AN INVESTIGATION OF ROAD NOISE MAPPING IN THE UK TO COMPLY WITH THE EU ENVIRONMENTAL NOISE DIRECTIVE

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1 INTRODUCTION

1.1 Overview

In the UK, the $L_{A10,18hr}$ as prescribed in the Calculation of Road Traffic Noise (CRTN) [1] is currently used to assess the impact of traffic noise, where it has been the preferred index since first introduced in 1975. Its introduction pre-dates the development of equipment that could readily measure acoustic energy-based noise measures such as L_{Aeq}. This helped establish the $L_{A10,18hr}$ as the most appropriate measure in the assessment of road traffic noise. In the early 1980's, advances in technology saw the introduction of noise instrumentation that could directly measure acoustic energy based measures, leading most Nations to adopt indices based on L_{Aeq} to assess road traffic noise. Within Europe, the UK & Ireland now stand alone in the use of the $L_{A10,18hr}$ for road traffic noise assessment. [2]

To comply with the EU Noise Directive [3], Member States were required to produce strategic noise maps for designated areas, including mapping road traffic noise from major roads and all roads within agglomerations. These maps are generated using the EU indicators L_{den} and L_{night} where L_{den} is defined as the A-weighted long-term average sound level determined for all day, evening and night time periods of the year where the day is the 12 hour period between 07:00-19:00hrs; the evening is a 4 hour period between 19:00-23:00hrs and attracts a 5dB penalty; and the night the 8 hour period between 23:00-07:00hrs attracting a 10dB penalty [3] and is given by the following formula:

$$L_{den} = 10\lg\frac{1}{24}\left(12*10^{\frac{L_{day}}{10}} + 4*10^{\frac{L_{evening}+5}{10}} + 8*10^{\frac{L_{night}+10}{10}}\right)$$

As both L_{den} and L_{night} indices are L_{Aeq} based parameters, the Transport Research Laboratory (TRL) published a paper describing a number of mathematical procedures that could be used to convert values of $L_{A10,1hr}$ and $L_{A10,18hr}$ to values of L_{den}, L_{day}, $L_{evening}$ and L_{night}. [2] This enabled the continued use of CRTN to estimate the necessary EU indices by applying a mathematical end correction to the calculated values of L_{A10}. This approach was favoured by Abbott & Nelson [2] over the EU recommended interim method; the French national standard, NMPB-Routes-96, and a similar method produced by the Noise Advisory Council, due to a number of shortcomings identified in their study, with the main limitation of both methods being the lack of appropriate vehicle noise input data; particularly for roads where vehicle speeds fall below 80 km/h. [2] However, given the potential for inaccuracies to occur in the conversion of $L_{A10,18hr}$ to L_{den}, coupled with changes to the composition and volume of traffic using the UK's roads since CRTN was first introduced, how accurate are the prediction of noise levels using CRTN and the subsequent end-corrections to calculate L_{den} and L_{night} for producing noise maps to inform National and regional noise policy?

1.2 TRL Conversions from L_{A10} to L_{den} and L_{night} for Various Conditions

Following analysis of the relationship between L_{A10} and L_{Aeq}, Abbott & Nelson [2] were unable to produce a single 'one fits all' end correction for UK road conditions due to variations in the relationship for different traffic flows. In addition, detailed traffic data is not always available and so to take account of these varying factors, a range of end correction methodologies were recommended depending on available traffic flow data and the category of road. The three methodologies take account of the variations in available traffic flow information.

1.2.1 Method 1

Where hourly traffic data is available, CRTN can be used to calculate values of $L_{A10,1hr}$ which can be converted to $L_{Aeq,1hr}$ values using the relationship below:

$$L_{Aeq,1h} = 0.94\times L_{A10,1hr} + 0.77 \text{ dB} \quad \text{(Normal Flow Formula)}$$

For non-motorway roads when hourly traffic flows are below 200 vehicles between 00:00-06:00 hrs, the relationship given below should be used instead:

$$L_{Aeq,1h} = 0.57\times L_{A10,1hr} + 24.46 \text{ dB} \quad \text{(Low Flow Formula)}$$

The converted values obtained for the full 24 hours can then be used to derive the values of L_{den} and L_{night} as required by the EU, using the formula given in section 1.1

1.2.2 Method 2

This provides a method of converting $L_{A10,18hr}$ levels generated by CRTN to corresponding L_{day}, $L_{evening}$ and L_{night} levels where traffic data is known or can be estimated for the day, evening and night-time periods using the relationships below:

$$L_{day} = 0.99\times L_{A10,18h} + 10\times\log_{10}\left(\frac{p_{12}N_{12}V_{12}^{\,2}}{p_{18}N_{18}V_{18}^{\,2}}\right)\text{dB}$$

$$L_{evening} = 0.99\times L_{A10,18h} + 10\times\log_{10}\left(\frac{p_{4}N_{4}V_{4}^{\,2}}{p_{18}N_{18}V_{18}^{\,2}}\right) + 4.76\text{ dB}$$

$$L_{night} = 0.99\times L_{A10,18h} + 10\times\log_{10}\left(\frac{p_{8}N_{8}V_{8}^{\,2}}{p_{18}N_{18}V_{18}^{\,2}}\right) + 1.75\text{ dB}$$

where $L_{A10,18hr}$ is the average hourly L_{A10} level measured between 06:00 – 00:00hrs; p_t is the percentage of heavy vehicles in the time period t hours; N_t is the total traffic flow in the time period t, and V_t is the mean traffic speed in the time period t. [2] The converted values can then be used to derive the values of L_{den} as required by the EU, using the formula given in section 1.1

1.2.3 Method 3

Where traffic data is not available then CRTN should be used to obtain values of $L_{A10,18hr}$ which should then be converted to L_{day}, $L_{evening}$, and L_{night} or, for single segment roads, directly to L_{den} using the following relationships.

For non-motorway roads:-

$$L_{day} = 0.95 \times L_{A10,18hr} + 1.44 \text{ dB}$$
$$L_{evening} = 0.97 \times L_{A10,18hr} - 2.87 \text{ dB}$$
$$L_{night} = 0.90 \times L_{A10,18hr} - 3.77 \text{ dB}$$
$$L_{den} = 0.92 \times L_{A10,18hr} + 4.20 \text{ dB}$$

For motorways:-

$$L_{day} = 0.98 \times L_{A10,18hr} + 0.09 \text{ dB}$$
$$L_{evening} = 0.89 \times L_{A10,18hr} + 5.08 \text{ dB}$$
$$L_{night} = 0.87 \times L_{A10,18hr} + 4.24 \text{ dB}$$
$$L_{den} = 0.90 \times L_{A10,18hr} + 9.69 \text{ dB}$$

Abbott and Nelson [2] state that Method 1 is preferred as the evidence from subsequent analysis is that this conversion produces acceptable errors and is more robust over a wider range of traffic flow conditions. It also states that Method 3 is potentially the least reliable as the method relies on the assumption that most road types, on average, produce a "reasonably consistent diurnal flow pattern", and therefore wherever and whenever significant deviations from the norm occur, then further errors in the conversion may occur. [2]

1.3 The UK Approach

Despite initial concerns over the accuracy of Method 3, this method was chosen by DEFRA for converting L_{10} values to L_{day}, $L_{evening}$ and L_{night} due to a lack of available traffic data, particularly during the night time. The correction was applied within the Lima noise mapping software used for the noise map generation. Method 3 was applied as a 'back-end' correction after the L_{10} values had been calculated using CRTN to provide outputs in terms of L_{den} and L_{night}.

The noise maps and Noise Action Plans (NAP's) present the results in terms of the harmonised indicators L_{den} and L_{night} as required by the Directive; however DEFRA then elected to use the $L_{A10,18hr}$ to determine which sites should be prioritised for further investigation over the EU indicators, given the $L_{A10,18hr}$ is the parameter used in the UK for the prediction and assessment of road traffic noise impact. These sites are classified as 'Important Areas' and the locations represent the 1% of the population exposed to the highest levels of $L_{A10,18hr}$. The 'Important Areas', where the population is exposed to road traffic noise levels in excess of 76dB $L_{A10,18hr}$ are categorised as 'First Priority Locations' and as such are to be prioritised. [4]

2 METHODOLOGY

2.1 Assessment Overview

This study focusses on analysing the suitability of the TRL corrections using measured noise data at 16 receptors located along a 5 mile stretch of the A6514 in Nottingham. Nottingham's ring road was selected as a suitable test site as it is typical of an urban road, surrounded and bordered by residential properties where the noise climate is clearly dominated by road traffic noise.

The road consists of a dual carriageway with a 40mph speed limit and separated by a central reserve of varying width along its length. The ring road is intersected by several arterial routes into the city centre, leading to varying traffic volumes along each section of the ring road.

2.2 Assessment Procedure

- Traffic noise was assessed in accordance with the measurement method contained in the Calculation of Road Traffic Noise (CRTN). Measurements at residential properties were undertaken at the most exposed façade. Due to screening effects from boundary treatments, the microphone was positioned approximately 1m in front of the first floor façade bedroom window, approximately 4m above ground level. A 2.5dB façade correction was applied to convert measurements to 'free-field' as required by END. [3]

- Noise monitoring was conducted over a period of 24hours at each of the 16 residential receptors and the measured parameters include; $L_{A10,1hr}$ and $L_{Aeq,1hr,}$ enabling a simple calculation of the $L_{A10,18hr}$, L_{day}, L_{eve}, L_{night} and L_{den} parameters. To account for varying traffic flows, noise monitoring was conducted at properties on both sides of the road (where applicable) and on each section of the ring road.

- The L_{den}, L_{day}, L_{eve} and L_{night} parameters were calculated from the measured $L_{A10,18hr}$ using the TRL conversion formulae for Methods 1 & 3 (see section 1.2). These were then directly compared to the measured levels for each parameter to determine the accuracy of the conversions. An analysis of Method 2 was not possible due to lack of accurate traffic speed data.

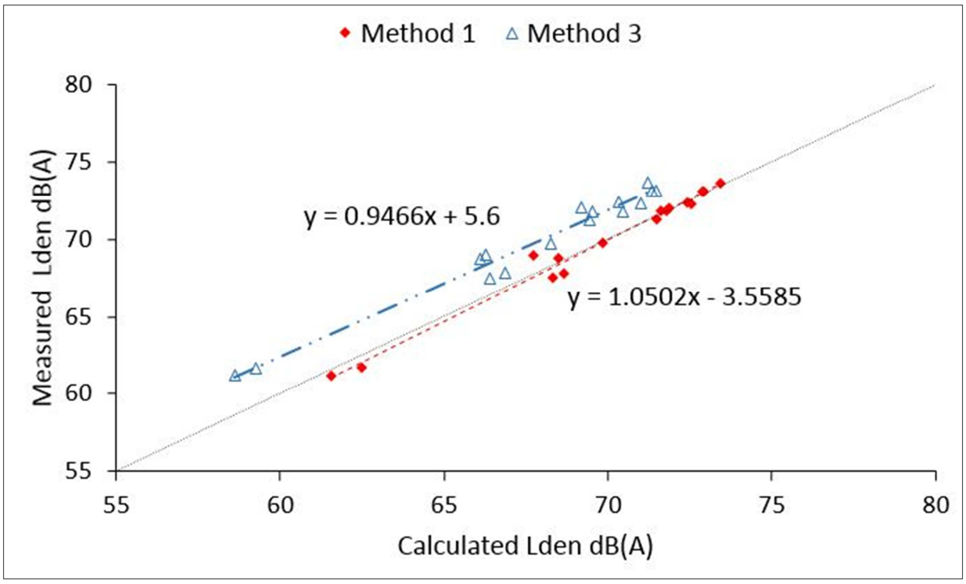
- The accuracy of the Method 3 conversions are analysed in detail, given that this method was used to produce noise maps in Rounds 1 and 2 of the mapping process and from this an examination of the accuracy and validity of the noise maps and subsequent NAP's is made.

3 RESULTS AND ANALYSIS

3.1 Comparison of Methods 1 & 3 for converting L10 levels to L_{den} & L_{night}

Abbot & Nelson [2] stated that Method 1 was the preferred methodology as following analysis it was found to be most robust over a wide range of traffic flow conditions. Therefore to analyse the accuracy of Method 3, a comparison was made of the measured and calculated values of L_{den} using both Methods 1 & 3 of the TRL formulae in Figure 3.1.

Figure 3.1 - Comparison of Methods 1 & 3 of measured L_{den} vs. calculated L_{den}



Method 1 is shown to give a relatively good agreement with a maximum variation of 1.3dB between the measured and calculated levels of $L_{den.}$ The results of Method 3 show a much greater variation of between 1.0 – 2.9dB with L_{den} underestimated at all receptors. The trend line is approximately parallel to the Y=X line indicating the margin of difference using Method 3 is relatively consistent across all properties. Analysis of the regression formula indicates that Method 3 underestimates the measured level by an average of 2.1dB

i.e. **Measured L_{night} = Calculated L_{night} + 2.1dB**

It is perhaps not entirely surprising that Method 1 is more accurate at predicting the L_{den} levels given that Method 1 translates the actual measured $L_{10,1hr}$ levels throughout the night time, rather than an estimation of the L_{night} level from the $L_{10,18hr}$ level as in Method 3.

To further analyse the issue of night time noise levels Figure 3.2 presents a comparison of the measured and calculated values of L_{night} using both Methods 1 and 3.

Figure 3.2 - Comparison of Methods 1 & 3 of measured L_{night} vs. calculated L_{night}

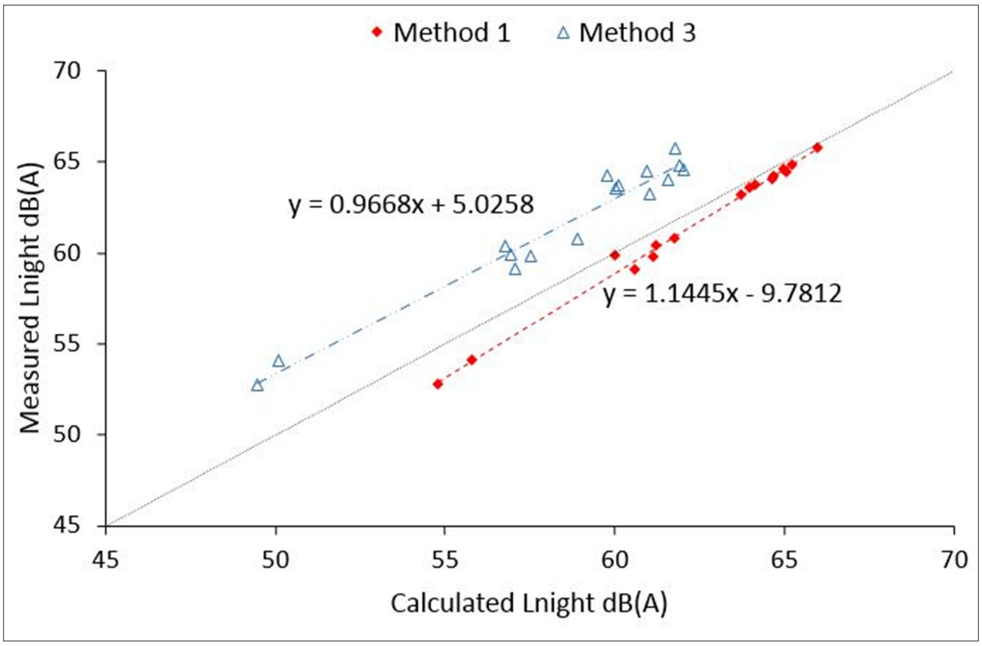


Figure 3.2 illustrates a good agreement when using Method 1 for higher noise levels, however this becomes less accurate where noise levels are lower, with L_{night} levels over estimated at these locations by up to 2.0dB. It is notable that Method 1 shows less agreement between measured and calculated levels at each receptor for L_{night} than for L_{den} in Figure 3.1 which may be caused by influences from other distant noise sources at the measurement positions during the night time. The plot illustrates that Method 3 is still less accurate overall with L_{night} underestimated at all 16 properties by between 1.9 – 4.5dB. Once again the trend line is approximately parallel to the Y=X line which indicates that the level of variation is relatively consistent across all 16 properties. Analysis of the regression formula indicates that Method 3 underestimates the measured level by an average of 3.1dB

i.e. **Measured L_{night} = Calculated L_{night} + 3.1dB**

3.2 Further analysis of Method 3

To provide for a greater understanding of the reasons for the differences between the measured and the calculated levels of L_{den} and L_{night} using Method 3; Figure 3.3 presents the average difference in the calculation of the parameters L_{day}, L_{eve} and L_{night} across all 16 receptors. Method 3 is intended for use where hourly traffic data is not available and therefore estimates the L_{day}, L_{eve}, L_{night} and L_{den} values directly from the $L_{A10,\ 18hr}$ value.

Figure 3.3 – Average difference between calculated and measured values of L_{day}, L_{eve} & L_{night} using Method 3

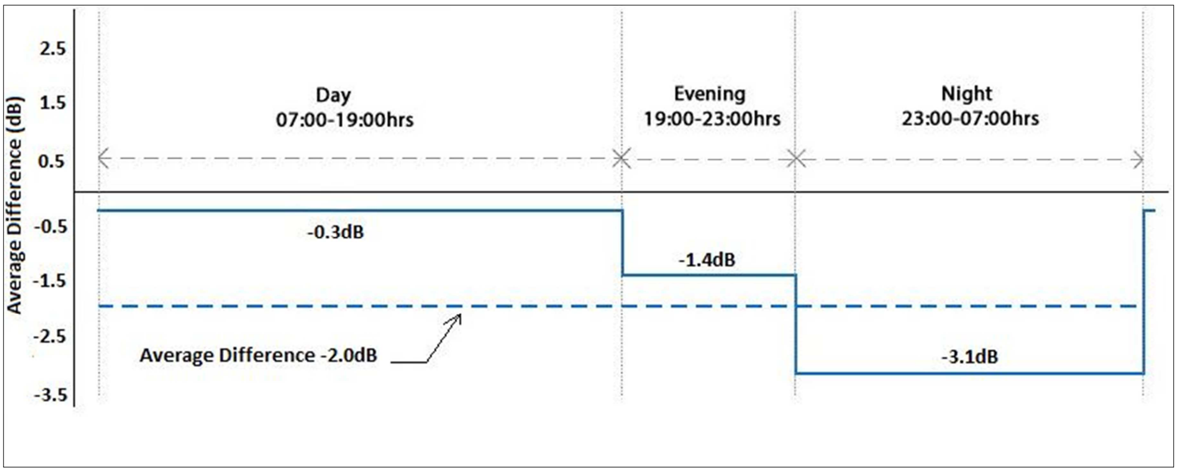


Figure 3.3 indicates that Method 3 is reasonably accurate at predicting L_{day} where the calculated level is an average of just 0.3dB lower than the measured levels of L_{day} across all 16 properties. However the level of agreement between measured and calculated levels of L_{eve} and L_{night} appears to reduce with falling traffic flows. The calculated level of L_{eve} is an average of 1.4dB lower than the measured level and the calculated level of L_{night} is an average of 3.1dB lower than measured levels. The disagreement in L_{eve} and L_{night} levels is presumably due to the assumptions made on traffic flows within the conversion formula for the evening and night time periods. The inaccuracies in the calculation of L_{eve} and L_{night} also influence the calculated L_{den} levels, particularly due to the penalties applied within the L_{den} formula. The overall average difference in L_{den} when using Method 3 is -2.0dB, and is comparable to the relationship given in Figure 3.1. Concerns over the accuracy of Method 3 were identified by Abbott & Nelson [2] who warned that Method 3 is potentially the least reliable as it relies on the assumption that most road types, on average, produce a reasonably consistent diurnal traffic flow pattern, and therefore where significant deviations from the norm occur then errors in the conversion may occur. The results of this study as presented in Figures 3.1 – 3.3 would appear to support these concerns.

3.3 Implications for Noise Action Plans

The noise maps produced in terms of L_{den} and L_{night} using the Method 3 conversions have then been used to calculate the population's exposure to road traffic noise levels within defined noise bands of L_{den} and L_{night} and these have been reported and utilised in the Noise Action Plans. DEFRA also elected to present data of population exposure within defined noise bands of $L_{A10,18hr}$ and to determine the 'Important Areas' and 'First Priority' locations based on these $L_{A10,18hr}$ results, rather than the EU noise indicators. The justification for this approach is that the $L_{A10,18hr}$ index is currently used in the assessment of noise impact in the UK and for eligibility for noise insulation. One advantage of this approach is that it removes the uncertainty of the error in the Method 3 conversions to L_{den} and L_{night} and is consistent with the current UK approach given the strategic noise maps were produced using software based on CRTN. However, significantly the $L_{A10,18hr}$ parameter ignores the traffic noise levels during the night period between 00:00-06:00hrs, which could lead to sites where night time noise is a particular issue being excluded from those identified as 'Important areas' in the NAP's.

3.4 The Future of Noise Mapping in the UK to Comply with EU Noise Directive

Until a harmonised methodology for the calculation of road traffic noise is introduced, noise mapping based on CRTN and subsequent corrections to calculate the EU parameters of L_{den} and L_{night} using Method 3 is likely to remain the favoured approach in the UK. However this study has identified that this approach may lead to significant errors in some situations, particularly with regard to night time noise as it is based solely on the $L_{A10,18hr}$ parameter from CRTN and excludes the period between 00:00-06:00hrs.

The $L_{A10,18hr}$ parameter dates back to the 1970's when there was significantly less traffic on the roads and in particular less freight movement during the night time periods. In an increasingly 24 hour society, many industrial and commercial operations run 24 hours a day and there has also been a significant increase in road freight movement in the UK since the introduction of CRTN. Much of this freight movement now occurs at night time when the roads are generally less congested. It is likely therefore that that since the $L_{A10,18hr}$ parameter was first introduced, noise levels from road traffic will have increased significantly during the night time period. In addition there are likely to be many localised examples of roads which attract significantly higher volumes of traffic during the night time period than considered typical, due to the location of nearby commercial/industrial facilities operating 24 hours a day.

The importance of night time noise impacts has seen a significant rise in profile over the last 20 years, with increased awareness of links between night time environmental noise and sleep disturbance and the consequential impacts on public health. Most notably WHO published the Night Time Noise Guidelines for Europe in 2009, [5] to try and tackle the issue of night time noise across Europe. Therefore the validity of prioritising sites based on the $L_{A10,18hr}$ index alone has to be questioned.

The difficulty though still lies in the lack of available data for traffic flows during night time periods; without such data, it is difficult to have a robust confidence that the sites selected as 'Important Areas' in the NAPs, are actually those sites experiencing the highest levels of road traffic noise particularly with respect to night time traffic noise.

4 CONCLUSION

This study has analysed the accuracy of Method 3 of the recommended conversion methodologies adopted by DEFRA for converting the UK traffic index of $L_{A10,18hr}$ to the EU parameters of L_{den} and L_{night}. The analysis compares the results of Method 3 to those produced by Method 1 which is considered to be the most robust of the three recommended methodologies by Abbott & Nelson, [2] and reveals that Method 3 is less accurate in predicting both the L_{den} and L_{night} levels presumably due to assumptions in diurnal traffic flow patterns during the evening and night time periods.

Method 3 was chosen over Methods 1 and 2 by DEFRA due to the lack of available hourly / night time traffic data and relies on a straight conversion from $L_{A10,18hr}$ to the L_{den} and L_{night} parameters. Reliance on Method 3 could lead to inaccuracies in the presented data on population exposure above defined thresholds of L_{den} and L_{night} in the Noise Action Plans (NAPs).

The 'Important Areas' identified in the NAPs produced by DEFRA, are based solely on the UK index of $L_{A10,18hr}$. Therefore there is potential for some sites to be overlooked, particularly where significant local variations occur during the night time. Consequently these sites may be not be investigated by Highway Authorities, which otherwise would have been identified as a priority had the full and correct traffic data been used. It is unlikely that Highway Authorities or end-users of the NAPs would be aware of the uncertainty in the methodology employed as these are not discussed in detail in the Noise Action Plans.

A move away from the $L_{A10,18hr}$ to an L_{Aeq} based parameter in the UK could offer improvements in noise impact assessment particularly for night time noise and would bring the UK in line with the rest of Europe. Such a change in approach would remove the need to convert L_{A10} levels to L_{Aeq} based parameters and could lead to greater accuracy in the noise maps produced and the subsequent determination of those areas to be prioritised for investigation in the NAPs, providing that sufficient and accurate traffic flow data for the full 24hours is made available.

5 REFERENCES

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