent to existing City Circle rail line (2015). Client: Golden Age
- Wheel squeal noise surveys – pre-lubrication (2014). Client: Transport for NSW
- Rail damper trials – ARTC test site, Wingham NSW (2015). Client: Transport for NSW
- 130 Elizabeth Street, Sydney - peer review of rail vibration assessment and mitigation design (2015). Client: Foresight Management

1.3 Methodology

Acoustic Studio carried out a desktop review of the NVIA by reviewing and commenting on a number of draft versions of the NVIA (and associated Appendices). During the review, we were also provided with an updated copy of the proposed Environmental Performance Requirements (attached as Appendix A).

A number of specific technical issues were discussed at meetings and teleconferences with AJMJV during the review process, particularly relating to:

- Ground borne vibration from excavation and construction in the Parkville precinct, and
- Ground borne noise and vibration from future rail operations throughout the project area.

This report summarises the findings of the peer review. Where items are no longer relevant because, in our view they have been adequately addressed in the current report, or or proposed design / construction methodologies have been modified to reduce impacts, they are not included here. We note that the great majority of items raised in our previous reviews have been addressed in the current report (version P4).

2 Construction Stage: Airborne Noise

2.1 Standards and Criteria

The Victorian EPA Noise Control Guidelines Publication 1254[1] has been correctly applied to the airborne construction noise assessment for this proposal.

The summary table of construction noise assessment periods and applicable environmental noise targets is replicated from the NVIA below.

Table A.1 : Time periods and guideline noise levels

Time Period	Applicable Hours	Guideline Noise Levels	
		Up to 18 months after project commencement	18 months or more after project commencement
Normal Working Hours	7am to 6pm Monday to Friday 7am to 1pm Saturday	No specified Guideline Noise Level - noise reduction measures apply	
Weekend / Evening work	6pm to 10pm Monday to Friday 1pm to 10pm Saturday 7am to 10 pm Sunday and Public Holiday	Noise level at any residential premises not to exceed background noise by 10 dB(A) or more	Noise level at any residential premises not to exceed background noise by 5 dB(A) or more
Night	10pm to 7am Monday to Sunday	Noise is to be inaudible within a habitable room of any residential premises	

Exceptions include *Unavoidable Works* which are works that cannot practicably meet the schedule requirements because the work involves continuous work (such as a concrete pour) or would otherwise pose an unacceptable risk to life or property, or risk a major traffic hazard. Affected premises should be notified of the intended work, its duration and times of occurrence. The relevant authority must be contacted and any necessary approvals sought.

EPA 1254 requires noise levels to be inaudible within a habitable room of residential premises for construction activities taking place during weekend and evenings. This internal noise criterion has been extrapolated in the NVIA to an equivalent external noise level, to facilitate an assessment using environmental noise modelling. The internal inaudibility requirement is conservatively taken to be equivalent to an external noise level of 10dB below the external ambient noise level.

The NVIA correctly states that EPA 1254 does not provide explicit noise targets for works during “Normal Working Hours”, or for “Unavoidable Works” carried out outside normal working hours. We note that the EPA Environmental Guidelines for Major Construction Sites[2] include the overall objective of reducing construction noise and vibration impacts, where possible. We note that, in Part 5 of Appendix A,

[1] Noise Control Guidelines, Publication 1254 October 2008, EPA Victoria

[2] Environmental Guidelines for Major Construction Sites, February 1996, EPA Victoria

the NVIA reviews noise levels from works during “Normal Working Hours” and “Unavoidable Works” carried out outside normal working hours.

2.2 Prediction Methodology and Results

The NVIA states that the construction equipment and methods used in the noise assessment have been reviewed by the relevant construction specialists involved with this project. It is assumed that the equipment and methods are representative of the types of construction activities associated with this project.

Our review suggests that the equipment and activities used in the noise modelling are consistent with the required works including tunnelling, station excavation and surface track works.

The NVIA uses octave band source sound power levels for construction equipment from the UK DEFRA[3] Noise Database, which is a recognised industry standard for construction noise modelling. Sound power levels from the Jacobs in-house database appear to be consistent with Acoustic Studio’s experience.

The environmental noise modelling in the NVIA is implemented with SoundPLAN acoustic modelling software and the ISO 9613-2:1996 *Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation (ISO 9613-2)*. The software and methodology is considered appropriate.

Modelling results for airborne construction noise are in line with other large infrastructure projects. High-level calculation checks have been performed to confirm that the modelling incorporates appropriate corrections for distance attenuation and typical sound absorption / reflection due to the landscape and built area.

As expected, the highest noise levels are associated with above ground works such as rock breaking, piling, excavation and rail sawing.

2.3 Mitigation and Assessment of Impact

We note that EPA 1254 does not have specific statutory noise targets for works during “Normal Working Hours”, or for “Unavoidable Works” carried out outside normal working hours. However, this contrasts with construction noise guidelines in other states, such as the NSW EPA Interim Construction Noise Guideline[4], which

[3] Update Of Noise Database For Prediction Of Noise On Construction And Open Sites, Department for Environment, Food and Rural Affairs (Defra), 2005

[4] Interim Construction Noise Guideline, Department of Environment and Climate Change NSW, July 2009

recommends noise management levels of 10dB above background during normal hours and 5dB above background for any out of hours work.

The NVIA typically predicts noise levels of around 60-70dB(A) at the nearest sensitive receivers during “Normal Working Hours” or “Unavoidable Works”; it also identifies some areas where noise levels could exceed 75dB(A) at times. We note that mitigation options are presented in Part 5 of Appendix A to the NVIA and that these represent examples of practical and beneficial steps that can be taken to reduce noise to acceptable levels.

Recommendation: that the Environmental Performance Requirements commit to reducing noise from these works (i.e. works during “Normal Working Hours” and “Unavoidable Works” carried out outside normal working hours) as far as practical, in line with the EPA Environmental Guidelines for Major Construction Sites[2].

The report states that at the Eastern Portal, where predicted mitigated noise levels shaft construction and retaining wall construction are “well above” the existing noise levels, then temporary relocation or respite periods may be offered. It is not clear how “well above” is defined and it is recommended that a framework is developed to define how additional noise and vibration mitigation and management measures would be implemented.

Recommendation: consider setting up a framework to better define how additional noise and vibration mitigation and management measures (such as temporary relocation or respite periods) would be implemented.

3 Construction Stage: Ground borne Noise and Vibration

3.1 Standards and Criteria

The NVIA establishes standards and criteria for all of the relevant potential effects of construction ground borne noise and vibration, as follows:

- Ground borne vibration
    - Damage to structures and utilities
    - Human perception and comfort
    - Interference with sensitive equipment
- Ground borne noise – human perception and annoyance

The ground borne noise and vibration criteria used in the NVIA are considered to be appropriate for the purposes of the EES. The criteria are conservative in some respects, as discussed below, but it is not considered that the criteria should be modified for the EES. Instead it is recommended that the precautionary nature of criteria are explained when communicating the likely effects to stakeholders and the community, noting that events that exceed the criteria are not necessarily cause for concern.

3.1.1 Damage to structures and utilities - Vibration

Domestic and commercial buildings

The criteria adopted in the NVIA are primarily based on the German standard DIN 4150 Part 3[5], culminating in vibration limits of 5mm/s and 10mm/s for domestic and commercial buildings respectively. We note that AS2187[6] recommends application of the vibration criteria in BS7385[7], commenting that they are “applicable to Australian conditions”. BS7385 recommends vibration limits of 7.5mm/s and 25mm/s for domestic and commercial buildings respectively, which are higher than those used in the NVIA.

Heritage buildings and structures

The NVIA applies a lower vibration limit of 2.5mm/s for heritage buildings and structures. This is an additional level of conservatism given that BS7385 notes that

[5] DIN 4150: Structural Vibration Part 3: Effects of vibration on structures, February 1999

[6] AS 2187: Explosives - Storage and Use - Part 2: Use of Explosives, 2006

[7] BS 7385: Evaluation and measurement for vibration in buildings Part 2, 1993

"A building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive". Although it is conservative, we consider that it is appropriate to apply this precautionary approach and to consider relaxing the limit if the building or structure is reviewed and confirmed to be structurally sound and able to accept higher vibration levels.

Utilities and underground structures

The NVIA criteria for utilities are 20mm/s generally, but 10mm/s for Melbourne Water unreinforced structures / pipework and 2mm/s for the South Yarra sewer main. Again, these are considered conservative given that BS7385 notes "Structures below ground are known to sustain higher levels of vibration and are very resistant to damage unless in poor condition".

Summary

In summary, the NVIA criteria for vibration damage are conservative compared to other available standards and guidance. This is acceptable for the purposes of the EES. However, we recommend that it is carefully communicated to stakeholders and the community, for example as a precautionary approach, so that the actual risk of damage to structures is not overstated or misunderstood.

Recommendation: ensure that that the precautionary nature of criteria are explained when communicating the likely effects to stakeholders and the community, so that the actual risk of damage to structures is not overstated.

3.1.2 Human Comfort - Vibration

The NVIA adopts vibration criteria for human comfort based on "Assessing Vibration: a technical guideline" published by the NSW EPA in (2006)[8]. This is consistent with standard Australian practice for large infrastructure projects.

3.1.3 Sensitive equipment - Vibration

The NVIA adopts the VC curves for sensitive equipment, such as microscopes and MRI machines. This is consistent with international practice and provides a good basis for identifying the potential risk of vibration affects on equipment. We note that the NVIA also discusses the impacts of potential vibration effects relative to measured baseline vibration levels, where available.

3.1.4 Ground borne Noise

The assessment adopts the ground borne noise criteria from the NSW Interim Construction Noise Guideline. This is consistent with the way ground borne

[8] Assessing Vibration: a technical guideline, NSW EPA 2006

construction noise has been assessed on several comparable infrastructure projects in NSW and elsewhere in Australia.

3.2 Prediction Methodology and Results

3.2.1 Source Vibration Levels

The source vibration levels assumed in the NVIA appear to be consistent with those used in comparable assessments, which are based on industry experience and vibration monitoring from many construction projects.

We note that the NVIA assumes that road-headers generate higher vibration levels than tunnel boring machines (TBMs), which is contrary to assumptions made for some recent infrastructure projects. However, we also note the findings of David Hiller[9], an internationally recognised expert in this field, which indicate that the nature of the ground being excavated may have more influence than the excavation method used. Hiller reports a wide range of measured vibration levels from both road-headers and TBMs in various ground conditions. The assumptions used in the NVIA are higher than the range reported by Hiller and are considered an appropriate worst-case basis for the purposes of the EES.

3.2.2 Vibration Propagation

The NVIA uses a detailed model for predicting ground vibration and resulting ground borne noise based on the FTA guideline[10]. This is a comprehensive and robust approach and is considered suitable for the EES.

3.2.3 Results

The NVIA modelling results indicate that vibration levels are expected be within the nominated criteria for damage at almost all locations near the project (the mitigation proposed at the small number of affected locations is discussed in Section 3.3).

In contrast, the NVIA results show that vibration and associated ground borne noise will be clearly perceptible, and potentially annoying, to occupants of many residential and commercial properties. Vibration levels may also affect the operation of sensitive equipment and hospital wards and ICUs at various facilities in the Parkville precinct. These outcomes are typical of tunnelling and underground construction projects and are considered to be representative of the likely impact.

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[9] The prediction and mitigation of vibration impacts of tunneling, Proceedings of ACOUSTICS 2011

[10] Transit Noise and Vibration Impact Assessment, US Department of Transportation FTA document FTA-VA-90-1003-06, 2006

We note that many of the impacts, such as from the tunnelling itself, are relatively short term. Experience on other tunnelling projects shows that community concern and complaints are often motivated by fear about the potential risk of building damage and that these concerns are best addressed by clear communication about the effects and associated risks.

3.3 Mitigation and Assessment of Impact

3.3.1 Damage to structures and utilities

The NVIA indicates that the project is unlikely to have any significant impact in terms of vibration-induced damage. At the small number of locations where vibration levels are predicted to exceed the criteria, appropriate mitigation is proposed, including vibration monitoring and, where necessary, the use of low vibration techniques when construction equipment is working immediately adjacent to affected buildings or structures. The Environmental Performance Requirements commit to this approach as part of the proposed management measures.

3.3.2 Human Comfort and Ground Borne Noise

Not surprisingly, the NVIA indicates that ground vibration and associated ground borne noise are likely to exceed the criteria for annoyance and comfort at many residential and commercial properties. This is to be expected for a project of this scale; appropriate mitigation and management measures are proposed, including community consultation and consideration of temporary relocation.

We note that the NVIA does not propose a framework for how temporary relocation would be managed other than "if vibration and/or ground-borne noise guideline targets are exceeded and the level and duration of disturbance is considered unacceptable, then temporary relocation may be an option." This is open to some interpretation so we would recommend a framework is developed to provide clarity on when affected receivers may be entitled to temporary relocation.

Recommendation: consider setting up a framework to better define how additional noise and vibration mitigation and management measures would be implemented. Several recent infrastructure projects in NSW have established construction noise and vibration management strategies, which include such a framework[11].

[11] Such as Appendix E of the North West Rail Link: Noise and Vibration Technical Paper for Major Civil Construction Works EIS (March 2012)

3.3.3 Sensitive equipment

The NVIA identifies risks of vibration affecting sensitive equipment at several facilities, particularly in the Parkville precinct. Appropriate mitigation is proposed via stakeholder consultation and scheduling of rock-breaking to minimize impact.

The NVIA also assesses the option of an alternative excavation technique based on the use of controlled blasting. This would reduce the overall duration and severity of vibration and ground-borne noise impacts at Parkville during excavation of the station box. This technique has been used successfully on several recent infrastructure projects in urban areas[12] and is considered to be an appropriate alternative construction methodology

[12] Examples include the Clem Jones tunnel in Brisbane, Banora Point Pacific Highway Upgrade in Northern NSW and the NorthConnex tunnel in Sydney

4 Operational Stage: Airborne Noise (Rail)

4.1 Standards and Criteria

The NVIA assesses operational airborne rail noise in accordance with the Victorian *Passenger Rail Infrastructure Noise Policy* 2013 (PRINP). The PRINP applies to wheel-rail noise and does not explicitly include noise from safety-related noise sources such as horns and level crossing audible warnings.

The PRINP provides Investigation Noise Thresholds, which are not noise criteria but are levels at which the proponent needs to consider mitigation methods for the rail noise.

Investigation Noise Thresholds applicable to the project for redeveloped rail lines are replicated from the assessment report below.

Time	Type of Receiver	Investigation Thresholds
Day **(6am – 10pm)**	• Residential dwellings and other buildings where people sleep including aged persons homes, hospitals, motels and caravan parks • Noise sensitive community buildings, including schools, kindergartens, libraries	65 dBL_{Aeq} and a change in 3 dB(A) or more or 85 dBL_{Amax} and a change in 3 dB(A) or more
Night **(10pm – 6am)**	• Residential dwellings and other buildings where people sleep including aged persons homes, hospitals, motels and caravan parks	60 dBL_{Aeq} and a change in 3 dB(A) or more or 85 dBL_{Amax} and a change in 3 dB(A) or more

Notes:

1. If an investigation shows that the thresholds are not exceeded then no further action is considered under this policy.
2. L_{Amax}, for this assessment, is defined as maximum A-weighted sound pressure level and is the 95 percentile of the highest value of the A-weighed sound pressure level reached within the day or night.
3. For the MMRP the location of assessment is at 1 m from the centre of the window of the most exposed external façade. All levels of buildings are included.

It is important to note that the Investigation Noise Thresholds are triggered only if *both* an absolute Day / Night L_{Amax} *or* L_{Aeq} level is exceeded, *and* the project results in a change of 3dB or more. This means that absolute noise levels may exceed the 85dBLAmax Investigation Noise Threshold, but if the project increases the noise level by less than 3dB, there is no requirement to investigate mitigation.

The operational airborne rail noise assessment correctly applies the PRINP approach.

4.2 Prediction Methodology and Results

The NVIA uses source noise levels for the different types of rolling stock expected to use the Melbourne Metro tracks, derived from a number of sources:

- The NSW Rail Noise Database Stage III Measurement and Analysis – January 2015 for TfNSW;
- NORD 2000 reference source noise levels for trains
- Noise measurements undertaken by Jacobs in the existing rail network area
- Noise levels used for the Victorian Regional Rail Link

These source noise levels are considered to be appropriate for the project assessment.

The NVIA makes adjustments to the source sound level values to reflect the measured statistical range for 95th percentile L_{Amax} and SEL, which are required for predicting $L_{Amax(Day/Night)}$ and $L_{Aeq(Day/Night)}$.

Noise modelling using SoundPLAN environmental noise software employs the NORD2000 methodology. Speed corrections (to account for different noise output depending on train speed) adopts the TfNSW Train Noise Database approach. This is considered to be appropriate for the project.

A split-height source model has been adopted which more accurately assesses the influence of topography and built environment in noise propagation than a single-height 0.5m noise source model. This is appropriate for understanding where mitigation may be required and for determining suitable noise barrier heights at locations where Investigation Noise Thresholds are exceeded.

The NVIA includes a check of the model accuracy by comparing existing scenarios modelled in SoundPLAN and against measured levels in two locations. The model was found to be within ± 2 dB of the measurements, which is considered to be a good correlation for an environmental noise prediction model. Absolute noise level predictions are typically more accurate closer to the source.

We note that the predicted change in noise level is likely to be more accurate than the prediction of absolute sound levels, provided that the inputs for train numbers are correct.

The $L_{Aeq(Day/Night)}$ prediction requires an accurate number of trains in each period. The increase in train numbers is particularly important for predicting the change in noise level, since the Investigation Noise Threshold is only triggered when there is an increase in 3dB or more.

It is essential for the assessment of the change in $L_{Aeq(Day/Night)}$ that the existing and future scenarios compare “like for like”, ie existing vs future timetable. Comparing existing timetables with future line capacity, for example, is not an accurate reflection of the predicted increase in noise as rail lines may not always operate to capacity.

The NVIA correctly compares existing with assumed future timetabled train numbers, and the proportion of each rolling stock type used in the two prediction scenarios is provided for reference.

Our basic calculations at three locations yielded similar results to the predicted levels reported in the NVIA, based on the train numbers, types, speeds and distance to nearest receivers shown in the NVIA.

4.3 Mitigation and Assessment of Impact

The NVIA recommends some noise barriers to mitigate operational airborne rail noise near the Western Portal. The height and extent of the barriers appear to be feasible and would effectively reduce airborne rail noise to the Investigation Noise Threshold levels in these areas.

In our experience, noise from safety-related audible warnings (eg train horns and level crossings), or from idling trains at turn-backs, can give rise to disturbance.

Recommendation: While not explicitly covered by the PRINP, it is recommended that consideration is given to the assessment of different characteristics of turn-back noise, such as from stationery idling trains.

5 Operational Stage: Air borne Noise (Fixed Infrastructure)

5.1 Standards and Criteria

The NVIA assesses noise from fixed infrastructure, such as railways stations, substations and tunnel ventilation shafts, in accordance with Victoria *State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade),* No. N-1 (SEPP N-1). This is the appropriate policy for assessment of noise from industrial noise sources such as ventilation equipment used in the ventilation shafts and substations.

5.2 Prediction Methodology and Results

The NVIA describes the method for measuring and determining existing background noise levels near proposed fixed infrastructure facilities, and presents the applicable environmental noise criteria for different periods in accordance with the SEPP N-1.

The NVIA identifies likely noise sources, such as chillers, extract fans, and ventilation systems. However, no attempt has been made to estimate environmental noise levels from these sources based on typical source sound levels for the various plant items.

Recommendation: assuming representative sound power level data is available, assess extent of noise control likely to be required for major plant items.

5.3 Mitigation and Assessment of Impact

The NVIA states that the selection of plant has not been finalised and that noise predictions cannot be carried out. The NVIA includes a general statement that the applicable SEPP N-1 criteria can be met with noise controls such as attenuators, lined ducts and plena, and acoustic barriers.

Based on our experience with similar large railway infrastructure projects, we agree that the SEPP-N1 noise criteria that apply to the MMRP can be met. However we also note that some plant items, such as tunnel ventilation systems, substations and large cooling plant can require significant attenuation.

Recommendation: assuming representative sound power level data is available, assess the mitigation requirements to confirm that the extent of required noise control for major plant items is feasible.

6 Operational Stage: Ground borne Noise and Vibration

6.1 Standards and Criteria

The NVIA adopts the same standards and criteria for the effects of operational ground borne vibration as those used in the construction assessment. This is considered appropriate.

The NVIA uses ground borne noise criteria from the NSW Rail Infrastructure Noise Guideline[13] for residential and educational receivers, together with suggested criteria for commercial and other receivers. These are considered to be appropriate.

6.2 Prediction Methodology and Results

6.2.1 Source Vibration Levels

We are satisfied that the operational source vibration levels used in the NVIA are appropriate. However, the operational source vibration levels initially assumed were lower than those used in comparable assessments for other projects. Assumed source levels are a critical component of the assessment and this was therefore discussed and reviewed in detail with AJMJV to determine whether the assumptions were valid and representative.

We conclude that the methodology used to determine the source vibration levels was detailed, robust and technically valid. In particular, we note that:

- The initial source vibration estimates were derived from measurements carried out by AJMJV within the existing MURL tunnels, with representative track condition, rolling stock types and operating speeds.
- The performance of different track support systems was modelled in detail by AJMJV to generate assumed vibration spectra for each of the representative track systems likely to be used in the final design.
- The assumptions were validated via ground surface vibration measurements near the State Library, above the existing MURL tunnel.

However, we were still concerned that the assumed source vibration levels were lower than comparable data from other operating railways, particularly at frequencies in the region of 100 to 160Hz. AJMJV therefore agreed to increase the

[13] Rail Infrastructure Noise Guideline, NSW Environment Protection Authority, 2013

assumed source vibration levels in these frequencies. The assumptions used in the updated NVIA are considered appropriate for the purposes of the EES.

6.2.2 Vibration Propagation and Results

The NVIA uses a detailed model for predicting ground vibration and resulting ground borne noise based on the FTA guideline[14]. This is a comprehensive and robust approach and is considered suitable for the EES.

Our rough calculations at 5 receiver locations showed similar (but generally lower) noise and vibration levels, indicating that the predictions in the NVIA are appropriate but perhaps a little conservative.

The NVIA results indicate that, without mitigation, vibration levels would affect sensitive equipment in the Parkville precinct and that ground borne noise levels would exceed the criteria at many affected locations. The NVIA demonstrates that these issues can be effectively mitigated by the use of resilient track support systems and that the applicable criteria would be met at all locations.

6.3 Mitigation and Assessment of Impact

The extent of resilient track support systems proposed in the NVIA is considered to be appropriate and the results demonstrate compliance with the applicable criteria at all locations.

[14] Transit Noise and Vibration Impact Assessment, US Department of Transportation FTA document FTA-VA-90-1003-06, 2006

7 Discussion and Conclusions

This peer review of the NVIA has examined the noise and vibration criteria; the noise and vibration prediction methodologies and results; the proposed noise and vibration mitigation; and the assessment of residual impacts.

We conclude that the criteria are appropriate and that the noise and vibration modelling has been carried out competently and appropriately for the scale of the project. The majority of comments raised during our review have been satisfactorily addressed.

The recommendations in this peer review reflect relatively minor issues, in our view. However we consider that addressing these issues through the EES process should ensure that:

- Construction noise impacts are described fully and mitigation is considered, even where not strictly required by the applicable codes;
- Procedures for respite and temporary relocation during construction are clearly defined;
- The risk of damage due to construction vibration is clearly communicated so as to avoid undue stakeholder concern; and
- Feasibility of attenuating noise from fixed plant can be demonstrated.

Appendix A: Updated Environmental Performance Requirements (received 18 April 2016)

Draft EES Evaluation Objective	EPR no.	Environmental Performance Requirement	Precinct	Timing	Risk No.
Noise & Vibration					
Amenity: To minimise adverse air quality, noise or vibration effects on the amenity of nearby residents and local communities, as far as practicable, especially during the construction phase	NV1	Develop and implement a plan to manage construction noise in accordance with EPA publication 1254 Noise Control Guidelines.	All	Construction	
	NV2	For construction works conducted between CBD South station and Domain station, comply with the requirements of the Notification of Referral Decision for the Melbourne Metro Rail Project (EPBC 2015/7549, dated 22 September 2015) under the EPBC Act for vibration monitoring and measurement, as follows: • Conduct preconstruction dilapidation surveys of the nearest Commonwealth Heritage listed structures to the construction activity, including the Former Guardhouse (Block B), to record structural condition and structural integrity prior to commencement of tunnelling • Conduct vibration monitoring at the commencement of tunnelling in geological conditions that are similar to those at Victoria Barracks in order to quantify the actual tunnel boring machine vibration characteristics (level and frequency) for comparison to the values derived from the literature and the German DIN (DIN 4150) target • Conduct continuous vibration monitoring at the nearest Victoria Barracks heritage structures to the construction activity, including the Former Guardhouse (B Block), to assess the actual tunnelling vibration for acceptability, taking into account both the vibration frequency and condition of structures, until monitoring of vibration at the Former Guardhouse (B Block) shows measurements equivalent to preconstruction vibration readings at the Former Guardhouse (B Block) • If monitoring conducted according to the above demonstrates the condition of heritage structures may be degraded as a result of vibration, ground vibration must be reduced by adjusting the advance rate of the tunnel boring machine until monitoring of vibration at the Former Guardhouse (B Block) shows consistent measurements equivalent to preconstruction vibration readings at the Former Guardhouse (B Block).	1 – Tunnels (between CBD South station and Domain station)	Construction	
	NV3	Appoint an acoustic and vibration consultant to predict construction noise and vibration (through modelling) and update the modelling to reflect current construction methodology, site conditions and specific equipment noise and vibration levels (this will require noise and vibration measurements). The model would be used to determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant will also be required to undertake noise and vibration	All	Construction	

<table>
<tr><td></td><td></td><td>monitoring to assess levels with respect to Guideline Targets specified in the Environmental Performance Requirements. Where monitoring indicates exceedances of Guideline Targets, apply appropriate management measures as a soon as possible.</td><td></td><td></td><td></td></tr>
<tr><td></td><td>NV4</td><td>Develop and implement a communications plan to liaise with potentially affected community stakeholders and land owners regarding potential noise and vibration impacts. The plan shall include procedures for complaint management.</td><td>All</td><td>Construction</td><td></td></tr>
<tr><td></td><td>NV</td><td>Implement management actions if construction noise exceeds the internal noise levels below for Highly Sensitive Areas (based on AS/NZS 2107:2000) and a noise sensitive receptor is adversely impacted.
<table>
<tr><th>Highly Sensitive Area</th><th>Maximum Internal Construction Noise Level
$L_{Aeq,\ 15\ mins}$</th></tr>
<tr><td>Intensive Care Wards</td><td>45</td></tr>
<tr><td>Operating Theatres</td><td>45</td></tr>
<tr><td>Surgeries</td><td>45</td></tr>
<tr><td>Wards</td><td>40</td></tr>
</table></td><td>All</td><td>Construction</td><td></td></tr>
<tr><td></td><td>NV5</td><td>Implement management actions if due to construction activity, the following DIN 4150 Guideline Targets for structural damage to buildings (for short-term vibration or long-term vibration) are not achieved.
Short-term vibration on structures
<table>
<tr><th rowspan="2">Type of structure</th><th colspan="3">Vibration at the foundation, mm/s (Peak Component Particle Velocity)</th><th>Vibration at horizontal plane of highest floor at all frequencies</th></tr>
<tr><th>1 to 10 Hz</th><th>10 to 50 Hz</th><th>50 to 100 Hz[1]</th><th>mm/s (Peak Component Particle Velocity)</th></tr>
</table></td><td>All</td><td>Construction</td><td></td></tr>
</table>

Type 1: Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 to 40	40 to 50	40
Type 2: Dwellings and buildings of similar design and/or occupancy	5	5 to15	15 to 20	15
Type 3: Structures that have a particular sensitivity to vibration e.g. heritage buildings	3	3 to 8	8 to 10	8

Notes:

1 At frequencies above 100 Hz, the values given in this column may be used as minimum values

2 Vibration levels marginally exceeding those vibration levels in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage.

3 For civil engineering structures (e.g. with reinforced concrete constructions used as abutments or foundation pads) the values for Type 1 buildings may be increased by a factor of 2.

4 Short-term vibration is defined as vibration which does not occur often enough to cause structural fatigue and which does not produce resonance in the structure being evaluated.

Long-term vibration on structures

Type of Structure	Vibration Velocity, mm/s (Peak Component Particle Velocity) in horizontal plane at all frequencies
Buildings used for commercial purposes, industrial buildings and similar design	10
Dwellings and buildings of similar design and/or occupancy	5
Structures that have a particular sensitivity to vibration eg heritage buildings	2.5

Notes:

1 Vibration levels marginally exceeding those in the table would not necessarily mean that damage would occur and further investigation is required would be required to determine if higher vibration

<table>
<tr><td></td><td></td><td>levels can be accommodated without risk of damage.
2 Long-term vibration means vibration events that may result in a resonant structural response.</td><td></td><td></td><td></td></tr>
<tr><td></td><td>NV6</td><td>Undertake condition assessments of above and below ground utility assets and establish construction vibration limits with asset owners.
Monitor vibration during construction to demonstrate compliance with agreed vibration guideline targets. Take remedial action if limits are not met.</td><td>All</td><td>Construction</td><td></td></tr>
<tr><td></td><td>NV7</td><td>Implement management actions if the following DIN 4150 Guideline Targets for buried pipework/underground infrastructure from construction are not achieved.
<table>
<tr><th>Pipe material</th><th>Vibration Velocity, mm/s (PPV)</th></tr>
<tr><td>Steel</td><td>100</td></tr>
<tr><td>Clay, concrete, reinforced concrete, prestressed concrete, metal</td><td>80</td></tr>
<tr><td>Masonry, plastic</td><td>50</td></tr>
</table>
Notes:
1 These values may be reduced by 50% when evaluating the effects of long-term vibration on buried pipework
2 It is assumed pipes have been manufactured and laid using current technology (however it is noted that this is not the case for the majority of buried pipework potentially affected by Melbourne Metro)
3 Compliance with is to be achieved with asset owner’s Utility Standards.</td><td>All</td><td>Construction</td><td></td></tr>
<tr><td></td><td>NV8</td><td>For the operation of TBMs and road headers implement management actions if the following Guideline Targets (VDVs) (based Table 1 in BS6472-1:2008) for continuous (as for TBMs and road headers), intermittent, or impulsive vibration are not achieved.
<table>
<tr><th rowspan="2">Location</th><th colspan="4">VDV (m/s$^{1.75}$)</th></tr>
<tr><th colspan="2">Day
7:00am to 10:00pm</th><th colspan="2">Night
10:00pm to 7:00am</th></tr>
<tr><th></th><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
</table></td><td>All</td><td>Construction</td><td></td></tr>
</table>

		Offices, schools, educational institutions, places of worship	0.40	0.80	0.40	0.80			
		Workshops	0.80	1.60	0.80	1.60			
		Notes: 4 The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures. If exceeded then management actions would be required.							
	NV9	Implement management actions if the following ASHRAE equipment vibration Guideline Targets or measured background levels (whichever is higher) are exceeded for vibration sensitive equipment during construction at Parkville and CBD North stations.					4 – Parkville station 5 – CBD North station	Construction / Operation	

Equipment requirements	Curve
Bench microscopes up to 100x magnification; laboratory robots	Operating Room
Bench microscopes up to 400x magnification; optical and other precision balances; co-ordinate measuring machines; metrology laboratories; optical comparators; micro electronics manufacturing equipment; proximity and projection aligners, etc	VC-A
Microsurgery, eye surgery, neurosurgery; bench microscope at magnification greater than 400x; optical equipment on isolation tables; microelectronic manufacturing equipment such as inspection and lithography equipment (including steppers) to 3mm line widths	VC-B
Electron microscopes up to 30,000x magnification; microtomes; magnetic resonance images; microelectronics manufacturing equipment such as lithography and inspection equipment to 1mm detail size	VC-C
Electron microscopes at magnification greater than 30,000x; mass spectrometers; cell implant equipment; microelectronics manufacturing equipment such as aligners, steppers and other critical equipment for phot-lithography with line widths of ½ micro m; includes electron beam systems	VC-D
Unisolated laser and optical research systems; microelectronics manufacturing equipment such as aligners, steppers and other critical	VC-E

		equipment for photolithography with line widths of ¼ micro m; includes electron beam systems			
	NV10	Implement management actions as agreed with potentially affected land owners to protect amenity at residences, sleeping areas in hospital wards, student accommodation and hotel rooms where the following ground-borne noise Guideline Targets (from the NSW Interim Construction Noise Guideline) are exceeded during construction. Time Period: Internal $L_{Aeq,15min}$, dB Evening, 6pm to 10pm: 40 Night, 10pm to 7am: 35 *Notes:* 1 Levels are only applicable when ground-borne noise levels are higher than airborne noise levels 2 The noise levels are assessed at the centre of the most affected habitable room 3 Management actions include extensive community consultation to determine acceptable level of disruption and provision of respite accommodation in some circumstances.	All	Construction	
	NV11	To protect buildings from blasting Comply with Australian Standard AS2187.2-2006, Explosives – Storage and use Part 2 – Use of explosives for all blasting • Apply a PPV Limit of 3 mm/s for Highly Sensitive Areas (hospital wards, operating theatres and bio-resources	4 – Parkville station	Construction	
	NV12	To protect the amenity of Bio-resources and sensitive research during construction and operation the following criteria apply: • Background noise should be kept below 50 dB and should be free of distinct tones (internal) • Short exposure should be kept to less than 85 dB (internal).	4 – Parkville station 5 – CBD North station	Construction / operation	
	NV13	Appoint an acoustic and vibration consultant to predict noise and vibration and determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake commissioning noise and vibration measurements to assess levels with respect to the Environmental Performance Requirements.	All	Operation	
	NV13	Avoid, minimise or mitigate rail noise where the following PRINP (Victorian Passenger Rail Infrastructure Noise Policy, April 2013) Investigation Thresholds are exceeded during	All	Operation	

operation:

Time	Type of Receiver	Investigation Thresholds
Day (6am – 10pm)	• Residential dwellings and other buildings where people sleep including aged persons homes, hospitals, motels and caravan parks • Noise sensitive community buildings, including schools, kindergartens, libraries	65 dBL_{Aeq} and a change in 3 dB(A) or more or 85 dBL_{Amax} and a change in 3 dB(A) or more
Night (10pm – 6am)	• Residential dwellings and other buildings where people sleep including aged persons homes, hospitals, motels and caravan parks	60 dBL_{Aeq} and a change in 3 dB(A) or more or 85 dBL_{Amax} and a change in 3 dB(A) or more

Notes:

1 If an investigation shows that the thresholds are not exceeded, then no further action is considered under the PRINP

2 L_{Amax}, is defined as maximum A-weighted sound pressure level and is the 95 percentile of the highest value of the A-weighed sound pressure level reached within the day or night

3 For Melbourne Metro the location of assessment is at 1m from the centre of the window of the most exposed external façade.

NV14	For operation, comply with State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade) No. N-1 (SEPP N-1).	All	Design / Operation
NV15	Where operational ground-borne noise trigger levels are exceeded for sensitive occupancies as shown in the table below (trigger levels are based on the Rail Infrastructure Noise Guideline,17 May 2013 (RING(1)), assess feasible and reasonable mitigation to reduce noise towards the relevant ground-borne noise trigger level.	All	Operation

Sensitive land use	Time of day	Internal noise trigger levels
Residential	Day (7am-10pm)	40 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more
	Night	35 dBL_{ASmax} and an increase in existing

			(10pm-7am)	rail noise level by 3 dB(A) or more			
		Schools, educational institutions, places of worship	When in use	40-45 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more			
		Hospitals(bed wards and operating theatres)	24 hours	35 dB(A) L_{ASMax}			
		Offices	When in use	45 dB(A) L_{ASMax}			
		Cinemas and Public Halls	When in use	30 dB(A) L_{ASMax}			
		Drama Theatres	When in use	25 dB(A) L_{ASMax}			
		Concert halls, Television and Sound Recording Studios	When in use	25 dB(A) L_{ASMax}			
		Notes: 1 RING provides trigger levels for residential and schools, educational institutions and places of worship, but does not provide guidance on acceptable ground-borne noise levels for other types of sensitive receivers. Ground-borne noise trigger levels for other types of sensitive occupancies have been devised based on RING and industry knowledge. 2 Specified noise levels refer to noise from heavy or light rail transportation only (not ambient noise from other sources) 3 Assessment location is internal near to the centre of the most affected habitable room 4 L_{ASmax} refers to the maximum noise level not exceeded for 95% of the rail pass-by events 5 For schools, educational institutions, places of worship the lower value of the range is most applicable where low internal noise levels is expected 6 The values for performing arts spaces may need to be reassessed to address the specific requirements of a venue.					
	NV16	During operation, achieve the Guideline Targets (based on Table 1 in BS6472-1:2008) for vibration as follows:				All	Operation	

Location	VDV (m/s$^{1.75}$)			
	Day 7:00am to 10:00pm		Night 10:00pm to 7:00am	
	Preferred Value	Maximum Value	Preferred Value	Maximum Value

Residences	0.20	0.40	0.10	0.20	
Offices, schools, educational institutions, places of worship	0.40	0.80	0.40	0.80	
Workshops	0.80	1.60	0.80	1.60	

Notes:

7 The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures

8 Compliance with these values implies no structural damage due to operation.

Appendix B: CVs for Dave Anderson and Sav Shimada

acoustic studio

Dave Anderson

Acoustic Engineer
Director, Acoustic Studio

Career Overview

Dave joined **Acoustic Studio** Pty Ltd in 2014, from RailCorp NSW. He has over 25 years of experience in acoustics, noise and vibration across a wide range of fields and is a recognised expert in transport noise and vibration.

Dave graduated from the **Institute of Sound and Vibration Research** in the UK and joined **Arup Acoustics** in 1989. He moved to the Australian office of Arup Acoustics in 1995, and then joined the **Rail Infrastructure Corporation** (which later became RailCorp and Transport for NSW) as in-house noise specialist in 2002.

Dave has in-depth experience in noise and vibration issues associated with rail and tunnel projects and has co-authored numerous technical papers on the subject (a selection of relevant references is attached at the end of this CV).

Dave has extensive experience in communicating with a range of stakeholders, including community, project design teams, researchers, regulators, operations and maintenance personnel and senior executives.

Qualifications

Master of Engineering (MEng) in Acoustics and Vibration

Professional Associations

Member of the Australian Acoustical Society
Member of the Institute of Acoustics, UK
Chair of the international committee for the **International Workshop on Railway Noise**
Chartered Engineer, UK

Expertise Areas

Dave's in-depth experience in noise and vibration includes prediction, impact assessment and design; the review, assurance and commissioning roles for numerous rail and tunnel projects; trouble-shooting and research & development for operational rail noise issues; and the role of Industry Chair for a Cooperative Research Centre project on rail noise.

In summary, Dave has in-depth experience in all areas of rail and tunnel acoustics, noise and vibration and across all stages of the asset life-cycle.

Key Projects

Western Port Rail Freight Line, Victoria

Feasibility study, expert witness statement and presentation to panel hearing (2014). Client: Department of Economic Development, Jobs, Transport and Resources, Victoria.

Sydney Metro North West (ongoing)

Sydney Metro is Australia's largest public transport infrastructure project. It includes construction of twin 15 km tunnels from Bella Vista to Epping, which are Australia's longest rail tunnels. The North West component has a project value of $8.3bn.

Dave leads Acoustic Studio's role as the ***Technical Advisor*** for Transport for NSW for acoustics, noise and vibration.

Singapore Circle Line, Stages 2 & 3 (2002), for LTA

Noise & vibration study encompassing empirical and numerical modelling of ground borne noise and vibration from the operation of the new line.

Scope included in-tunnel and ground surface vibration measurements near Novena Station on the existing North-South line.

Sydney Airport Rail Link ('97-'99)

Noise and vibration prediction, assessment, design and commissioning for tunnel fit-out contractor, Rail Services Australia. Vibration mitigation design included the first significant use of under-ballast mats in Australia [2].

Other Relevant Experience

Sydney Light Rail, Sydney ('95-'97)

Dave provided expert advice to CityWest Development Corporation on noise and vibration impacts and mitigation requirements for residential and commercial redevelopments in Pyrmont, adjacent to the new light rail system.

Epping Chatswood Rail Link, Sydney ('02-'09)

Dave had extensive involvement in this project throughout the design, construction and commissioning stages, including:

- Peer review during design phase.
- Construction noise and vibration management during interface works at Chatswood and Epping.
- Noise and vibration design for track support system in Rail Enclosure Structure at Chatswood.
- Technical leader of noise task force during 2008, to resolve issues with in-train noise (culminating in the first use of rail dampers in Australia [4]).

Rail Clearways, Sydney ('05-'09)

Dave led the in-house technical review of noise and vibration impact assessments and mitigation designs for rail clearways projects, including:

- Cronulla Duplication
- Kingsgrove to Revesby Quad
- South West Rail Link

RailCorp Environment Protection Licence ('02-'11)

Dave provided technical support for compliance with Pollution Reduction Programs required under RailCorp's Environment Protection Licence.

Wheel squeal research and development ('04-'13)

Dave has had a long-term involvement with wheel squeal issues, both in NSW and also in collaboration with rail agencies in South Australia and Queensland. The work spans:

- The first use of top-of-rail friction modifiers in Australia [5];
- The installation of a wayside angle-of-attack monitoring system on a curve (a world first) [6];
- Industry Chair of a Cooperative Research Centre (CRC) project on rail noise, including wheel squeal [6,7];
- Extensive track-based testing of lubrication and friction modifier treatments [8];
- Engagement with rail operators to investigate rolling stock curving performance.

Strategic Noise Action Plan, NSW ('12-'13)

Dave was seconded to the Freight and Regional Development Division of Transport for NSW to assist with the implementation of the Strategic Noise Action Plan (SNAP), which addresses noise from rail freight operations by tackling noise at source as well as ensuring appropriate controls are incorporated in the planning and the design of new projects.

Northern Sydney Freight Corridor, NSW ('11-'13)

Technical advice to support the development of the Operational Noise and Vibration Review.

Sydney City Recital Hall, Angel Place, Sydney ('96-'99)

Project engineer involved in acoustic design, building isolation and commissioning of this 1250 seat international standard chamber music hall in Sydney. The City Recital Hall is now regarded as the benchmark for future concert halls in Australia.

Selected Technical References (copies available on request)

1. Anderson D, "Engineering Prediction Of Railway Vibration Transmitted In Buildings", 1994, Environmental Engineering Volume: 7 Issue Number: 1 ISSN: 0954-5824
2. Anderson D, "Manchester Concert Hall: Vibration Isolation", Proceedings of Internoise 1996, Liverpool UK
3. Anderson D, Harris M, *"New Southern Railway, Sydney – Noise and Vibration Attenuation Systems"*, Proc ExpoRail (Asia), Hong Kong, 2000
4. Coker D, Anderson D, *"Reducing In-train Noise on the Epping to Chatswood Rail Link"*, Proceedings of Conference on Rail Engineering 2010
5. Kerr M, Kalousek J, Elliot G, Mau F, Anderson D, *"Squeal Appeal: Addressing Noise at the Wheel/Rail Interface"* Proceedings of Conference on Rail Engineering 1998
6. Jiang J, Anderson D, Dowdell D, Wang C, *"The impact of angle of attack on curve squeal"*, Proceedings of World Congress on Railway Research (WCRR) 2013, Sydney, Australia
7. Jiang J, Dwight R, Anderson D, *"Field Verification of Curving Noise Mechanisms"*, Proceedings of 10th International Workshop on Rail Noise, Japan 2010
8. Curley D, Anderson D, Jiang J, Hanson D, *"Field trials of gauge face lubrication and top-of-rail friction modification for curve noise mitigation"*, Proceedings of 11th International Workshop on Rail Noise, Sweden 2013
9. Anderson D and Hiller D, "Noise and vibration issues in tunnels", Tunnel Management International, 2000

acoustic studio

Sav Shimada

Acoustic Engineer

Key Personal Data

Qualifications

BE (Hons) Mechanical Engineering
BA (Hons) Japanese, German

Professional Associations

Member of the Australian Acoustical Society

Career and Professional Information

Sav joined Acoustic Studio Pty Ltd in February 2014 from RailCorp NSW.

Before discovering acoustic engineering, she researched New York City building trends for the Japanese Ministry of Housing and Urban Development, edited a children's science magazine, was a freelance translator, and taught English in Japan.

Sav worked as an acoustic consultant in architectural acoustics, building services noise and vibration control and environmental noise, before working as an in-house noise specialist at RailCorp from 2006 to 2013. Her work spanned technical advice and research; strategy and policy; regulation; and rail projects.

Sav's interest in a wide range of engineering and design disciplines informs her drive for integrated acoustic design with the aim of delivering environmentally viable systems which are comfortable and functional for the end users.

She communicates comfortably with people of any background and with subject matter experts in a wide range of fields including urban planning, environmental policy, community relations, human factors, engineering design, construction and maintenance, building acoustics, noise modelling and mapping, and electro-acoustics.

Projects and Experience

During her career as an acoustic engineer, Sav has worked on a range of residential, commercial, cultural, health and road and rail operation and developments. She has experience in transportation noise and vibration, room acoustics, mechanical services and human factors and safety.

Transportation Acoustics

Policy and planning advice, RailCorp
Advice included Environmental Protection Licence and developing noise policies, standards and guidelines.

Rail infrastructure project reviews
RailCorp acoustic advisor for Epping to Chatswood Rail Link, South West Rail Link, Kingsgrove to Revesby Quadruplication, and Stabling Yards.

Ground Borne Noise, ECRL
Coordinated the development of a wayside monitoring system to manage regenerated noise from the rail tunnel.

Safety-related Acoustics
Led reviews of Level Crossing Audible Warning System standards, and stabling yard horn audibility requirements.

Station Public Address Systems
Design review and environmental policy development for railway station public address system upgrade.

Rail Infrastructure Noise Research
Topics included effectiveness of friction modifiers to control curve noise; turnout noise, steel bridge structureborne noise, corrugated rail and grinding-induced noise.

Bespoke Software Development
Acoustic input and data integrity review for Ground Borne Noise monitor, Wayside Information Management System, TrackSide Noise and Locomotive Extraction Tool rail noise.

Rail Maintenance Noise Review
Managed review of maintenance works practices to identify improvements.

Road Project Noise Assessments
Assessment and community consultation for highway upgrades (Bruce Hwy QLD and Pacific Hwy Tintenbar to Ewingsdale NSW).

Building Acoustics

Office Buildings
RMS Office Headquarters at Ennis Rd Kirribilli and James Craig Rd Rozelle.

Health Care Facilities
Brain and Mind Research Institute, Westmead Breast Centre.

Educational Buildings
St Luke's Grammar Multipurpose Hall; Stella Maris Science & Technology redevelopment; Roseville College performing arts complex; University of Western Sydney Film and TV School.

Performing Arts

ODEON Acoustic Modelling
Acoustic modelling of theatres in Sydney Opera House – Opera Theatre, Wyong Cultural Centre, PLC Melbourne Creative Arts Centre, Bunjil Place (Casey).

CarriageWorks at Eveleigh
Three flexible theatre spaces, a workshop and offices in a heritage listed building. The acoustic works included mitigation for airborne and ground borne railway noise and variable control of reverberance in performance spaces, mechanical services noise.

Recording Studios

Chief Entertainment Relocation
Acoustic services from concept to commissioning, for purpose-built TV studios, audio recording facilities, edit suites and control rooms.

Greenland Creative Hub Studios
Acoustic design review on behalf of the City of Sydney for TV and audio recording studios, dance and drama rehearsal rooms, and control rooms.

Multi-use developments

Hillsong Epicentre
Acoustic design of new auditorium, TV and music studios and recording facilities, college facilities, children's classrooms, and indoor recreation and performance rooms.

UNSW Roundhouse refurbishment
Acoustic design for live performance space shared with student / conference facilities.

Bunjil Place (Casey Cultural Precinct)
Acoustic design for library, council facilities, function space, theatre, art gallery, and performance studio.

Surry Hills Community Centre
Acoustic design for Community Centre, library, conference room, child care centre.

Outdoor Developments

Taronga Zoo
Acoustic Operational and Construction DA Assessments for Centenary Theatre and Sumatran Tiger Exhibit.

Sydney Opera House
Acoustic DA for outdoor site activation.

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