Outcome based optimisation of road traffic noise mitigation

Simon KEAN

Roads and Maritime Services, Australia

ABSTRACT

New South Wales, Australia has shifted to an outcomes based approach to delivering traffic noise solutions with mandatory principles that must be met. Supporting procedures give guidance to achieving the principles most of the time. Key tasks in meeting desired outcomes are to identify appropriate noise criteria and to design an equitable mix of 'at-source' and 'at-receiver' road traffic noise mitigation. Particular attention has been given to noise barrier optimisation. This paper presents how legacy approaches have been revised to address recent criteria changes and a shift to outcomes based policy. In New South Wales road traffic noise criteria are set by the State Environmental Protection Authority based on how the road functions in a network. These criteria are guidelines rather than mandatory legislation. Road construction proponents such as the State's Roads and Maritime Services are required to meet these criteria where reasonable and feasible. This is in recognition that it may not always be reasonable to mitigate barely perceivable changes in noise level.

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1. NSW CONTEXT

Road traffic noise in NSW has been mitigated under a feasible and reasonable process to meet noise criteria guidelines. Whether it is feasible relates to what it is technically possible to achieve while reasonable considers the change in impact compared to the existing noise levels, overall benefits provided by mitigation, community views, urban design and cost.

The previous approach published by Road and Maritime Services in the *Environmental Noise Management Manual* (ENMM) (1) has been successful since its publication in 2001 but had room for improvement to provide more equitable outcomes for the community and for it to be simplified. In particular the update required a method to practically implement newer State noise criteria published by the NSW Environment Protection Authority's (EPA) in the *Road Noise Policy* (RNP) (2) and to also improve noise barrier optimisation.

In NSW the EPA, as the State's environmental regulator, is responsible for setting criteria. In NSW, for residences, this is based on how generic road types function in an overall road network. New roads also have 5dBA more stringent criteria, for residences, than upgrades of existing roads. Receivers other than residences have the same noise criteria for new and redeveloped roads. A road construction proponent, such as the State's Roads and Maritime Services, has responsibility for assigning criteria to sensitive receivers on specific roads and to also demonstrate to the EPA they have met criteria where feasible and reasonable. Criteria are not set by the EPA for individual road projects.

This paper summarises Roads and Maritimes new Noise Criteria Guideline (3) and Noise Mitigation Guideline (4) which supersede practice notes one and four of the ENMM. Key changes introduced in each guideline are to define principles that must be met. Each guideline also has supporting procedures to assist in meeting these principles, however if a situation arises where the procedure results in an outcome that does not meet the principles then the approach must be reviewed so that the principle is met.

2. NOISE CRITERIA GUIDELINE

2.1 Overview

Roads and Maritimes Noise Criteria Guideline identifies how the NSW Road Noise Policy is applied on State and Federal road projects. The following describes key changes that have been made

compared with Roads and Maritimes superseded ENMM.

2.2 Study Area

The study area for a road project is nominally 600m either side of the road project as defined by the EPA in the RNP. In rural areas Roads and Maritime may extend this to include additional receivers on a case by case basis where it can be demonstrated that criteria are exceeded beyond 600m.

In highly urban areas Roads and Maritime may consider reducing the 600m distance as a guide to exclude where the road project, when it is built, contributes less than 2dBA to the total noise level. This is then evaluated and extended out to stop at natural boundaries such as, but not limited to roads, rail corridors and parks.

2.3 Assigning New and Redeveloped Categories to Roads

The definitions of a new road and redeveloped road have been refined. A road is new if:

- the road has been substantially realigned
- it is constructed in a previously unbuilt road corridor, from where it extends beyond the current road corridor
- the road is a new bypass
- the project changes how the road functions in the road network.

A key improvement is that a definition is provided of when a road has definitely been substantially realigned. This provides greater consistency around minor curve straightening and parallel road duplication near the existing corridor. The definition provides a tolerance band that is six times the existing total lane width from the edge of the existing pavement.
The existing total lane width is defined as 3.5m per formed traffic lane excluding pedestrian and cycle lanes. This provides a tolerance band that scales with the size of the existing road. Any road segment beyond this tolerance band is defined as new.

If a road is not new it is considered redeveloped if it is an upgraded existing road where:

- the purpose of the upgrade is to increase its traffic carrying capacity, or
- changes have been made to significantly increase the percentage of heavy vehicle traffic by 50% or more.

Provision for local context is given allowing the tolerance band to be reduced if necessary.

2.4 Applying Criteria to Receivers

One of the first things a community will see when a proponent seeks approval to build or upgrade a road is a line on a map showing the road relative to other buildings and features in the landscape. Upon inspecting this map the community could reasonably expect that the noise criteria would reflect the type of road that they will be affected by. This is the approach now taken by Roads and Maritime which is summarised in the following principle:

1. Criteria are based on the road development type a residence is affected by due to the road project.

Previously existing noise exposure influenced whether a receiver was assigned new or redeveloped criteria with additional allowance for high existing noise levels that already exceeded the criteria. However this artificially constrained outcomes as existing noise exposure may not relate to the noise exposure from the upgraded road. It also introduced the potential for ongoing inequity for individual community members based on previous exposure.

The NSW EPA and Roads and Maritime also recognised a need to have a smooth transition in criteria between different road types (Figure 1), especially where new and redeveloped road segments of the same road project meet. Previously there was a 5dBA jump in criteria between adjacent receivers near the junction between new and redeveloped roads which created a sense of inequality in the community. Principle two to cover transition zones is that:

2. Adjacent and nearby residences should not have significantly different criteria for the same project.

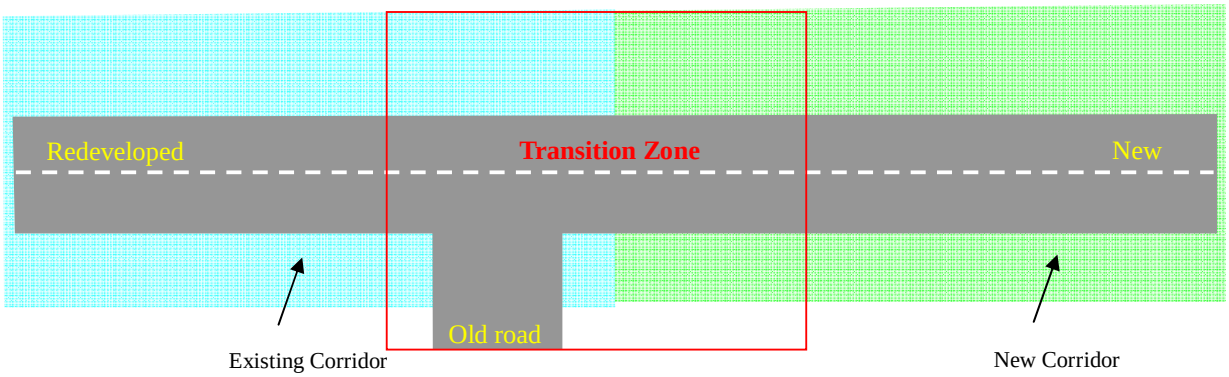

Figure 1 Junction between an existing upgraded (redeveloped) road and a bypass (new)

The new approach assigns transition zone criteria based on the contributed proportion of noise coming from the new and redeveloped pavement in the road project. Transition zone criteria change in 1dBA increments with the receiver at the junction of a new and redeveloped road, halfway between daytime new and redeveloped criteria (Table 1) of 55dBA and 60dBA respectively. Criteria affected wholly by new, redeveloped roads or transition zones can automatically be assigned to receivers using modelling software and the transition zone approach in Table 1.

Table 1 – New and redeveloped road transition zone criteria

Contribution Difference (dBA), New minus Redeveloped noise level	Daytime Criteria (dBA), Total Noise Levels, $L_{Aeq,15hr}$	Night time Criteria (dBA), Total Noise Levels, $L_{Aeq,9hr}$
Contribution Difference ≥ +3.0	55	50
+3.0 > Contribution Difference ≥ +1.5	56	51
+1.5 > Contribution Difference ≥ 0	57	52
0 > Contribution Difference ≥ -1.5	58	53
-1.5 > Contribution Difference ≥ -3.0	59	54
-3.0 > Contribution Difference	60	55

The contribution differences may be used to produce a criteria map which may be overlaid one areal photos to identify which criteria apply to residences.

Roads and Maritime considers traffic impacts due to our projects on connecting roads. Most of our projects are to increase the traffic carrying capacity of a State or Federal road which can reduce change road network flow patterns, particularly if this reduces congestion. In this situation Roads and Maritime applies an approach that is consistent with the Road Noise Policy criteria and assessment for traffic generating developments. This approach is summarised under principle three:

- Criteria for the surrounding road network are assessed where a road project generates an increase in traffic noise greater than 2dB on the surrounding road network.

The EPA and Roads and Maritime also recognise that in some locations without any significant traffic noise the new and redeveloped criteria may still represent a significant impact. This has been a source of community concern where there has been significant realignment of a road to an acoustic environment where there is no or little traffic noise. The Road Noise Policy introduced the relative increase criteria to address this which sets a criteria of existing traffic noise plus 12dBA. This can set noise criteria to as low as 42dBA in the daytime and night time. Detailed guidance on how to apply the relative increase criteria is given in the guideline and is summarised in principle four.

- Protect existing quiet areas from excessive changes in amenity due to traffic noise.

3. NOISE MITIGATION GUIDELINE

3.1 Overall Methodology

Roads and Maritime's Noise Mitigation Guideline (NMG) describes the overall principle and approaches to evaluating noise mitigation to meet the criteria in the Noise Criteria Guideline (NCG) where feasible and reasonable. As with the NCG there are principles that must be met with supporting procedures.

Noise mitigation must be investigated at each stage of a project from initial preliminary studies, route options assessments, environmental assessments upon which the project receives formal approval, detail design and post construction operational compliance. The level of detail and certainty in specifying mitigation must be appropriate for the project stage. Please refer to the NMG for detailed guidance. A discussion of how a receiver qualifies for consideration of noise mitigation and the new noise barrier design process is summarised below.

3.2 Qualifying for Consideration of Noise Mitigation

NSW has a feasible and reasonable approach to applying noise mitigation. Having a feasible and reasonable approach to meeting noise criteria rather than mandatory limits requires a balanced approach. The process needs to allow small increases in noise without permitting noise levels to cumulatively grow to unacceptable levels.

The RNP differs from the superseded *Environmental Criteria for Road Traffic Noise* (ECRTN) (5) when setting new and redeveloped road criteria by removing the allowance for when existing noise levels exceed the criteria. In practice noise levels were previously permitted to increase 2dBA or 0.5dBA for redeveloped or new roads respectively if the existing noise levels already exceeded the criteria. Removal of the allowance criteria has placed a need for greater consideration on addressing small cumulative increases in noise from successive projects and natural traffic growth in a feasible and reasonable process. Under the ECRTN Roads and Maritime set a limit of 65dBA day ($L_{Aeq,15hr}$) and 60dBA night ($L_{Aeq,9hr}$) at which point receivers qualified for consideration of noise mitigation regardless of whether noise levels due to a project increased or decreased. This limited how far noise levels could increase with the ECRTN allowance criteria. However under the RNP this limit would be up to 10dBA above new road criteria of 55dBA day ($L_{Aeq,15hr}$) and 50dBA night ($L_{Aeq,9hr}$) and up to 9dBA above the newly introduced transition zone criteria. To address Roads and Maritime has introduced the cumulative limit where a receiver qualifies for consideration of noise treatment where the noise level is at or more than 5dBA above the controlling criterion.

In terms of noise level increase a trigger for when it is reasonably to consider noise mitigation has been if there is an increase of more than 2dBA. Noise level increases of more than 2dBA are regarded in NSW to be just more than barely perceivable. In Roads and Maritimes revised approach a receiver qualifies for consideration of noise mitigation for new and redeveloped roads if the noise levels increase by more than 2dBA due to the project and exceed the criteria either at the year of opening or 10 years after opening.

In some instances the trigger is reduced to 1dBA where due to road configuration, an opportunity exists to not increase noise levels. The purpose of this is to capture situations where previously opportunities existed to reduce high noise level but instead the existing lanes and additional lanes were paved with noisier pavement. This could occur due to the combined effects of quieter road configuration and the 2dBA trigger In policy these instances with a 1dBA trigger are limited to the following examples in Figure 2 and Figure 3.

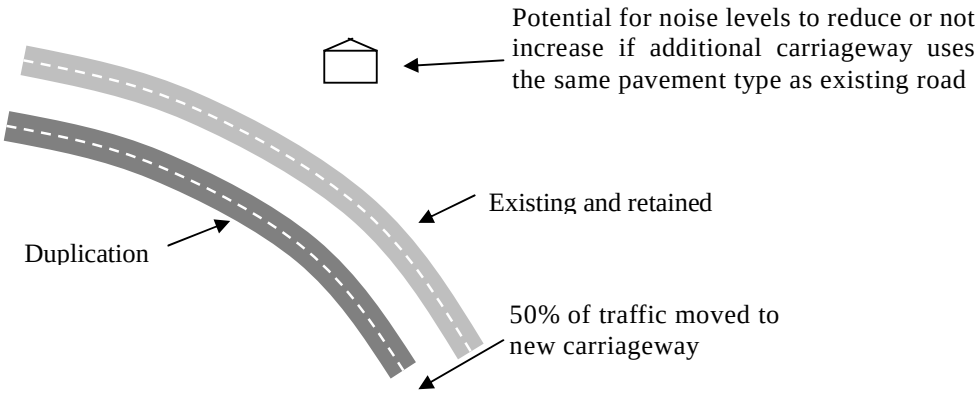

Figure 2 Duplication with additional carriageway further away from receiver

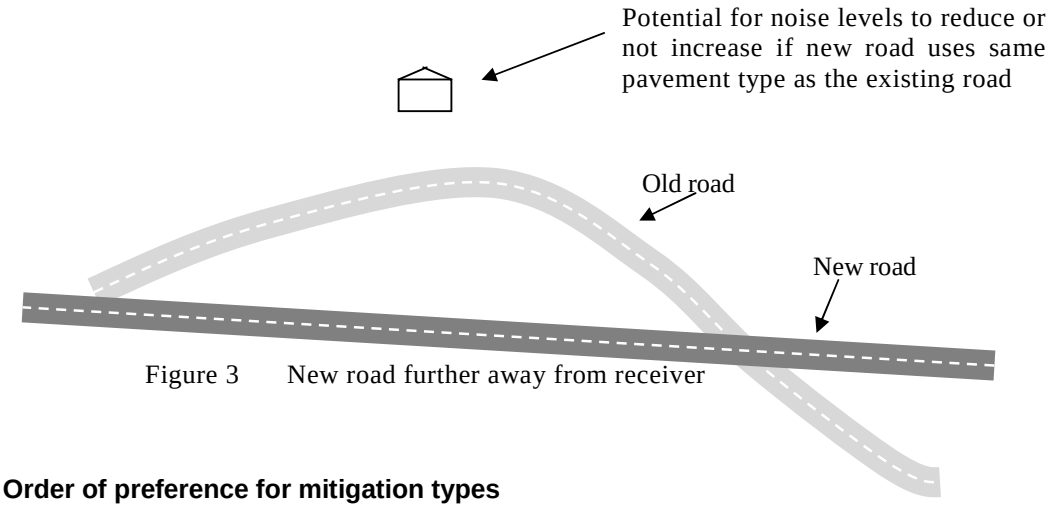

Figure 3 New road further away from receiver

3.3 Order of preference for mitigation types

The preference given in the RNP is to reduce noise at source through road design during planning or mitigation such as low noise pavements. This is followed by noise mounds, noise walls and finally at receiver treatment such as the upgrade of the buildings architectural components.

3.4 Noise Barriers

The approach taken in NSW has been to identify and assess a barrier height determined by policy for cost comparison with a barrier height where all criteria are met. Setting an assessed barrier height through policy recognises that while a barrier will often be less cost effective than architectural treatments at reducing internal noise levels it also protects outdoor areas of a home, allows windows to remain open to provide natural ventilation and also provides tangible benefits for other receivers in the community that may not exceed NSW criteria. In NSW any residual exceedences with the barrier are addressed using at receiver mitigation. The maximum barrier height Roads and Maritime considers is 8 metres due to cost, urban design, community and engineering constraints.

The assessed barrier height in NSW, rather than being fixed at a set height, was determined in the ENMM for each location by modelling noise reduction for different barrier height increments to find the height with the greatest marginal noise reduction. The approach involved first and second order gradients of noise reduction curves and made practical sense to be calculated at height increments relating to standard panel dimensions. This process worked well most of the time, however:

- the greatest marginal noise reduction could be missed as it can occur between height increments of standard panels

- some designs were very sensitive to subtle design changes and ground height error due to the first and second order terms
- some barrier heights were too low to be effective
- the height identified did not relate to the final noise level outcome

Acoustically the greatest marginal reduction occurs using the ENMM process where the barrier breaks line of site, on average with the bulk of receivers, which is where the barrier just becomes effective. This provides noise barriers with a similar amount of noise reduction for each location. From a community perspective this approach is difficult to understand and did not always appear to be equitable. This was because the two outcomes the community could observe were barrier height and the noise level behind the barrier. However the noise reduction at each receiver provided by the barrier can not be heard. Roads and Maritimes new approach is simpler to understand and relates directly to final noise levels behind the barrier.

Roads and Maritime noted that the number of receivers requiring at receiver noise mitigation at each barrier height, to address residual exceedences, formed an 's' curve (Figure 4). Typically there was a point where further increases in barrier height only provided a minimal reduction in the number of at receiver treatments. In an 's' curve this occurs in the final one-third. Roads and Maritime new approach identifies an initial design height where two-thirds of the receivers that no longer need at receiver treatment at a maximum barrier height of 8 metres, no longer need treatment. This approach identifies a height by policy that relates directly to community noise level outcomes which meet the criteria at most receivers. It achieves this without having to set a target noise level other than the criteria. The outcome is based on equitable noise levels, which is a measure communities can observe.

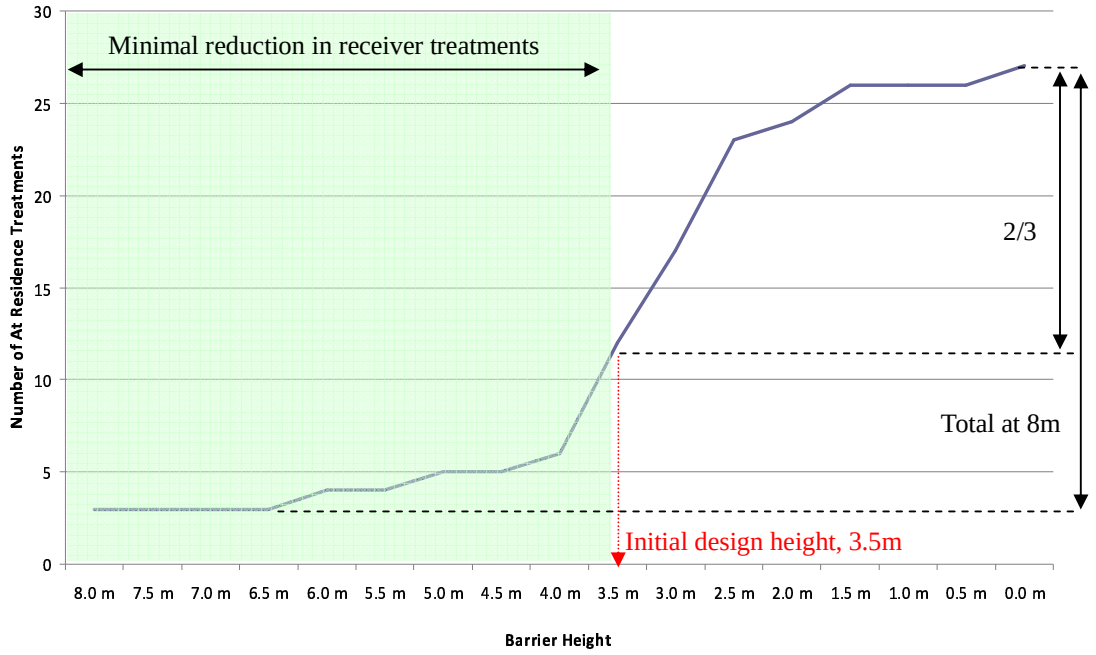

Figure 4 Example number of at receiver treatments for various barrier heights

In the example in Figure 4 indicates that there is a significant reduction in receivers if the wall height is increased to 4.0 meters and some incremental reductions at 5.5 metres and 6.5 metres. The new process uses a weighted analysis to determine if it is reasonable to increase the initial design barrier height. The weighted analysis uses dollars as the basis but has converted these into points. The reason for this is to ensure consistent policy outcomes between projects. When expressed in dollars a temptation for practitioners when using the ENMM was to update and optimise the values. Dollars in the new process have been converted to points by dividing by 250 and discounting the barrier costs by 50%. Roads and Maritime discounts the barrier cost by 50% to give preference to barriers which also protect outdoor areas and other receiver over at receiver treatments. Consideration is also given to the benefits provided by a barrier to receivers where noise levels are greater than 50dBA day and 45dBA

night which are representative of façade corrected threshold levels where health effects due road traffic noise exposure have been documented (6, 7).

Table 2 – Point values for weighted dollars

Item	Points
Noise Barrier (wall or mound)	1 per m^2 of area through the longitudinal height cross section
At receiver mitigation for less than 10dBA exceedence	40 per receiver per floor
At receiver mitigation for greater than 10dBA exceedence	120 per receiver per floor
Other residences	4 per dBA exceedence of 50dBA day or 45dBA night

These points have been applied below Figure 5 to the example in Figure 4. It shows that there is a minimum in the points curve at 4 metres between the initial design height of 3.5 metres and 8 metres. This indicates it is reasonable to set the design height at 4 metres.

If however there were relatively few receivers behind a long length of barrier there would not be a minimum and the points curve in Figure 5 would trend progressively up from right to left and it would not be reasonable to increase the barrier height.

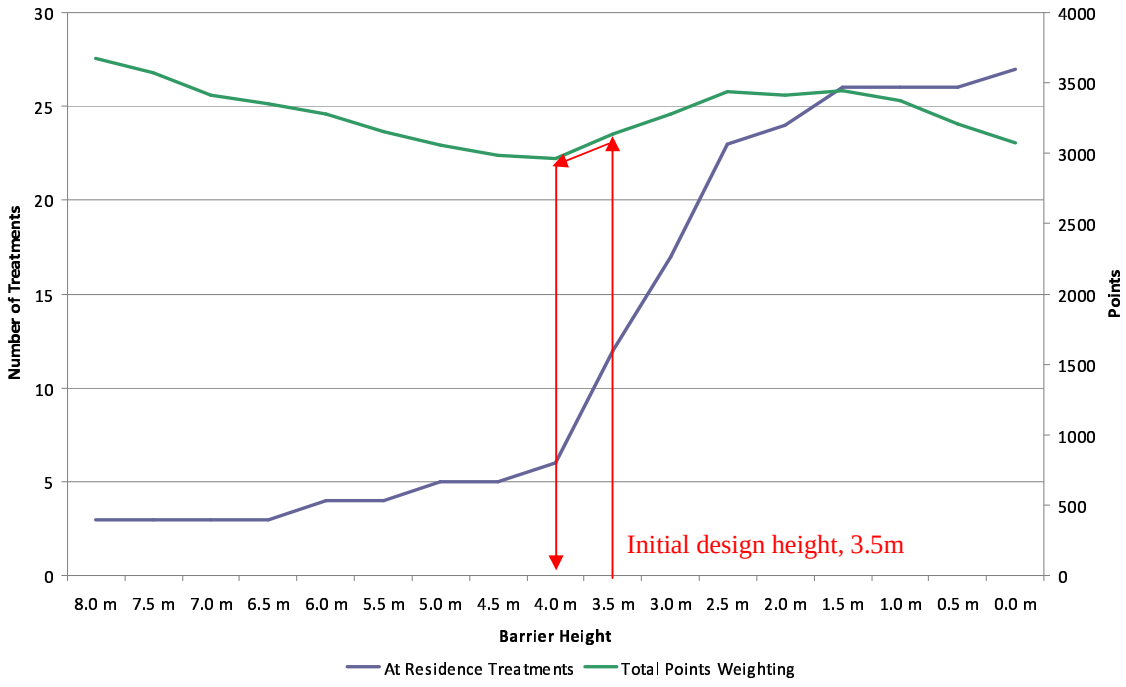

Figure 5 Example showing points at each barrier height

Roads and Maritime then compares the current cost of the barrier and at residence mitigation for the design height against a barrier where criteria are met at all receivers. If the difference is greater than 25% then the design barrier is recommended. Otherwise it is reasonable to recommend a barrier where criteria are met at all receivers.

The new barrier design process has a number of advantages. The approach results in more equitable noise levels within different communities as the process relates directly to meeting criteria at most

receivers. It is also simpler to understand as the main metric, number of receivers needing treatment, at each barrier height has physical meaning.

It is also compatible with software optimisation procedures and barrier heights that vary along the length. These designs may be plotted against average height allowing a number of different designs to be ranked and compared. It is also not necessary to evaluate the barrier design at set barrier height increments, for example the horizontal axis step size does not need to be evenly spaced. This is because unlike the approach in the ENMM it does not take first and second derivatives for gradient and curvature to evaluate marginal benefits. The shift away from marginal analysis using first and second order terms also makes the design less prone to change with different noise models, small errors in ground height and small road design changes as noise level predictions are reasonably consistent.

4. CONCLUSIONS

Roads and Maritime has revised the Environmental Noise Management Manual through the new Noise Criteria Guideline and the Noise Mitigation Guideline. These two guidelines have focused on providing clear outcomes. This is achieved through the use of principles which must be met with supporting procedures to assist in achieving these outcomes. The principles are overarching and if the procedure does not achieve the principle then the proponent must work with Roads and Maritime to identify a solution that meets the principle.

Road criteria are now assigned with regard to the road that is being built or upgraded rather than through consideration of existing noise exposure. This aligns with community expectations and removes unnecessary constraints on noise level outcomes.

The process of a receiver to qualify for consideration of noise mitigation through a feasible and reasonable process has been amended to respond to the NSW Road Noise Policy. Key changes in the RNP were the removal of allowances in higher noise areas where criteria were already exceeded and the introduction of transition zones. The RNP also places greater emphasis on looking at what may be achieved for a given road design during planning and design.

Roads and Maritime has simplified the noise barrier design process to align with community expectations. These changes have also reduced the sensitivity of the process to small design changes, errors in modelling while providing greater flexibility and compatibility with software optimisation algorithms.

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