AN INTEGRATED ASSESSMENT APPROACH

FOR

ROAD TRAFFIC NOISE

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ABSTRACT

This paper describes a project to utilise the outputs of microsimulation to improve road traffic noise prediction. This involves developing software to manipulate microsimulation outputs to produce appropriate additional metrics. The technique follows other recent Transport Scotland software developments to utilise microsimulation in the road scheme assessment processes. These include the Program for the Economic Assessment of Road Schemes (PEARS), and the Analysis of Instantaneous Road Emissions (AIRE).

The technique has been applied and developed to theoretical models and has been further applied to an actual project (Test Model 1 and Test Model 2 respectively). Findings are discussed and next steps for the project are described.

1 NOISE ASSESSMENT

Road traffic noise is an environmental issue. It is acknowledged to affect health, sleep, activity at school, and property values. The World Health Organisation (WHO) state road traffic noise is harming the health of almost every third person in the WHO European Region, and one in five Europeans are regularly exposed to sound levels at night that could significantly damage health.

Complaints due to road traffic noise may increase, as the provision of information on environmental noise and its effects on the public, develop further. Noise complainants, in the recent past, have questioned the current noise prediction methodology, developed at the early stages of personal computing, and based on average parameters. Seeking improved accuracy in the prediction of noise levels is therefore important.

Road traffic noise assessment starts at the point where a charge of fuel is ignited in the engine, a section of tyre impacts on a road surface, and air is disturbed as the vehicle is propelled forward. Ultimately all road traffic noise emanates from these sources, as noise is generated by the vehicle. Noise assessment ends with an individual or population either angry at the noise received or blissfully unaware of it, depending on the many steps in between. This process, from source to receiver, can be evaluated in a complex or simple way dependent on the methodology used.

In simple terms, the purpose of road traffic noise assessment is to predict the various noise levels, and noise nuisance values, and to evaluate what mitigation measures may be appropriate to reduce these to acceptable levels.

Types of Assessment

Accurate and robust noise assessment can be very onerous. Detailed 3D models of the streetscape are required, absorbent and reflective surfaces are modelled, individual noise emitters are positioned in the model, and the spectrum and direction of their sound emissions quantified. Commercially available software evaluates this data and computes the paths from source to destination, including reflection and diffraction from buildings, and absorption from the ground or from vegetation. Weather effects can be included too, and the process repeated as the noise emitters move. The result is a detailed map of sound levels in the assessed area over a period of time, which enables assessors to evaluate the overall noise levels that the road development will produce.

This process can get quite expensive.

Noise assessment may also be quite simple. In the Calculation of Road Traffic Noise (CRTN) method, each chosen road link is treated as a line source of noise and the noise level is computed using a relatively simple formula based on vehicle speed, flow, proportion of HGVs, and gradient, with a correction for road surface. The result is a noise level expressed in dB at 10m from the road edge as a constant over a one hour or one day (18 hour waking time) period. This level may be modified using a set of rules for barriers, absorbent surfaces and reflection, which produce a fixed change in noise level at the listener point as the sound propagates from the road. Note the change in propagation is fixed; it does not vary with the sound produced by the road. There is an (unsupported) online calculator available to perform these calculations at the National Physical Laboratory website:

http://resource.npl.co.uk/acoustics/techguides/crtn/

Noise assessment at a single point can be evaluated by summating (in a mathematically appropriate way) the noise received from a number of representative road sections using CRTN.

There are many options between these two extremes (onerous and simple) and the approach across Europe differs in complexity.

Whatever approach is used the noise level from a road may be evaluated using noise assessment software. Multiple listener points may be evaluated and noise contours produced. However, outside of the research community, the authors believe there are few cases in the UK where the noise levels from individual vehicles are used in this way. In general average flows (as in CRTN) are used to produce average noise levels over long periods.

In road traffic noise assessment it is assumed that, as the noise is due to many vehicles in a homogenous flow, this approach is adequate. This is at odds with noise assessment for aircraft and train noise where it is assumed the individual train or plane is the source of the problem as the flow is more broken. The same can be true of road noise. Traffic flows are not always constant and homogenous; they rise and fall during the day and traffic comes and goes in platoons. This also aligns with anecdotal evidence from complaints where there is a suggestion that individual vehicles climbing a hill, changing gear, or speeding are an issue. These individual vehicles are not appraised by the current parading approach.

2 PROJECT GOAL

The goal of the project is to provide a cost effective noise assessment software tool to measure road traffic noise at a finer level than daily average flows, and to allow analysts to compare road scheme options in terms of the noise they produce and the characteristics of that noise. The tool will utilise the outputs from microsimulation and will build on existing work in economic assessment and gaseous emissions assessments. The tool will include components of the contemporary vehicle noise generation research undertaken by the EU in the HARMONOISE project and the Common Noise Assessment Methods in EU (CNOSSOS).

The software tool will enable noise assessors to compare noise emissions between a base traffic model and a design model at defined (CRTN linked) listener points and therefore evaluate the effect their schemes have on noise at an individual vehicle level. There is no current intention to develop the tools to include noise propagation in the wider sense; however it is envisaged that appropriate outputs from the tool could be used to input to commercially available propagation software.

3 IMAGINE HARMONOISE AND CNOSSOS

The IMAGINE Project (Improved Methods for the Assessment of the Generic Impact of Noise in the Environment.) is an EU funded research project which is intended to provide guidelines, examples and databases that allow a harmonised approach to noise assessment and propagation within the member states of the European Community. This initiative is related to the Environmental Noise Directive (END) and the strategic noise mapping of Europe.

The IMAGINE project is closely linked to the HARMONOISE project, in which computation methods (CNOSSOS mentioned in Section 2 above) are being developed for strategic noise prediction and propagation under END.

The HARMONOISE project ran from August 2001 to January 2005. The group worked with expert noise professionals to develop CNOSSOS, and the methodology is currently under discussion pending agreement. The methods within CNOSSOS are intended to become the harmonised methods for strategic noise mapping, under END, for all EU member states. HARMONOISE separated the tasks of modelling the sound from the noise emitter and propagating it to the listener, a distinction preserved in this project.

The CNOSSOS noise prediction methodology for road vehicles has individual algorithms for both vehicle rolling noise (from the tyres and road surface), and for the propulsion noise (emitted by the engine and exhaust). Each of these separate sources is given a height and directivity. Noise can be predicted in 27 frequency bands of 1/3 octave each and five different vehicle categories have been defined, each with their own characteristics. The CNOSSOS model allows calculation of the noise emission at different speeds, with different acceleration and on different road gradient. Corrections may be added for tyre type, road surface type and road wetness. Directivity is include in the emission model but has been configured such that the average change due to direction as a vehicle drives past, or as noise is aggregated over several vehicles in different orientations, the nett effect is close to zero, i.e. the correction factor has both positive and negative components. This allows the analyst to opt for a complex approach, including directional effects, or a simple omnidirectional approach using the same base noise calculations.

While the IMAGINE project focuses on application, the HARMONOISE project, and CNOSSOS, focuses on prediction methods. Similarly, the project discussed in this paper uses the algorithms developed by HARMONOISE to enable noise assessments to be undertaken. The CNOSSOS prediction method is currently under discussion and review however it is in the public domain and components of the methodology have been utilised in the tool.

4 SOFTWARE

Implementation

The computation component of the software has been implemented as a DLL (Dynamic Linked Library) written in C++. A DLL is a reusable module that may be referenced by different software systems. For example, the DLL may be linked to a new software application written in C++, C#, Visual Basic or Java. Alternately, it may be linked to an Excel spreadsheet or an Access database and accessed through Visual Basic macros (VBA).

The user interface and results analysis are implemented by a simple spreadsheet which will be used to provide a tool to study the application of the assessment method on a set of test models. The spreadsheet provides a mechanism to enter the input parameters to the calculation and a receptacle to deposit the output for further processing. The macro that performs the calculation is a link to the reusable library. In effect the spreadsheet is a prototype of a tool to be developed once the project has gained further expertise in noise assessment with the methodology.

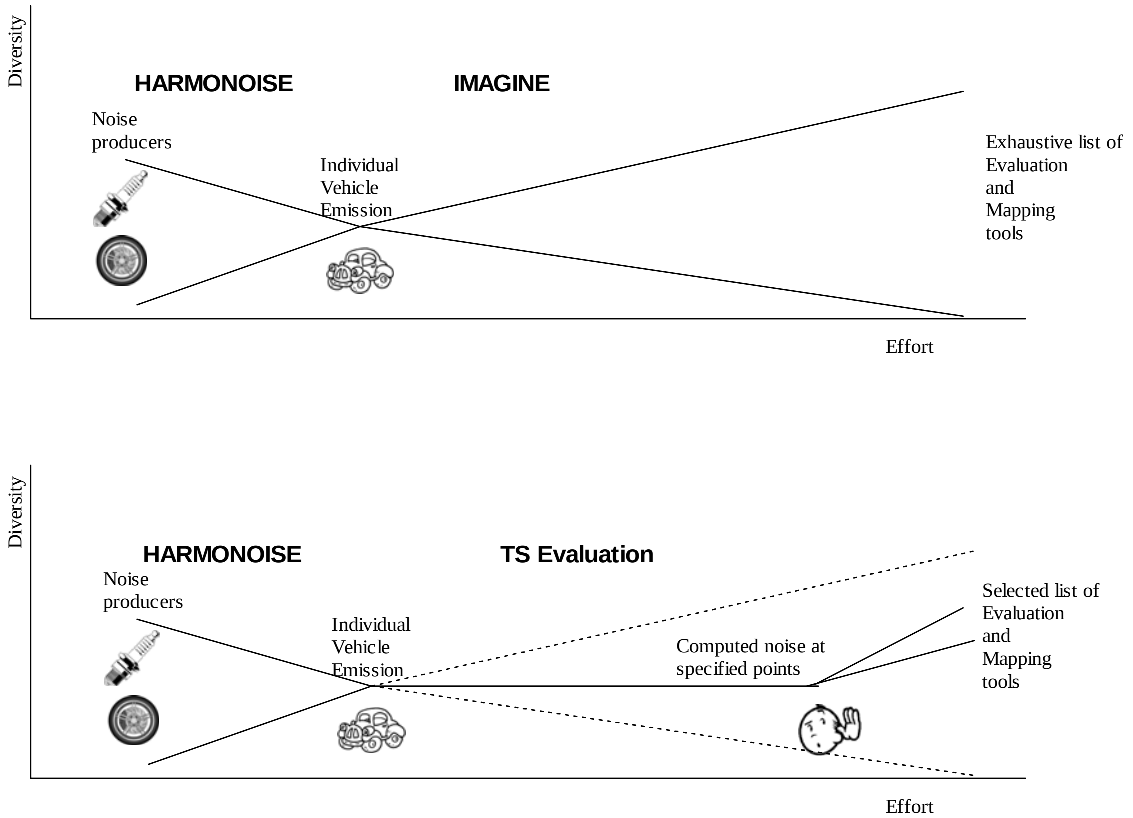

Figure 1 : Software Position

Figure 1 illustrates the position of the proposed software and demonstrates the similarities between this and the IMAGINE/HARMONOISE project. The horizontal axis approximates to the effort required to produce software to process data from raw vehicle data to an evaluation measure. The vertical axis approximates to the richness of representation at each stage.

In the HARMONOISE project the noise emission for each vehicle is calculated by a standardised method. At the nexus point, the noise emission is presented by the HARMONOISE frequency spectrum. This provides a common input to the evaluation tools and the richness of data allows almost any perceivable level of evaluation and mapping. The common data representation allows each evaluation tool to be based on the same inputs for consistency. It also reduces the effort required in producing each tool as the HARMONOISE element is shared.

This project processes the HARMONOISE outputs further to provide a set of data inputs for a smaller, selected set of evaluation methods. The revised common data input is a set of sound intensity levels at a set of predetermined points derived from the HARMONOISE algorithms and the vehicle positions from a microsimulation run. The set of evaluation methods is necessarily reduced from the full set available to the IMAGINE project, but each method will be produced more readily as much of the work will already be done in processing the raw data to the common data set.

Inputs

Three different types of input are required to the tool:

Microsimulation data: A vehicle positions file from a run of a microsimulation model. This gives the position, speed and acceleration of each vehicle at each timestep in the simulation. It also gives the gradient of the link the vehicle is on.

Listeners: The positions of the listener points at which the noise is to be evaluated and the time interval, from one second up to the length of the simulation run, over which it is to be averaged.

Control: The geographical area for the assessment and the start and end times. The area should include the listener points and all adjacent roads. The controls also include the maximum distance each listener will use to search for adjacent vehicles and any changes in the HARMONISE calculations.

Outputs

The outputs from the tool are a time series of noise levels in db(A) at each of the listener points at time intervals determined by the analyst.

No further automated processing of the results is undertaken by the spreadsheet prototype. In the analysis undertaken on this project, the data has been either manually reorganised into a table of comparative results or graphed to examine spatial or temporal variance.

Algorithms

To generate the listener point sound levels, the following steps are considered:

- For each timestep, the vehicle positions are imported.
- Each listener searches the space around it with a simple spatial search algorithm. i.e. one that is not linked to the topology of the road system which would require the noise assessment software to also include specific details of the simulation model network and hence be simulation software vendor specific.
- The noise emitted by each vehicle in range is calculated using the HARMONOISE algorithm based on speed, acceleration, gradient, and vehicle type.
- The noise emitted from each vehicle is reduced to a single db(A) value from the 27 points in the frequency spectrum produced by HARMONOISE. It is also now assumed to be omnidirectional. The db(A) filter is applied to produce a sound intensity measure as perceived by the human ear and involves corrections to the dB levels of each point in the spectrum.
- The sound is propagated to the listener point. Propagation is simple and assumes no refraction, reflection or absorption, just propagation over a plane.

- The noise level from all vehicles in range is added logarithmically to produce a single level at the listener point in that second.

$$L = 10 * Log\left(\sum_{v=0}^{v=n} 10^{\frac{L_v}{10}}\right)$$

where L_v is the sound pressure from each vehicle and Lwt is the total sound pressure

- At the evaluation interval, the individual timestep levels are averaged logarithmically and a single value for that time interval is found.

$$L = 10 * Log\left(\frac{\sum_{t=0}^{t=n} 10^{\frac{L^t}{10}}}{n}\right)$$

where L' is the sound pressure in each timestep and L is the sound pressure in the evaluation interval

5 DEMONSTRATION MODELS

Two demonstration models (Test Model 1, and Test Model 2) have been used in evaluation of the methodology. Some sample results are shown in the following text.

Test Model 1 – Simple Junction

A simple T junction model was used with a fixed demand. Three listener points were positioned in the model:

1. On a straight link, 1km from the junction; queues from the unsignalised junction do not build back to this location.
2. On a straight link 100m from the junction; queuing is expected here.
3. Adjacent to the junction 10m from the kerb.

The model is shown in Figure 2. Two listener points are shown, and the third is 1km to the west of the junction. The single carriageway roads are all 7.4m wide with a 60mph speed limit. The 1 hour turning movements are shown in Figure 3 and the demand profile is flat.

Figure 4 shows the noise assessment at the three listener points at 30 second intervals for 1 hour. Examination of the results shows that the highest noise level is found in the free flow area where traffic is flowing at around 60 mph. The junction area where traffic is slower is slightly quieter, by around 2.3dB.

Investigation of the HARMONOISE output shows that the noise emitted by a car at slow speed 6mph is 67dB and at 60mph is 88dB. The change in noise from light vehicles due to acceleration in the area near the junction is a maximum of 3.7dB. Therefore, the effect of speed in the uncongested area outweighs the effect of accelerating traffic nearer the junction and also outweighs the effect of summation of noise from several vehicles. The result seen here, that greater volumes of road noise are produced where traffic is fast flowing, is justified.

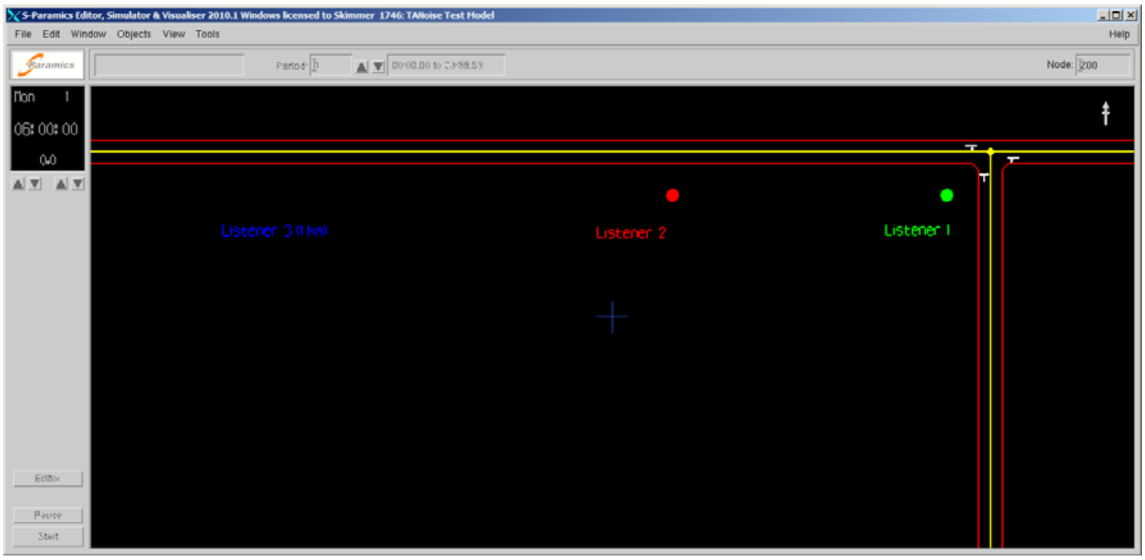

Figure 2 : Base Model

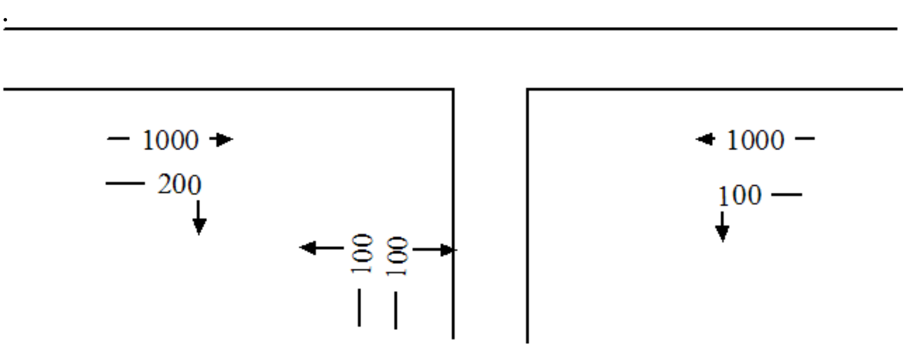

Figure 3 : Turning Movements

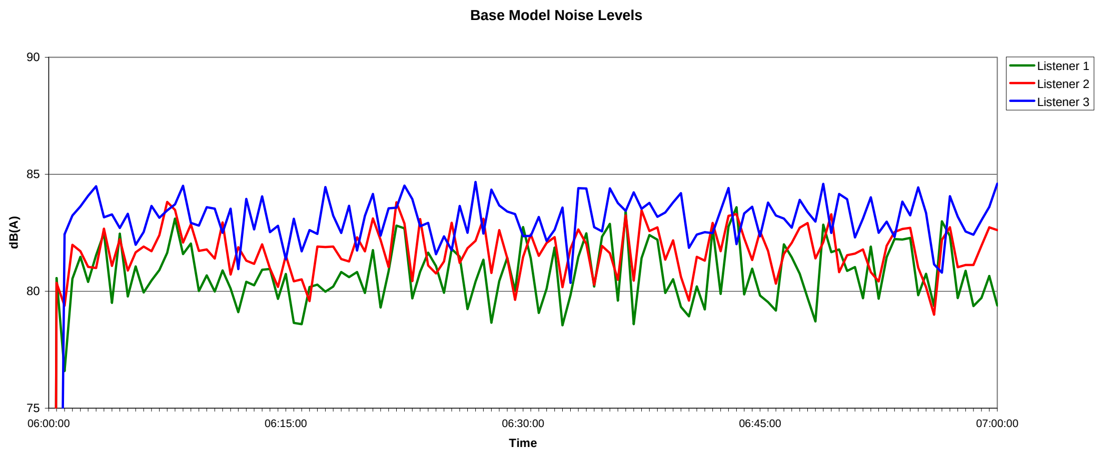

Figure 4: Base Model Noise Assessment

In a later test, the same base model was used but the junction was signalised. To expedite flows, the right turn was given a 100m dedicated lane. The green times of the signals were:

- 35s Stage 1: main road
- 30s Stage 2: side road

Queuing was extensive and propagated back to the remote listener point. Figure 5 shows the noise levels at the listener points.

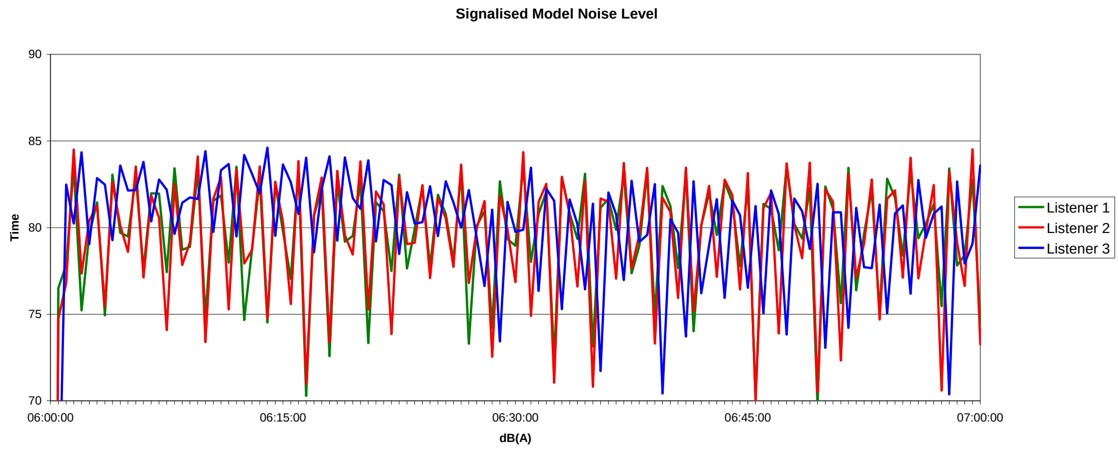

Figure 5 : Signalised Junction Model Noise Assessment

The overall sound levels at the junction are comparable with the base model reflecting the similar numbers of slow queuing traffic. The overall level at the remote listener is reduced when compared to the base model. This can be attributed to the lower average speed.

The marked difference is in the variability of the sound level over time. The maximum remains approximately the same but the minimum is reduced by between 13 to 19dB when the traffic is stationary.

More detailed investigation of the variation of noise at the signalised junction was undertaken by analysing the noise received at listener point 2, 100m from the junction adjacent to the start of the widen area. The noise level was calculated every second for a period of 10 minutes. Figure 6 shows the overall noise varies as the queue accelerates and moves towards the junction. Occasional peaks are seen in the "quiet times" which correspond to vehicles passing the listener coming from the junction after having exited the side road. For example, at 06:11 two individual vehicles which have turned out of the side road pass the listener.

It is also noticeable that while the 1 hour average is 80.6dB(A), the peak noise measured on a second by second basis often exceeds this and for periods of tens of seconds can be constantly several dB higher.

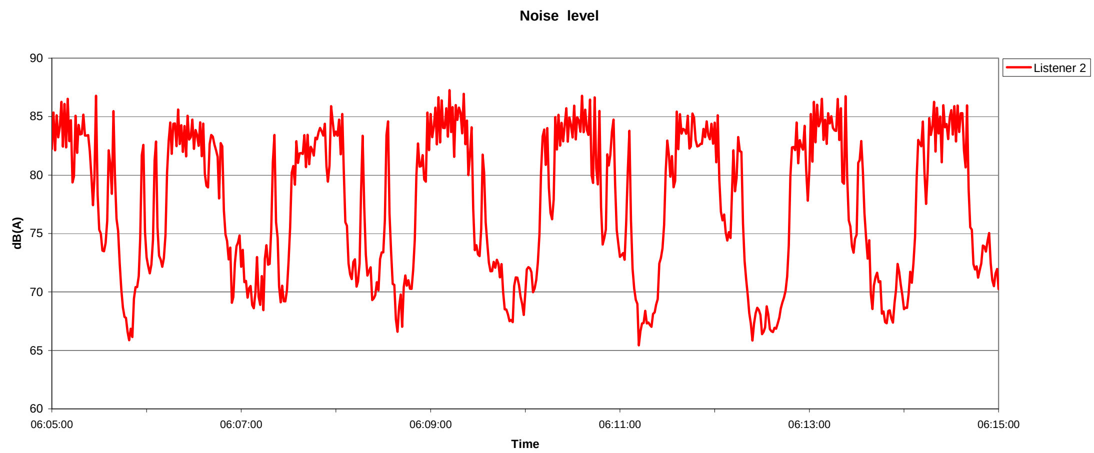

Figure 6: Signalised Junction Model, Detailed Noise Assessment

Test Model 2: Inverurie

The Crichie Farm Development forms part of the 2016 Local Development Plan (LDP) content proposals, as promoted by Aberdeenshire Council (AC). The aim of the traffic modelling study was to provide supplementary traffic modelling results to complement a local assessment being undertaken by WSP. The key aim of the study was to ensure that a robust cumulative assessment of the traffic impact was made at the critical junctions in the model network.

Three variants of the model were used and only the AM peak period was investigated.

- **2007 Weekday Base AM (07:00 – 10:00)**
  The weekday model which contains 2007 flows. It is fully profiled and has 18,453 vehicles during the AM Peak. The model represents the current Inverurie road network as observed on the ground.
- **2016 Reference AM (07:00 – 10:00)**
  The 2016 Reference Case model contains flows for the year 2016. This model is fully profiled and has 21,234 vehicles during the AM Peak. The model contains some slight changes to the Base network.
- **2016 Scheme AM (07:00 – 10:00)**
  The scheme model, which includes proposed developments to the west of Inverurie is profiled and has 23,414 vehicles in the AM Peak. The changes to the Base network include a new grade separated interchange connecting the A96 to the B993. This junction replaces the two at grade roundabouts on the A96 in the Base network and serves as the main access for traffic to/from Inverurie.

Several listener points were positioned in the network, two are described here. The listener points were positioned 10m from the roadside and were the same for each of the runs of the Base, Reference and Scheme models to allow for direct comparability between these three scenarios.

The Noise Assessment Software was run for each listener for the period 07:00 – 10:00. The average value of the noise emission was calculated every 1 minute.

The equivalent CRTN values were also calculated based on the average two-way hourly flow in the same period for the first three listener points. The base value of noise pressure, 10m from the road side was calculated with no further propagation calculations.

Listener Point 1

This location by the A96 south of the northern roundabout junction with the B9170 is in a relatively uncongested area that remains uncongested in the 2016 models despite the rise in traffic volume.

Listener Point 1 Summary Noise Values

		Noise Assessment Software		
	CRTN	**Minimum**	**Mean**	**Maximum**
2007 Base AM	77.8	73.2	76.2	78.7
2016 Reference AM	78.7	75.0	78.7	80.8
2016 Scheme AM	79.1	76.0	79..2	81.4

The variance in the Noise Assessment Software results is shown in Figure 7. The noise profile during the AM period is clearly visible. The comparison between average values between CRTN results and Noise Assessment Software results is good in the base case. Increased congestion in 2016 means that in the peak period between 08:00 – 09:00 the noise level is consistently much higher than the average level calculated by CRTN over a 3 hour period.

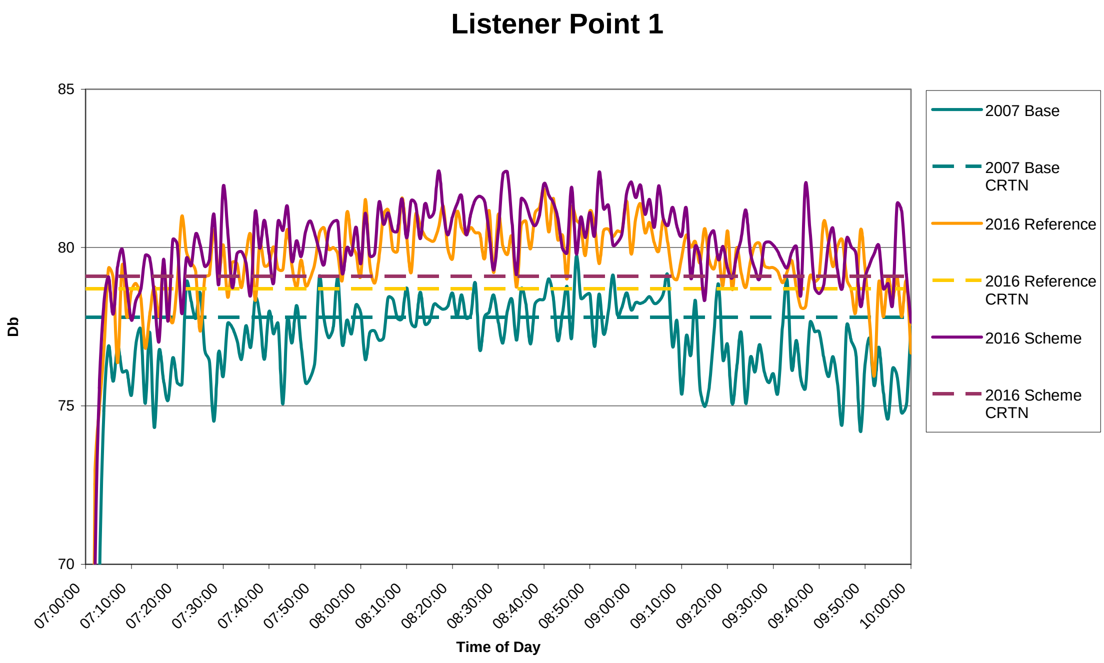

Figure 7 : Listener Point 1

Listener Point 3

The development to replace the Thainstone roundabout is shown in Figures 8 and 9. Listener point 3 was chosen to assess the impact of higher traffic flows at this location in the Scheme model.

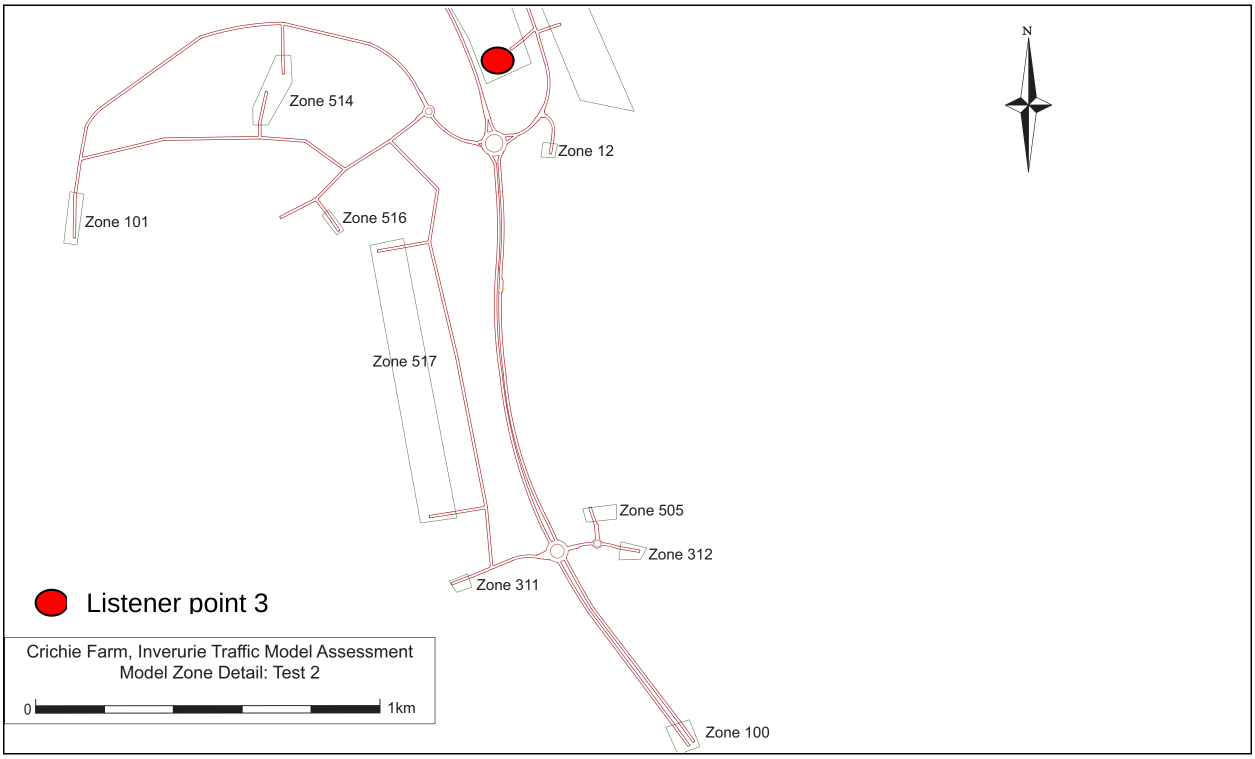

Figure 8 : Base Model

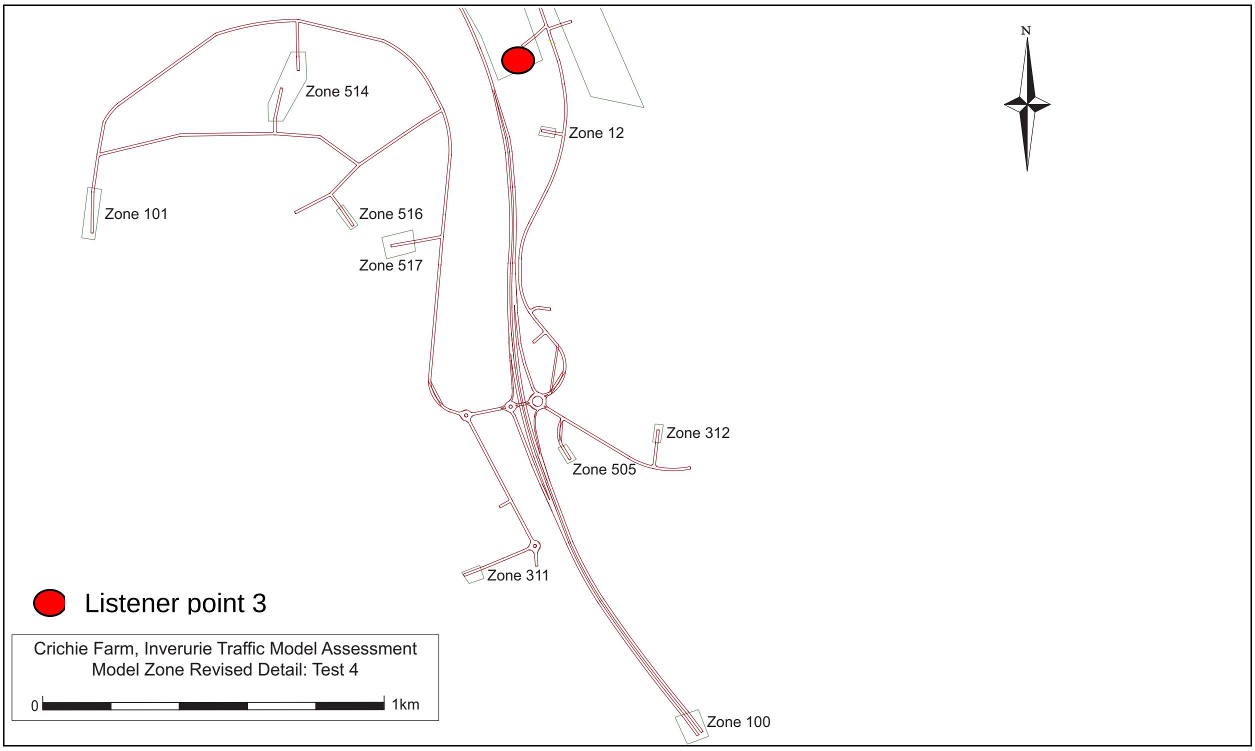

Figure 9 : Scheme Model

Listener Point 3 Summary Noise Values

		Noise Assessment Software		
	CRTN	Minimum	Mean	Maximum
2007 Base AM	76.2	74.5	78.1	80.3
2016 Reference AM	76.3	73.4	77.6	79.8
2016 Scheme AM	79.1	76.2	79.2	81.2

The variance in the Noise Assessment Software results is shown in the table above. In this case the 2016 Scheme noise levels are generally above the levels of the 2007 Base and the 2016 Reference case. This is consistent with the rise in average speed at this point due the relocation of the roundabout and the consequent removal of the queuing traffic.

The CRTN results and the Noise Assessment Software results are significantly different in the 2007 Base and the 2016 Reference cases. These two cases are the only ones tested where the listener point is adjacent to queuing traffic, rather than free flowing traffic, which may account for the difference.

6 CONCLUSIONS

Software

A software library has been provided to undertake the HARMONOISE noise calculations using vehicle positions and characteristics from a microsimulation model. The DLL is a library written to undertake the calculations only. It does not include any user interface or any reporting or analysis tools. This software is reusable in that it is not bound to any particular application of its results, neither is it bound to any particular form of user interface or to any predetermined technology for implementing a future user interface or particular application.

A simple application applying this software has been built using Microsoft Excel with a simple macro to manage the calculations and make the results available in a worksheet. Further processing of the results has been limited to manual production of graphs and manual comparisons with CRTN.

Results

The software was used to analyse noise in several hypothetical cases and in one active project. Confidence was gained in the hypothetical cases that the results were consistent with observed behaviour in the models.

Differences between average values reported by CRTN and the Noise Assessment Software were found when the listener point was located adjacent to queuing traffic as opposed to free flowing traffic. No adjustment is made in CRTN for acceleration which is assumed to account for the difference.

CRTN reports a constant value for a 1 hour or an 18 hour period, whereas the Noise Assessment Software can report at much shorter intervals. In all but one case, the variance in noise minute by minute in each scenario that was modelled exceeded the difference in average noise between the scenarios. This leads the analyst to examine not just the simple average noise level but the amount of time the noise level exceeds an annoyance threshold. Noise annoyance is based on a number of measures: average day time noise, night time noise, and intermittent peak noise levels. The approach adopted in this project is able to report on all three measures assuming a suitable traffic model is available.

Further Work

Application of the Noise Assessment Software has been restricted to confidence testing in a limited set of abstract models and a demonstration of its application in a single case. Further work may include:

- Systematic assessment of differences between this new methodology and CRTN
- Production of a tool dedicated to a single type of analysis