ROAD TRAFFIC NOISE EXPOSURE IN AUSTRALIAN CAPITAL CITIES

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ABSTRACT: This paper reports the exposure of dwellings, in Australian mainland capital cities, to road traffic noise. The exposure of Australian dwellings has been reported previously, but the current study, based on a sample of 200 dwellings per city, provides estimates of exposure in each city. Estimates were based on rigorous sample selection and on predicted levels using measured traffic and geometric data. Some 8-20% of dwellings are exposed to $L_{A,10,18h}$ levels above 63dB, and 5-11% above 68 dB. The results suggest that efforts to date to ensure that Australian urban populations are not exposed to high levels of road traffic noise have had little success. An analysis of jurisdictional responsibility for the roadway sources confirms that management of this problem must be accepted by both local and State authorities.

1. INTRODUCTION

Reliable quantitative information on the extent and intensity of exposure to pollutants is essential for their proper consideration as policy matters and in determination of the appropriate level of resources that should be devoted to the pollutant's management.

Road traffic noise is largely an urban problem and in highly urbanised Australia the population exposed to noise is concentrated in metropolitan areas. As most effects of traffic noise are on people in their own homes, the problem of estimating the community's exposure to road traffic noise is effectively a problem of estimating the levels of road traffic noise incident on the facades of the population of dwellings in Australian cities. Different methodologies can be used to obtain estimates of road traffic noise exposure of populations (Brown and Cliff, 1988) but any methodology must be based on rigorous sampling of the specific population of interest to provide a measure of exposure that has known sampling errors.

Brown (1994) reported the exposure of the population of Australian dwellings to road traffic noise. That national study, based on a random sample of Australian dwellings located in Urban Centres with a population greater than 100,000, provided a definitive estimate of the exposure to road traffic noise of the Australian urban population as a whole. Confidence limits were provided for these exposure estimates and this distinguishes these estimates from those of previous studies of road traffic noise exposure in Australia. The national study used a sample size of 264 dwellings selected randomly across eleven of the country's largest cities. The national sample included sub-sample sizes of 80 dwellings in Sydney, 72 dwellings in Melbourne, and 112 dwellings across the remaining nine urban centres. That study was designed to estimate the exposure of the Australian population in order to be able to compare Australian exposure with exposure of other OECD countries and as a result, the small sub-sample size for any particular city meant that estimates of the exposure to road traffic noise within Australian cities, and comparisons between them, were not possible.

This current paper reports the results of a similar, but much larger, study designed to provide adequate estimates of road traffic noise exposure in each of Australia's mainland state capital cities.

A two-stage methodology was used. It drew a random sample of dwellings from each of five state capital Urban Centres with subsequent estimation of road traffic noise exposure at each dwelling in the sample. As in the 1994 work, this study used traffic noise calculation at individual dwellings, rather than traffic noise measurement.

The choice of calculation over measurement was one of economy and efficiency. As Brown (1994) points out, errors on studies that estimate traffic noise exposure of a population arise from two sources: sampling error and errors in noise estimation. Considerable tolerances are acceptable in the latter because error in noise estimates obtained by measurement or prediction should be largely random, not systematic, (providing adjustment is made for any systematic error in the prediction model) and this has little effect on the estimated levels of exposure of the *population* (of course, it does affect the estimate of exposure at any *individual* site, but individual site exposure is of no interest for current purposes). Thus limited study resources are better expended in reducing the sampling error by increasing the sample size and by reducing bias through rigid enforcement of a random sampling regime, rather than in reduction in the magnitude of the error in the noise estimate. Noise levels were calculated using the best available methodology, including the inclusion of corrections based on validations conducted under Australian conditions. To further reduce error in the noise estimate it would have been necessary to replace prediction by expensive noise measurement procedures. Within the constraints of resources available to this study this would have been possible only with a large reduction in the size of the sample of dwellings in the cities for which noise level exposures were to be estimated, with consequent increase in sampling error of the estimates.

2. SAMPLE SELECTION AND FIELD PROCEDURES

Determination of Sample Size in Each City

The area to be covered by the sample in the present study comprised the Urban Centres (as defined by the Australian Bureau of Statistics) for each of the five cities of Sydney, Melbourne, Brisbane, Perth and Adelaide.

To ensure that different city results were comparable (in terms of sampling error in the proportion of dwellings exposed to various levels of traffic noise) the same sample size was required for each city. Within each city, the study rigorously selected a random sample of dwellings within the boundaries of the Urban Centre, and predicted the level of traffic noise at the facade of each sampled dwelling.

The expected sampling error was estimated by using data from Brown (1994). If it is assumed that in a particular city the true proportion of dwellings exposed to various levels of traffic noise is equal to the proportion found in the national study, then the error in estimating that proportion for samples of various sizes can be estimated. Of course, the true proportion would differ between cities, and could not be known ahead of time, but errors calculated in this way gave the best estimate of prediction errors for different sample sizes, and could therefore be used to determine a sample size that provided a compromise between study costs and sampling error.

Table 1 shows 95% confidence limits (two-tailed) for the proportion of dwellings in a city with noise levels above specified values, for various city sample sizes.

Table 1 illustrates the trade-off between sampling error and sample size. It was believed that for the survey results to be valuable in detecting future changes in noise levels, and differences between cities, the percentage of dwellings with noise levels greater than 60dB $L_{Aeq,24h}$ should be able to be specified to within better than five percentage points in each city. Based on the results from Brown (1994), an overall change of 3dBA in noise level would result in a change of about five percentage points in percentage of dwellings exceeding 60dB $L_{Aeq,24h}$, and this is the magnitude of change which it was considered important to detect. From Table 1, this dictates a sample size of 200 (confidence limits for the percentage of dwellings then range from 4.9 points below the estimated value to 5.0 points above it.) Expanding the sample size to 250 per city provides only small gains in terms of sampling errors. For this reason, it was determined that the appropriate sample size for this project was 200 dwellings per city.

Selection of Dwellings

The acquisition of a truly random sample of dwellings within each of Australia's five largest urban centres was a difficult task, and required a large part of the resources of this study.

Addresses of dwellings in each Urban Centre were randomly selected from lists based on electoral rolls. In these lists, multiple entries for the same dwelling had been deleted. The available electoral roll data were current to 1994 for Sydney and 1993 for Brisbane, Melbourne, Perth and Adelaide.

Data based on electoral rolls are available by postcode area only, and postcodes boundaries are not necessarily contiguous with the boundaries of Urban Centres. To overcome this 300 dwellings were randomly selected from each city from a list of all postcodes that were either wholly or partially within the Urban Centre. Addresses in postcodes which lay only partially within the Urban Centre were then individually checked and deleted if they fell outside the Urban Centre boundaries.

Of these 300, the first 200 were given to field operatives as the primary sample, while the remaining addresses (in randomised order) were used for possible replacement dwellings.

The use of electoral roll data was preferable to alternatives such as telephone connections since it provides a more comprehensive coverage of dwellings. Even so, it was known that this sampling procedure would result in some non-representation of the city population of dwellings. Dwellings constructed since the preparation of the rolls would not be included in the sample, and dwellings demolished since roll preparation (without constructing a replacement at the same address) would result in "non-response" at that address. In

Table 1 CONFIDENCE LIMITS FOR THE PROPORTION OF DWELLINGS EXPOSED TO NOISE LEVELS GREATER THAN A SPECIFIED VALUE

Noise Level, $L_{Aeq,24}$	Assumed True Proportion of Dwellings (based on Brown, 1994)	Lower and Upper 95% Confidence Limits for the True Proportion, Based on a Sample Sizes of 100 to 250 Dwellings			
		100	150	200	250
70 dB	1.5%	0 – 3.8	0 – 3.3	0 – 3.0	0 – 2.9
65 dB	8.3%	2.6 – 13.5	3.6 – 12.8	4.3 – 12.0	4.9 – 11.8
60 dB	16.7%	9.5 – 24.1	11.0 – 22.6	11.8 – 21.7	12.2 – 21.3
55 dB	31.1%	22.1 – 39.7	23.7 – 38.4	24.7 – 37.5	25.2 – 36.7

addition, the sample based on electoral rolls would not include dwellings where no resident was on the roll. This would include: unoccupied dwellings, dwellings where all residents were either not Australian citizens or were under 18 years of age, and dwellings containing Australian citizens over 18 who were, illegally, not on the electoral roll. The proportion of dwellings in the first two of these categories can be estimated from census data and Table 2 shows the proportion of dwellings in each of these categories for each city. To the extent that unoccupied dwellings, and dwellings occupied solely by non-Australian citizens or people under 18 years of age, could have exposure to traffic noise which differs from the rest of the population, this non-representation could represent possible bias in the sample, though the effect of such bias could not be quantified without further study.

Field assessments on a total of 996 dwellings were conducted, approximately 200 in each of the five cities. The sampling procedures ensured that, irrespective of type, every dwelling unit had an equal chance of inclusion in this sample (whether the structure of the dwelling unit was a detached dwelling, a duplex, terrace house, unit, flat, apartment or part of a high-rise building complex).

Survey Procedures

Operatives trained in survey work were used to conduct the field study. A one-day training course was conducted in each city, including field trials, to ensure that the operatives were familiar with the techniques required.

On arrival at a site, operatives selected the window on the dwelling facade that was exposed to the highest level of traffic noise. This could be at the front, back or side of the residence. The name of the road causing the greatest traffic noise at this location was noted, together with any other roads if they also were the source of noticeable road traffic. The distance to the road(s) was measured, as well as the angle of view from the dwelling to the roadway, or if the road was not visible, the approximate location and height of barriers. The road gradient, speed limit and road surface material were noted. A plan and cross-section to the most important road(s) were sketched.

In addition, a 15 minute L_{Aeq} check noise measurement was made, one metre from the most exposed facade of the dwellings. The purpose of the short-term noise measurements was to identify those dwellings in the sample where it was unlikely that even moderate (>55 dB L_{Aeq}) road traffic noise levels would exist, obviating the need to collect the expensive traffic parameter data for these sites, and hence reducing the resource requirements of the study. All field work was conducted over 1997/1998.

3. NOISE LEVEL CALCULATION

Road traffic noise levels were calculated at all dwellings where the measured 15-minute level (from road traffic) exceeded 55 dBA. The measured $L_{Aeq,15min}$ noise level provides a conservatively high estimate of the $L_{Aeq,24h}$ value, so that locations excluded by this procedure will almost certainly have $L_{Aeq,24h}$ levels below 55 dB. At sites with measured 15-minute noise levels exceeding 55 dBA it was necessary to obtain information on the traffic flows and percentage of heavy vehicles for the road(s) identified as generating traffic noise at the residence. These traffic data were obtained by the relevant road authority, either from existing records or by purpose-made counts.

Based on the road traffic flow information, together with the geometric and other site-specific information recorded for each dwelling, the CORTN prediction method was used to calculate the noise level exposure at the site (Great Britain 1988). The following assumptions were made in the calculations:

- 18 hour traffic volumes were scaled as 0.94 times the Annual Average Daily Traffic;
- traffic speed was estimated as the speed limit for the roadway;
- for sites with more than 50% soft ground between source and receiver, a ground effect mid-way between the CORTN hard and soft ground calculations was used;
- standard corrections to the CORTN calculations, derived from validation under Australian conditions were applied. A uniform correction of –1.7 dB (Saunders et al, 1983) was applied to all calculated levels (to remove the known systematic error in the prediction estimates);
- the CORTN procedure was used to predict $L_{A10,18h}$ levels.

In addition to reporting exposure in terms of this noise scale, results are also reported in the $L_{Aeq,24h}$ scale obtained by applying linear translation of $L_{Aeq,24h} = L_{A10,18h} - 3.5$ dB (Brown 1989).

Table 2 ESTIMATED PERCENTAGES OF DWELLINGS IN URBAN CENTRES NOT INCLUDED IN THE ELECTORAL ROLL SAMPLING FRAME

Urban Centre	Proportion of Dwellings Unoccupied	Proportion of Dwellings occupied only by Non-Australian Citizens or People Under 18
Sydney	6.3%	10.7%
Melbourne	8.2%	9.2%
Brisbane	5.7%	7.7%
Adelaide	5.8%	7.7%
Perth	6.7%	10.7%

4. RESULTS

The study estimates the proportion of the population of each city exposed to road traffic noise in excess of any nominated level of noise exposure above about 55 dB L_{Aeq24h}.

Based on the sample of dwellings in each city, Figure 1 provides an estimate of the proportion of dwellings within the Urban Centres of Sydney, Melbourne, Brisbane, Adelaide and Perth for which the calculated traffic noise level exceeds various values of $L_{A10,18h}$. Figure 2 shows the same results, but using the L_{Aeq24h} scale.

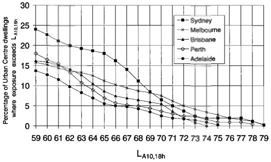

Figure 1. Cumulative noise exposure of dwellings in Australian capital cities, $L_{A10,18h}$

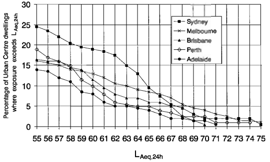

Figure 2. Cumulative noise exposure of dwellings in Australian capital cities, L_{Aeq24h}.

For Sydney, over 11% of the population are exposed to $L_{A10,18h}$ of 68dB or above and 19% of the population are exposed to $L_{A10,18h}$ of 63 dB or above. Confidence limits can be calculated for the estimated proportions (Zar, 1984). The confidence limits are not symmetrical. For example, the confidence band for the percentage of dwellings in Sydney exposed to 68dB or above is 7.7% to 15.5%, and for the percentage of dwellings exposed to 63 dB or above is 14.6% to 24.3% ($p < 0.05$). For Adelaide, over 4% of the population are exposed to $L_{A10,18h}$ of 68dB or above and 8% of the population are exposed to $L_{A10,18h}$ of 63 dB or above. The confidence band for the percentage of dwellings in Adelaide exposed to 68dB or above is 2.2% to 7.2% and for the percentage of dwellings exposed to 63 dB or above is 5.2% to 12.0% ($p < 0.05$). The exposures for the other cities lie generally between the exposures for these two cities.

The results can also be compared to the estimates from the national sample obtained in 1994. Figure 3 replicates the data from Figure 1, but adds to it the previously estimated exposure of the Australian urban population. The results are reasonably consistent. Note that the Australian urban population data, representing exposure of dwellings in all urban centres greater than 100,000 across the country, drew near 60% of its sample from the two cities of Sydney and Melbourne alone. This is apparent in Figure 3 at the lower noise exposures, but the Australian urban population results are somewhat lower than the results from the current study at the higher noise exposures. There is no obvious explanation for this, and in fact the differences are small relative to the confidence limits to the estimates of the proportions. It should be noted that the national results, as published in Brown (1994), did not include the -1.7 dB(A) Australian correction to the CORTN model. This correction has been applied to all results in Figure 3.

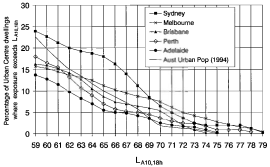

Figure 3. Comparison of the noise exposure of dwellings in Australian capital cities estimated in the current study with that of the noise exposure of the Australian urban population of dwellings estimated in 1994 (Brown, 1994).

In Figure 1, there is quite remarkable consistency across all cities in the proportions of the population exposed to levels above about 70 dB and across all cities, other than Sydney, to levels below 70dB. Most of the apparent (small) differences between the sample proportions for the cities are not significant for the population proportions when the confidence limits of each of the city estimates are taken into account. However, in the sample data, there is a trend for some correlation between city size and exposure, with Sydney and Melbourne recording a higher proportion of dwellings exposed to moderate to high levels of road traffic noise, with Brisbane, Perth and Adelaide generally having lower exposures. The Melbourne sample has a marginally higher proportion of dwellings exposed to levels above 70 dB than do other cities. The proportion of dwellings in Sydney exposed to levels of 60 – 70 dB is somewhat higher than any of the other cities. Such differences presumably result from a different pattern of road location and use in Sydney, with its road system constrained by topography.

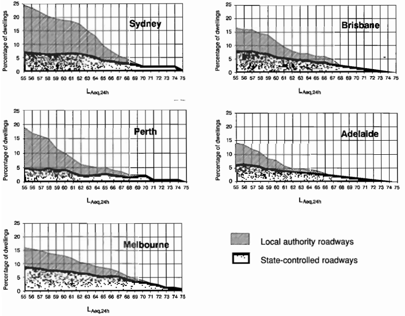

Figure 4. Jurisdictional responsibility for the roadways generating noise exposure at dwellings in Australian capital cities. The lower line shows the cumulative noise exposure of dwellings where the noise is generated from State-controlled roadways alone. The upper line shows the cumulative noise exposure where the noise is generated from either local authority roadways or State-controlled roadways.

In this respect it is unfortunate that Canberra, a planned city in which there has been considerable effort in design of a hierarchical road system and separation of residential land uses adjacent to the upper end of the road hierarchy, was not included in the study. It would be hoped that Canberra results would have shown a significantly lower level of traffic noise exposure than all of the other cities where there has not been similar opportunities to achieve noise control through land use planning .

Road Traffic Noise Exposure generated by State-Controlled or Local Authority-Controlled Roadways

While it is a matter of little interest to any resident exposed to high levels of road traffic noise, there is an important jurisdictional distinction regarding roads in Australian urban areas. In each city, a certain number of roads are designated as state-controlled roadways, or "declared" roadways, which are the responsibility of the respective State road authority. The rest of the city's road system is the responsibility of the local government or municipality. Such jurisdictional differences can become very important in terms of action with respect to road traffic noise control. For example, Queensland has different planning noise levels for these different categories of roadway (Queensland Government, 1997). To date, in any data on urban road traffic noise exposure, quantitative information on jurisdiction has not been available.

In the current study the jurisdictional control of the roadways generating noise exposure of the sample was identified. The results, shown in Figure 4, distinguish the proportion of dwelling in each city exposed to noise generated from State-controlled roads from the proportion exposed to noise generated from local authority-controlled roads. Figure 4 shows, as would be expected, that the very highest noise exposures in each city are generated from State-controlled roadways but, at all other exposure levels, the source of noise exposure is shared between State-controlled and local authority-controlled roadways.

5. CONCLUSIONS

This study has provided a definitive estimate of the exposure of the population of dwellings in Australian capital cities to road traffic noise. The results demonstrate that the situation in all capital cities is poor. Some 8-20% of dwellings are exposed to levels above 63 dB, and 5-11% of dwellings above 68 dB. These are unacceptably high proportions subject to these levels of noise, particularly given that the above levels, variously adopted as criteria in Australian states, are considerably higher than those recommended by a WHO expert task force (WHO, 2000), as necessary to protect against annoyance and sleep disturbance. The results suggest that efforts to date have had little success in ensuring that Australian urban populations are not exposed to high levels of road traffic noise. The jurisdictional analysis confirms that the responsibility for management of this problem must be accepted by both local and State authorities responsible for roadways, land use controls and building controls. There would be little doubt that most expenditure and effort in the control of noise from roadways has been directed at limited-access controlled roadways such as freeways. While road traffic noise from these sources warrants attention, they represent only the tip of the iceberg in terms of the number of urban dwellings exposed to high noise levels. A concerted effort in management of the road traffic noise problem, not only the road traffic noise problem from newly constructed roadways, needs to be an area of national, State, and local authority priority.

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