A Practical Review of Traffic Noise Model Simplifications

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ABSTRACT

The use of computational noise modelling is commonplace for the prediction of noise levels from transport corridors. Results of such noise models are used as basis for the assessment of environmental noise against local statutory regulations. Non-compliance with the regulations would often trigger the requirement for the assessment of acoustic mitigation measures such as noise walls or building modifications to provide suitable amenity. However, due to the geographic scale of transport projects and the large number of potentially affected properties, simplifications of building geometry are frequently employed to decrease the time spent developing the noise model. With the use of a computational noise model and site measurements, this paper investigates the potential impacts of typical simplifications of building geometry and discusses the implications for the internal noise limits and requirements for building modifications as defined in New Zealand Standard NZS 6806:2010. It is shown that typical simplifications of building geometry can lead to significant over–prediction of incident traffic noise levels and that including additional detail into the computational model can be an effective method of achieving better correlation with on–site measurements.

INTRODUCTION

Forecast noise levels from transport projects are often used as a basis of design for acoustic mitigation strategies. Typically this would involve the development of a computational noise model in software such as SoundPLAN or CadnaA. The results of the simulation would then be compared against applicable criteria and mitigation measures developed to reduce noise exposure (either internal or external) to an appropriate level. These mitigation measures may include changes in road surface, noise barriers, or construction upgrades to building envelopes.

Most standards and guidelines however, provide insufficient guidance concerning the required level of detail within the computational model and allowable model simplifications to avoid significant reductions in prediction accuracy. The level of detail incorporated into the model is often left up to the individual and driven by time constraints.

This work looks at the noise levels received at a specific property after the construction of an altered road directly adjacent, and how the difference between modelled and actual noise levels on site can have significant cost implications where construction upgrades are required.

This work reviews results from post-construction noise monitoring conducted within New Zealand and provides comparison with noise levels previously modelled using SoundPLAN. The on-site measurements showed that the geometry of the buildings such as overhanging balconies, balustrades and setbacks neglected in the SoundPLAN model provided significant shielding with incident noise levels on the facades up to 5 decibels lower than noise levels predicted in SoundPLAN. Where noise levels are elevated to an extent where a property requires additional mitigation, this difference has a significant effect on the required construction and cost of reducing internal noise levels in line with the applicable New Zealand Standard.

As part of a post-construction noise monitoring program for an altered road, façade sound insulation measurements and façade upgrades at a number of properties have been conducted. The houses were elevated above the road and were typically built on steep terrain leading to complicated building geometries. The external noise level used as the basis of the calculation was to be taken from predictions previously modelled in SoundPLAN. Modelled incident noise levels on the building facades were predicted to be in the order of 70 – 73 dB $L_{Aeq(24hr)}$ which indicated that building upgrades would typically be required to achieve an internal noise level compliant with the New Zealand Standards. This paper investigates the results from one such property.

NZS 6806:2010 Acoustics – Road-traffic noise – New and altered roads

New Zealand Standard *NZS 6806:2010 – Road traffic noise – New and altered Roads* recommends noise criteria for road traffic noise at protected premises and facilities (PPFs). PPFs are defined as noise sensitive receivers and include; buildings for residential activities, marae, teaching spaces, spaces for overnight patient medical care and teaching areas in educational facilities. The Standard is intended to be used primarily by local authorities and road controlling authorities.

For the purposes of this study, we are only considering the criteria for an Altered Road. The relevant NZS 6806:2010 noise criteria are provided in Table 1.

Table 1 NZS6806:2010 Noise criteria for altered roads

Category	Altered Road dB $L_{Aeq(24hr)}$
A (primary free field external noise criterion)	64
B (secondary free field external noise criterion)	67
C (internal noise criterion)	40

Where consistent with the best practicable option (BPO), the criteria of Category A should apply. Where it is inconsistent with the adoption of the BPO, Category B shall apply. Where it is inconsistent with adoption of the BPO to achieve Category A & B, the criteria of Category C shall apply. Upgrades to the building façade and building ventilation systems may be required to achieve the Category C internal noise criterion.

For properties in Category C with traffic noise exposure above 67 dB $L_{Aeq(24hr)}$, the building façade is required to provide a noise reduction (D_{tr}) of at least 27 decibels to achieve the internal noise criterion of 40 dB $L_{Aeq(24hr)}$,. This would typically involve the installation of an acoustically treated ventilation system, heavy glazing, door seals, cavity insulation and other façade upgrades. Typically, the cost of such façade upgrades is estimated to be in the order of NZ$15,000 per property.

NZS6806:2010 requires the assessment of noise levels at all PPFs within 100m of any new or upgraded road with greater than 2,000 vehicles per day in an urban area. Due to the density of housing within the urban area, this would typically involve the assessment of a large number of properties. Time constraints mean that simplifications to the building geometry must be made to achieve an acceptable modelling time.

Modelling traffic noise levels

Typically when considering noise emissions from a road corridor, given the large area and number of receiver properties, a number of simplifications are employed to allow a reasonable modelling time. Simplifications may include:

- Taking building outlines from aerial photographs. This generally does not account for accurate assessment of the height of buildings, on–site setbacks of upper floors, solid balustrades, shielding provided by fences on-site etc.
- The ground level and relative level of floors of the house may be taken from ground contours
- On-site noise monitoring conducted at a small number of properties to calibrate the model
- Building heights may be assumed to be simplified to 5 metres for a single storey building or 7.5 metres for a two storey building

Modelling road traffic noise using computational simulations has been shown to be generally relatively accurate when compared to onsite monitoring with accuracy typically expected to be in the order of +/– 2 dB. However, if using the modelled data at specific properties to assess what construction upgrades may be required, a difference of as little as 3 decibels can have a significant effect on the construction and cost of façade upgrades.

Assessing Building Upgrades for Category C properties

Where noise levels at properties are predicted to exceed both Categories A and B in NZS6806:2010, internal noise levels are to be assessed. The typical procedure to assess internal noise levels is as follows:

- Assess the external free field noise level, one metre from façade, at design year. This can either be calculated from on-site noise logging measurements or from the computational noise model with appropriate corrections to approximate free field levels
- Undertake noise measurements to determine the existing sound insulation performance of the façade (e.g. ISO 140-5:1998)
- Calculate the internal noise level in each habitable space
- Identify required upgrades to the building envelope and ventilation systems to achieve the internal noise level criterion

Based on a minimum external noise level of 67 dBA, and a maximum internal noise level of 40 dBA, the standard requires that the building façade has to reduce overall noise levels by at least 27 decibels. Generally this would require that all windows are to be closed unless there is ventilation available from another façade; hence mechanical ventilation is typically required. Upgrades to glazing and lightweight facades may also be required.

SOUNDPLAN MODEL SIMPLIFICATIONS

For the purposes of this study we have considered only modelling simplifications related to building geometry. Other simplifications and assumptions such as building façade absorption, accuracy of building heights and relative level of building floors are outside the scope of this investigation.

Building geometry

When modelling receiver properties, the building outline is typically taken from an aerial photo, and the height/number of floors is determined through a site visit or other means. In reality houses are not simple boxes; balustrades, balcony overhangs, semi-enclosed balconies and set-backs at upper floors can mean that noise levels can vary significantly across one façade. Figure 1 shows an example of 'simple' building geometry next to more detailed or realistic building geometry.

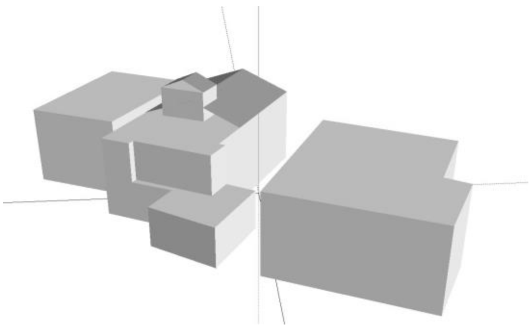

Figure 1. Geometric differences in building outline

Complicated real world geometry reduced to simplified geometry in SoundPLAN neglects actual localised shielding effects and other local effects. The modelled simplified geometry is generally therefore conservative however in some cases can significantly over predict the incident noise levels on the building facade.

Assessment Location

NZS 6806:2010 requires noise levels to be assessed at the exterior wall most affected by noise from the road. In instances where the building geometry is not simple, there can be large differences between the modelled and on-site assessment locations. Figure 2 below shows the potential error in assessment location due to a building set back on the first floor which may not be apparent from the assessment of an aerial photograph.

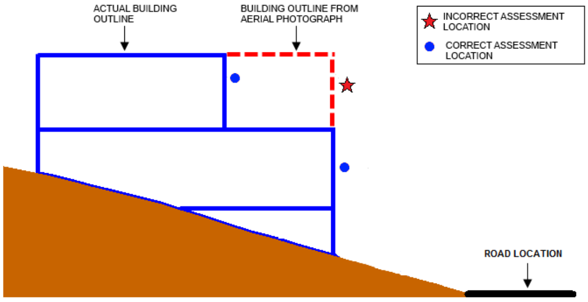

Figure 2. Indication of potential difference between modelled and on-site assessment location (not to scale)

Reported noise levels within an assessment of environmental effects report would typically be presented as the highest predicted noise level at the most affected façade, or predicted noise levels at the various floors. However, due to the simplifications in the model, the reported results at the modelled location may be significantly higher than the actual levels when measured on site.

Case study

The property investigated includes complicated geometry with the house split over three levels and located on steep terrain. Several habitable rooms are exposed to traffic noise including living, dining, home office and bedroom areas.

Developing a model based on the building outline from an aerial photograph would result in a simplified model similar to that provided in Figure 3. This is considered to be an example of simplifications of building geometry typical for a transport project during the design phase. The model would be expected to predict noise levels at each of the two main floors. Without a site inspection and developing the model based on an aerial photo alone, the second floor may be missed all together

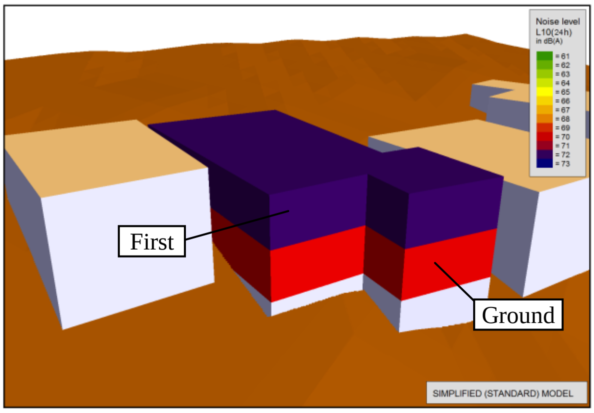

Figure 3. Simple (standard) model

Road traffic noise emissions were calculated using the CoRTN emission standard with road surface corrections applicable to the local conditions. Results of the simplified SoundPLAN model shown in Figure 3 can be seen in Table 2 below. Based on the simplified model, both modelled floors of the property would be classified as Category C under NZS6806:2010 and therefore all rooms would be required to achieve an internal noise level of 40 dBA.

Table 2 Simplified SoundPLAN results (Figure 3)

Location	Predicted noise level dB LAeq(24hr))
First floor	72
Ground Floor	70

An on-site investigation of the building geometry shows that the building does not follow the outline suggested by the aerial photo; the first floor is significantly stepped back and shielded by a roof–top deck area. In addition, each floor is separated into discreet rooms, each subject to local acoustic shielding dependent on its particular location.

By incorporating additional detail to the SoundPLAN model, predictions can be made for each individual room allowing more accurate calculation of façade treatment requirements. This includes modelling each individual room as an independent 'building' element within the SoundPLAN model, and incorporating solid balustrades and balconies. The resulting building model with additional detail and associated predicted noise levels are provided in Figure 4.

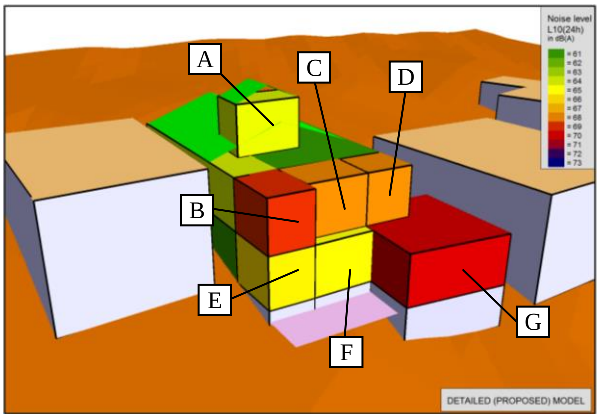

Figure 4. Detailed model

To validate the modelling results, on–site measurements at the property under investigation were conducted. Measurements were taken in general accordance with NZS6801:2008, at a distance 1 metre from the building façade and a –3dB facade correction has been applied to approximate the free field incident level. The modelled incident noise levels on each of the exposed rooms were compared with the on-site measured noise levels to verify the accuracy of the detailed noise model. Results are provided in Table 3.

The results of the detailed SoundPLAN model are found to be within an acceptable tolerance of +/–2 decibels at all monitoring locations.

Table 4 below compares the results of the simplified model with the results of the detailed model. It can be seen that errors of up to 5 decibels are predicted with the simplified model due to setbacks on the first floor and additional acoustic shielding not accounted for in the simplified model.

Compared to the simplified model where all rooms would require façade upgrades, three rooms in the detailed model are reduced to below 67 dB $L_{Aeq(24hr)}$ and therfore within the criteria of Category B in NZS6806:2010, indicating that upgrades would not be requied to these façades.

Table 3 Comparison of modelled and on-site noise levels

Location	SoudPLAN detailed dB $L_{Aeq(24hr)}$	Measured dB $L_{Aeq(24hr)}$	Difference dB $L_{Aeq(24hr)}$
A (2nd floor)	65	64	+1
B (1st floor)	69	69	0
C (1st floor)	68	69	–1
D (1st floor)	68	67	+1
E (Gnd floor)	65	66	–1
F (Gnd floor)	65	66	–1
G (Gnd floor)	70	72	–2

Table 4 Comparison of detailed and simplified SoundPLAN models

Location	SoudPLAN detailed dB $L_{Aeq(24hr)}$	SoundPLAN Simplified dB $L_{Aeq(24hr)}$	Difference dB $L_{Aeq(24hr)}$
A (2nd floor)	65	N/A*	N/A
B (1st floor)	69	72	+3
C (1st floor)	68	72	+4
D (1st floor)	68	72	+4
E (Gnd floor)	65	70	+5
F (Gnd floor)	65	70	+5
G (Gnd floor)	70	70	0

* Unlikely to be identified on aerial photograph

PRACTICAL CONSIDERATIONS

Where the noise exposure of a building façade is high, lowering the design incident noise levels by only a few decibels can make a significant impact on the practicality and cost of façade upgrade treatments. Where on–site measurements are not possible to determine incident noise levels, modelled noise levels must be used as a basis of design. However, the additional time required to provide an accurate prediction of noise levels at every building alongside a transport route by developing a detailed model for each property would be infeasible. The development of a detailed model for all properties adjacent a transport corridor within a suburban setting would require the acoustic consultant to inspect an insurmountable number of properties as well as a tremendous amount of time to develop the SoundPLAN model. NZS6806:2010 requires assessment of noise levels at all properties within 100 metres of roads with greater than 2000 vehicles per day.

It is considered that a screening test using the simplified model to identify potentially noise affected properties requiring additional investigations would be the most practical approach to assessing any noise mitigation requirements. The additional investigations may include on site monitoring where possible, or in the case of a new road, the development of a more detailed SoundPLAN model for the potentially noise affected properties.

RECOMMENDATIONS

Assessing the noise impacts of transport corridors requires noise modelling to be conducted in a time and cost efficient manner. However, a conservative estimate of incident noise levels associated with an overly simplified model can have significant impact on the cost of required façade upgrades.

The simplified type model is found to provide a conservative estimate however is an efficient method of identifying likely noise affected properties. Using the resulting incident noise levels from the conservative simplified model as a basis of façade upgrades would likely dictate more stringent façade upgrades than if the incident noise levels were based on on–site measurements or a detailed SoundPLAN model. This may have significant cost implications for example thicker glazing, additional façade upgrades etc.

The detailed type model is found to achieve good correlation with site measurements and would therefore be considered to be an acceptable alternative to on–site measurements. This would allow the specification of the façade performance to be lower and more cost effective while achieving the stipulated internal noise level criteria.

On this basis it is recommended that the simplified model should only be used as a screening procedure to identify potentially noise affected properties. For specification of façade upgrades, additional detail concerning the incident noise level at each façade is required, and it is suggested that the following procedures may be employed.

New roads

For new transport corridors where additional detailed on–site measurements of the transport noise at each façade cannot be conducted, a site survey of building heights and geometry should be conducted for properties identified in the screening test as being potentially noise affected. Additional detailed modelling incorporating accurate building geometry of affected properties should be conducted to determine incident levels on each floor and the façade of each exposed room.

This would allow façade upgrades to be completed prior to the completion of the construction of the transport corridor.

Existing roads

Where the transport corridor is existing and detailed measurements can be undertaken, it is recommended that unattended logging is conducted at each identified noise affected property. In conjunction with the monitoring, short term simultaneous measurements correlated to the logger position should be taken at various locations around the building facade to determine incident levels on each floor, and the facade of each exposed room.

Where it is not possible to conduct noise measurements at each property, a detailed type model may be used to assess noise levels at each façade.

ACKNOWLEDGEMENTS

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