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THE COMPARISON OF A COMPUTER MODELLED PREDICTION OF NOISE AT A CITY CENTRE LOCATION WITH MEASURED LEVELS

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1. INTRODUCTION

The European Commission's Green Paper on 'Future Noise Policy'[4] recognised that environmental noise is one of the main environmental problems in Europe. It is claimed that approximately 20% or 80 million of the European Union's population suffer from exposure to noise levels that the OECD considers to be unacceptable[4]. A further 170 million are living in so-called 'grey areas' where noise levels are such to cause serious annoyance during daytime. A conservative cost of 12 billion ECU[6] has been put on the annual cost of noise to European society. The EC believes that further work needs to be carried out in assessing the noise problem. It recognises that noise mapping has the potential to be an effective and relatively inexpensive method for assessing noise, for presenting noise information to the public and as a basic planning tool. It makes it easy to recognise the noise exposure range and thereby identify areas where action is required and other quiet areas where exposure should not increase.

1.1 Location

Dublin City is surrounded by two canals, which form an inner cordon, with the river Liffey dividing the city into a Northside and Southside. O'Connell Street is the premier street in Dublin, being the main connection between the North and South City for vehicular traffic. It consists of four lanes of carriageway both north and south bound and each 12 metres in width. The two carriageways are divided by central median 10 metres in width. The buildings in the street are predominantly 3-4 floors over ground level in height.

Within the inner cordon there is limited heavy industry that could be considered as potential large noise sources. The predominant noise source within the inner cordon is traffic. Traffic noise dominates the ambient sound levels. Due to increasing traffic volumes in Dublin, - private car registrations have grown by 59%[7] over the ten year period 1987 -1997, the citizens will be exposed to longer periods of high noise levels with night time periods becoming more noisy.[4] Generally, data on the overall exposure of the citizens of Dublin is patchy. Currently noise levels are measured on a complaint basis. There is no noise mapping being carried out presently.

1.2 Effects of Noise

Noise of sufficient intensity and duration can cause temporary and permanent hearing loss. It can also interfere with speech communication and the transmission of other auditory signals. Noise can disturb sleep and act as a general source of annoyance or disturbance and interfere with the performance of complicated tasks and the opportunity for privacy. However there is no evidence to demonstrate conclusively that exposure to transportation noise sources is of sufficient magnitude

1.2 Effects of Noise contd..

and duration to reduce hearing ability. Sleep disturbance arises at noise levels of 30dB(A) for steady state continuous noise, at the sleeper's ear. The maximum peak level of exposure, however, is one of the most important noise parameters for sleep disturbance. Studies have shown that to ensure undisturbed sleep the maximum sound level should not exceed 45 dB (A) [4]. Symptoms such as tiredness, headache and nervous stomach arise where heavy traffic occurs at night and the recommended values have been exceeded. This can lead onto physiological stress responses

Noise from traffic also interferes with communication especially in gardens, streets and balconies. This can lead to individuals closing windows and thus interfering with ventilation requirements, in order to carry on conservation. It is generally accepted that noise levels in homes should not exceed 40 - 45dB(A).

1.3 Traffic Noise Assessment

The response to noise depends mainly upon the nature of the noise, the duration and the range in which the noise varies in a given environment. The equivalent continuous noise level, LAeq, is used as indices for measurement of long term noise in dB (A). For a given LAeq it could be found that a lower intermittent sound would be more annoying than the higher more steady LAeq level. Therefore the Leq does not fully describe the effect intermittent, variable, or unusual noises have in causing nuisance or annoyance. Although road noise at a distance from a roadway can be perceived as a consistent steady state or 'drone' without fluctuation, in this project, because people are close to the carriageway and the noise source, individual components of the traffic stream may cause annoyance in excess of the Leq sound pressure emitted. Because noise levels from traffic vary temporally it is useful to describe the cumulative noise distribution. This is a statistical descriptor for the variations of noise and is expressed as $L_{AN,T}$, i.e. the noise level exceeded for N% of the time T. The 18-hr L_{10} parameter was chosen as the measurement parameter, as it has been recognised that this equates well with perceived annoyance[1]. This parameter is used in the 'Calculation of Road Traffic Noise' (CRTN), Dept. of Transport, Welsh Office.

1.4 Noise source

In the main, engine noise, transmission and the exhaust system of vehicles cause road traffic noise emissions. The noise produced by the contact between tyres and the road surface also play an important role. This noise also increases with higher speeds[1] and is the dominant source at speeds above 60 km/h[4]. Behaviour behind the wheel is an important factor influencing noise emissions, which is relevant to city centre driving. Fast acceleration and revving the engine in traffic may result in emissions up to 15dB(A) higher than the normal levels of emission resulting from smooth driving[4].

2. METHOD OF PREDICTION AND MEASUREMENT

2.1 Calculation of Road Traffic Noise, Department of Transport, Welsh Office

The method used for calculating the current noise levels in O' Connell St. was the 'Calculation of Road Traffic Noise' - Dept. of Transport and The Welsh Office -- 1988 version. This standard is commonly known as CRTN. It is recognised as a method for predicting noise from road traffic. It is also appropriate for more general applications such as environmental appraisal of road schemes and land use planning. This version revises the original published in 1975. The newer version extends the method to cover a wider range of applications. *'The aim has been to permit prediction in as many cases as possible covering both free and non-free flowing traffic'* (para.3 CRTN).

The standard is divided into three sections: -

A) **Prediction Method,**
B) **Prediction Method(additional measures required)**
C) **The Measurement Method**

The prediction is based on emissions from a line source, which is defined by breaking the traffic flow into appropriate segments. A basic sound pressure is predicted based on the volume of traffic passing a 'receiver point'. Adjustments are made in relation to barrier effects, reflections, ground absorption, path difference from source to receiver, source and receiver height and for barrier reflections. It is not proposed to outline in detail, the Prediction Method or Measurement Method as this is comprehensively covered in CRTN. The Annexes in CRTN also provide worked examples as guidance.

3. COMPUTER MODEL

3.1 Predictor Type 7810 Version 2.0

The B&K Predictor Model incorporates Sections I and II. of CRTN with a graphical interface which guides and assists in entering the required data and corrections. The data can be overlaid on a map of the area being monitored in the form of coloured contours. In order for calculations to be made the following data had to be assembled:

- Map of area in DXF or BMP format
- Composition of traffic flows for each carriageway by Light Vehicles (LV) and Heavy Vehicles (HV)
- The speed of the traffic flow.
- The height of the buildings on either side of the carriageway
- The width of the carriageway
- The nature of the surface of the roads.
- The gradient of the road.
- The receiver point.
- Barrier heights.

Predictor calculates the L_{10} level as described in CRTN. The calculation is as follows:

$L_{10} = E_{road} + C_{attenuation}$

3.1 Predictor Type 7810 Version 2.0 contd.

where:

L_{10} : is the noise level that exceeds 10 percent of the period in dB (A). The period can be one hour, 18 hours (day period) or six hours (night period)

E_{road} : Emission number for a road in dB (A)

$C_{attenuation}$: Correction or attenuation for noise propagation from source to receiver in dB (A)

$E_{road} = E_{emissions} + C_{speed} + C_{road} + C_{gradient}$

The attenuation **A** is calculated as follows:

$A = A_{distance} + A_{ground} + A_{barrier} + C_{reflection} + C_{angle} + C_{low}$

For each receiver\line source combination, the model makes intersections for direct sound path as well as all possible reflection sound paths in reflecting objects, such as buildings or barriers. All distances and heights of the items in the intersections are determined. Based on these intersections, the attenuation and correction are determined. Only first order reflections are taken into account. The model does not calculate imissions at a receiver point which is placed less than 3.5m from a sound source. Buildings can only be displayed as rectangular objects. Barriers are constructed as polylines. Also, the speed correction due to a gradient is not incorporated in Predictor. It is recommended that use be made of speed that is representative for the particular road. The model can produce a rectangular grid, which consists of a set of calculated receiver points. Each point in the grid is predicted as individual receiver points. These points are in turn interpolated to make contour maps. The Bruel and Kjaer manual outlines aspects of the modelling procedure that must be adhered to,in order to comply with the CRTN. (Sec. 3-3), thus one can assume that if such procedures are followed, the predicted levels are compatible with the CRTN method.

4. MEASUREMENT

Actual measurements were carried out in accordance with section 3 of CRTN. Bruel and Kjaer Precision integration Sound Level Meter Type 2236 was used for measurement purposes. It is a Type 1 sound level meter complying with BS5969 and BS6698. It has the capability of measuring the following parameters. Maximum SPL, Minimum SPL, Maximum Peak Level, Peak Level, SPL - maximum RMS level in 1s intervals, Leq, Lepd, L_{90}, L_{10} SEL. It can also produce 'one off' Level and Cumulative distributions. The sound level meter was located in an underground public toilet on the central median in O'Connell St. The microphone, with a wind shield, was placed on a six meter extension and locate on the central rail of a railings which surrounded the toilets, at a height of 1.5m. There are no extract fans or mechanical equipment operating in the toilets. Full day measurements were carried out mid week on Tuesday the 20/4/99, Wednesday 21/4/99 and Thursday 22/4/99. This was to avoid abnormal traffic flows. It has been recognised that this can happen outside these periods. Also measurements had to be delayed until the Easter Holiday period was over and until the schools re-opened. The measured parameters were in dB (A), Fast setting, over a 15 minute period. The equipment was set to measure and store quarter hourly readings of the LAeq, L_{90} and L_{10}

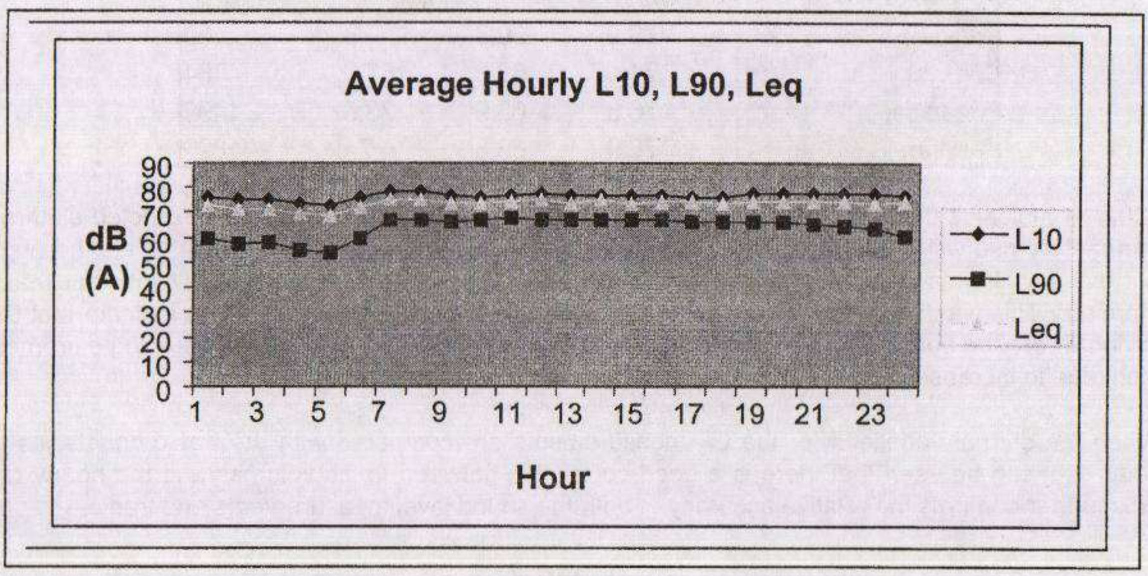
4.1 Measurement Results

Continuous measurements were taken in quarter hourly periods for LAeq, LA_{90} and LA_{10} values. The sound level meter continually logged the measurements. Once the data was down loaded the four

4.1 Measurement Results contd.

quarter hourly figures were arithmetically averaged to give overall hourly values *Chart 1* sets out the average diurnal variation of these parameters during the day.

Chart 1



The L_{10} for the period of interest – 20th, 21st and 22nd of April were then extracted. ***Table 1*** sets out the results for the three consecutive days and an overall average.

Table 1

O'Connoll St.	Day	Night
20/04/1999	77.2	74.1
21/04/1999	77.2	74.2
22/04/1999	77	74.8
Average	77.1	74.4

Monitored Results L_{10} 18hr, dB (A)

4.2 Traffic Count Measurements

Due to the logistics involved, traffic counts could not be carried out at the same time as measurements (par. 41.3 CRTN). The traffic count was carried out on Tuesday the 16th of February 1999. Dublin Corporations Traffic Department took counts at quarterly intervals from 08.00hrs to 18.30hrs. Traffic counts were extrapolated from these figures for the remaining periods using figures produced by the coils embedded in the road surface at traffic light signals. The traffic speeds used were the standard estimated traffic speeds used for Dublin Corporations traffic prediction models.

Table 2 sets out a general summary of the results. The hourly results over the measurement period were remarkable consistent. Despite the variable weather on the first two days, there did not appear to be any inconsistencies due to this.

4.2 Discussion of Measurements Results contd

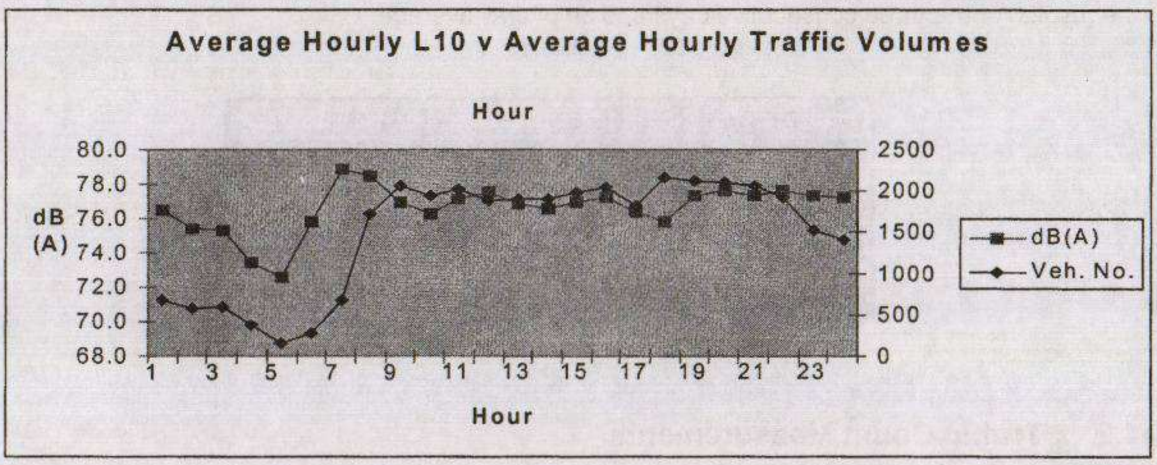
Table 2

Summary of Results				
O'Connell St.	19/4/99 11 AM - 23/4/99 10 A.M.			
Ave.Hourly Values	LA10	LA90	LAeq	Vehicles
Max.	79.9	69.3	78	2160
Min.	71.4	53.8	67.6	164
Mean	76.6	63.9	73.6	1499
Median	76.9	66.3	74	1890

Chart 1 indicates the diurnal variations of the LAeq, LA_{10} and LA_{90}. As would be expected all three parameters rise with the early morning traffic, but thereon, remain at early morning levels thorough out the day. It was surprising to see such high LAeq and LA_{10} levels so late at night and early morning. This was an unexpected outcome of the measurement. However it does indicate that the period where the sound levels are high is being extended rather than the levels becoming extremely high, due to increased traffic volumes.

When the diurnal variations for the L_{10} measurements are compared with the traffic counts, as in Chart 2, it can be seen that there is a good correlation between traffic volumes and the hourly $L_{10.}$ This further confirms the relative accuracy of both the sound level measurements and traffic.

Chart 2

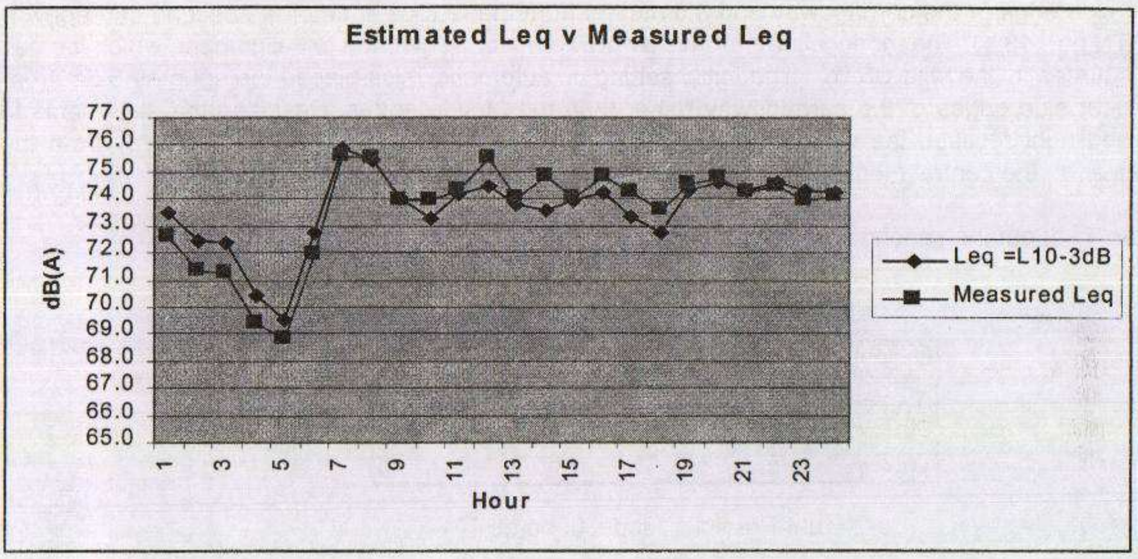


The measurements indicate that the average daytime LAeq of 73.6dB is high and being above 65dB could cause '*constrained behaviour patterns, symptomatic of serious damage caused by noise arise*' – OECD, 1986. Having spent some time in the street while taking measurement, it has been my personal experience that noise from the traffic does interfere with speech conversation. This is further reinforced by the measurements, showing a high average hourly LA_{10} level of 76.6dB. The average background level of 63.9dB(A) would justify action being taken to reduce it by approximately 10dB. This would ensure a much more pleasant 'atmosphere' .

4.4 LAeq *v* L_{10}

It is generally accepted that the relationship between L10 and Leq of Leq = L_{10} – 3dB +/- 2dB can be used as a 'rough rule of thumb', The implications of confirming that this relationship holds true for the City Centre is that the L_{10} modelled result can then be converted to a LAeq. Working Group 1 on 'Future EU Noise Policy' has suggested that the Leq should be the basis for indicators in assessing noise. A straight forward comparison between the 373 actual measured 15 minute LAeqs and the calculated LAeq using the above mentioned formula, gave a median value of –0.1dB i.e. over half the calculated figures were within –0.1dB of the true LAeq. A correlation was also carried out between the two sets of arrays. The correlation gave a factor of 0.88, which indicates an extremely good correlation. The standard deviation was found to be 2dB(2.01dB). Therefore it can be assumed with good confidence that the relationship as stated above holds true for this particular case study. ***Chart 3*** shows this relationship over an average day.

Chart 3



5. Predictions

The data inputs were completed and an initial run of the model was made. One receiver point and a gird pattern of 31X47 points spaced at 10m intervals was modelled. It produced a daytime L_{10}18 hour of 78dB(A) and a night-time level of 66.1dB(A).

Table 3

O'Connell	Day	Night	24 Hour
Nth. Boun	73.9	61.6	72.7
Sth. Boun	75.8	64.2	74.7
Total	78	66.1	76.8

1st run -Predictor Model L_{10} in dB (A)

Before a second run of the model was carried out a 'manual prediction' using CRTN was carried out for two receiver points at the North and Southbound carriageways, opposite the measurement point. These gave a L_{10}18hr for the Northbound receiver of 76.5dB(A) and 76.97dB(A) for the Southbound receiver. These did not support the first run Predictor modelled results of the Northbound carriageway.

5.1 Second Run Predictions

A second and final run of the model was made. Some alterations were made to the model inputs. Two extra receivers were located at the North and Southbound carriageways opposite the measurement point, for which calculations had already been carried out manually, using CRTN. The model provides for modelling two carriageways that are more than 5 metres apart. It provides an 'automatic alignment', which was selected on the first run. 'Automatic alignment' positions the source of the noise 3.5 metres from the near side edge of the carriageway where the receiver is located. CRTN requires that in this scenario that the two sources be positioned 3.5 metres from the near side edge of the carriageway and 3.5 metres from the farside edge of the second carriageway (CRTN par. 13.1). The model allows for this by providing for a right and left alignment, which locates the sources in line with CRTN. The initial setting of 'automatic' miss-placed the sources 3.5m from the near side edges of the carriageway rather than the farside edges. Resetting the alignments to left and right rectified the matter. This meant the sources being removed further away from the receiver on the central median with a reduction in the L_{10} anticipated.

Table 4 set out the second run results. As anticipated the L_{10} was reduced.

Table 4

O'Connell St	Day	Night	24 Hour
Nth. Bound	71.3	61.4	70.2
Sth. Bound	75.8	64.6	74.6
Total	77.1	66.3	76

2nd run -Predictor Model L_{10} in dB (A)

5.2 Discussion of Prediction Results

The comparison of the predicted versus the modelled results at the Central Median position can be found in ***Table 5***

Table 5

	Toilets, O'Connell St
Predicted L10 18 Hr.	77.1dB(A)
Measured L10 18 Hr.	77.1 dB(A) Average

Predicted v Measured

As can be seen the LA_{10} 18 Hr is 77.1dB(A) for both measured and predicted methods.
At face value this would seem to be a 'fluke' result. However the results at receiver positions on both the North and Southbound footpaths when predicted by the Predictor Model and using CRTN manually, showed that the levels were the same on the North footpath (76.5dB(A)) and approximately the same (76.7dB(A) v 76.97dB(A)) on the South footpath – ***Table 6***. It would therefore be reasonable to expect that a measurement point in between these two receivers would

5.2 Discussion of Prediction Results contd

be equal if not greater than these two levels. The nighttime levels were seriously underestimated with an LA_{10} 6Hr of 66dB v 74.4dB

Table 6

O'Connell St	Day	Night	24 Hour	CRTN Manual
Median Nth. Bound	71.3	61.4	70.2	----------
Median Sth. Bound	75.8	64.6	74.6	----------
Total	77.1	66.3	76	----------
Receiver Kerb Nth. Bound	76.5	-------	-------	76.5
Receiver Kerb Sth. Bound	76.8	-------	-------	76.97

Predictor Modelled Results V CRTN Manual Calculations

6. General Discussion

The closeness of the predicted and the monitored results does raise questions as to the accuracy of the results. If there was a difference in the results of +/- 1.5dB it would be taken as acceptable. However the fact that they are identical casts some doubt. To confirm the results, spot measurements were take at a further six receiver points. These were 15 minute LA_{10} and LAeqs.
An analysis of the 373 quarter hourly L10 values shows that the average difference between the LA_{10} 18 hour and the LA_{10}15min was 0.5dB. Adding this difference to the LA_{10}15 min should give an approximation of the LA_{10} 18Hr at the further six receiver points. These were then compared with the modelled results. ***Table 7*** sets out these results

Table 7

O'Connell Street Spot Readings 1/6/99 *15min. samples*			
	LA10 +0.5	Predicted	Difference
Location 1	72	71.8	0.2
Location 2	70	64.4	5.6
Location 3	77	76.2	0.8
Location 4	77	77	0
Location 5	75	76.6	-1.6
Location 6	68	65.8	2.2

Values in dB(A)

As can be seen locations 1,3,4 show very good correlation with the predicted levels. All these locations were sited on the main thoroughfare. Location 2 was complicated by the fact that no buildings had been placed opposite the receiver. O'Connell St. alone was the subject of this project. However it would be expected that this predicted level would increase due to reflections if the buildings were to be inserted. Location 5 was sited close to the overlap of two contours. This may have led to the discrepancy between measured and predicted. Location 6 was sited down a relatively quiet lane. No traffic source was put in for this lane, although it leads to a 400 vehicle carpark. This could also explain the under prediction. However all locations excluding location 2 fell within the drawn contours of the Predictor model. Contours were set in 4dB bands

7. Conclusions

This case study for the prediction of noise from traffic in a City Centre location, in one respect was very straightforward. The source segments were two straight lines with no complications of junctions, roundabouts etc. The topography and building heights are all regular in shape with a limited amount of gaps between buildings. The monuments on the central median were not considered to be barriers thus excluding any reflections or attenuation's from them. The sound in the street was considered to be diffuse.

However although the modelling was very straight forward, collating the data inputs for the model was complex. This include complex traffic patterns and volume flows. The resulting good accuracy of the prediction was mainly due to the good data inputs that were made available, including precise traffic counts, traffic pattern analysis, and a good GIS system. The supporting spot measurements confirm that the contours produced by the model give an accurate and good visual perspective of existing sound levels for the mapped area. Overall the Predictor model stood up to validation. This case study has shown that predictions by the model are acceptable and can be compared with measured levels with a good degree of confidence. However the method by which it produces contours may give discrepancies in sound levels between specifically placed receptors and the drawn contour.

List of references

1. *Calculation of Road Traffic Noise, Dept. of Transport Welsh Office 1988 version*
2. *Technical Documentation, Precision Integration Sound Level Meter, Type 2236, Bruel & Kjaer*
3. *Technical Documentation, Predictor Type 7810, Bruel & Kjaer*
4. *Future Noise Policy, European Commission Green Paper, COM(96) final CB-CO-96-548-EN-C*
5. *SPEECH/98/167 Ritt Bjerregaard, Commission member responsible for the Environment,*
6. *" Invitational Conference on the EU's Future Noise Policy" Copenhagen, September 7, 1998*
7. *"Operational information to support Noise Policy in EU", Domingo Jimenez-Beltran, Exec. Director, EEA. Copenhagen, September 7, 1998*
8. *Irish Bulletin of Vehicle and Driver Statistics 1997, Dept. of Environment and Local Government.*