Rail noise and vibration in Australia – A case study

Vincent Chavand*

*Corresponding author's address: GHD, Newcastle, 2300, NSW, Australia, vincent.chavand@ghd.com

This paper reviews the various stages of a major rail project undertaken in New South Wales (NSW), Australia, between 2010 and 2012. This case study involves 40 kilometres of new track adjacent to existing railway lines in the Hunter Valley, NSW. The project is located within a mixture of rural and urban settings and had the potential to impact on a large number of sensitive receivers during both the construction and operational phases. The project approvals required compliance with a number of relatively new noise and vibration guidelines and policies, which provides an opportunity for the author to reflect on the recent evolutions in noise and vibration control practices and policing in Australia. This paper reviews the project from the approvals process to its commissioning phase from a noise and vibration point of view. It explores the construction and operational noise modelling methodologies, reviews the design process and adopted mitigation measures and, in doing so, it discusses the practical challenges met through the course of the works.

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INTRODUCTION

The Hunter Valley rail network extends from the Port of Newcastle, New South Wales (NSW), Australia to Ulan and Narrabri approximately 300 kilometres west of Newcastle. The network is used by passenger services, freight, wheat and coal services. The majority of trains carry coal from mines located across the Hunter Valley to Newcastle for loading onto ships for export.

Due to the forecast increase in coal throughput at the Port of Newcastle, a number of rail infrastructure improvements to the Hunter Valley Rail Network have been proposed. One of the key improvement projects is a 40-kilometers third track adjacent to the existing Main Northern Railway between Maitland and Singleton.

Noise and vibration impact associated with the construction and operation of the project were identified as a potential major issue due to the relatively high number of residents located along the project route. Noise and vibration issues have been monitored and addressed throughout the life of the project, which can be split into the following major stages.
- Environmental assessment.
- Construction phase.
- Operational noise and vibration management review.
- Commissioning.

PROJECT DESCRIPTION

The proposed third track would run adjacent to the existing Main Northern Railway, which consists of two existing lines. The third track would be used as a relief track for the existing ‘up’ track (carrying loaded trains from the Hunter Valley to Newcastle, as opposed to the ‘down’ track going in the opposite direction).

The project involve the following major elements:
- Earthworks: major cut and fill earthworks along the route.
- Track: approximately 40 kilometres of new track including turnouts and junctions, upgrade of maintenance sidings and existing track reconditioning.
- Drainage: central and cess drainage, amendments to over 50 culverts for cross drainage, realignment of a local creek.
- Bridges: ten new rail bridges over local creeks and roads.

The land surrounding the project route mostly consists of rural land with pockets of built-up areas with approximately 250 residential receivers with a potential to be immediately affected by the construction and operation of the project.

Construction activities were planned to occur over an approximately 24-months period between 2010 and 2012.

ENVIRONMENTAL ASSESSMENT

Legislative Requirements

Construction Noise

Construction noise is assessed with consideration to the NSW Department of Environment and Climate Change (DECC) Interim Construction Noise Guidelines (ICNG) (2009). The ICNG recommend standard hours for construction activity as detailed in Table 1.

<table>
<thead>
<tr>
<th>Work type</th>
<th>Recommended standard hours of work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Construction</td>
<td>- Monday to Friday: 7 am to 6 pm</td>
</tr>
<tr>
<td></td>
<td>- Saturday: 8 am to 1 pm</td>
</tr>
<tr>
<td></td>
<td>- No work on Sundays or Public Holidays</td>
</tr>
<tr>
<td>Blasting</td>
<td>- Monday to Friday: 7 am to 6 pm</td>
</tr>
<tr>
<td></td>
<td>- Saturday: 8 am to 1 pm</td>
</tr>
<tr>
<td></td>
<td>- No work on Sundays or Public Holidays</td>
</tr>
</tbody>
</table>
The ICNG provides noise management levels for construction noise at residential receivers. These management levels are to be calculated based on the adopted rating background level (RBL) at nearby residential locations, as shown in Table 2.

**TABLE 2. ICNG Construction Noise Criteria at Residential Receivers, dB(A)**

<table>
<thead>
<tr>
<th>Time period</th>
<th>Management Level $L_{Aeq}(15 \text{ min})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended standard hours</td>
<td>Noise affected level: RBL + 10</td>
</tr>
<tr>
<td></td>
<td>Highly noise affected level: 75 dB(A)</td>
</tr>
<tr>
<td>Outside recommended standard hours</td>
<td>Noise affected level: RBL + 5</td>
</tr>
</tbody>
</table>

The above levels apply at the boundary of the most affected residences or within 30 metres from the residence where the property boundary is more than 30 metres from the residence.

The *noise affected level* represents the point above which there may be some community reaction to noise. Where the *noise affected level* is exceeded all feasible and reasonable work practices to minimise noise should be applied and all potentially impacted residents should be informed of the nature of the works, expected noise levels, duration of works and a method of contact.

The *highly noise affected level* represents the point above which there may be strong community reaction to noise and is set at 75 dB(A). Where noise is above this level, the relevant authority may require respite periods by restricting the hours when the subject noisy activities can occur.

**Operational Noise**

Operational rail noise goals are derived from the Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects (IGANRIP).

Within NSW, in the area where works associated with a rail infrastructure project are likely to occur, the interim guideline presents non-mandatory noise goals that trigger the need for a project assessment to be conducted.

Under the terms of the IGANRIP, the Project qualifies as the redevelopment of existing rail lines. Typically, exceedance of the trigger values shown in Table 3 and Table 4 must be met to initiate an assessment of rail noise impacts and investigate mitigation measures.

**TABLE 3. Airborne Rail Traffic Noise Trigger Levels for Residential Land Uses**

<table>
<thead>
<tr>
<th>Type of Development</th>
<th>Noise Trigger Levels dB(A)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redevelopment of existing rail line</td>
<td>Day (7:00–22:00)</td>
<td>Development increases existing rail noise levels and resulting rail noise levels exceed:</td>
</tr>
<tr>
<td></td>
<td>Night (22:00–7:00)</td>
<td>These numbers represent external levels of noise that trigger the need for an assessment of the potential noise impacts from a rail infrastructure project. An ‘increase’ in existing rail noise levels is taken to be an increase of 2 dB(A) or more in $L_{Aeq}$ in any hour or an increase of 3 dB(A) or more in $L_{Amax}$.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$65 L_{Aeq}(15h)$ 60 $L_{Aeq}(9h)$ 85 $L_{Amax}$ 85 $L_{Amax}$</td>
</tr>
</tbody>
</table>

**TABLE 4. Ground-borne (internal) Noise Trigger Levels**

<table>
<thead>
<tr>
<th>Receiver</th>
<th>Noise Trigger Levels dB(A)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>Day (7:00–22:00)</td>
<td>Development increases existing rail noise levels by 3 dB(A) or more and resulting rail noise levels exceed:</td>
</tr>
<tr>
<td></td>
<td>Night (22:00–7:00)</td>
<td>40 $L_{Amax}$ (Slow) 35 $L_{Amax}$ (Slow)</td>
</tr>
</tbody>
</table>
The IGANRIP was jointly released in 2007 by the NSW DECC and the Department of Planning (DoP). Prior to this, noise impacts from new rail projects were addressed in Chapter 163 of the NSW Environment Protection Authority (EPA) Environmental Noise Control Manual (ENCV) under the following terms:
- Planning levels: 55 dB(A) $L_{eq}$ (24 hours) and 80 dB(A) $L_{max}$
- Maximum levels: 60 dB(A) $L_{eq}$ (24 hours) and 85 dB(A) $L_{max}$

Compared to the ENCM, the IGANRIP provides a number of clarifications and details for the assessment process, some of the main ones being:
- Distinction between new rail line projects and the redevelopment of existing rail corridors.
- Provision of separate noise targets for airborne and ground-borne noise.
- A defined process to instigate reasonable and practical mitigation measures.
- Rail noise monitoring and data analysis procedure.
- Guidance for noise modelling.

### Construction and Operational Vibration

The NSW DECC’s publication, Assessing vibration: A technical guideline (2006) outlines methods of assessing potential impacts and ways to manage vibration from rail operations such as ground induced vibration created by rolling stock movements. Acceptable values of vibration dose are presented in Table 5 for residential receivers.

<table>
<thead>
<tr>
<th>Location</th>
<th>Daytime Preferred Value</th>
<th>Daytime Maximum Value</th>
<th>Night-time Preferred Value</th>
<th>Night-time Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residences</td>
<td>0.20</td>
<td>0.40</td>
<td>0.13</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Vibration limits for structural damage were obtained from German Standard DIN 4150-3: 1999 Structural Vibration – Part 3: Effects of vibration on structures.

### Baseline Noise and Vibration Monitoring

Attended and unattended noise monitoring was undertaken at seventeen locations representative of the various receivers and settings along the project route between July and September 2009. Attended noise monitoring was undertaken at all logging locations to further detail train pass-by noise levels along the Project route. Pass-by measurements were taken alongside noise logging. A minimum of 10 train pass-by’s was measured at each location.

Unattended vibration monitoring was undertaken using ground vibration monitors at five locations representative of the potentially most affected buildings along the project route. Generally, train pass-by vibration was discernible from background vibration levels within 50 meters from the rail lines.

### Construction Noise and Vibration Impacts

Because at the environmental assessment stage of the project construction needs and requirements were not fully known, the construction impact assessment was undertaken generically and included:
- A review of the potential noise impacts of the project main construction activities.
- An estimate of typical vibration impacts at the nearest receivers.
- An outline of a Construction Noise and Vibration Management Plan (CNVMP) for the project.

Due to the absence of detailed construction information, it was proposed that construction noise impacts be assessed through Noise and Vibration Impact Statements (NVIS) prepared for discrete work activities (eg. site compounds, track possession works, cut and fill work, drainage) as design and construction progressed. The purpose of the NVIS would be to:
- Determine construction noise impacts at sensitive receivers from specific construction activities.
- Outline specific control measures where exceedances of the construction noise and vibration goals are anticipated.
The construction vibration impact assessment essentially focused on potential structural damage to properties in close vicinity of the study area. The NSW Road & Traffic Authority (RTA) Environmental Noise Management Manual (ENMM) (2001) states that the vibration level of a source is inversely proportional to the distance source-receiver although field variations show that the distance relationship generally varies between $d^{-0.8}$ and $d^{-1.6}$, rather than $d^{-1}$. This relationship was applied to the known vibration levels from typical sources at 10m and propagated at distance. When compared to the structural vibration goals, results indicated that structural damage may occur within 10 to 50m from buildings, depending on the activities being carried out.

### Operational Noise Impacts

**$L_{Aeq}$ Rail Noise Levels**

Existing rail volumes were determined from a detailed log of trains that passed through the subject area during the monitoring period. Rail volumes and distribution were determined from strategic documents for the Hunter Valley Rail Corridor, as shown in Table 6.

<table>
<thead>
<tr>
<th>Year</th>
<th>Existing Up Track</th>
<th>Existing Down Track</th>
<th>Third Track (Up Relief)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day</td>
<td>Night</td>
<td>Daytime</td>
</tr>
<tr>
<td>2009</td>
<td>23</td>
<td>15</td>
<td>22</td>
</tr>
<tr>
<td>2012</td>
<td>23</td>
<td>15</td>
<td>35</td>
</tr>
<tr>
<td>2022</td>
<td>23</td>
<td>15</td>
<td>44</td>
</tr>
</tbody>
</table>

With consideration to the IGANRIP, the existing absolute rail noise $L_{Aeq}$ at each of the monitoring location is determined as follows:

$$L_{Aeq(T)} = 10 \log \left( \frac{1}{T} \sum_{i} (n_i t_i 10^{0.1 L_{Aeq(i)}}) \right)$$

(1)

Where
- $T$ is the total time in the relevant period (day or night) in seconds.
- $t_i$ is the average time of each type of event in seconds, derived from site measurements.
- $n_i$ is the number of each type of event.
- $L_{Aeq(i)}$ is the representative $L_{Aeq}$ level for each event as measured at the receiver.

Acoustic modelling was undertaken using Datakustik’s Computer Aided Noise Abatement (CadnaA) to predict the effects of rail traffic noise from the proposed project. CadnaA is a computer program for the calculation, assessment and prognosis of noise propagation. Rail traffic noise modelling was conducted using the United Kingdom Department of Environment, Food and Rural Affairs (DEFRA) Calculation of Railway Traffic Noise (CoRN) algorithm.

**Modelling Scenarios**

The following modeling scenarios were undertaken:
- Existing situation (2009), in order to validate the model against site measurements.
- Project commencement (2012).
- 10 years after project commencement (2022).

**Model Configuration**

The following assumptions were made with regard to the model configuration:
- A general ground adsorption coefficient of 0.5 was used throughout the model to reflect local conditions.
- Atmospheric conditions of 20°C and 70% humidity were used.
- Neutral weather conditions.

**Rail Traffic Assumptions**

Coal trains were modelled at 60km/h when loaded (up direction) and 80km/h when empty (down direction). Trains were modelled using CoRN train input data and the model was then validated against the site measurements (equation 1).
Based on the above methodology and assumptions, modelled rail noise levels were found to be consistently within 2dB of the absolute rail noise levels. This is within the generally accepted +/- 2dB accuracy for noise models and, as such, the model was considered to be validated.

Modelling results showed that $L_{eq}$ rail noise levels were predicted to increase by 2 to 3 dB(A) by 2022 compared to the existing situation as a result of the increased train volumes facilitated by the third track. With regards to the IGANRIP, this also indicates that one of the conditions for the consideration of noise mitigation had been triggered. Noise contours for the 2012 and 2022 modelling scenarios were then produced to identify the sensitive receivers that would require noise mitigation.

$L_{Amax}$ Rail Noise Levels

The IGANRIP requires the $L_{Amax}$ levels from the 50th and 95th percentile of rail pass-by’s to be reported and ensuring that a sufficient number of pass-by’s are considered in the analysis. As $L_{Amax}$ noise levels are typically specific of individual train pass-by’s, they are in principle not dependent on traffic volumes on the rail lines.

$L_{Amax}$ levels on the up side are expected to increase as a result of the third rail track being approximately 8 m closer to residences than the existing up track. The increase was estimated by using the site measurements and the ratio between the existing track-to-receiver distance ($d$) and the future track-to-receiver distance ($d-8$).

Distance from the nearest rail line to receivers on the down side would not change as a result of the Project, therefore $L_{Amax}$ noise levels on the down side were not expected to increase noticeably.

Calculations showed that $L_{Amax}$ noise levels were generally expected to increase at upside receivers by 1 to 2 dB(A). This is less than the 3 dB(A) increase mentioned in the IGANRIP and, as such, IGANRIP triggers were not met for $L_{Amax}$ levels alone.

Operational Vibration Impacts

The DECC Assessing Vibration: a Technical Guideline provides a methodology to assess VDV levels from root mean square (rms) velocity levels. A conservative estimate of the relationship between VDV and rms velocity is given by the following equation:

$$eVDV = 0.07V_{rms}^{0.25}. \tag{2}$$

Where
- $eVDV$ is the estimated vibration dose in m/s$^{1.75}$.
- $t$ is the cumulative pass-by duration for the relevant period. This can be determined from the average pass-by duration at each monitoring location and the existing and future number of pass-by’s
- $V_{rms}$ is the representative vibration level for a train pass-by.

This equation is then used to conservatively estimate $V_{rms}$ from the required VDV goals. Results indicated a risk for human comfort goals to be exceeded for dwellings located within approximately 40 m from the rail line once the third rail track would be in operation.

Operational Mitigation Measures

Potential noise and vibration mitigation measures were reviewed with regards to the site context as well as practicality and feasibility considerations. Mitigation measures available for this project are as follows.

Noise Mounds and Barriers

Depending on the situations, in particular local topography and barrier height, noise barriers can achieve 10 to 15 dB(A) attenuation. Mounds and barriers would generally be considered to reduce noise in built-up areas where they can achieve significant noise attenuation at a number of receivers at once. However, the presence of excess spoil from earthworks on the project would allow the construction of earth mounds for individual dwellings on a case-by-case basis.

Architectural Treatment

Architectural treatment essentially consists of soundproofing residences in order to meet internal noise levels as shown in Table 7.
TABLE 7. Internal Noise Goals – Residential Buildings

<table>
<thead>
<tr>
<th>Type of Occupancy</th>
<th>Noise Level dB(A) L_{eq} (1hr)</th>
<th>Applicable Time Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleeping areas (bedroom)</td>
<td>35</td>
<td>Night 10 pm to 7 am</td>
</tr>
<tr>
<td>Other habitable rooms (excl. garages, kitchens, bathrooms and hallways)</td>
<td>40</td>
<td>At any time</td>
</tr>
</tbody>
</table>

Practically, this would generally involve retrofitting of thicker glazing, roof insulation, door and windows acoustic seals and the like. Architectural treatment may also include fitting of mechanical/forced ventilation so that windows can be kept closed if the occupant so desire. Architectural treatments would be considered for isolated and scattered residences where other options are not effective enough.

Approval

Following public exhibition and submission of the Environmental Assessment to the authorities, Conditions of Approval (CoA’s) were issued by the NSW Government. The CoA’s outline the various environmental conditions the project is to comply with throughout its construction phase and operational life, including:
- Confirmation of applicable noise and vibration targets.
- Requirements for the content and format of the CNVMP and NVIS documents.
- Approval protocols and requirements for construction works outside standard hours.
- Requirements for the validation of mitigation measures following completion of detailed design.
- Commissioning requirements.

CONSTRUCTION PHASE

The CNVMP constitutes the overarching document for the management of noise and vibration issues throughout the construction phase. The CNVMP reviews the following:
- Sensitive receivers.
- Applicable noise and vibration targets.
- Potential impacts.
- NVIS’s to be prepared throughout the project.
- Standard mitigation measures.
- Noise and vibration monitoring requirements.
- Protocols for the management of exceedances and complaints.

In accordance with the CNVMP, NVIS were developed for each discrete work activities (approximately 50 assessments, from site clearing to welding works) to assess the relevant noise and vibration impacts and identify additional mitigation measures, where needed, with consideration to Table 8.

TABLE 8. Additional Mitigation Measures – Airborne Construction Noise

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Mitigation Measures</th>
<th>L_{Aeq}(15 min) noise level above background (RBL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>Mon –Fri (7am-6pm)</td>
<td>0 to 10dB(A) 10 to 20dB(A) 20 to 30dB(A) &gt;30dB(A)</td>
</tr>
<tr>
<td></td>
<td>Sat (8am–1pm)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Sun/Pub Hol (Nil)</td>
<td></td>
</tr>
<tr>
<td>OOHW</td>
<td>Mon –Fri (6pm-10pm)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Sat (1pm-10pm)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sun/Pub Hol (8am-6pm)</td>
<td></td>
</tr>
<tr>
<td>OOHW(^1)</td>
<td>Mon –Fri (10pm-7am)</td>
<td>LB</td>
</tr>
<tr>
<td></td>
<td>Sat (10pm – 8am)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sun/Pub Hol (6pm-7am)</td>
<td></td>
</tr>
</tbody>
</table>

Note: \(^1\) OOHW: Out-of-hours Work
Where
- AA is Alternative Accommodation
- M is Monitoring
Noise and vibration monitoring was undertaken throughout the construction phase, under the following circumstances:

- During night-time track possession work (generally occurring every three months).
- In case vibration generating activities are conducted within 30 metres of a dwelling.
- Upon receipt of a noise or vibration complaint.
- When construction noise and vibration targets are expected to be exceeded.
- At the nearest residence, when blasting is being undertaken (vibration and overpressure monitoring).

**OPERATIONAL NOISE AND VIBRATION MANAGEMENT REVIEW**

Following completion of the Environmental assessment, the noise model was iteratively refined to include any changes in the detailed design of the project as they occurred (e.g. local earthworks design changes) and study options for noise barriers and mounds throughout the project route.

Up to three reasonable and feasible options were developed for each particular receiver, having regards to the following:

- Topographical conditions of rail corridor and land between the rail and the receiver.
- The nature of the dwelling at the receiver.
- Geotechnical conditions (to assess potential structural issues).
- The cost of construction and maintenance of the measure (including property).
- The implications for the ongoing operation, and maintenance of the rail corridor.

Further review of the above criteria was undertaken to determine the most reasonable and feasible noise attenuation measure. The design and cost of this measure was further developed to facilitate receiver/landholder negotiations and inclusion in the noise model.

The noise model was updated to verify the effectiveness of the potential noise mitigation measure (noise mounds and noise walls). Alternatively, consideration was given to the effectiveness of the proposed architectural treatment.

The affected receiver/landholder was presented with this proposed mitigation measure. Feedback was received from the landholder, and where proposed changes did not affect the ability of the measure to attenuate noise, where reasonable and feasible they were incorporated into the design.

In the event that the landholder did not agree with the proposed measure, another of the alternative measures was presented to the landholder/receiver. Negotiations continued until agreement was reached.

The agreed measure was again included in the noise model to confirm its effectiveness.

Once the noise model (for noise mounds and walls) confirmed the effectiveness of the potential noise mitigation measure, or a review of the architectural treatment confirmed it effectively mitigates noise, final negotiations with the affected landholder were undertaken.

Further vibration measurements were undertaken to estimate existing and future VDV’s at dwellings located within 40 meters from the nearest rail track. Results confirmed that human comfort targets were met at all monitoring locations.

**COMMISSIONING**

Commissioning aimed at ground-truthing the findings of the Operational Noise and Vibration Management Review and confirm the efficiency of the deployed mitigation measures.

Noise and vibration measurements were undertaken using the same methodology as described in the Environmental Assessment at a number of locations along the project routes following handover of the third track. This work was carried out independently, as required by the CoA’s, to ensure the integrity of the process.

Rail noise levels were monitored at all locations provided with noise walls or mounds, with additional locations fully exposed to rail noise monitored to assist the model validation process. The independent verifier then developed a new model of the project based on these measurements to verify results along the entire project routes. Results of noise monitoring and modelling indicated compliance with the CoA’s.
Similarly, independent rail vibration measurements confirmed compliance of the project with the vibration limits.

REFERENCES


