Web-based calculators for transportation noise and vibration

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ABSTRACT

The NZ Transport Agency has developed a number of on-line calculators for road-traffic noise and construction noise and vibration. These tools allow members of the public, project managers, and contractors to perform calculations that would typically be the domain of an acoustics specialist. The calculators use recognised methods (CRTN, BS 5228) applying the simplifications necessary for a 2-dimensional model. This paper discusses the benefits of empowering non-specialists to perform acoustical calculations, as well as identifying where oversimplification can lead to invalid conclusions. The New Zealand implementation will be presented as a case study, providing lessons learnt from the five years of development.

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1. INTRODUCTION

Acoustics predictions are generally performed to guide decision making. In many instances, it could be beneficial for decision makers to perform these predictions themselves. While the generation and propagation of sound is a complex scientific field, numerous standards exist which give simple mathematical relationships between input parameters and output sound levels. It is these relationships that are used by most acoustics software packages, rather than trying to model the physics directly. Many of these standards were developed prior to the availability of computers to industry, and were designed to be used by hand. These simple algorithms are well-suited to implementation on web calculators.

It is normally the emitter of noise who performs calculations, either for demonstrating compliance with regulatory limits, or out of good practice considering potential effects. The receiver may also be interested in how noise will affect them.

For non-specialists to perform predictions, the inputs must be suitably explained, with information readily available. It is also important for the output to be presented in a useful format, with explanation of the uncertainty in the predictions and sensitivity to inputs. Calculators can either present a numeric result which the user has to interpret, or a qualitative assessment which guides the user on the significance of the result.

In this paper, a review of other selected web-based calculators is performed before presenting the suite of calculators developed by the Transport Agency. The benefits and risks of allowing non-specialists to use such calculators is discussed, before concluding with lessons learned from developing the Transport Agency's calculators.

2. LITERATURE REVIEW

A review of other online calculations has been performed by undertaking a web search. Three examples of other sites are presented with a particular focus on the form of the inputs, and what conclusion the calculator allows the user to form.

2.1 UK National Physical Laboratories

The UK National Physical Laboratories (NPL) has developed an online implementation (1) of the Calculation of Road Traffic Noise (CRTN) (2). This online calculator follows the stepwise procedure detailed in CRTN, calculating the basic noise level, propagation effects and other corrections in separate steps. Multiple road segments can be combined to determine a total noise level.

The input form for stages 2 and 3 is presented in Figure 1. It would appear that the online implementation

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is intended for a user with a scientific background who is familiar with the standard. Therefore this tool may not be suitable for use by a non-specialist user, although explanatory help text is provided for some inputs.

Most inputs are numeric, with drop-down lists available for absorbent ground cover, and road-surface correction (restricted to impervious, pervious, or no correction).

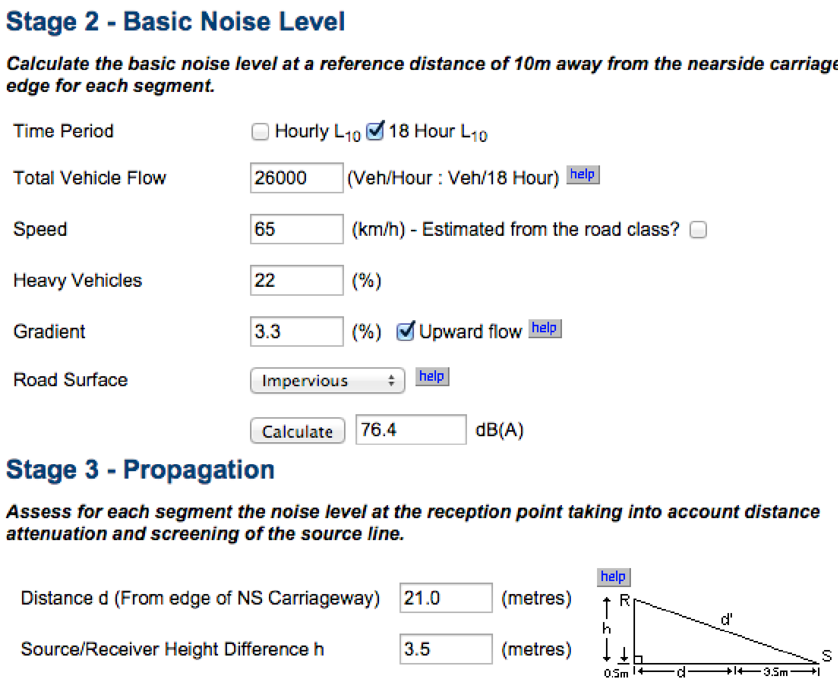

Figure 1 – Road-traffic noise input form for NPL calculator.

2.2 US Department of Housing and Urban Development

The Department of Housing and Urban Development (HUD) has developed a web-based application that calculates the Day/Night Noise Level (L_{dn}) from roadway and railway traffic sources (3). Aircraft noise data may be input for inclusion in the total site exposure, however a calculation method is not provided.

The input to this calculator is simply a table, with a screenshot presented in Figure 2. Minimal help text is provided within the calculator, however a PDF user guide is available (4).

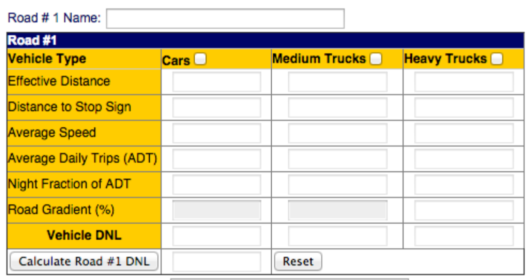

Figure 2 – Road-traffic noise input form for HUD calculator.

The output is a predicted noise level and a comparison to a 65 dB criteria, which is the basis for acceptability. A barrier performance module is also available to review potential mitigation options.

This calculator is mandated for use on HUD projects and the target audience is acoustics specialists. If it was not mandated, specialists would probably use other tools such as software packages (for example, SoundPLAN or Cadna/A) or in-house spreadsheets. Where complex topography or large distances are involved, these other methods are likely to produce more accurate predictions.

2.3 Adelaide City Council (Australia)

For several years the Adelaide City Council has had a ‘Noise Ready Reckoner’ available online (5), that allows users to consider the effects of traffic noise (with different street classifications), general activity (speech, dogs, individual vehicles), and aircraft noise (based on location relative to flight paths).

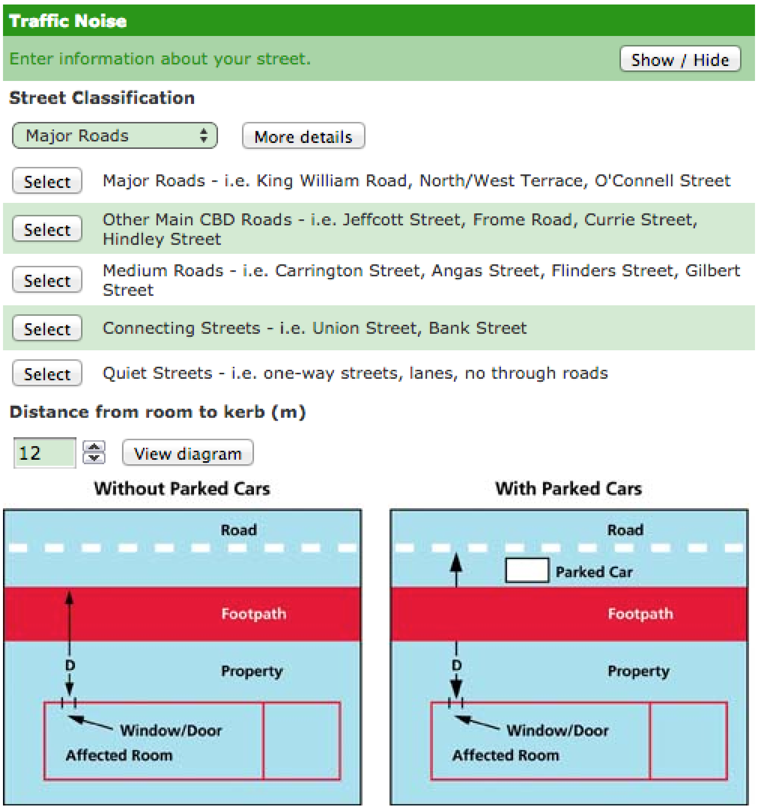

Figure 3 – Road-traffic noise input form for 'Noise Ready Reckoner' .

The inputs are presented in Figure 3. Unlike the HUD calculator, the user does not specify vehicle counts, but rather the street classification and the distance between the house and the road. Examples of streets for each classification type are provided.

Similar to the inputs, the result of this tools is not numeric but rather a commentary on the likely acceptability of the sound. The result is displayed in terms of the following three categories: likely to be acceptable; marginal; and unlikely to be acceptable

3. CASE STUDY

The NZ Transport Agency's responsibilities include being the road controlling authority for the state highway network. It has developed a suite of calculators associated with the Transport Noise and Vibration website (6). In addition it has also developed air quality calculators (7) and there are plans to develop content for other environmental disciplines.

3.1 Road-traffic noise

The first Transport Agency tool was a simple implementation of CRTN for a single road segment. It takes the basic traffic data (AADT, speed, and %HV), road (surface and gradient) and intervening terrain (absorption, barriers, and height difference) as well as angle of view and reflecting surfaces. The input is presented in Figure 4. Collapsable help text is provided for each input to guide the user to select an appropriate value.

The noise level is determined using the standard CRTN equations, with some modifications for New Zealand use. Specifically, corrections are also made to present the predicted noise level as a free-field value, and also as a daily time average $L_{Aeq(24h)}$rather than an $L_{A10(18h)}$.

A useful feature is the ability to standardise inputs, particularly the road-surface type. In New Zealand, separate surface corrections are applied to cars and heavy vehicles. A drop-down box is provided for the user to enter there road surface type. For existing roads, these can be determined from Auckland Motorway's portal into the Agency's RAMM database (8). Example RAMM data for a segment is shown in Table 1, which includes the surface type and maintenance details.

The Transport Agency has determined standard corrections to be used on projects for difference surface types (9). An abbreviated list of surfaces corrections is provided in Table 2.

The CRTN correction C_r is defined in Equation 1 and the combined correction R in Equation 2. The -2 correction is for the reference surface.

Figure 4 – Road-traffic noise input form for Transport Agency calculator.

Table 1 – Example RAMM data.

Value
0.245km to 0.348km, offset 0 - 6m SMA 1st Coat 01/2008

$$C_r = 10\lg(R) - 2 \tag{1}$$

$$R = 10 \times \lg\left(\frac{[1 - p/100] \times 10^{R_c/10} + [p/100 + 5p/V] \times 10^{R_t/10}}{1 + 5p/V}\right) \tag{2}$$

3.2 Road-traffic noise screening tool

A screening tool has also been prepared to assist in determining whether detailed assessment is required. The same receiver location is used for two different scenarios (with and without project). The New Zealand Standard NZS 6806 (10) requires a minimum increase in noise level over the existing environment.

Further simplifications are made to the standard CRTN calculation in this tool, particularly the user only has to specify whether the road surface is chip seal or not, no angle of view is required, and the user only specifies whether reflecting surfaces are present. It is intending that a planner or project manager would be able to use this tool.

3.3 Construction noise

The construction calculator follows the method from BS 5228-1 (11) for stationary and slow-moving sources. The geometric inputs are provided in Figure 5.

Table 2 – Road-surface corrections.

Surface	R_c	R_t
Asphaltic concrete (reference)	0	0
Chip seal	6	1
Porous asphalt	0	-2

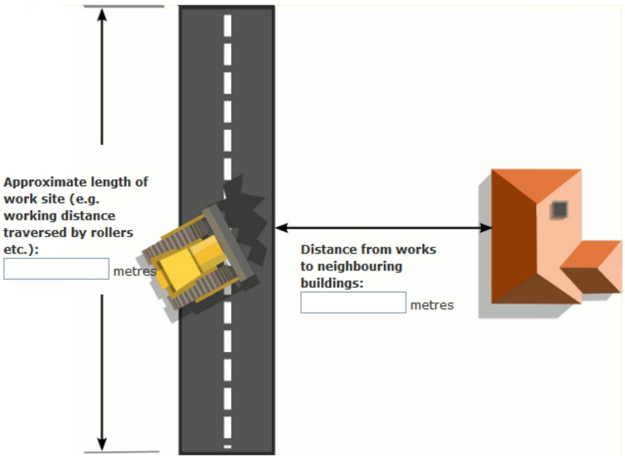

Figure 5 – Construction noise calculator.

The key component of the calculations is selecting the source equipment. The website allows users to define a list of equipment that will be used throughout the project. Ideally these source levels will be based on measurements, however the user can select from the list of sources in BS 5228-1.

3.4 Internal noise

A calculator has been prepared to approximate internal noise levels based on external road-traffic noise and generic building constructions. The incident noise level may either be calculated using the road-traffic noise calculator, or be based on a measurement or other source. The transmission paths considered are the walls, roof/ceiling, doors and windows.

The calculator adopts the general method from EN 12354-3 (12). The A-weighted external traffic noise level is scaled with a C_{tr} spectrum. Octave band sound reduction indices are used for typical constructions. Options for for poorly sealed doors and windows are also provided.

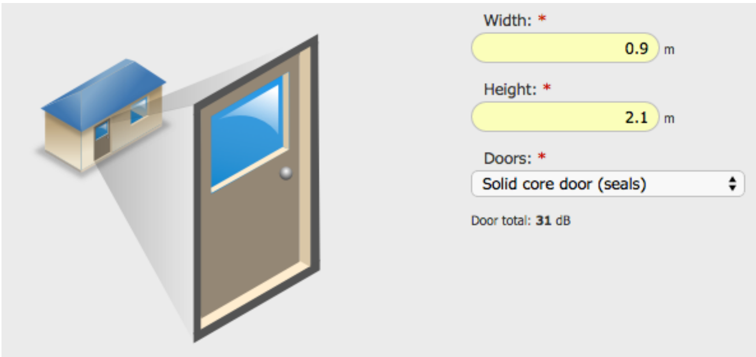

Figure 6 – Internal noise calculator.

4. BENEFITS

4.1 Education

In New Zealand, there was previously a Noise Improvement Programme, for which which eligibility required a minimum noise exposure of 65 dB.The public generally has a poor appreciation of the difference between noise levels, although the prevalence of smart phones with sound level meter applications is may improve this. The road-traffic noise calculator allows users to determine their likely exposure. While the traffic noise may seem excessive to residents if they have just moved into the area, the calculation may reveal that noise levels are closer to 55 dB and that noise is not at a level whereby the Transport Agency would investigate mitigation.

The road-traffic noise calculator is useful to demonstrating the relative insensitivity of noise level to traffic volume.

4.2 Flexility

On construction projects, the time between planning specific construction activities and implementation can be short. Therefore, having the ability to perform predictions as soon as the equipment and methodology is decided allows the project team sufficient time to address any noise issues. It also allows consideration of multiple techniques. Involving an acoustics specialist external to the team for routine predictions can add delays, often with little benefits if the team are able to make basic assessments by themselves with the calculator.

While contractors may have their own spreadsheets, using an approved system gives greater level of assurance for the Transport Agency as the party with ultimate responsibility for compliance with regulatory requirements.

4.3 Transparency

Conditions on environmental approvals will often require action and reporting when certain thresholds are exceeded, however regulators will generally not see predictions below this threshold. By giving regulators access to the website, they are able to see what predictions are being performed (amongst other information).

5. RISKS

5.1 Sensitivity of inputs

Consideration has been given to the availability of data required for the calculations, and how critical this data is. Table 3 lists each input, potential sources, and provides a commentary on the sensitivity. A similar exercise for construction noise is presented in Table 4.

Table 3 – Consideration of road-traffic noise inputs and significance on result.

Item	Source of data	Sensitivity
Traffic volume (AADT)	Booklets, survey	Relatively insensitive (3 dB per doubling)
Speed	Posted speed	N/A
%HV	Modelling or survey	Quite sensitive. Recommended to provide guidance of where to obtain data, or to check the sensitivity to this parameter.
Road surface	RAMM data available	Quite
Gradient	Estimate	Relatively insensitive
Ground absorption	Description	Sensitive, however often in New Zealand this is fixed as $I = 1$
Barriers	Design or measurement.	While heights are critical, they are simple to obtain. The distances between the road and the barrier are critical. When modelling a wide road as a single line, predictions are less accurate
Propagation height difference	Estimate	Relatively insensitive
Angle of view	Estimate	Relatively insensitive
Reflecting surfaces	Estimate	Relatively insensitive

5.2 Complex terrain

It is unlikely that road-traffic noise calculations would be performed using this a simplistic calculator for situations were complex terrain is involved. Generally the environmental approvals required for permanent facilities are greater than temporary effects such as construction noise. Therefore, the road-traffic noise calculator would not be used in the formal assessment of most new road projects.

5.3 Large distances

The construction noise calculators only use A-weighted data. Propagation is therefore limited to geometric spreading. At distances where effects are greatest, excluding other losses is reasonable. However, to meet the night-time noise limit of 45 dB from a relatively noisy source of say a concrete breaker Item 9 from Table C.1 from BS 5228-1 with a noise level of 90 dB at 10 m, would need separation of approximately 1800 m. Table 5

Table 4 – Consideration of construction noise inputs and significance on result.

Item	Source of data	Sensitivity
Equipment source level	Measurements, BS 5228 library	Directly. BS 5228 can be quite difficult to find the most appropriate equipment to match what is on site
Operating time	Estimate or observe on site	$10\lg(t/T)$. Determining the representative operating time can be quite difficult. It is better to measure source levels over an entire operating cycle rather than measuring the maximum level then correcting for operating time
Length of worksite	Modelling or survey	Only applies to slow moving sources. Only sensitive when receivers are close to the source

shows an example calculation with and without air absorption at this order of distance, which demonstrates the actual level including air absorption will be substantially lower.

Table 5 – Comparison of sound propagation with and without air absorption.

	Octave band centre frequency (Hz)								
Item	63	125	250	500	1000	2000	4000	8000	A
Input level (at 10 m)	79	82	81	82	86	86	86	85	
Distance correction (2200 m)	-47	-47	-47	-47	-47	-47	-47	-47	
Facade correction	3	3	3	3	3	3	3	3	
Level at receiver	35	38	37	38	42	42	42	41	48.5
Air absorption	0	-1	-2	-7	-16	-28	-51	-130	
Revised level at receiver	35	37	35	31	26	14	-9	-89	32

It would be feasible to add air absorption for a typical spectrum (with a low-frequency bias to maintain conservatism), to determine an air absorption correction in terms of dB(A)/km. Alternatively, as the 2008 revision of BS 5228-1 has octave band data for equipment, the ISO 9613 algorithm to be used. This would require contractors (and other uses) users performing noise measurements of their equipment to be able to report octave band data. Simple sound level meters often do not allow this.

6. LESSONS LEARNED FROM USE OF TOOLS

6.1 Stakeholder engagement

Early identification and engagement and clear statement of objectives of tools is beneficial. For example, the construction noise calculators have primarily been targeted at contractors, however the initial advisory group was composed of consultants.

The first implementation of the project system included a complaint management system. This appears a logical inclusion; this information is important and recording it on the website would be useful to the Agency. However most contractors have other systems (often Customer Relationship Management based) that are more suited. The complaints management system is no longer used on the site.

6.2 Slow introduction with adequate testing

During the introduction of new systems, bugs and performance issues are commonplace. While ideally beta testing (that is, external user acceptance testing) would be performed as a separate exercise, the reality is that this testing is performed by using the systems on actual projects.

By forcing people to use it before the system is stable you can meet resistance, and once confidence is lost it can be hard to regain. By the Transport Agency proving staff to train contractors, receive feedback and act on it, the first project users have had a high degree of acceptance of the system.

6.3 Web standards

New Zealand Government web standards require that content is accessible to all users and limits the use of JavaScript and other such technologies. During the initial implementation, the Transport Agency strictly enforced this requirement resulting in several potential enhancements for users being rejected.

Websites must work and be tested in a number of listed browsers, which proved problematic when some browsers (notably Internet Explorer 6) do not operate in accordance with the same web standards. While web browsers have significantly improved in recent years, a strategic decision has been made for those noise calculators: public facing (generally static) content will be 100% compliant with web standards; and 'private' content intended for staff, consultants and contractors only has to work on modern (standards compliant) browsers, and allows the use of JavaScript without providing an alternative.

6.4 Scope creep

The initial implementation of the road-traffic and construction noise calculator allowed the user to save the calculations, however did not have any way to share them. A 'project system' was developed which allowed calculations to be saved to a project, which other users could then view and edit. This project system grew with more and more features added. Incremental design can lead to poor integration and this facility now requires redevelopment.

The authors recommend periodically stepping back and have a look at the big picture, as once your system has outgrown the framework, it is often too late.

6.5 Testing

When specifying calculators, having test data with sufficient coverage of all input parameters is essential. Ideally, testing would be automated to ensure that any bugs introduced when changing other parts of the calculators can be identified prior to deployment.

The authors' experience is that a large amount of manual testing using a variety of different browsers remains essential.

7. FUTURE WORK

The Transport Agency is currently reimplementing the existing tools as part of a more integrated project management system. Calculations will be tied to a geographic location, and source and receiver locations will be selectable from online maps / aerial photos.

Online calculators for construction vibration are proposed using the methods from Appendix E from BS 5228-2 (13). These methods have well-defined inputs and can generally be used by non-specialists.

8. CONCLUSIONS

Web-based calculators enable non-specialist users to make decisions that would normally require input from a third party. The developers of such calculators need to ensure that sufficient information is available to allow users to understand the limitations of the calculators, in particular when selecting inputs which the result is highly sensitive to.

The Transport Agency regularly receives positive feedback about the on-line calculators and intends to continue supporting these tools as one approach to improving understanding and decision making on noise issues, and critically to assist in improving environmental outcomes.

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