A low-budget road traffic noise model for individual building evaluation - a case study in Western Australia

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ABSTRACT

The primary function of the project was developed to a nationwide traffic noise immission model, using as a case study a major city at the west coast of Australia (Perth WA). In this framework the relevant acoustic input parameters were prepared and verified by measurements during the process on site. The concept originates from the consideration, that a wide range of technologies and necessary information about the model treatment becomes available nowadays by internet. Much of this information is provided free-of-charge.

This project used geoinformation for the terrain and the internet for details of the buildings. Some noise measurements were taken on site, to compare the measured traffic noise to the software based traffic noise immission model. In addition, traffic counts were also done to verify the traffic volumes. The project describes the ability, to create a traffic noise model in a very simple way, by means of a concrete application, namely traffic noise impact for a city area of Perth Western Australia.

Keywords: Traffic Noise, Cadastre, Traffic noise model

I-INCE Classification of Subjects Number: 52.3

1. INTRODUCTION

Traffic noise emission is a central issue of the environmental protection. It is regulated through legislation, regulation and guidelines. In many cases, effective verification for control is required. However, such systems for verification are very complex and time-consuming.

By way of example, the ñState Planning Policyò from Government Gazette WA [1] aims to evaluate the road traffic noise of Western Australia. The Directive was set by the Western Australian Planning Commission issued in 2009.

According to chapter 3 "Application of the Policy" the Policy applies throughout Western Australia. Notification should be provided to prospective purchasers and be required as a condition of subvision for the purposes of noise-sensitive development. A noise management plan should be elaborated in accordance with the guidelines, if necessary.

The evaluation of the noise immission should be assessed for every building. The State Planning Policy [1] describes the pass criteria with the target value und the limit value as listed in Table 1.

Table 1 ï Outdoor noise criteria; The State Planning Policy [1], Chapter 5.3

Daytime	Noise Target	Noise Limit
Day (6 amï 10 pm)	$L_{Aeq(Day)}$ = 55dB(A)	$L_{Aeq(Day)}$ = 60dB(A)
Night (10 pmï 6 am)	$L_{Aeq(Night)}$ = 50dB(A)	$L_{Aeq(Night)}$ = 55dB(A)

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The noise criteria represent an acceptable margin for compliance as the noise limit is +5dB higher than the noise target. But in fact, there is currently no suitable opportunity for the public, to see the traffic noise immission such as a freely available noise map. Similarly it is difficult for the Government agency to check the traffic noise impact in particular areas. This project describes a simple means to assess traffic noise impact using freely available geoinformation for the terrain and details on the buildings from the internet.

2. STRUCTURE OF THE ROAD TRAFFIC NOISE MODEL

2.1 Arrangement of the 3D-Model

The working cast serves on a Google Earth Orthofoto. It is a simple feature which is accessible for free. The photographs are already georeferenced (relative referenced to the model) and the mosaic elements offer a high resolution. However the high resolution rapidly increases the calculating process demands. For this study, two resolution levels were used during the processing and calculating (working size 500MB/2GB).

Figure 1 - Section of the City Centre of Perth with the appropriated mosaics; without scale

The calculating model is composed of several layers - the sum of all layers (total of 8 layers) due to the traffic noise model. The 3-dimensional traffic noise model comprised of the following components:

geometric condition:

- georeferenced photographs; mosaic-built
- elevation-layer with contour lines, georeferenced
- layer with ground cover correction

noise emission:

- freeway noise emission with correction set for CRTN [2]
- bus layer with correction set for total traffic flow
- road traffic layer set with the necessary correction

noise impact:

- layer with the calculating area (noise mapping featured with scaled isopleths)
- geometrical building-layer with relative and absolute building height
- layer with integrated building information, featured with scaled isopleths to each floor
- layer with noise impact to the building; maximum noise exposure levels $L_{Aeq(Day/Night)}$

The following Figure 2 shows the results of the completed layers.

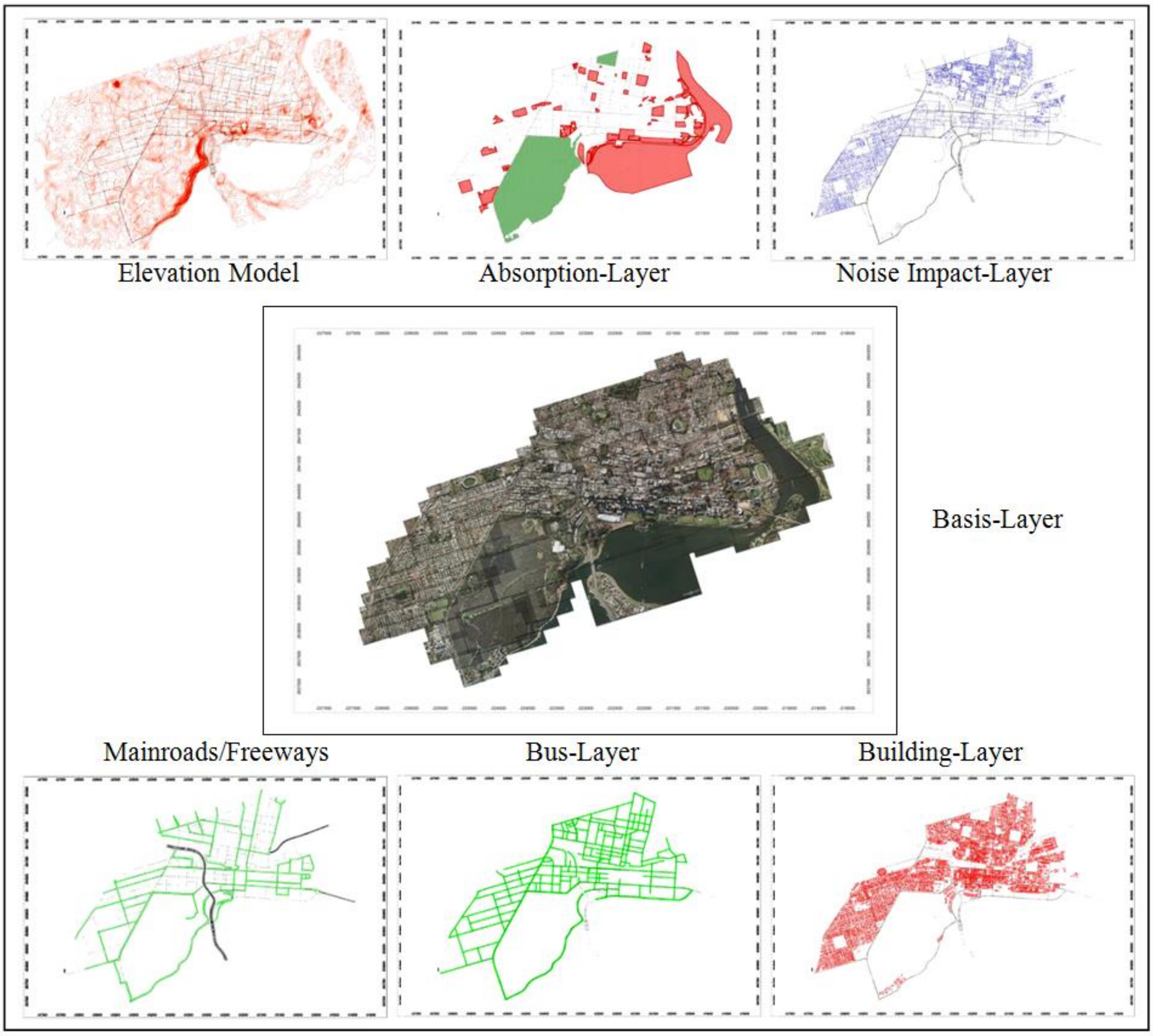

Figure 2 - The images represent each layer of the complete road traffic noise model

2.2 Processing

The processing of the workflow proves to be complex and extensive. In addition to the necessary information for the model, some suitable editing software products were needed. The following scheme shows the processing procedure of each layer. The processing is undertaken with information, which is mostly available from the internet for free.

<table>
<tr><th colspan="5">Scheme of the processing procedure</th></tr>
<tr><th colspan="5">Layers</th></tr>
<tr><td rowspan="2">Elevation Model
Noise Barriers</td><td colspan="2">Traffic Emission</td><td rowspan="2">Buildings</td><td rowspan="2">Ground Absorption</td></tr>
<tr><td>Bus Traffic</td><td>Main Roads</td></tr>
<tr><th colspan="5">Editor</th></tr>
<tr><td>USGS [3]
Earth Resources Observation and Science Center (EROS)</td><td>Transperth WA [4]</td><td>Mainroads WA [5]</td><td>Landgate [6]</td><td></td></tr>
<tr><th colspan="5">Data Type</th></tr>
<tr><td>RAW data of satellite profile; HGT</td><td>Geospatial data
shp-file</td><td>PDF/Excel</td><td>DXF-Format
x/y/z-coordinates
Georeferenced</td><td></td></tr>
<tr><th colspan="5">Attributes</th></tr>
<tr><td>• height at concontur lines</td><td>• bus number
• frequency
• timetable</td><td>• section designation
• speed limit
• traffic volumes per day/year
• average traffic volumes</td><td>• relative height
• absolute height
• absoprtion of the facade
• type of landuse</td><td></td></tr>
<tr><th colspan="5">Work Procedure</th></tr>
<tr><td>1. Correct any faults in the height model</td><td colspan="2">1. Develop the required correction factor for harmonizing the volumes</td><td>1. Classification the type of use by attributes</td><td>1. Visual controlling on Google Earth</td></tr>
<tr><td>2. Generate contour lines</td><td colspan="2">2. Determination of the traffic noise emission</td><td>2. Determine additional attributes; building absorption, type of landuse</td><td>Note: an alternative GIS-application was not tested in this project</td></tr>
<tr><td>3. Georeference and adapt the attributes</td><td colspan="2" rowspan="4"></td><td>3. Transfer to calculating program</td><td rowspan="4"></td></tr>
<tr><td>4. Transformation to DXF</td><td>4. Define the evaluation parameters</td></tr>
<tr><td>5. Transfer to calculation program</td><td rowspan="2"></td></tr>
<tr><td>6. Visually determination, eg Google Earth</td></tr>
</table>

Figure 3 - Scheme of the processing procedure

The calculation model CRTN [2] is used as the standard for calculating the road traffic noise in Australia. The CRTN [2] is based on semi-empirical equations, while the emissions are not considered as a point source but as a classic line source with appropriate segmentation [9]. All further computer calculations were made by using the software CadnaA [8] with a configuration of CRTN [2].

In densely populated areas the reflection component is normally higher between parallel facade surfaces. The calculation model CRTN [2] does not fully consider this circumstance. Other approaches for calculating reflection corrections in urban areas have been described by Hothersall and Simpson [7] and Tang and Kuok [10].

It was the goal to develop an appropriate calculation configuration validated by on-site measurement. On this basis, 6 different traffic situations were measured and compared to the prediction from CadnaA [8]. The measurements were made according to the procedure described in AS 2702-1984 [12]. The individual measurements points were selected to cover the variables:

- Terrain model (slope, gradient e.g.)
- Road type (state roads, highways, urban roads e.g.)
- Traffic routing (one way and dual traffic routing)
- Building density (closed first series, loose overbuilt, not developed)
- Signed speed limit

The location for measurements designation M1-M3 and M5-M6 are typical two-lane and four-lane carriageways respectively in the city center of Perth. The roads for measurements M1-M3 have been developed on both-side (continuous row of houses) and for M5-M6 have only built on one-side (opposite to the measurement point). Measurement M4 was done at a four-lane state road with dual carriageway.

The following Figure 4 presents an example of the noise prediction from CadnaA [8] as color-scaled isopleths and the location of the validation measurement point.

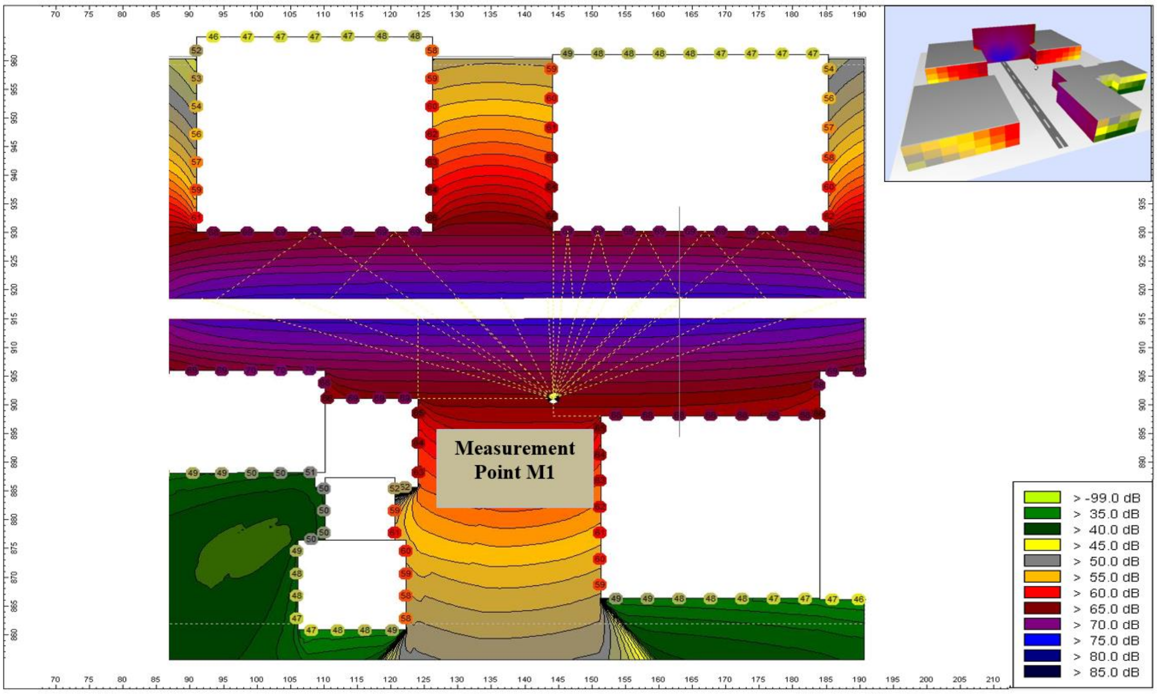

Figure 4 ï CadnaA [8] calculated situation for $L_{Aeq(Day)}$ with color- scaled isopleths.

To consider the reflection in an appropriate way, the reflection method was verified once to the flat surface according to CRTN [2] and twice to the mirror method under the term of ISO 9613-2 [12]. Both methods were compared with the measurements results. The reflection methods were also analyzed and calculated by CadnaA [8]. The predictions compared 6 different cases: (1) without any reflection: (2) to (5) with reflection from first to fourth level; and the basic calculation (6) using CRTN [2]. The predicted values were compared with the results from the site measurements (measurement designation: M1-M6).

Additional calculating models were verified at measurement M4. The four-lane axes were entered in the calculating model as a one traffic noise source (variation M4.1). In a second step, two traffic noise sources for each direction (variation M4.2) were entered in the calculating model.

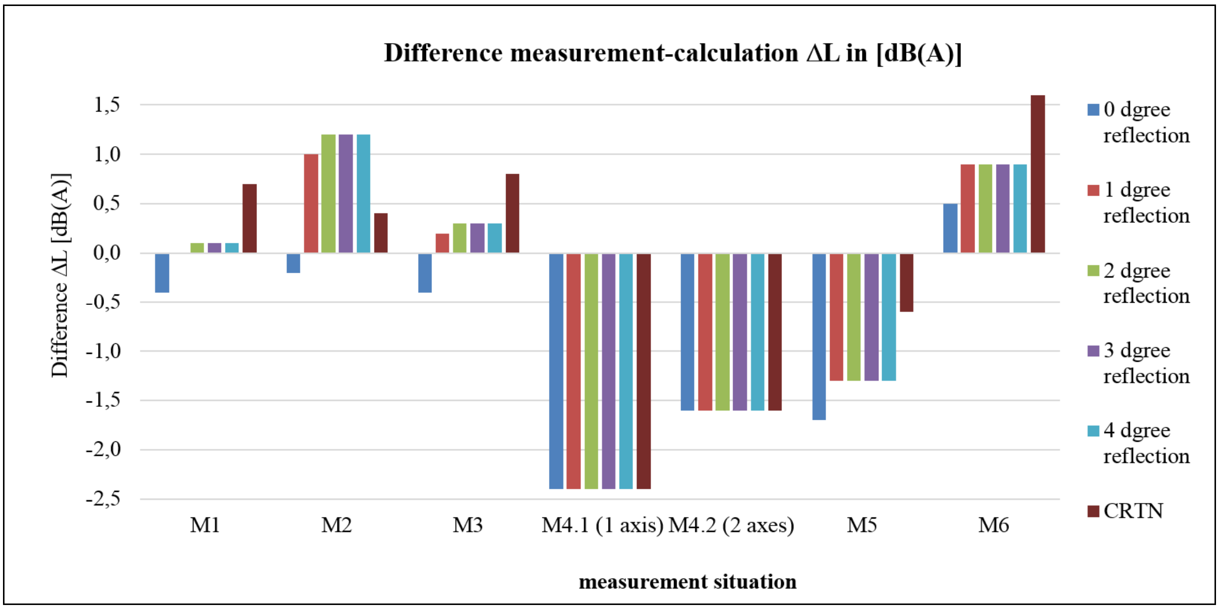

Figure 5 - Difference between the measured level $L_{Aeq,T}$ and predicted the levels L_{Aeq} for each measurement

The differences between prediction and measurement are shown in Figure 5. The review of the mirror source method with the CadnaA [8] calculation model provides good results between measurement and calculation for easy streets without separation of the carriageways (here M1 to M3 and M6). The maximum deviation is ΔL +1.2 dB for first-degree reflections or higher, compared with +1.6 dB for the CRTN [2]. In addition it can be shown, that the difference with the zero-degree reflection can be negative.

The location of the measurement situation M5 has a special feature. This measurement was made across to an intersection with a minimal traffic access (Side Street). The calculation shows a negative level difference, i.e. the predicted result is lower than the on-site measurement result. For M4 the dual road layout a better agreement is seen when the two separate carriageways are considered. In this case with such a wide road the façade reflections have negligible contribution to the predicted value.

3. NOISE IMMISSION

The total area is 25.4 km^2; 7.8 km long and 5.3 km wide. The area includes the City Center, East Perth and West Perth and the suburbs of Northbridge, Highgate und Subiaco. The study area includes more than 9,600 buildings with 7 different types of buildings. The street axes are divided into 2,780 segments and there are 224 bus routes with 1,200 bus segments.

Figure 6 shows the calculation model in form of a noise mapping for $L_{Aeq(Day)}$ (grid 15 m x 15 m; mapping height 4 m). In these images the sound prediction has been made using the Google Earth Orthofoto, the traffic data from Main Roads WA and Transperth and the mirror method [12] for the prediction method. In addition to a noise map for day or night it is also possible to demonstrate the noise impact on the surfaces of the buildings.

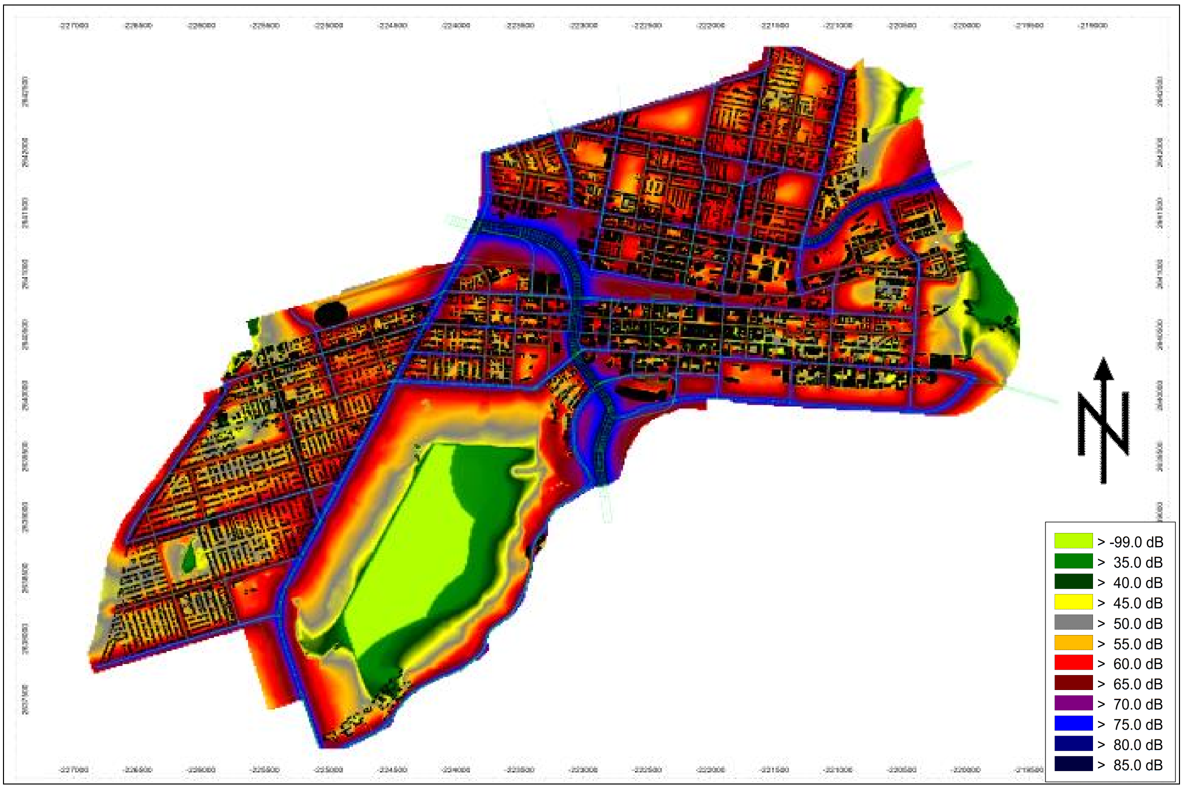

Figure 6 - The calculated noise mapping (grid 15 m x 15 m; mapping height 4 m) for noise level $L_{Aeq(Day)}$

4. EVALUATION OF TRAFFIC NOISE IMMISSION ON BUILDING FACADE

In addition to a noise map for day or night it is also possible to demonstrate the noise impact on the surfaces of the buildings. From further analysis of the prediction used to produce the noise map in Figure 6, the distribution of the maximum noise exposure on the most effected building facades can be determined. This is shown in Figure 7 and it can be seen that the highest exposures to traffic noise are up to 80dB (A) in the day and up to 75dB (A) at night.

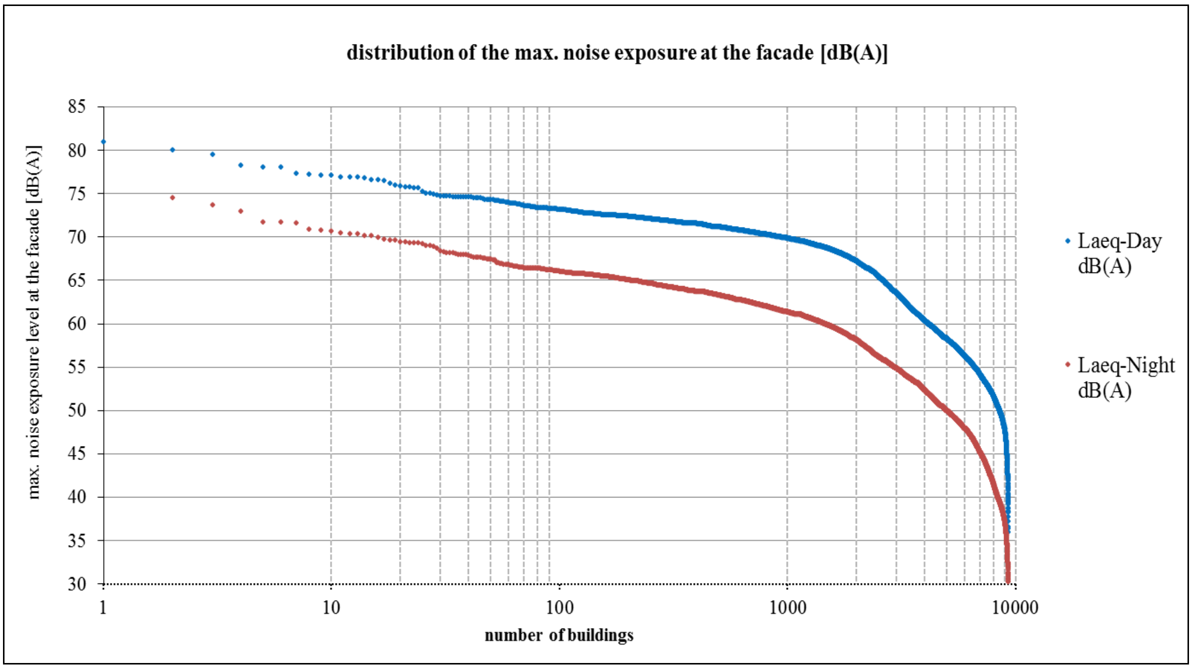

Figure 7 Distribution of the maximum noise exposure at the facade by day and night in dB (A)

During the model input, every building was added with a designation so the building evaluation could be more precisely specified. The designation and its respective categorization are shown in Table 2, which has been self-compiled.

Table 2- Categorizing noise to the building use; Category A to F

Cat.	Mode of Usage	Explanations
A	living: mansions, apartments, buildings	living with trade is categorized as living
B	trade: bureaus, companies, industries, shopping	none
C	hotel, hostels	small hostels are not taken into account
D	municipal offices, hospital, university	
D	fire brigade, hospitals, police station	safety facilities
E	parking garages on surface	outside parking spaces are not taken into account
F	sports, churches	special buildings are not taken into account

With the categorizing it is possible to subdivide all buildings in the model according to the exposure traffic noise and to the mode of usage. Figure 8 shows the distribution of day time traffic noise exposure at the façade for each category. Superimposed on this Figure are the day time target and limit values in the WA State Planning Policy [1]. Note that these limits are not applicable to existing buildings, existing road systems or to all building categories. They are included here for comparison purposes only.

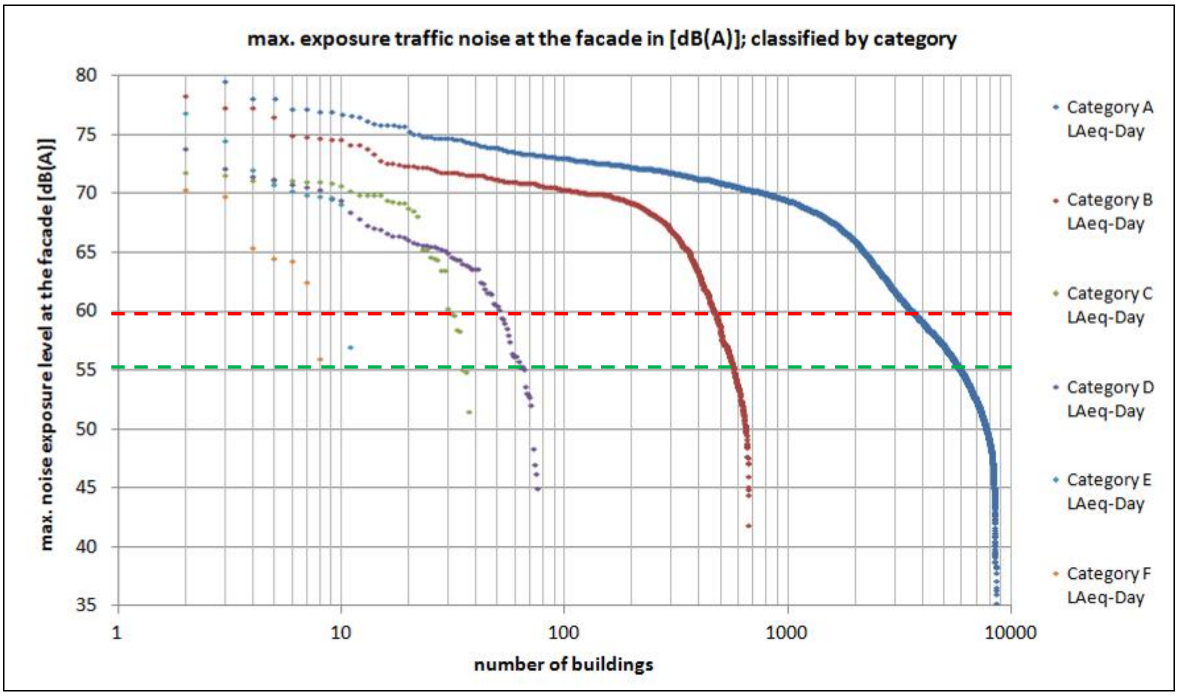

Figure 8 - Distribution of the day time traffic noise exposure on the facades for each building category. The horizontal broken lines are the WA State Planning Policy target (green) and limit (red) values for $L_{Aeq(Day)}$

5. CONCLUSION

The outcome of this approach illustrates the viability of building up a traffic noise immission model for a major Australian city using a range of data that is freely available, with the only costly item being the noise prediction component. To validate the prediction model, measurement data was compared with the predicted noise levels. Google Earth Orthofoto was used to develop the area model for the predictions. Traffic data was obtained from Main Roads WA and Transperth [4] and CadnaA [8] was used for the traffic noise predictions.

The noise map provides an aerial view of the distribution of the traffic noise. The modelling can also provide the predicted noise level on the building facades. This information can be used for analysis of noise exposure statistics and also can be presented visually by importing into Google Earth as shown in Figure 9. Using the application it is possible to present an estimation of the exposure traffic noise for every building and even on every floor.

Due to the geo-referencing of the model-system, visual representations can be provided of the effects of changes to the road structure and to the existing buildings investigations well as of the effect on new buildings and roads.

This project has demonstrated that with the use Google Earth and other freely available information, it is possible to develop a traffic noise model at a low cost. This model can not only be used to investigate in some detail current and future noise impacts but as the information can be presented visually in the form of a noise map or as a three dimensional representation on the building facades, it can be used with planning and assist with public communication.

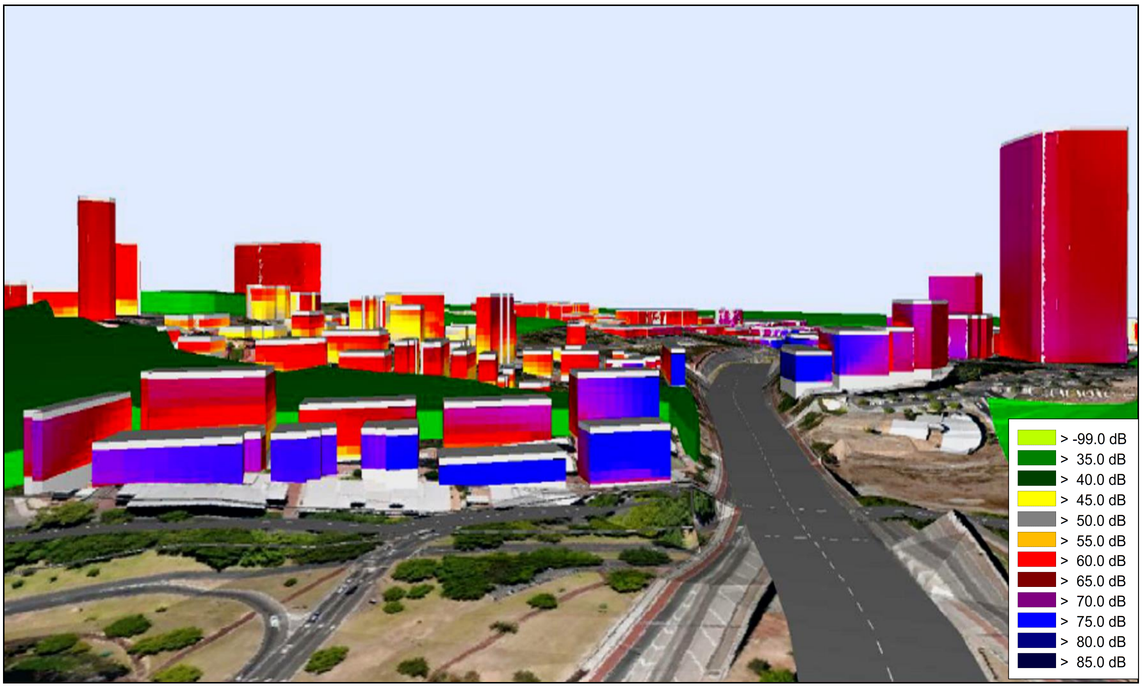

Figure 9 - The 3-dimensional application in Google Earth used to present visually the exposure traffic noise to every building/floor, $L_{Aeq(Day)}$

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