DEVELOPMENT OF A LINE BASED RAIL NOISE POLLUTION REDUCTION PROGRAMME

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Abstract

RailCorp is currently implementing a programme of noise reduction initiatives in the Sydney metropolitan area, which involves some 38 specific projects. In order to develop the programme, Rail Access Corporation (RAC now RailCorp) initiated an extensive study, evaluating the noise emissions, mitigation options and the cost-benefit of these options. The study focused on five "priority" lines that had been qualitatively identified as having the highest noise impact. Computer noise modelling was undertaken over a total of 130 corridor km, including many thousands of buildings located within 100 m of the five lines. The modelled noise levels were used in conjunction with the number of sensitive receivers to determine a rating of the community noise burden along each line. Specific mitigation options were identified and the task of prioritising these options was undertaken on the basis of the potential reductions in Community Noise Burden and the overall cost-benefit. The final programme of actions was confirmed by RAC following consultation with the rail stakeholders and EPA (now DEC). This paper describes the development of the Noise Pollution Reduction Programme, the noise mitigation measures identified and the process of prioritising the measures to obtain a cost effective outcome.

Introduction

As the owner, maintainer and operator of the NSW Government rail infrastructure, RailCorp is currently implementing a programme of noise reduction initiatives in the Sydney Metropolitan Area.

This five year programme, known as the Line Based Noise Pollution Reduction Programme (PRP) was developed during the year 2000, with implementation commencing mid 2001. The study examined a total of 341 possible noise mitigation actions and selected 38 specific projects for inclusion in the PRP through cost-benefit analysis and stakeholder consultation.

This paper describes the development of the PRP, the noise mitigation measures identified during the study and the process of prioritising the measures to obtain the most cost effective outcome. The current implementation status is also briefly described.

Background

RailCorp operates under an Environmental Protection Licence issued by the NSW Department of Environment and Conservation (formerly the EPA). Since the year 2000, this licence has included a requirement to develop and implement a five year Noise Reduction Programme on each of five priority lines in metropolitan Sydney.

The Licence provides the following facade noise level goals for the five PRP lines:

- Maximum passby level 85 dBA ($L_{Amax,\ Fast}$)
- Equivalent continuous level 60 dBA ($L_{Aeq(24hour)}$)

At the time the PRP was developed, Rail Access Corporation (RAC) was the owner of the rail infrastructure, and as such, held the Environment Protection Licence. RAC has since been amalgamated with other government rail entities to form Rail Infrastructure Corporation.

In order to develop the programme, RAC contracted Maunsell McIntyre Pty Ltd (Maunsell) and Richard Heggie Associates Pty Ltd (now Heggies) to undertake an extensive study, evaluating the operational rail noise emissions, land use, community noise burden, mitigation options and the cost-benefit of the mitigation options.

The study focused on five "priority" lines that had been identified in a preliminary study of 57 lines by RAC as having the highest potential noise impact. These lines are:

- Inner West (Lidcome Junction to Redfern)
- North Strathfield Junction to Hornsby
- Auburn and Merrylands to Penrith
- Erskinville Junction to Waterfall
- North Shore Line (Waverton to Hornsby)

In total, these lines comprise 130 km of rail corridor.

Structure of the Line Based Noise PRP Study

The study was undertaken in a structured manner, which initially involved a series of working papers, referred to as "building blocks". These working papers then served as common inputs to the studies on the five individual lines.

Each of the working papers constituted a formal report in its own right, suitable for ongoing use as a technical reference. The subject areas covered were:

- Railway Noise Sources [1]
- Community Noise Burden Assessment Method [2]
- Noise Mitigation Measures [3]
- Land-use Policies and Mitigation Options [4]

Assessment of the individual lines involved computer noise modelling of 130 corridor km, including approximately 67,000 dwellings or other sensitive receivers located within 100 m of the five lines. The modelled noise levels were used in conjunction with the number of sensitive receivers to determine a rating of the community noise burden along each line.

Specific mitigation options were identified and cost estimates were developed for each. The task of prioritising the options was then undertaken on the basis of the potential reductions in community noise burden and the overall cost-benefit. The final programme of actions was confirmed by RAC following consultation with the rail stakeholders and EPA (now DEC).

Noise Sources

The Noise Source Working Paper [1] identified the main sources of noise generated by normal rail operations in the Sydney metropolitan area and defined the noise levels for general reference and for use in the modelling.

These noise levels were sourced from previous studies commissioned by RAC and from previous studies carried out by Heggies. The primary source of reference data was the Rail Noise Database [5], which contains many hundreds of measurements, categorised by train type, speed and (in the case of locomotives) estimated notch setting.

Table 1 presents a summary of the noise source data tabulated in the Working Paper and used as a basis for the computer modelling. The LAmax levels are presented in terms of the average (mean) event and the indicative maximum (95th percentile) event. In both cases data are derived from "Fast" response measurements. The indicative maximum level (95th percentile) was used in the modelling.

The L_{AE} noise levels in Table 1 represent the logarithmic average L_{AE}. These values were used as a basis for modelling the $L_{Aeq(24hour)}$ noise levels.

The Working Paper also includes plots of noise level versus speed for each type of train showing both the relationships used in the modelling and the data from the Rail Noise Database.

The values in Table 1 are largely based on data collated in 1997 for the Rail Noise Database. Much of the rollingstock remains in service relatively unchanged, however some additional rollingstock has since been introduced, such as the Millennium trains.

Subsequent measurements [5] have shown the Tangara trains to be typically 2 dBA quieter than indicated. Noise levels from InterCity trains increased for a time, but are believed to have returned to previous levels.

Train Type	Noise Source	Noise Level at 15 m (dBA)			Speed (km/h)	Speed Dependence (dBA)
		L_{Amax} Average	L_{Amax} Indicative Maximum	L_{AE}		
Tangara	Wheel-Rail	85	90	89	80	Note 1
Suburban	Wheel-Rail	87	92	92	80	Note 1
Intercity	Wheel-Rail	87	92	90	80	Note 1
XPT	Wheel-Rail Engine, Low Engine, High	87 78 86	90 80 88	89 79 86	80	Note 1 Note 2 Note 2
Endeav'r/ Xplorer	Wheel-Rail/ Engine	87	90	90	80	Note 1
Loco Hauled	Wheel-Rail	87	90	89	80	Note 1
	Engine	As per locomotives				Note 2
Diesel Electric Loco	Wheel-Rail Engine, Low Engine, Medium Engine, High	78 75 82 87	81 78 85 91	81 76 84 90	50 50 50 50	Note 1 Note 2 Note 2 Note 2
Freight Wagons	Wheel-Rail	83	87	96 [3]	50	Note 1
	Bunching	80	88	-	-	Nil
Coal Wagons	Wheel Rail	81	85	94 [3]	50	Note 1
	Booming [4]	81	85	96 [3]	50	Note 1
	Bunching	80	90	-	-	Nil

Note 1: The L_{Amax} speed relationship in dBA is 30 log (V/V_o), The L_{AE} speed relationship is 20 log (V/V_o), V is the operating speed and V_o is the reference speed.

Note 2: For Diesel Engine noise, the L_{Amax} is independent of speed, the L_{AE} speed relationship is -10 log (V/V_o).

Note 3: The L_{AE} noise level applies for a train length of 1000 m.

Note 4: Excluding booming noise for NHRH 120 tonne coal wagons, which are more variable and are not included in the Railway Noise Database. These wagons do not operate within the Sydney Metropolitan Area.

Note 5: Average bunching noise is representative of the normal "float" occurring when trains are coasting. The typical maximum values are regarded as indicative levels. As the occurrence of this noise cannot be reliably predicted, no L_{AE} value is proposed.

Table 1. Noise Source Data used for Modelling

Community Noise Burden

The study brief required evaluation of the "Community Noise Burden" (CNB), an indicator derived specifically for this project in order to assist in ranking the priority of each locality for noise mitigation.

In order to establish a suitable methodology, it was first necessary to define the relationship between the various noise parameters (eg is the impact greater if ten people are exposed to an $L_{Aeq(24hour)}$ of 65 dBA or if one hundred people are exposed to 60 dBA?).

The CNB formula adopted in the working paper [2] was based on literature regarding the percentage of people "highly annoyed" by noise at various levels of exposure, but also incorporated factors to account for the increased offensiveness of tonal or impulsive noise.

The "highly annoyed" response parameter is consistent with the approach used by the EPA (now DEC) in setting environmental objectives (which for transport noise are often set at exposure levels corresponding to 10% of the exposed population being "highly annoyed").

Data from Schultz [6], Fidell [7] and Andersen [8] were used to determine the typical response to various noise levels. Where the response data was presented in terms of LDN (day-night) levels, the values were converted to approximate $L_{Aeq(24hour)}$ levels by applying a -4 dBA adjustment (following a review of typical train scheduling in the study area).

Figure 1 shows the trends (approximations) adopted for the purpose of the CNB formula.

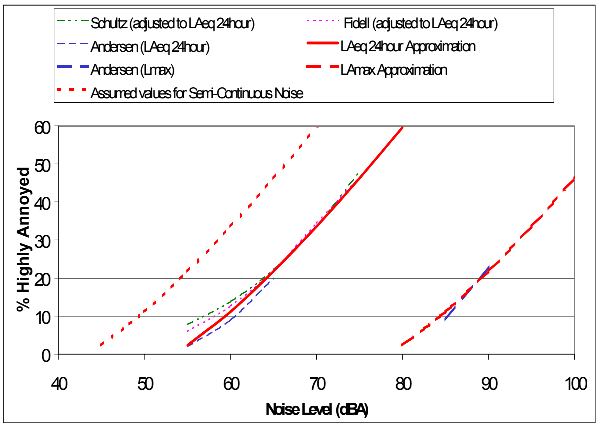

Figure 1. L_{Amax} and L_{Aeq} Annoyance Curves.

RAC's project brief required the CNB to provide a repeatable, quantified indicator of noise impact for the purpose of prioritising noise-affected areas. It was not intended that this CNB rating should have any ongoing use beyond this prioritisation project.

The CNB rating takes into account the noise level (LAeq and LAmax) as well as the character of the noise. CNB is summed over a track length of 100 m to take into account the number of receivers in local community groupings (to a resolution compatible with the "prioritisation by area" process). It also addresses noise from trains held stationery for extended periods.

The Community Noise Burden formula defined for a single receiver is as follows. Each of the three components of this formula correspond approximately to the percentage highly annoyed, however the overall CNBi is not directly comparable to any other rating.

$$CNB_i = ((L_{Aeq(24hour)} - 53 + c)^{1.24} + (L_{Amax} - 78 + c)^{1.24} + (L_{Aeq,stationary} - 43)^{1.24})/100$$

The Community Noise Burden over a length of track is the sum of the individual CNB values:

CNB = ∑ CNBi	Summed over a defined area including any number of receivers
CNB100 = ∑ CNBi	Summed over 100 m

The following definitions apply:

CNB_i Community Noise Burden for an individual receiver.

CNB The total Community Noise Burden in any defined locality.

CNB100 The sum of individual CNB values for all receivers evaluated for a track length of 100 m. This may also be broken down into Up side and Down side, referring to the portion of the CNB100 occurring on each side of the track.
The purpose of summing the CNB over 100m was to aggregate the burden in small community areas. At local track features, the CNB100 would thus indicate the impact within ±50m along the track. In the reports, the CNB100 was graphically presented as a "running total" allowing the CNB100 to be evaluated at any point along the track.

$L_{Aeq(24hour)}$ Equivalent continuous noise level due to all train operations over a typical 24 hour period.

L_{Amax} Indicative maximum noise level predicted for normal train operations.

$L_{Aeq,stationary}$ LAeq noise level due to stationary locomotives where the cumulative period regularly exceeds 1 hour per day.

c Adjustment of up to 5 dB to take into account the tonal or impulsive character of the noise.

Noise Mitigation

The purpose of the Noise Mitigation Working Paper [3] was to identify and discuss noise mitigation measures that could be considered for inclusion in the Pollution Reduction Programs for each line. Table 2 provides a summary of these noise mitigation options.

At the time, it was recognised that some of the options could be implemented directly by RAC, whereas others would need the cooperation of the operators.

Description	Noise Reduction [1]
Track Measures	
Rail grinding	0-10 dBA
On vehicle noise monitoring	Linked to rail grinding
Swing-nose crossings on turnout	3-6 dBA
Spring wing crossings	3-6 dBA
Increased turnout maintenance	Minimise noise due to wear
Weld out mechanical joint	3-6 dBA
Rail contact zone friction modifiers	Substantially reduce curve squeal
Upgraded gauge-face lubricant	Reduce flanging noise
Resilient baseplates	5 dBA on open transom steel bridge
Corridor Measures	
Wheel impact detectors	Linked to wheel truing
Noise barriers	5-12 dBA (where screening occurs)
Replacement of Steel Bridges	8-15 dBA
Relocate signals/turnouts	Move stationary locos, bunching, brake noise, and turnout noise
Operational Measures	
Improve through running	Reduce loco, bunching, brake noise
Reduce horn usage	Less tonal noise
Driver/controller training	Avoid unnecessary noise
Rollingstock	
Wheel truing	Up to 3 dBA overall
Wheel damping	Reduce curve squeal and flanging
Wheel lubrication	Substantially reduce squeal/flanging
Locomotive replacement	3-8 dBA
Locomotive upgrade	1-5 dBA
Buildings	
Treatments to dwellings	10 dBA

Note 1: Indicated noise reductions apply to relevant noise sources only. In many cases several sources contribute to the received LAmax and LAeq noise levels. Overall noise reductions would not be the sum of the individual reductions, but would need to be determined on the basis of the combined noise level of the various sources following mitigation.

Table 2. Summary of Noise Mitigation Options

Noise Modelling

The computer noise modelling utilised SoundPLAN software and incorporated the following elements:

- Ground topography.
- Buildings digitised from aerial photographs, with heights attributed on the basis of site observations.
- Railway noise sources, as discussed above, centred on each track and with the source noise level parameters set for each track feature (eg bridge, turnout, etc) and at each change in speed or traffic.
- One or more receiver points at each level of every residential or otherwise sensitive building, depending on the size, number of dwellings and variation in exposure to railway noise.

Noise emissions from each increment of each track were pre-calculated to take into account the relevant speed, notch or dynamic brake setting for the various train combinations and source heights.

The relevant train operations data was obtained primarily from RAC, but for freight trains was also supplemented with speed and notch information from an experienced train driver. The locations of track features, such as bridges, turnouts, and diamond crossings, were taken from the relevant "Track Books" and the bridge database obtained from RAC.

Presentation of the data included noise contour diagrams and plots of the CNB100 parameter as shown in Figure 2.

Receiver noise levels were plotted against track location as a further means of presenting the concentrations of receivers exposed to high noise levels (see Figure 3).

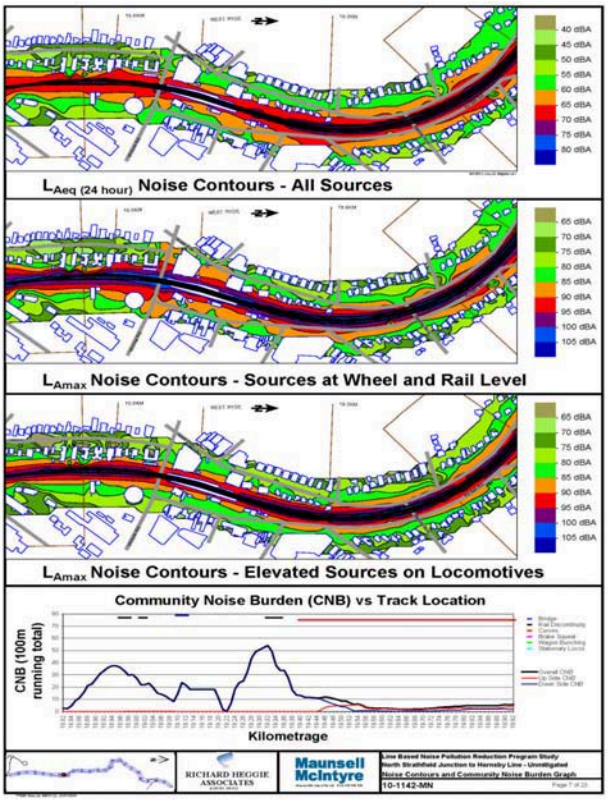

Figure 2. Noise Contours and CNB Plot.

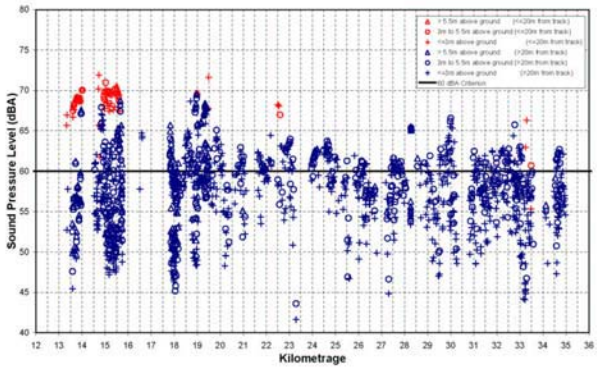

Figure 3. Receiver Noise Level vs Track Location

Land Use

Well before the PRP study, RAC was conscious that the Community Noise Burden depends not only on the railway noise levels, but also on the surrounding land use. The concentration of high density housing in close proximity to rail can dramatically increase the number of people exposed to rail noise.

For this reason, the brief for the PRP study incorporated a Land Use component, which included examination of the existing land use and zoning in the vicinity of the rail corridor throughout the project area and investigation of options to improve future land use planning.

At the time, the government rail entities (SRA, RAC and RSA) were not notified of a significant proportion of the development applications affecting adjacent land. Of those that were notified, many were sent to inappropriate departments.

As a result, the rail organisations found it difficult to provide a consistent and coordinated input into land use planning.

Consideration was given to the possibility of a State Environmental Planning Policy to facilitate a consistent approach to rail noise planning across all government areas, however Planning NSW (now DIPNR) indicated that this was not a prospect in the short to medium term.

The recommended options therefore related to improved liaison between the rail entities and local government. This has led to RailCorp preparing and promoting new guidelines to assist council officers in setting consistent approval conditions and to encourage developers to obtain expert acoustic assessment for developments near rail lines. These guidelines are currently available from these authorities.

Prioritisation of Mitigation Measures

Prioritisation of the noise mitigation options was undertaken on the basis of cost-benefit. The cost included the estimated capital cost plus present value of future maintenance or operational costs. The benefit was assessed as the potential reduction in CNB.

It was found that “whole-of-line” mitigation options such as improved wheel condition and improved lubrication performed better in the cost-benefit analysis than localised options such as noise barriers, even though the noise level reduction may have been less. This is simply because of the larger number of receivers who stand to benefit from the whole-of-line options.

For some options, the reduction in CNB could not be quantified, despite the fact that the options clearly had potential to decrease (or control the increase of) noise impact on the community. Examples include: improved land use planning; low noise designs for future bridges and monitoring of wheel and rail condition.

Some of these options were recommended on merit in addition to the options subjected to cost-benefit analysis. Following the prioritisation process and RAC stakeholder review, the following projects were adopted as PRP actions:

- Rail grinding (all lines).
- Noise barriers (one project on each of three lines).
- Land-use planning (provide guidelines to councils).
- Continuously welded rail in areas with jointed rail.
- Improved rail gauge-face lubrication (all lines).
- Rail head friction modification (3 sites).
- Increased maintenance at turnouts (77 turnouts).
- Improved wheel condition value management study.
- Wheel impact detection.
- On-vehicle track noise monitoring.
- Review operational requirements for crossovers (identify any redundant crossovers).
- Design and trial noise mitigation for steel bridges.
- Design guideline for future bridges (preferably ballast topped, concrete span with parapets).
- Develop low noise turnouts and crossovers.
- Review potential for electric locomotives.
- Review horn usage practices.
- Enhance training for drivers and operations staff.

Implementation Status

At the time of writing, RailCorp is three years into the five year program. Some measures have been implemented on an ongoing basis (eg land-use planning guidelines for local government [9][10]), others have been implemented on an annual scheduled basis (eg continuously welded rail, regular rail grinding program, improved rail lubrication).

Most notable of these is the land-use initiative, which has resulted in improvements both in RailCorp’s response to DA notifications and in the consistency of responses from local government. The guidelines appear to have gained a good degree of acceptance from councils and the “roll-out” has clearly raised awareness of the need to manage rail noise in the planning process.

Some actions currently have technical studies or hardware development/installation underway (eg curve squeal, wheel impact detection and on vehicle track noise monitoring). Others require a degree of research and development, either to adapt existing technologies or to develop new capabilities to assist in the management of railway noise.

One example is a follow-up study of wheel condition initiated by Rail Infrastructure Corporation (now RailCorp) and undertaken by Heggies in 2002 [9]. This engagement involved a desktop review regarding the types of wheel tread conditions that cause audible noise and a measurement program to review the state of wheel condition in comparison to the Rail Noise Database.

For rollingstock operating in the Sydney area (ie PRP lines), it was concluded that skidded wheels and spalled wheels were both common forms of audible wheel defect. It was found that, overall, noise emissions from Tangaras had reduced, noise emissions from Double Decker Suburbans had remained unchanged and noise emissions from InterCity trains had increased over time (which was considered most likely to be a temporary condition at the time of measurement).

Whilst the Rail Noise Database relied on subjective observations to identify the incidence of audible wheel defects, this follow-up study also sought to compare the observations against more objective measurement based methods. Two methods were investigated, these being:

- Noise measurements, mid-way between the rails.
- Vibration measurements on the foot of the rail using an array of eight accelerometers.

Of these two measurements methods, the rail vibration (appropriately filtered) was found to show very good correlation with the subjective observations of wheel defects and also provided reasonable differentiation between bogies.

Another example of a research project is the on-vehicle track noise monitoring system, which is under development through the Rail CRC. The principle is relatively simple: a microphone mounted close to the wheels can be used to identify or trend any increase in noise level as the carriage travels around the network.

In practice, however, there are many factors to consider, including how to ensure that the wheels on the test vehicle remain in "control" condition, how to identify and record the locations of specific defects, how to distinguish between noise generated by joints, turnouts, wheel-burns, corrugation, flanging, curve squeal, brake squeal, etc and how to compensate for speed with respect to each defect type.

Development of this initiative thus represents a significant research project in its own right. Once completed, however, it should enable RailCorp to map the noise emission characteristics of its network on a regular basis and to prioritise maintenance to specific defects.

This, in combination with wheel monitoring initiatives, is intended to give RailCorp the ability to identify and respond to abnormal noise emissions in a more proactive manner than has been possible in the past.

Conclusions

The Line Based Noise Pollution Reduction Program Studies discussed in this paper represent a very substantial undertaking by RAC (now RailCorp), providing a broader insight into the nature and extent of noise emission than was previously possible.

The implementation of the prioritised activities over a five year period represents a sensible structure and timeframe within which to implement improved noise management.

The activities include both common sense items, such as removal of joints, as well as forward-looking actions, such as the development of new techniques to undertake widespread monitoring of the condition of the network and rollingstock.

References

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[9] Rail Infrastructure Corporation and State Rail Authority "Interim Guidelines for Councils - Consideration of Rail Noise and Vibration in the Planning Process", November 2003

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