EVALUATION OF NOISE AMELIORATION TREATMENTS WITHIN AND OUTSIDE THE ROAD RESERVE

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Abstract

In urban environments road traffic volumes are increasing and the density of living is becoming higher. As a consequence the urban community is being exposed to increasing levels of road traffic noise. It is also evident that the noise reduction potential of within-the-road-reserve treatments such as noise barriers, mounding and pavement surfacing has been exhausted. This paper presents a strategy that involves the comparison of noise ameliorative treatments both within and outside the road reserve. The noise reduction resulting from the within-the-road-reserve component of treatments has been evaluated using a leading application of the CoRTN Model, developed by the UK Department of Transport 1988 [1], and the outside road reserve treatment has been evaluated in accordance with the Australian Standard 3671, Acoustics – Road traffic noise intrusion – Building sitting and construction [5]. The evaluation of noise treatments has been undertaken using a decision support tool (DST) currently being developed under the research program conducted at RMIT University and Department of Main Roads, Queensland. The case study has been based on data from a real project in Queensland, Australia. The research described here was carried out by the Australian Cooperative Research Centre for Construction Innovation [9], in collaboration with Department of Main Roads, Queensland, Department of Public Works, Queensland, Arup Pty. Ltd., Queensland University of technology and RMIT University.

Nomenclature

AADT	Annual average daily traffic
$L_{A10(18\ hours)}$	Level of noise exceeded for 10% of 18 hours, from 6:00 am to 24:00 pm, dB(A)
L_{Aeq}	Equivalent noise level of noise over a period, dB(A)

Introduction

The noise pollution caused by motor vehicles has increased substantially, particularly in urban areas. In last decade much effort including building noise barriers and mounds, reducing noise level of vehicle engines, introducing low-noise pavement and landscape designing has been put into minimizing the effect of noise emission. Unfortunately, the situation of urban noise pollution has not been improved as expected due to the continual rise in vehicle numbers and increase of speed limit on the road. In response to this issue, a user-friendly Decision Support Tool (DST) for urban noise management is currently being developed by RMIT. The benefit of such a tool is that it would adequately equip a decision maker to mitigate the problem where it is most effective with the potential to produce the optimum outcome.

This paper aims to demonstrate the DST built-in process for evaluation of alternative ameliorative treatment strategies. The study approach shows as follows

- Noise impact and code assessment are presented based on a noise study area from Queensland which was introduced as a case study input data source;
- Potential ameliorative options are identified within and outside road reserve;
- All potential options have amelioration analysis to investigate the possible options that can achieve the relevant target;
- Feasible ameliorative options are identified by undertaking feasibility analysis of the possible options;
- Concept costing is estimated for the feasible ameliorative options;
- Benefit analysis is developed for the feasible ameliorative options by using hedonic pricing method.

Noise Impact and code assessment

For a given noise study area, the first issue to be discussed was if ameliorative treatment was required.

The noise study area to be investigated in this study was located along the Old Northern Road between Jinker Track and Keong Road in an urban suburb, Albany Creek, Queensland [2]. The traffic flow and road surface data were

Old Northern Road:	
AADT	22,893
% Commercial Vehicles	6.0%
Growth rate (cumulative)	4.27% p.a.
Posted traffic speed	70 kph
Existing road surface type	Dense-graded asphalt (DGA)

The relevant terrain and feature data including roadway, surrounding topography, existing noise barriers (west side), residential locations and residential property boundaries, were provided in AutoCAD DXF format.

According to the relevant noise criteria [3], the study area was addressed as existing residences and existing roads (no road works). An external level, 68 dB(A) $L_{A10(18\ hours)}$, was recommended as the noise criterion for adjacent residential properties of the study area [3].

Table 1 listed existing noise levels predicted by SoundPlan, a software package based CoRTN method [1],

Table 1. Calculated external levels of noise receptors, Old Northern Road

Receptor No.	Building Height (Storey)	$L_{A10\ (18\ hours)}$ dB(A) 1999
R1	Single	66
R2	Double	63
R3	Single	**71**
R4	Single	65
R5	Single	66
R6	Single	67
R7	Double	**73**
R8	Single	**73**
R9	Single	**72**
R10	Double	**74**
R10 Granny	Single	**75**
R11	Single	**69**
R12	Single	59
R13	Single	65
R14	Single	68
R15	Single	68
R16	Single	64
R17	Single	64
R18	Single	65
R19	Single	61
R20	Single	62

Note: Road surface type is Dense-graded asphalt (DGA)

It was found that on the east side of Old Northern Road, out of 12 receptors, from R1 to R11, 7 receivers were predicted to exceed the noise criterion, 68 dB(A) $L_{A10\ (18\ hours)}$. The highest $L_{A10\ (18\ hours)}$ was 75 dB(A) at receptor R10 that exceeded the criterion by 7 dB(A). Hence, ameliorative treatment was needed along the east side of Old Northern Road, for the noise study area.

Option identification

Option identification started with two ameliorative methods, barrier/mound and pavement resurfacing, within road reserve, and one method, building façade treatment, outside road reserve that were presented as three potential ameliorative treatment options for the noise study area. Three combination methods, barrier/mound and resurfacing, barrier/mound and building treatment, resurfacing and building treatment, and barrier/mound, resurfacing and building treatment, were also considered as three potential options.

Note that according to Australia Standards 2107, an indoor satisfactory sound level of 35 L_{Aeq} dB(A) and a maximum sound level of 45 L_{Aeq} dB(A), are recommended for living areas of dwellings near major roads [5]. In terms of $L_{A10(18\ hours)}$,, the indoor satisfactory sound level is equal to 38 $L_{A10(18\ hours)}$, and a maximum sound level of 48 $L_{A10(18\ hours)}$,, since L_{A10} is generally 3 dB(A) higher than L_{Aeq} dB(A) [3]. On the other hand, according to the NSW RTA, most buildings will achieve an internal noise level 10 dB(A) below the external noise level with the window open, without additional treatment applied [4]. It means that the internal noise level will be 58 dB(A) $L_{A10(18\ hours)}$, under the external noise criterion of 68 dB(A) $L_{A10(18\ hours)}$, for the dwellings in the study area. There is a difference of 10 dB(A) between the internal noise criteria within and outside road reserve.

In response to this situation the indoor noise criterion for building treatment was based on the external criterion. The indoor noise criterion used in this case was 58 dB(A) $L_{A10(18\ hours)}$.

For each potential ameliorative option an attainable reduction value in noise level was indicated in Table 2 [4].

Table 2. Acoustic summary of potential ameliorative options

Option	Attainable reduction dB(A)	Criterion $L_{A10\ (18\ hours)}$ dB(A)	Criterion type
Barrier / Mound	10	68	External
Resurfacing	2 ~ 4	68	External
Building treatment	10 ~ 25	58	Internal
Barrier / Mound & Resurfacing	12 ~ 14	68	External
Barrier / Mound & Building treatment	20 ~ 35	58	Internal
Resurfacing & Building treatment	12 ~ 29	58	Internal
Barrier / Mound, Resurfacing & Building resurfacing	22 ~ 39	58	Internal

For reductions, 7 dB(A) in external noise level and 17 dB(A) in internal noise level, the option of resurfacing was discarded and five potential ameliorative options for the study area were selected for further study and shown in Table 3.

Table 3. Selected potential ameliorative options, east side of Old Northern Road

Treatment Option	Required reduction dB(A)	Attainable reduction dB(A)	Criterion type
Barrier / Mound	7	10	External
Building treatment	17	10~ 25	Internal
Barrier / Mound & Resurfacing	7	12 ~ 14	External
Barrier / Mound & Building treatment	17	20 ~ 35	Internal
Resurfacing & Building treatment	17	12 ~ 29	Internal
Barrier / Mound, Resurfacing & Building resurfacing	17	22 ~ 39	Internal

Amelioration analysis

The task of amelioration analysis was to determine if the potential ameliorative options identified in the previous section could achieve the noise reduction required. And the task was carried out by physically designing and acoustic modelling of the potential ameliorative options.

For the potential ameliorative options within the road reserve, the modelling results processed used SoundPlan indicated four possible options listed in Table 4

For the potential ameliorative options related to building treatment, the results of the evaluation were based on the Australian Standard 3671. It was found that with an open window area of up to 40%, or with air gaps having an equivalent opening in the façade and with the window closed, the required noise reduction of 17 dB(A), could be achieved without the application of sealing the façade for all seven dwellings [7]. However, due to the requirement for fresh air and other uncertainties such as the size of air gaps in the façade, it was recommended that mechanical aeration and air conditioning be installed for the dwellings with noise levels that exceeded the criterion [7].

Hence, five possible ameliorative options were developed including the building treatment option of mechanical aeration and air conditioning and four options listed in Table 4.

Table 4. Possible ameliorative options within road reserve, east side of Old Northern Road

Option 1: Barriers
Surface type: Dense Grade Asphalt (DGA)

Barrier No.	Height (m)	Length (m)	Area (m^2)
Barrier 1	4.5	61	275
Barrier 2	3.5	111	387
Barrier 3	2.5	118	296
		Total Barrier Length 290	Total Barrier Area 959

Option 2. Barriers & Resurfacing
Surface type: Open Grade Asphalt (OGA)

Barrier No.	Height (m)	Length (m)	Area (m^2)
Barrier 1	4.0	61	245
Barrier 2	2.0	117	234
		Total Barrier Length 178	Total Barrier Area 479

Option 3. Barriers & Resurfacing
Surface type: Stone Mastic Asphalt SMA

Barrier No.	Height (m)	Length (m)	Area (m^2)
Barrier 1	4.0	61	245
Barrier 2	3.0	98	294
Barrier 2	2.0	131	262
		Total Barrier Length 290	Total Barrier Area 801

Option 4. Barriers and Mounds (Barriers on the top of the mounds)
Surface type: Dense Grade Asphalt (DGA)

Barrier No.	Height (m)	Length (m)	Area (m^2)
Barrier 1	4.5	61	275
Barrier 2	1.5	111	167
Barrier 3	1.0	118	59
		Total Barrier Length 291	Total Barrier Area 502
Mound No.	Height (m)	Length (m)	Volume (m^3)
Mound 1	2.0	54	217
Mound 2	2.0	225	899
		Total Mound Length 279	Total Mound Area 1,116

Note: for both mound 1 and mound 2 in option 4, slope left was 1 m, slope right was 1 m, height was 2 m and top width is 1m.

Feasibility of option

The feasibility study of the ameliorative options was to investigate if the possible ameliorative options recommended in the previous section could be practically built in the noise study area according to engineering considerations.

The on-site investigation showed that both resurfacing and mounding were not feasible for the study area due to the pavement schedule of local road authority and actual terrain features. Hence, two feasible ameliorative options listed in Table 5 were selected for the study area.

Table 5. Feasible ameliorative options, east side of Old Northern Road

Option 1: Barriers Surface type: Dense Grade Asphalt (DGA)			
Barrier No.	Height (m)	Length (m)	Area (m^2)
Barrier 1	4.5	61	275
Barrier 2	3.5	111	387
Barrier 3	2.5	118	296
		Total Barrier Length	Total Barrier Area
		290	959
Option 2. Mechanical aeration and air conditioning Surface type: Open Grade Asphalt (OGA)			

Concept costing

The two feasible ameliorative options developed in the previous sections have been evaluated in terms of concept costs in this section. And a cost comparison study of the two options has been carried out and presented in Table 6.

The initial installation of option 2, mechanical aeration and air conditioning, was estimated as $15,000 per dwelling [7]. The cost of total initial installation of seven dwellings was

$15,000*7 = $105,000

It is assumed that for the ameliorative option of mechanical aeration and air conditioning, the costs of items listed in Table 6 were the same as the barrier option except for the “Construction of Barriers” and “Architectural Measures”. In option 2, the cost of “Construction of Barriers” was nil and “Architectural Measures” it was $ 105,000. Hence, the total cost of option 2 was $268,144.

Comparing the total costing estimations of $302,672 and $268,144, the building treatment outside road reserve, involving mechanical aeration and air conditioning, was about 11% less than the barriers option within road reserve. However, building treatment has an additional running cost. Over a time period, *e.g.* a ten year period, such running costs could be up to hundreds of thousands of dollars. If the running costs are included the building treatment such as mechanical aeration and air conditioning, could cost even more than the within the road reserve, barriers option. Further studies are needed for evaluating the total costing of ameliorative treatment options over a time period [7].

Table 6. Concept costing of barrier ameliorative option, east side of Old Northern Road

	Option #:	1
	Option Description :	Barriers
A	Project Management (5 %):	$ 9,753
B	Survey :	$12,826
	Design:	$26,222
	Planning:	$17,058
C	Land Acquisition:	$ 0
D	Service Relocation:	$ 0
E	Construction of Noise Barriers:	Plywood & Concrete $139,528
F	Construction of Mounds:	No Mound constructed
G	Road Resurfacing	$ 0
H	Architectural Measures:	$ 0
I	Landscaping:	$ 12,500 L/S
J	Site Specific Civil Works:	$ 55,000
K	Contingency:	$ 29,250 L/S
	Total:	**$302,672**

Note: L/S: Lump Sum

Benefit analysis

Benefit analysis of noise amelioration has used a broad range of criteria to evaluate and compare the noise ameliorative options in terms of benefit. Some are readily expressed in dollar terms *e.g.* costs, and used in economic benefit evaluation. Some, such as environmental and social benefits, are not readily expressed in dollar terms and can only be presented in relative terms for comparisons between treatment options.

Table 7 shows the non-dollar benefits for the noise study area due to implementing the feasible ameliorative options.

AUSTROADS recommended the Hedonic Price technique to evaluate people’s willingness to pay for peace and quiet [8]. For benefit cost analysis of road noise reduction options, it was suggested that in Australia, property values decreases 0.9% for every decibel over 50 dB(A) [8]. In this study the hedonic price technique was introduced as one term to evaluate the benefit of noise ameliorative options.

Since the real state information related to the noise study area was not available, the percentages in property value increasing due to the implementation of ameliorative options were listed in Table 8 and Table 9.

Table 7. Comparison of benefits due to the noise reduction resulting from implementing ameliorative options at Old Northern Road

Benefits for dwellings with exceeded noise criterion	Feasible Option 1: Barrier s	Feasible Option 2: Building treatment
Quieter indoor areas provided	Yes	Yes
Quieter outdoor areas provided	Yes	No
Free window open preserved	Yes	No
Natural vision preserved	No	Yes
Benefits for the surrounding dwellings in the study area	**Feasible Option 1: Barriers**	**Feasible Option 2: Building treatment**
Quieter indoor areas provided	Possibly	No
Quieter outdoor areas provided	Possibly	No
Natural vision preserved	No	Yes

Table 8. Benefit of property values due to noise reduction by implementing barriers, east side of Old Northern Road

Receptor No.	L_{A10} (18 hours) without barriers dB(A)	L_{A10} (18 hours) with barriers dB(A)	Noise reduction by barriers dB(A)	Increase in property value (%)
R1	66	66	0	0
R2	63	63	0	0
R3	**71**	63	8	7
R4	65	60	6	5
R5	66	60	6	5
R6	67	59	8	7
R7	**73**	68	5	5
R8	**73**	63	10	9
R9	**72**	61	11	10
R10	**74**	62	13	11
R10 Granny	**75**	67	8	7
R11	**69**	67	3	2

Note: external criterion, 68 dB(A) $L_{A10(18\ hours)}$, and predicted results were used

Table 9. Benefit of property values due to noise reduction by implementing building treatment, east side of Old Northern Road

Recepto r No.	L_{A10} (18 hours) without building treatment dB(A)	L_{A10} (18 hours) with building treatment dB(A)	Noise reduction by building treatment dB(A)	Increase in property value (%)
R1	56	56	0	0
R2	53	53	0	0
R3	**61**	58	3	2
R4	55	55	0	0
R5	56	56	0	0
R6	57	57	0	0
R7	**63**	58	5	4
R8	**63**	58	5	4
R9	**62**	58	4	3
R10	**64**	58	5	5
R10 Granny	**65**	58	6	6
R11	**59**	58	1	1

Note: internal criterion, 58 dB(A) $L_{A10(18\ hours)}$, and predicted results were used

Conclusions

A comprehensive process based on the decision support tool, DST, for identifying and evaluating feasible noise ameliorative options within and outside road reserve has been demonstrated.

For the given noise study area, one ameliorative option within the road reserve, barrier treatment, one option outside the road reserve, building treatment – mechanical aeration and air conditioning, have been investigated with amelioration analysis, feasibility analysis and cost and benefit analysis. Evaluation of the two ameliorative options based on cost and benefit analyses was developed.

It is concluded that the DST features make it possible for use by the decision makers in order to encourage forethought and effective management practices when planning and investing in noise management strategies in areas of continuous growth and redevelopment such as urban environments.

References

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