Application of traffic noise models for estimating the environmental capacity of arterial roads

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Abstract

Three alternative models of traffic noise prediction have been applied to two major roads in a large provincial city in Australia. The roads are segmented into links and the environmental capacity of each link is determined. Both one-hour and 18-hour noise levels are used for capacity estimation. This allows a rational comparison of the ease of use, data requirements as well as limitations of alternative traffic noise models. The sensitivity of the environmental capacity to changes in setback distance, traffic composition, traffic speed, and acceptable noise levels is explored. This is useful in the formulation of rational strategies for improving the environmental capacities of roads. The amelioration models should, wherever possible, allow the environmental capacity to be as close as is practical to the physical capacity at level of service E. An opinion survey of the residents in the study area has been conducted with a view to determining acceptable noise levels. Based on these studies, noise levels for various land uses and times of day are recommended and estimates of environmental capacities of the two roads are presented.

1 Introduction

Capacity considerations are of fundamental importance in the planning, design, and operation of roads. Traditionally, capacity analysis is based upon the "ability of a facility to accommodate traffic under given roadway, traffic and control conditions. This definition does not take into account the degradation of the environment caused by the traffic. Recently, environmental considerations have become an essential part of planning process besides engineering and economics. The environmental capacity (EC) of a road is defined as "the maximum traffic volume that may pass a given point without causing excessive degradation for given environmental factors". These may include air quality, noise levels, safety, aesthetics etc. A number of techniques have been developed to assess specific environmental impacts of the road and road traffic on the surrounding environment.

In this study, three alternative models of traffic noise prediction have been applied to two major roads in Townsville - a large provincial city in Queensland, Australia. The sensitivity of the environmental capacity to changes in setback distance, traffic composition (proportion of heavy vehicles), traffic speed, and acceptable noise levels is also explored in detail. The application of the quantitative traffic noise models has been supplemented by a qualitative survey of the residents in the study area.

The study is useful in the formulation of sensible and efficient strategies for improving the environmental capacity of roads. Wherever possible, the environmental capacity should be raised so as to be as close to the physical capacity (at level of service E) as practical to ensure optimal utilisation of road infrastructure.

1.1 Acceptable Noise Level

The EC of a road may limit the traffic volume and composition to a level that does not cause an unacceptable level of noise to the population affected by the road traffic. If the level of noise where normal conversation can be carried out without the necessity of raising voice is considered acceptable, then it is possible to quantify an acceptable "standard" level of traffic noise propagation. Time is an important dimension of noise levels. Traffic noise over a period of time is represented by a "noise index." Australia has followed Britain and has adopted the L_{10} (18-hr) index. The "L_{10}" refers to a noise level that is exceeded for 10 % of the time, the (18-hr) represents the period over which the readings are taken. It is generally accepted that between 3000 to 4000 veh/day can be allowed on residential street to comply with noise pollution constraints.

To define the EC for noise pollution, the noise level at which the majority of people find annoyance must be ascertained. This can be done by a "noise annoyance survey," in which people express their level of

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annoyance to noise levels by scoring on a scale of one (minimal) to five (extreme). The acceptable noise level may be taken as the level causing an annoyance of 2.5 on the scale. Noise studies carried out in the U.K. have found that the noise dissatisfaction level generally lies between 65 and 73 dBA, depending on land use.

1.2 Environmental Capacity and Deficiency Index

The EC based on noise is the maximum traffic volume without exceeding the acceptable noise level. Environmental capacity is influenced by many factors including the proportion of heavy vehicles in the traffic stream, traffic speed, as well as acceptable noise level.

The Environmental Deficiency Index (EDI) is the ratio of the actual traffic volume to the EC for either the 18-hr or 1-hr traffic volumes. Where the EDI is less than one, it can be concluded that the current traffic flow causes no detriment to the local environment. The extent of detriment is reflected by the magnitude of the EDI (>1).

2 Noise Prediction Models

There are various methods for the prediction of traffic noise levels. The following three models were used in this study.

- U.K. Department of Transport, traffic noise prediction model (CoRTN - Calculation of Road Traffic Noise)[1].
- Ontario Ministry of Transportation and Communication Noise Prediction Model[2]
- Ove Arup Transportation and Planning Collaborative "EC" technique[3].

2.1 CoRTN (Calculation of Road Traffic Noise)

The CoRTN noise prediction model was developed in Britain by the U.K. Department of Transport and is a useful tool in the environmental appraisal of road use schemes, highway design and land use planning.

The CoRTN procedure provides a general method of calculation for predicting noise levels at a specified distance from a road, taking into account different traffic parameters, intervening ground cover, road configuration and site layout. It also provides supplementary procedures to predict noise levels in specific situations (eg. on bends in a road, or road junctions). The source of the noise is taken to be a line 0.5m above the carriageway and 3.5m in from the nearside carriageway edge.

2.2 Ontario Noise Prediction Model

In 1976, the Ontario Ministry of Transportation and Communications developed a predictive equation based upon the energy equivalent (L_{eq}) concept. The empirical equation has the form:

$$L_{eq} = 42.3 + 10.2\log(V_c + 6V_t) - 13.9\log D + 0.13S \qquad (1)$$

Where L_{eq} = energy equivalent sound during 1 hour, (dBA)
V_c = volume of automobiles (veh/hr)
V_t = volume of trucks (veh/hr)
D = Distance from the edge of the pavement to the receiver, (m)
S = average speed of traffic flow during one hour, (km/h)

This method is relatively easy to apply. Note that the noise level from a truck is assumed to be equivalent to six automobiles.

2.3 Ove Arup Transport Planning and Planning Collaborative

The "Environmental Capacity" (EC) technique was developed by Ove Arup Transport Planning Collaborative in 1980. A derivative of the CoRTN procedure, EC technique uses predefined acceptable and desirable levels within each segment. Corrections for traffic and road characteristics are taken into account and the number of cars producing the predetermined level is calculated for both 1-hr and 18-hr time periods.

3 Study Area

The two major roads selected in this study are Woolcock Street and Kings Road. Woolcock Street is a divided arterial road with a minimum of two lanes in each direction, and an allowable speed limit of 70 km/hr. This road has a generous right-of-way with a very wide depressed median and service roads in both directions. Kings Road is a two-lane, sub- arterial road, with predominantly residential land use on either side of the road. This road has an allowable speed limit of 60 km/hr, and has limited clearance from the kerb-edge to the right-of-way boundary on both sides.

Commercial and retail outlets have been established for the majority (>70%) of road frontage of Woolcock St.. Residential establishments are accessed via other adjoining service roads. The propagation distance to the buildings varies between 30 to 80 m. Private housing accounts for more than 85 % of the land-use. The average setback is approximately 12 m from the edge of the roadway. The "average house" is recessed by approx. 6 m. Housing is moderately dense along the road.

The roads were divided into 7 links (0-3 Woolcock, 4-6 Kings) based on similarity of land-use, traffic volumes, and physical characteristics of the area. Data on traffic volumes and proportion of heavy vehicles (net mass > 1525 kg) were obtained from the Townsville City Council and are shown in Table 1. Traffic signals, designated turning lanes and roundabouts are the main traffic control devices used on these roads

Table1: Traffic Volume (1hr) and Composition: (1 Direction)

Section	Av. Speed	Heavy Veh.	Others	% H.V.
0,1	66.2	79	1025	7.7
2,3	67.1	82	1122	7.3
4,5,6	56.0	28	431	7.4

(Source: Townsville City Council)

The service flow rate at LOS E was found assuming a design speed for Woolcock Street of 100 km/h. This is consistent with the design speeds of other urban arterial roads. The service volume at LOS E was found to be 3,300 veh/hr. For Kings Road a design speed of 60 km/h, corresponding to the maximum regulatory speed of the road, was assumed. At LOS E, the service volume was found to be 1145 veh/hr

Noise monitoring was undertaken at the middle of the link, which was assumed to represent the entire link. In case of environmentally sensitive land use (hospital, school etc.), the data was collected immediately adjacent to the facility rather than at the middle of the link.

4 Attitudinal Survey of Residents

Residents from the study area were asked about the degree of bother from traffic noise. They were specifically questioned on the effects of traffic noise on indoor activities.

Almost 80% of the respondents were extremely/highly bothered and only 9 % were not bothered/only slightly affected by traffic noise. The decrease in quality of life due to the interference with sleep patterns was a topical point with those interviewed. Of the responses within the extreme category, the outdoor noise levels bothered 37% while 43% were bothered by traffic noise while indoors. The interference of traffic noise with everyday life activities was explored. The two roads in this study yielded very different results for noise acceptance. People on Woolcock Street had a higher tolerance to noise than the residents of Kings Road. This is attributed to different land use.

5 Environmental Capacity Estimation

5.1 Environmental Capacity and Deficiency Index

Environmental capacity was determined for both roads using 1-hr and 18-hr. levels with all noise models. At 70 dBA (established from the survey and used as a standard in this study), the EC and associated EDI are given in Table 2.

Table 2: 1-hr EC Traffic Volumes and EDIs: Woolcock St.

	Environmental Capacity (veh/hr)			Environmental Deficiency Index		
Section	CoRTN	Ove Arup	Ontario	CoRTN	Ove Arup	Ontario
0	4225*	3000	2549	0.26	0.37	0.43
1	700	800	385	1.72	1.50	3.12
2	1490	1040	662	0.61	0.88	1.38
3	1174	1040	662	0.78	0.88	1.38

- EC is greater than the physical capacity of the road (LOS E)

The reduced EC of section 1 is due to reduced setback distance. The EC and EDIs for the 18-hr traffic volumes are shown in Table 3.

Table 3: 18-hr EC Traffic Volumes and EDIs: Woolcock Street

Section	EC (veh/hr)		EDI	
	CoRTN	Ove Arup	CoRTN	Ove Arup
0	86268*	70000*	0.21	0.26
1	14300	16500	1.29	1.12
2	30440	28000	0.61	0.66
3	23979	28000	0.77	0.66

* EC is greater than the physical capacity of the road (LOS E)

The corresponding EC and EDI for Kings Road are shown in Table 4. The Ontario noise prediction model is obviously the most conservative of the predictive models.

Table 4: EC Traffic Volumes and EDIs: Kings Road

	1-hr. noise level		18-hr noise level	
	EC (veh/hr)	EDI	EC (veh./18 hr)	EDI
CoRTN	544	1.58	10,704	0.73
Ove Arup	911	0.95	20,600	0.38
Ontario	438	1.97	N/A	N/A

5.2 Comparison of Noise Prediction Models

The results for the predicted noise levels for the current levels of traffic are shown in Table 5.

Table 5: 1-hr Traffic Noise Levels - Predicted and Measured.

Section	Ove Arup	Ontario Model	CoRTN	Measured
0	64.5	67.8	63.9	65.8
1	70.9	73.3	71.7	78.3
2	69.0	70.7	68.8	75.1
3	69.0	70.7	69.8	73.1
4	69.8	65.9	68.7	70.9
5	69.8	65.9	68.6	68.7
6	69.8	65.9	68.1	68.8

The Ove Arup model correlates well with CoRTN, which is to be expected (as it is a derivation of the CoRTN model). The measured results for section 0 are predicted adequately from the CoRTN and EC noise models, however the measured values in the other three sections are considerably higher than those predicted. This indicates that all models underestimate the noise levels. The CoRTN model was, however, able to predict the noise levels in Kings Road with a high degree of accuracy.

6 Sensitivity Analysis

The average speed, composition of traffic, and the average setback distance are the three primary sources of variation in the traffic noise levels. Section 2 on Woolcock Street was chosen to investigate the effects of the variations in the traffic composition, average speed, and setback distance on noise levels, and derivatively on the EC of the link. This section was deemed to representative of the entire road. The effect of varying acceptable noise level was also investigated

6.1 Setback Distance

The effect of setback distance on the noise levels and EC was determined by using the CoRTN model, assuming the average value for speed and percent heavy vehicles. As shown in Figure 1, the EC increases linearly with increase in average setback distance.

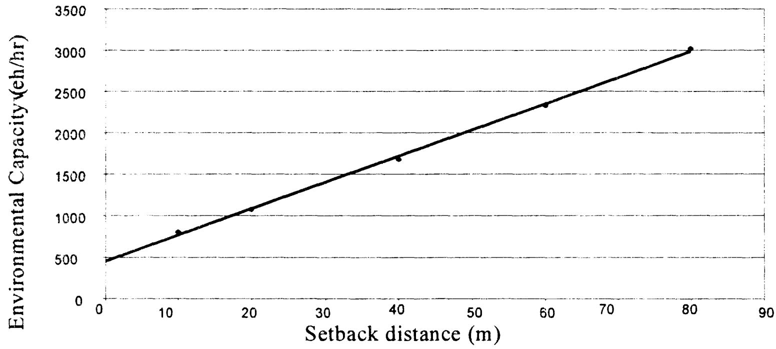

Figure 1: Effect of Setback Distance on Environmental Capacity

6.2 Heavy Vehicles

Noise emissions from heavy vehicles are much higher than for cars and are, therefore, very sensitive to change in the proportion of heavy vehicles. Noise from heavy vehicles has been identified as a major source of annoyance due to the louder, deeper, and lower frequency sounds, which are often associated with traffic induced vibrations.

The effect of increase in the proportion of heavy vehicles on the traffic noise level was studied, using the actual values for the average traffic speed and setback distance. The resulting variation in the EC of the road is shown in Figure 2. The EC decreases exponentially with the increase in the proportion of heavy vehicles.

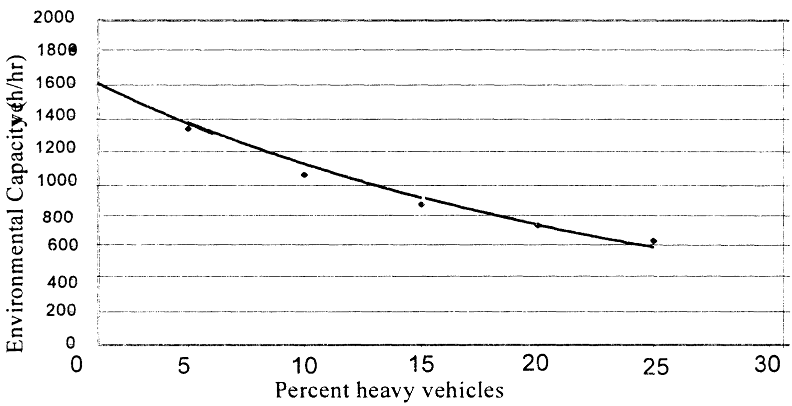

Figure 2: Effect of Heavy Vehicles on Environmental Capacity

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6.3 Traffic Speed

Traffic produces more noise at high speeds due to the increased cyclic requirements of the engines and increased noise from the tyre road interaction. Vehicular acceleration also contributes significantly to the increase in traffic noise. However, the noise levels readings were taken "mid-block" and include very little traffic noise due to acceleration, as most vehicles are already at cruising speeds. The effect of increased traffic speed was estimated using the actual measurements for the proportion of heavy vehicles and average traffic speed. As the average speed of the traffic rises, the EC decays exponentially.

6.4 Acceptable Noise Level

The EC of a road increases exponentially with the noise acceptance level. There is a six-fold increase in EC with increase in noise acceptance level from 65 dBA to 73 dBA, as evident from Figure 3. This points to the significance of setting realistic levels of noise acceptance.

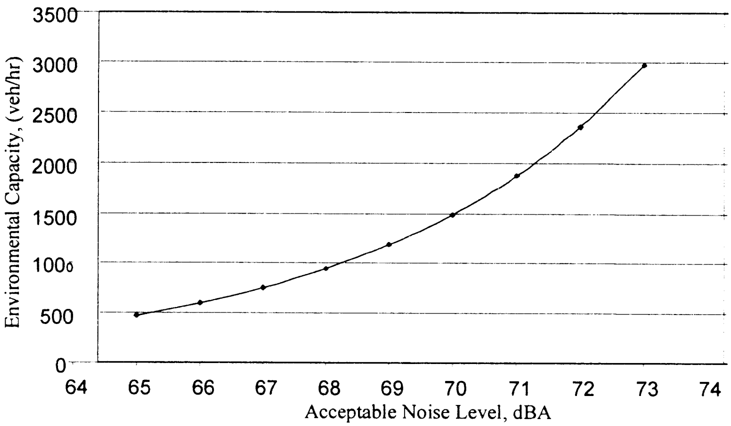

Figure 3: Effect of Acceptable Noise Level on Environmental Capacity

6.5 Summary

The above analysis shown that at a noise acceptance level of 70 dBA, the EC of the road link is between 1000 to 1100 vehicles for an average setback of 20 m, a heavy vehicle proportion of 10% and a speed of 70 km/hr. These volumes correspond to a LOS A which implies that the normally acceptable LOS C or D are environmentally unacceptable.

Based on this study and the results of the attitudinal survey, the following standards are proposed. The corresponding EC for the two roads in the study are given in Table 6.

Table 6: Suggested Noise Standards for the Study Area

	Woolcock Street (Comm/ Retail)		**Kings Road (Residential)**	
	Day	Night	Day	Night
Noise Level(dBA)	72	69	71	68
EC (veh/hr)	1755	880	660	242

7 Conclusions

Three noise prediction models have been applied to two major roads in a provincial city in Australia. Based on acceptable noise levels, the environmental capacity of these roads have been estimated. The accuracy of these models in predicting noise levels has been assessed by comparing the model results with observed values. The sensitivity of the environmental capacity to changes in setback distances, traffic speed, proportion of heavy vehicles and acceptable noise levels has been examined. Finally, based on attitudinal survey and application of noise models, recommendations have been made on the noise level standards based on area and time of day, and applied to reassess the environmental capacities of the two roads.

8 References

[1] United Kingdom Department of the Environment, *"Calculation of Road Traffic Noise"*, Department of the Environment and Welsh Office Joint Publication, HMSO, London, 1975.

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[3] Ove Arup Transportation and Planning Collaborative, *"Environmental Capacity: A Research Study to Develop a Methodology for Traffic Management based on Environmental Criteria"*, prepared for the City of Collingwood, Victoria, Australia, 1980.