REASSESSMENT OF THE IMPACT OF ROAD TRAFFIC NOISE FOR THE PACIFIC MOTORWAY UPGRADING. (LOGAN MOTORWAY TO NERANG)

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Abstract

Members of the public residing beside the Pacific Motorway, in particular the Portland Cement Concrete (PCC) pavement sections, have expressed strong concerns with respect to the impact of the road traffic noise on their life style with the opening of the new eight-lane motorway. As such, Queensland Department of Main Roads engaged the services of independent consultants, Professor Lex Brown (Griffith University) and Dr Stephen Samuels (TEF Consulting), to undertake a review of the implementation of the impact management plan with respect to road traffic noise. An outcome of this review was to undertake an independent comprehensive post-construction noise measurement and modelling program. Richard Heggie and Associates (RHA) and ASK Consulting Engineers (ASK) were engaged to carry out the program. Established standard practices were used throughout the program. In addition, because of the significant length of road (42 km), the complex terrain and the eight-lane facility, in excess of 150 measurements were undertaken and high quality data were collected. A robust statistical analysis was performed as it became evident that, due to the complex nature of the project, an evaluation, calibration and validation of the CoRTN model was necessary for noise level predictions along the motorway. This resulted in project specific calibration factors being incorporated into the CoRTN model for calculating and predicting pre-construction, post-construction and future road traffic noise levels. As a result, the Queensland Government has allocated $7.5 million to deal with noise problems along the motorway where noise levels have exceeded the departmental criterion level and wherever possible, to manage noise impacts such that there will be no sustained increase in baseline ambient noise levels at sensitive receptors.

Introduction

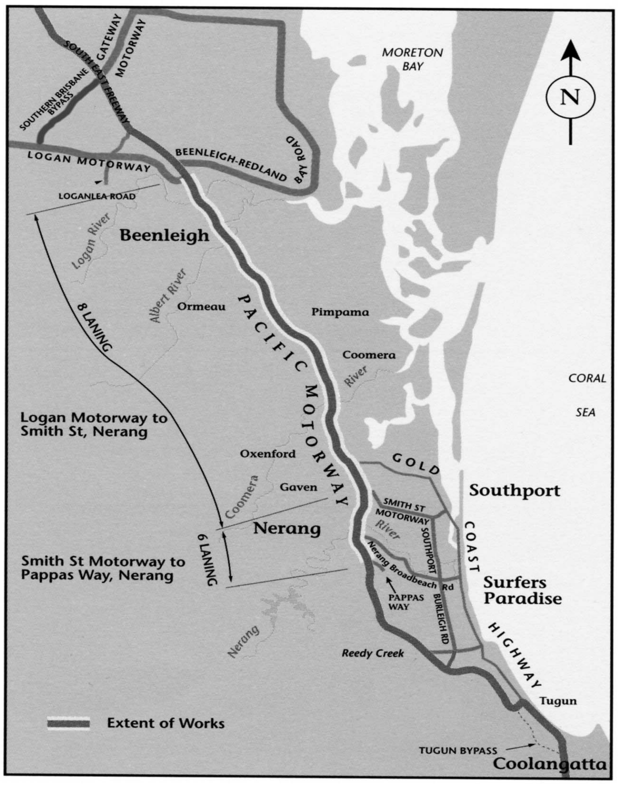
Prior to the construction of the motorway, the original Pacific Highway consisted of a four lane divided facility (two lanes in each direction) with a dense graded asphalt (DGA) pavement surface type.

On completion of construction, the new road facility comprised an eight lane divided Pacific Motorway (four lanes in each direction) from the Logan Motorway in the north to Nerang in the south (refer to Figure 1). After sections of the motorway became operational, some residents strongly indicated that, in their opinion, they were severely impacted by road traffic noise, mainly along the PCC pavement sections of the motorway. There is a section of PCC pavement approximately 28 km in length; the remaining 14 km consists of open graded asphalt pavement surfacing. An extremely strong residents' action group (R.A.I.N – Residents Against Increased Noise) was formed and to date, has actively challenged the government and the Queensland Department of Main Roads (DMR) about their concerns.

Background

As part of the planning for the motorway, an Impact Management Plan (IMP)[1] was prepared. The intent of this plan was to develop a contract with the community; those living beside the proposed motorway and those travelling along the motorway. The impact of road traffic noise was one of the issues that were identified in the IMP, as follows.

Figure 1. Pacific Motorway



"Noise impacts generated by the operation of the Motorway shall not exceed DMR's Guidelines for road traffic noise and wherever possible shall be managed such that there will be no sustained increase in baseline ambient noise levels at sensitive receptors adjacent to the Motorway. Noise mitigation measures will be implemented at affected areas identified by detailed modelling. The location and specifications of mitigation measures will be determined in consultation with local residents and businesses taking into account physical constraints, road geometry and costs."[1]

RAIN had specifically challenged DMR with respect to their concerns about the implementation of the intent of the IMP. Specifically this dealt with the possibility that the departmental criteria in this instance will be exceeded for a ten year traffic planning horizon and that the commitment in the IMP to "endeavour to mitigate against any sustained increase in base line ambient noise levels at sensitive receptors adjacent to the motorway corridor" had not been met. It should be noted that the IMP prefaced the "sustained increase" statements with the words "shall endeavour" and in other places "wherever possible" and "wherever practical". This particular commitment was unique to the Pacific Motorway project and is not consistent with usual departmental practice.

As such, DMR appointed Professor Lex Brown and Dr Stephen Samuels, as independent reviewers of the department's implementation of the intent of the IMP. The conduct, outcomes and recommendations of their independent review were comprehensively documented. [2]

The following recommendations were made by the reviewers [2]:

- Recommendations regarding post-construction noise measurements for the motorway.
  - Independently establish the location of all potential noise sensitive receptors within the motorway corridor at which achievements of the intent of the IMP need to be tested.
  - Complete a post-construction noise monitoring program for the motorway ensuring that there is a full spatial coverage of all potential noise sensitive receptors by use of a clustering-based site selection process.
  - Apply the outcomes of this noise monitoring program to assess compliance with the intent of the IMP.

- Recommendations regarding noise modelling.
  - Where the post-construction noise monitoring program has revealed that the departmental criterion level has been exceeded, investigate whether the pavement surface types and noise barriers (where they exist) conform with the initial modelling work.
  - Model the pre-construction noise levels at noise sensitive receptors that would have been generated by traffic on the original Pacific Highway as at 1996. These modeled levels should be accepted as the base line ambient noise levels due to the absence of suitable measured data for pre-construction noise levels.
  - At all potential noise sensitive receptors, remodel the noise levels that will be generated by traffic on the motorway ensuring that the height and location of all existing noise barriers are taken into account.

- Recommendation regarding Main Roads processes for future road traffic noise investigations.
  - Prepare a rigorous specification for how modelling is to be conducted to avoid the variety of assumptions and procedures previously adopted by consultants.
  - Establish a series of modelling "test cases" by which the ability of consultants to conduct accurate, high quality modelling may be assessed.
  - Introduce a quality control system for future modelling.
  - Recognise and further investigate the differences in noise attributes that exist between Portland Cement Concrete (PCC), Open Graded Asphalt (OGA) and Dense Graded Asphalt (DGA) pavement surface types and ensure that their differences are appropriately allowed for in all modelling.
  - Noise investigations and remedial works for major projects should be primarily based on sound scientific principles and secondly on a complaint driven basis.
  - Develop a consultation protocol to ensure that the community is provided with realistic appraisals of what the post-construction noise environment will be like for those living near a roadway. This is to ensure that their expectations are not raised beyond what can be reasonably delivered.

An outcome of the independent review was to undertake a comprehensive post-construction noise measurement and modelling program.

Post-Construction Noise Measurement.

As a necessary input to the verification of noise modelling, an extensive post-construction noise measurement program was prepared. This program complied with a recommendation in the independent review report.

Some stringent quality control procedures were put in place to ensure that the data being collected were of a uniformly and consistently high standard. These procedures included regular attendance by the consultants at each site during every measurement to ensure that interference from unforeseen events or circumstances such as weather, especially wind conditions, were eliminated as far as possible.

Road traffic noise measurements were undertaken at some 150 sites along the motorway as a result of establishing the location of all potential noise sensitive receptors and a full spatial coverage of these receptors.

All measurements were undertaken by consultants ASK and RHA in accordance with Australian Standard 2702 [3].

Noise Modelling Accuracy.

An initial road traffic noise modelling exercise involving both consultants was undertaken with the aim of ensuring that both consultants conducted road traffic noise calculations using the Calculation of Road Traffic Noise Method (CoRTN) [4] in the same, consistent manner. As each of the two consultants was to undertake modelling for approximately half of the length of the motorway, it was essential that these two sets of calculations would be directly comparable and hence the modelling exercise was conducted in accordance with a recommendation in the independent review report.

This exercise was undertaken to review the modelling techniques of both consultants who use different software to calculate the CoRTN algorithms.

Noise data were collected hourly over a period of six hours (11.00 to 17.00) at each of three random sites by DMR staff. Detailed traffic data were also collected simultaneously with the noise measurements at each site, along with all relevant site data. The three sites were as follows:

- A PCC site on the Pacific Motorway;
- An OGA site on the Pacific Motorway; and
- A DGA site on the Warrego Highway.

All the data were provided to both consultants who then conducted noise calculations for each hour at these sites which were located close to the roads.

The modelling accuracy involved analyses and interpretations of the values of the prediction differences (PDs) associated with the calculated levels which included the mean and standard deviations of the PDs at each site. Neither consultant applied pavement surface correction factors nor did they adopt the calibration factors for Australian conditions [5]. However, in Table 1, the PDs obtained by the consultants are presented along with the values that would have been obtained if the factors for pavement surface type and Australian conditions were applied.

Table 1. Prediction Differences obtained by both consultants.

Location	Pave't Surface Type	Modelling condition	Mean PD (dB(A))		Std Dev of PD (dB(A))	
			ASK	RHA	ASK	RHA
Pacific Motorway	PCC	Original	+5.2	+4.4	0.2	0.2
	PCC	+ Factors	+9.5	+8.7	0.2	0.2
Warrego Highway	DGA	Original	+0.2	-0.1	0.7	0.3
	DGA	+ Factors	-0.5	-0.8	0.7	0.3
Pacific Motorway	OGA	Original	+8.9	+8.3	0.5	0.6
	OGA	+Factors	+6.2	+5.6	0.5	0.6

In the final analysis, an important input to the modelling process was the application of the appropriate correction factors pertaining to the different pavement surface types.

These factors were determined by the statistical passby methodology in response to a recommendation in the independent review report.

PCC = +5 dB(A)
OGA = -2 dB(A)
DGA = 0 dB(A)

The calibration factors for Australian conditions for a free field calculation is an adjustment to the final calculated level of –0.7.[5]

It was acknowledged that the scientific and statistical validity of doing this for data taken over six consecutive hours at any particular site is questionable since the degree of independence of the data from hour to hour at the site is not particularly strong. However, this technicality was put aside for the purposes of this modelling exercise.

Overlooking the absolute values of the mean PDs, it was apparent that the results of each consultant were very close, that is there were negligible differences in either the means or standard deviations.

Therefore, it was concluded that if either consultant was given a set of input data, they would both apply CoRTN correctly and would both obtain essentially the same results.

A further exercise was undertaken in response to the independent reviewer's recommendations that the consultants undertake a noise modelling exercise at sites in each of two test sections along the motorway. This exercise was set up to ensure that both consultants were undertaking noise calculations in a consistent manner that would produce essentially the same results at the test section sites. A test section was chosen in each of the consultant's packages. Three sites in each section were chosen for comparison purposes with due regard to the following three issues:

- The motorway is an eight lane divided facility, (four lanes in each direction) which is perhaps beyond the intended use of CoRTN.
- Each consultant had proposed to use different noise source locations.
  - 3.5 m from the edge lines as per CoRTN, or
  - along the middle of each lane, or
  - along the middle of each carriageway.
- Each consultant proposed to use different source heights.
  - single source height (ASK)
  - three source height (RHA).

Consequently it was decided that each consultant would undertake modelling for each noise source location for each site in each test section.

From the results of the measurements and modelling, the following three issues became apparent:

- The choice of the location of the noise source does not alter the outcomes of the modelling.
- The choice of the source height does not alter the outcomes of the modelling.
- Both consultants produced essentially the same results.

As well, the consultants undertook modelling at a total of 134 of the measurement sites of which 53 were in one consultant's packages and 81 were in the other consultant's package. Upon review of the differences between the measured and calculated levels and the relative large differences in the means of the PDs, it was highlighted that further consideration of the modelling needed to be undertaken.

As such, it became evident that undertaking road traffic noise predictions along a substantial and complex roadway such as the Pacific Motorway is a technically demanding and challenging task. It would be fair to say that doing these predictions to a satisfactory level of accuracy stretches modelling techniques about to the limit. Therefore this became one of the primary reasons for undertaking an evaluation, calibration and validation of CoRTN for predictions along the motorway.

Evaluation, Calibration and Validation of CoRTN.

There are several important issues involved with the evaluation, calibration and validation of traffic noise prediction models and these are as follows:

- The outcomes of these processes apply only to the noise indices involved in the predictions. In the present case this meant that the primary focus was on the L_{10}(18 hour). This was because of the nature of the variations in the data sets involved and the various statistical requirements for data independence.
- Prediction models can only be confidently applied in practice once they have been calibrated. This means that when CoRTN is applied subsequently in assessing noise impacts from the Pacific Motorway, it will be mandatory that the calibrated version of CoRTN be adopted for these noise predictions.
- The processes of calibration and validation must be independent of one another to meet the various scientific and statistical requirements that envelop these processes. A primary implication of this is that the two processes each require their own data set. In other words, the data set put together for the calibration process can not be used subsequently for the validation process. The latter requires another data set collected independently of the calibration set.
- Because of the variables inherent in both measurements and predictions of traffic noise, both calibration and validation require quite sizeable data sets. While there are complex techniques available to estimate the sample sizes necessary, a detailed discussion of these is not warranted herein. What can be said, however, is that a sample size involving less than 20 sites is unlikely to be adequate for either process.

Upon applying the correction factors for the effects of pavement surface type to the calculated noise levels, both consultants compared their measured levels with their calculated levels in order to produce a set of PDs. The PD parameter is defined by the following equation:

$$PD = PNL - MNL \tag{1}$$

Where PD = Prediction Difference
PNL = Predicted Noise Level (or calculated noise level)
MNL = Measured Noise Level.

Analysis of the sets of PDs represented the core elements in the review process for evaluation, calibration and validation of the CoRTN model for the motorway.

Evaluation of the accuracy of the prediction model

This initial phase involved comparing a set of measured noise levels with a corresponding set calculated with the model. For this procedure to be statically and scientifically robust, it must be undertaken within the framework for well established scientifically based methods. Of particular importance here was the requirement of firstly ensuring that the data set utilized covered the requisite ranges of parameter spaces over which the model is applied. This means in practice that the data must be collected at a reasonable number of sites.

The PD was calculated as shown in Equation (1) and the relevant distributions of the PDs were determined. The means and standard deviations of these distributions provided the figures with which the accuracy of the prediction model was quantified.

Due to further refinements, data were available from 110 sites along the motorway and the distributions of these are summarized in Table 2.

Table 2. All sites

Consultant	Sites		Total
	PCC Pavement Surface	OGA Pavement Surface	
ASK	28	18	46
RHA	42	22	64
Total	70	40	110

The data from sites of Table 2 were subdivided into two sets; one for the evaluation and calibration (70 sites) (Table 3) and one for the subsequent validation (40 sites) (Table 5)

Table 3. Evaluation and calibration sites

Consultant	Sites		Total
	PCC Pavement Surface	OGA Pavement Surface	
ASK	19	10	29
RHA	26	15	41
Total	45	25	70

The accuracy of CoRTN in predicting L_{10}(18hour) noise levels was then determined. These results are presented for all 70 sites and for the sub-populations based on pavement surface type (Table 4). It is apparent initially that all these means are very high and positive. This indicates that CoRTN has consistently over predicted to a considerable degree. It is most likely that the high values of these means have ensued from some complex noise propagation factors. On the other hand, the standard deviations are all at or about a stastically satisfactory value.

Table 4. Accuracy evaluation results for CoRTN predictions

Statistical parameter	Prediction Difference (dB(A)) & Sample Size		
	All sites	PCC Sites	OGA Sites
Mean	8.4	9.7	6.0
Standard deviation	3.6	3.4	2.6
Sample size	70	45	25

Calibration of CoRTN for future predictions.

In this second phase, the outcomes of the accuracy evaluation were applied. Calibration of the model involves application of the results shown in Table 4. The calibration factor is the negative of the mean and the accuracy is generally set at 95% confidence limits which are two standard deviations either side of the calibrated calculated noise level. However, it was necessary to decide which of these particular results should be adopted in the calibration process. Should there be just one calibration factor for all sites or should there be separate factors for the PCC and OGA sites? The answer to this key question required determining whether there were any statically significant differences between the PCC and OGA sub-populations shown in Table 4. This was undertaken via a t-test which showed that, at the 95% confidence level, there was a significant difference between the means of these two sub-populations. Therefore, separate calibration factors had to be applied to future predictions at PCC and OGA sites. The calibration factor for PCC sites was set to –9.7dB(A) while that for the OGA sites was set to –6.0 dB(A). The 95% confidence limits on future predictions at PCC sites were determined to be $\pm$6.8dB(A) and at OGA sites were $\pm$5.2dB(A).

Validation of the prediction model.

This is a particular process that could only occur following the calibration of the model. Again it involved comparing measured levels with calculated levels. However in this case, the calculated levels were those produced by the calibrated model. A model can be regarded as being validated if the distribution of what might be termed the "validation prediction differences" has a mean value that is close or equal to zero. Here the "validation prediction difference" is determined as the "calibrated prediction level" minus the corresponding measured level. The validation was undertaken using the specific set of data set aside in Table 5. Again it is emphasized that this set was different from that set used for the calibration process (Refer to Table 3). The results of the validation process are shown in Table 6. The outcomes were very good indeed in that all the means were small and close to zero and the standard deviations were similar to those shown in Table 4 of the evaluation process. A t-test was also conducted to compare the PCC and OGA sub-populations of Table 6 and the result showed that there was no significant difference between the means of these two sub-populations at the 95% confidence level. Thus there was a strong conclusion drawn that the calibrated version of CoRTN had been well validated for future L_{10}(18hour) predictions along the motorway.

Table 5. Validation sites

Consultant	Sites		Total
	PCC Pavement Surface	OGA Pavement Surface	
ASK	9	8	17
RHA	16	7	23
Total	25	15	40

Table 6. Validation of CoRTN predictions

Statistical parameter	Prediction Difference (dB(A)) & Sample Size		
	All sites	PCC Sites	OGA Sites
Mean	0.6	0.3	1.2
Standard deviation	3.3	3.8	2.4
Sample size	40	25	15

Thus for the future calculations and prediction of L_{10}(18hour) noise levels along the motorway, a calibrated CoRTN model was able to be applied to determine the 2003 and 2011 road traffic noise levels, the results of which were subsequently reported by the consultants.

Discussion

Despite the scientifically and statistically excellent outcomes set out above for the PCC and OGA sites, questions still arose as to why the calibration factors were so large. It was felt by RAIN members that these calibration factors might not be portraying the audible effects of pavement surface type and traffic conditions on the noise generated by traffic on the Pacific Motorway and to which they have been exposed since the Pacific Motorway became operational. It is the authors' considered and experienced opinion, in response to these questions, that the calibration factors reflected what could be termed "complex propagation effects" between the Pacific Motorway and the receptor locations, particularly given the nature of firstly the Pacific Motorway with 8 lanes and secondly the intervening topography and ground cover conditions. It must be emphasised again here that the calibration factors were derived from the data at the first series of 70 sites used for the evaluation and calibration of the model. When they were subsequently applied to the calculations at the second series of 40 sites used for the validation of the model, the calculated noise levels matched the corresponding measured levels extremely well. This important outcome confirmed that the calibration factors correctly allowed for those "complex propagation effects" or what ever was the cause of the observed discrepancies between the measured and calculated traffic noise levels at the 70 sites in the first series discussed above.

Conclusion

The re-assessment project reported in the present paper has been one of the most comprehensive noise monitoring and modelling studies ever carried out on any road in Australia.

Consultants ASK and RHA concluded in their reports that, between 1996 and 2011, modelling of noise levels at sensitive receptors along the motorway produced varying results as follows:

- Some noise levels would increase but would be below the departmental criteria.
- Some noise levels would exceed the departmental criteria.
- Some noise levels would remain unchanged.
- Some noise levels would in fact decrease.

Unique to this project, a commitment was made to "endeavour to mitigate against any sustained increase in baseline ambient noise levels at sensitive receptors adjacent to the motorway corridor."

As a result, the government has allocated $7.5 million to work towards addressing the noise problems, both in terms of where the criteria have been exceeded and where sustained noise level increases have occurred. Main Roads' usual practice and policy is to construct noise reducing measures within the road reserve where the Main Roads criteria will be exceeded. However, there has been an exemption sought from this usual practice for this Pacific Motorway project. This exception was adopted because of the unique circumstances associated with the eight lane section of the Pacific Motorway. Following community consultation, Main Roads will not limit action taken to construction of noise barriers only, but may also give consideration to treatment outside the road reserve where traditional treatment within the road reserve may not feasibly achieve the intent of the IMP.

References

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