Road-traffic noise calculation methods

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Subject:	Considering methods for road-traffic noise calculation in New Zealand	

1. Introduction and methodology

This document considers methods for road-traffic noise calculation in New Zealand. Features and capabilities of four methods are summarised with evaluation relative to the New Zealand context, as if considering validation and application of the method in New Zealand.

The four calculation methods selected are CRTN, Nord2000, CNOSSOS-EU, and TNM. CRTN is the method most commonly used in New Zealand currently.

The calculation methods selected are based on mathematical or empirical models. Other techniques, such as neural networks, have not been included. Although they are appearing in the academic domain, there is not sufficient support or demonstration of any method to be considered as a candidate for adoption in New Zealand.

The accuracy of the calculation methods is not investigated in this project. Each method is accepted as accurate and appropriate for its “native” application. If a candidate method for adoption in New Zealand is identified, subsequent investigations would validate the method for New Zealand application.

This project’s evaluation of the calculation methods focuses on the method itself, and not software platforms the method may be implemented by. These software platforms are regularly interpreting and in some cases complementing the method separately from the original method development. The software can add functionality and effectively extend application or capability of the method. Software features can influence perceptions of the method being used.

Section 2 gives a brief overview of each of the four calculation methods included in the project. The evaluation of the methods is in section 3. Section 4 provides commentary suggesting how New Zealand may proceed with road-traffic noise calculation methods. The evaluation and commentary are generally based on published information about the methods, supplemented by professional judgement and awareness of road-traffic noise assessment in New Zealand.

2. Road-traffic noise calculation methods

2.1. CRTN (Calculation of Road Traffic Noise)

CRTN has been validated for New Zealand and is the road-traffic noise calculation method most commonly used here.

CRTN was developed in the United Kingdom. It was first published in 1976 and its original purpose was to assess whether a property was entitled to additional noise insulation under the UK Noise Insulation Regulations of the time. The method was revised in 1988. In 2008 and 2011 additional advice on CRTN procedures was published in the UK Highways Agency Design Manual for Roads and Bridges (DMRB).

The CRTN source emission model uses a reference noise level representing a stream of uninterrupted traffic, taken at 0.5 metres above a densely-graded asphaltic concrete surface and positioned 3.5 metres in from the nearside road edgeline. That noise level is then adjusted to account for various aspects of the traffic (e.g. composition and speed) and road (e.g. gradient and surface type).

To calculate the noise level at a receiver position, the CRTN method segments the roads being modelled into multiple discrete line sources and calculates the contribution from each segment to the noise level at the receiver position. CRTN adjusts the source emission level for distance from the edge of a nearside carriageway to the receiver location, angle of view of the road from the receiver location, proportion of “absorptive” ground cover, diffraction attenuation and reflection effects. The CRTN method bases its calculations at the receiver, compared with other methods that calculate from the source and using propagation models to calculate the spread of noise from the source to receivers.

The CRTN method was designed to be available to a wide range of users and its charts and simple correction formulae can be used manually. The CRTN method is available through third-party software platforms. It is noted that implementing the CRTN method (by example) to situations of topography and screening, as enabled by software platforms, can require the software developers to devise their own modelling rules where the method does not itself include procedures that fully handle the complexity.

The CRTN method is described in DoT, U. K. (1988). Department of Transport. Calculation of Road Traffic Noise (CRTN). London: Department of Transport, Welsh Office, HMSO. This is the primary reference used in populating section 3 for the CRTN method.

2.2. Nord2000 (joint Nordic noise prediction method)

Nord2000 is primarily a calculation method for prediction of noise propagation outdoors.

The Nord2000 method contains one model for calculating road noise emissions and a second, separate, model for calculating noise propagation (from any source) to find the noise level resulting at receivers. Development of the NORD2000 method focused on accurately modelling the physical phenomena behind noise emission and propagation, and as such it is possible to account for meteorological effects in the propagation calculation. In some complex cases adjustment factors have been used to correct noise levels rather than using physically correct models. Both the emission and propagation models use noise levels in 1/3 octave bands as opposed to a broadband noise level.

The emission model treats vehicles as a cluster of point sources (for tyre noise, engine noise etc) with different emission properties depending on vehicle class, vehicle speed, road surface etc. Propagation of these emissions for different traffic classes, speeds and metrological conditions are used to calculate noise exposures from different road segments. The contribution from these segments is then combined to calculate noise levels at the receivers.

Several software platforms are available to implement the Nord2000 method.

The selection of Nord2000 for this project includes consideration that its predecessor, the Nordic model, was found to be the most accurate of four calculation methods included in work undertaken in 1999 on “Validation of L_{eq} models for road noise assessment in New Zealand”[1]. Though the Nord2000 method represents significant revision upon the Nordic model as it was in 1999, it may retain the attributes that made the Nordic model perform well in calculating New Zealand road-traffic noise levels.

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[1] Dravitzki, V., and C. Wood, 1999. Validation of L_{eq} models for road noise assessment in New Zealand. *Transfund New Zealand Research Report No. 121.* 33pp.
The four calculation methods were Nord2000, CRTN (UK), CETUR (France), and the FHWA Traffic Noise Model (US).

The Nord2000 method is described in Kragh, J., Jonasson, H., Plovsing, B., Sarinen, A., Storeheier, S., & Taraldsen, G. (2006). User's Guide Nord2000 Road. Delta, SINTEF, SP and VTT. This is the primary reference used in populating section 3 for the Nord2000 method.

2.3. CNOSSOS-EU ("Common Noise Assessment Methods in Europe")

CNOSSOS-EU was a European Project from 2010 to 2015 and is also the name of the noise calculation method resulting from that project. The CNOSSOS-EU method is capable of modelling road traffic, rail, aircraft, and industrial noise sources. The core road-traffic noise methodology was established earlier by the HARMONOISE project (2001-05), and the road-traffic source data largely derives from IMAGINE (2003-2006). EU Directive 2015/996 made CNOSSOS-EU the European standard noise method for strategic noise mapping, including road-traffic noise.

The CNOSSOS-EU method features separate source and propagation models. For road-traffic noise, the source includes a vehicle model and a traffic model (made up of many vehicles).

The vehicle model includes four classifications, broadly corresponding to the NZ Transport Agency's Economic Evaluation Manual classifications. The purpose of the vehicle model is to predict the sound power spectra of individual passing vehicles, and it distinguishes between "rolling noise" (e.g. mostly tyre/road) and "propulsion noise" (e.g. powertrain noise) in that calculation. Corrections for surface type, gradient, acceleration, tyre configuration, and so on can be applied on a per-vehicle-classification basis. This model is based on data from a large Europe-wide measurement effort during the IMAGINE project, and therefore reflects European vehicle fleets and road surfaces.

The traffic model takes the instantaneous sound power spectra of the individual vehicles at a specific location, speed, and classification, as defined by the vehicle model as an input, and integrates the contribution of each individual vehicle into a line source, according to the specified volumes and speeds of each vehicle classification.

The traffic sound power spectra are then propagated according to a derivative of the French NMPB road-traffic noise calculation method (factoring in atmospheric attenuation, refraction, reflections, ground absorption, etc) to determine receiver sound pressure levels and spectra. Either single point receivers or large areas can be evaluated, making the method suitable for noise assessments and large-scale noise mapping.

Since its standardisation in 2015, the CNOSSOS-EU method has been implemented by several noise software platforms.

The references primarily used in populating section 3 for the CNOSSOS-EU method are Stylianos Kephalopoulos, Marco Paviotti, Fabienne Anfosso- Lédée (2012). Common Noise Assessment Methods in Europe (CNOSSOS- EU) EUR 25379 EN. Luxembourg: Publications Office of the European Union, 2012, 180 pp. and Kephalopoulos, S., Paviotti, M., Anfosso-Lédée, F., Van Maercke, D., Shilton, S., & Jones, N. (2014). Advances in the development of common noise assessment methods in Europe: The CNOSSOS-EU framework for strategic environmental noise mapping. Science of the Total Environment, 482, 400-410pp.

2.4. TNM 3.0 (Federal Highway Administration Traffic Noise Model)

The TNM method is from the United States and sponsored by the Federal Highway Administration. It is included in this project as it has been used previously in New Zealand and the latest version of the method, TNM 3.0, was released in 2020. TNM method version 1.0 was released in 1998 and acoustical algorithms in the method have been substantially updated (at least twice) since version 1.0.

The TNM 3.0 method calculates emissions for five standard vehicle types and applies adjustments, such as speed and traffic volume to calculate a noise level at 15 m from the road. This noise level is adjusted for various propagation and attenuation effects. The method can account for intersections and gradients by adjusting the vehicle speed and modelling the acceleration effects.

The TNM method works similarly to many other methods where the roads are treated as line sources which are segmented and the contributions from each segment are combined at the receiver.

The TNM method contains data for four (asphaltic and/or concrete) road surfaces. Vehicle types can be adjusted for user-defined emissions. All noise calculations are done in 1/3 octave bands.

The TNM method can account for some variation in metrological effects (excluding wind) and accounts for sound propagation changing with distance and ground surface characteristics. Eight ground types are included in the method and further customisation is available.

The TNM method and user interface are freely available. The TNM method also has it its own Geographical Information System (GIS) interface or can be used through third-party software platforms.

The TNM 3.0 method is described on the website www.fhwa.dot.gov/environment/noise/traffic_noise_model/tnm_v30/ and this is the primary source for references used in populating section 3 for the TNM 3.0 method.

3. Evaluation of the methods

		CRTN	Nord2000	CNOSSOS-EU	TNM 3.0
	Method parameters				
1	**Source emission:** How is the road-traffic noise source defined? (Line v point, spectra v broadband, vehicle v stream, etc.)	The basic noise level is given by the traffic flow (1 hour or 18 hour) at a mean speed of 75 km/h with no heavy vehicles and zero gradient. The effective source position is 3.5 m in from the edge of the nearside kerb and 0.5 m high. The basic noise level is broadband, with no spectral information.	Each noise source on a vehicle is modelled individually (tyre, engine etc). Multiple point sources at different heights are attributed to each vehicle. Sound power level is derived from pass-by measurements with the result normalised to 10 m. The method provides 1/3rd octave band results from 25 Hz to 10 kHz.	Sound power levels for vehicle classifications (in terms of rolling and propulsion noise) are combined into traffic streams using a single emission line height. Calculations are performed in octave bands for road-traffic noise from 125 Hz to 4 kHz.	Reference sound levels are established the vehicle types and two flow conditions (cruise and full throttle).. The reference sound levels are used to calculate the noise level resulting from a single lane of single vehicle type traffic at a receiver. This calculation is then repeated for all combinations of lanes and traffic types. Calculations are in 1/3rd octave bands from 50 Hz to 10 kHz.
		Neutral: while New Zealand does not have applications requiring spectral content, there may be little distinction between methods using broadband noise levels compared with those offering spectral content.	**Slight positive:** detailed representation of source and spectral nature of road-noise.	**Slight positive:** detailed representation of source and spectral nature of road-noise.	**Slight positive:** detailed representation of source and spectral nature of road-noise.
2	**Traffic flows:** Does the method provide for interrupted (intersections) and uninterrupted traffic flows?	Traffic flow is assumed at the average traffic speed of the uninterrupted traffic flow, right through the intersection. There is no distinction between control type at the intersection.	The component of the source noise for propulsion is corrected by +3 dB for urban and start/stop scenarios.	The method includes acceleration and deceleration corrections for each vehicle classification and can manage interruptions such as signalised intersections and roundabouts.	Manages all interruption types, such as signalised or non-signalised intersections and roundabouts.
		Negative.	**Positive.**	**Positive.**	**Positive.**

		CRTN	Nord2000	CNOSSOS-EU	TNM 3.0
3	**Traffic volumes:** Does the method have recommendations for lower/upper traffic volumes?	Minimum 1,000 vehicles per 18-hour day.	No lower or upper traffic volume as each vehicle is modelled specifically.	No lower or upper traffic volume as each vehicle is modelled specifically.	No lower traffic volume.
		Negative: this is too high for a lot of New Zealand roads.	**Neutral.**	**Neutral.**	**Neutral.**
4	**Traffic volumes:** Is traffic entered as a daily total or hour-by-hour profile?	Hour-by-hour or method expects an 18-hour daily total	Hour-by-hour or daily total, depending on outputs required.	Hour-by-hour.	Hour-by-hour.
		Slight negative: some users may input an 18-hour traffic volume and some users may input a 24-hour traffic volume.	**Neutral:** hour-by-hour data may be unavailable in many New Zealand situations so assumptions would likely be required.	**Neutral:** hour-by-hour data may be unavailable in many New Zealand situations so assumptions would likely be required.	**Neutral:** hour-by-hour data may be unavailable in many New Zealand situations so assumptions would likely be required.
5	**Vehicle types**: What vehicle classifications does the method use, or what assumptions and customisations are available to align with the New Zealand vehicle fleet?	The CRTN method assumes light vehicles and adjusts for the percentage of heavy vehicles in the traffic flow. The source height is 0.5 metres for all vehicle types (in the native method).	The NORD2000 method has input parameters for light, medium, and heavy vehicles Source heights for different vehicle types and noise sources are 0.01, 0.3, and 0.75 metres and an extra source height of 3.5 for exhausts of heavy vehicles.	Powered 2-wheelers, light vehicles, MCVs, and HCVs, corresponding very closely to the NZ EEM classifications, and “other vehicles” as a placeholder for electric vehicles. The source height is 0.05 metres above the road surface.	Five vehicle types; Automobiles, medium trucks, heavy trucks, motorcycles, and buses. User-defined vehicle types are also available. Source heights for different vehicle types and noise sources are 0, 1.5, and 3.7 metres above the road surface.
		Slight positive: New Zealand data to fulfil these classifications is reliable and available, generally.	**Neutral:** New Zealand data to fulfil these classifications may be available or some assumptions may be needed.	**Neutral:** while many vehicle types are available in the method, the value may be negligible as assumptions would generally be required to fulfil these five classifications with New Zealand data.	**Neutral:** while many vehicle types are available in the method, the value may be negligible as assumptions would generally be required to fulfil these five classifications with New Zealand data.

		CRTN	Nord2000	CNOSSOS-EU	TNM 3.0
6	**Road gradient:** How does the method manage source noise on road gradients?	Gradient correction to the basic noise level applies only for the upward flow. The method notes alternative procedures may be appropriate in the case of a one-way flow downhill on gradients exceeding 10 %.	The method can alter the propulsion component of source noise for medium and heavy vehicles for upward and downward gradients.	A broadband correction is made to the propulsion component of each vehicle classification, accounting for upward and downward gradients.	Method computes adjusted speeds based on upgrade gradient and length.
		Slight negative: this appears an over-simplification, based on observations and the approach of other accepted noise calculation methods.	**Slight positive:** more realistic representation of noise generation.	**Slight positive:** more realistic representation of noise generation.	**Slight negative:** this appears an over-simplification, based on observations and the approach of other accepted noise calculation methods.
7	**Road surface corrections:** How is the reference road surface defined? (Frequency spectra or total noise level?)	Conventional dense-graded asphaltic concrete surfacing of 2 mm texture depth is assumed to have a surface correction of 0 dB at speeds where the mean traffic speed is ≥ 75 km/h and –1 dB where the mean traffic speed is < 75 km/h. There is no spectral information for the reference road surface.	The reference road surface is defined for Denmark and is an average of dense-graded asphaltic concrete (DAC 11) and stone mastic asphalt (SMA 11) with controls on age and temperature. Other Nordic countries have an additional road surface correction to this reference road surface. The reference road surface can be defined by 1/3rd octave bands or the total A-weighted value.	A "virtual reference surface" representing the average noise octave spectra from dense-graded asphaltic concrete (DAC 11) and stone mastic asphalt (SMA 11).	The reference road surface is defined using data combined from dense-graded asphaltic surfaces and concrete surfaces.
		Neutral: the reference road surface type is not common in New Zealand, but a relationship between New Zealand's asphaltic concrete and the reference road surface was established in 1994.	**Slight negative:** to replicate the reference road surface would require measurements on two road surfaces (and possibly also preferably air temperature of 20 °C), and there appears to little use of dense-graded asphaltic concrete in New Zealand.	**Slight negative:** to replicate the reference road surface would require measurements on two road surfaces, and there appears little use of dense-graded asphaltic concrete in New Zealand.	**Negative:** to replicate the reference road surface would require measurements on two road surfaces. There appears little use of dense-graded asphaltic concrete in New Zealand and there are very few concrete road surfaces in New Zealand.

		CRTN	Nord2000	CNOSSOS-EU	TNM 3.0
8	**Road surface corrections**: Are road surface corrections customisable or available to align with New Zealand road surfaces?	A customisable correction is used to correct for road surface. These are based on pass-by tests compared with the reference surface.	17 road surface types/corrections are given, including five chip seals. Road surface corrections can be user-defined. The method suggests corrections are determined by pass-by tests to collect the data for comparison with the reference surface. The change in pass-by noise level caused by a change in temperature should also be determined and stated.	Road surface corrections are suggested for a range of surfaces and corrections can be user-defined.	Four road surface types/corrections are given, representing concrete, dense-graded asphalt, open-graded-asphalt, and the “combination” reference surface. No chip seal surfaces are built-in. The method does not directly provide for user-defined road surface corrections. However, the method allows for user-defined vehicles which duplicate the spectral shape and sub-source heights of one of the built-in vehicle types and the user can define the overall noise level. This effectively provides for inclusion of other road surfaces, it is considered.
		Neutral: corrections can be customised.	**Neutral:** corrections can be customised.	**Neutral:** corrections can be customised.	**Negative:** data collection and the algorithms would need to be well understood to develop reliable road surface corrections.
9	**Special conditions:** Does the method allow for special conditions such as wet roads, engine braking, or user-defined conditions?	No.	Corrections are available for wet roads and studded tyres. The number of axles can be defined for heavy vehicles.	Corrections are available for wet roads and studded tyres.	No.
		Neutral.	**Slight positive.**	**Slight positive.**	**Neutral.**

		CRTN	Nord2000	CNOSSOS-EU	TNM 3.0
10	**Reflections:** How does the method generally manage reflections?	CRTN provides a correction for reflections where there are houses, other substantial buildings or a noise barrier beyond the traffic stream on the opposite side of the road. The method does not take account of absorption characteristics of surfaces.	Reflections are generated by vertical or nearly vertical surfaces and taken into account as separate sound paths. It seems reflections are not calculated from horizontal (non-ground) surfaces. Effect of absorption characteristics of surfaces can be included.	Reflections are generated by vertical or nearly vertical surfaces and taken into account as separate sound paths. It seems reflections are not calculated from horizontal (non-ground) surfaces. Effect of absorption characteristics of surfaces can be included.	TNM calculates reflected noise, but it is limited to reflections from vertical or nearly vertical surfaces such as far-side barriers and retaining walls. Reflections are not calculated from horizontal (non-ground) surfaces such as the underside of bridges. Effect of absorption characteristics of surfaces can be included.
		Neutral for most New Zealand situations. (In its native form, CRTN may omit some reflections.)	**Neutral** for most New Zealand situations	**Neutral** for most New Zealand situations	**Neutral** for most New Zealand situations
11	**Ground effect:** Are ground effect assumptions and options available to align with New Zealand?	The method makes an adjustment for the proportion of sound-absorbing ground between the nearside carriageway and the receiver	The method accounts for reflections from the ground and has 7 in-built ground options, based on flow resistivity.	The method accounts for reflections from the ground and has 8 in-built ground options.	The method accounts for reflections from the ground and has many in-built ground options based on flow resistivity.
		Slight negative: this may be a bit coarse and not represent sound reflections from the ground, but may not significantly affect the method's results.	**Neutral.**	**Neutral.**	**Neutral.**

		CRTN	Nord2000	CNOSSOS-EU	TNM 3.0
12	**Spread**: How far from the source can the method be applied?	The CRTN method suggests 4 to 300 metres from source. Supplementary advice suggests the method can be used for up to 600 metres from source but the order of uncertainty is not given, and likely to be high.	The Nord2000 method can be used with uncertainty in the order of ± 1 dB over 400 metres and in the order of ± 2 dB over 1,000 metres.	The propagation method applies for distances up to at least 300 metres from the source.	The TNM 3.0 method can be used with uncertainty in the order of ± 1.5 dB over 150 metres.
		Slight positive: the method covers the spread required for New Zealand road-traffic noise assessments to NZS 6806.	**Slight positive:** the method covers the spread required for New Zealand road-traffic noise assessments to NZS 6806.	**Slight positive:** the method covers the spread required for New Zealand road-traffic noise assessments to NZS 6806.	**Slight negative:** the method may be less reliable towards the edge of coverage required for New Zealand road-traffic noise assessments to NZS 6806.
13	**Meteorological effects:** How does the method manage wind and temperature effects on noise emission and propagation?	Negligible, in the CRTN method constant conditions are assumed consistent with moderately adverse wind velocities and directions.	The Nord2000 propagation model accounts for temperature and simple wind conditions. This can assist with calibration between calculated noise levels and measured noise levels. Air temperature is an input parameter. For calculating average noise levels, the average temperature can be used.	The CNOSSOS-EU method expects inputs of temperature and wind conditions. The method can manage temperature gradients, wind gradients, and statistical data on meteorological conditions however it appears possible to input more simplistic data using some assumptions. The method can calculate for homogenous, favourable, and unfavourable conditions.	Air temperature and relative humidity are input parameters to the TNM method.
		Slight negative: the effect of wind on road-traffic noise assessments is often raised in consenting processes but the CRTN method does not provide much information to resolve the questions.	**Slight positive:** if the type of information available in New Zealand (such as regional wind roses and air temperatures) improves the realism of calculations or allows the testing of conditions.	**Slight positive:** if the type of information available in New Zealand (such as regional wind roses and air temperatures) improves the realism of calculations or allows the testing of conditions.	**Slight negative:** the effect of wind on road-traffic noise assessments is often raised in consenting processes but the TNM method does not provide much information to resolve the questions.

		CRTN	Nord2000	CNOSSOS-EU	TNM 3.0
14	**Caveats:** Does the method have known technical limitations or caveats?	The core CRTN method uses several simplifications that are non-physical. Some roading features now common were not accounted for in the 1988 publication of CRTN. In 2008 and 2011 the UK Highways Agency has provided additional advice for using CRTN in situations such as dual source lines, median barriers, and vehicle classification. Where CRTN is non-specific in its handling of situations, software platforms develop their own interpretations and methods. These may be explicitly stated in the software documentation or can be considered Intellectual Property and not shared.	The NORD2000 method expects some complex input information, including the metrological data and surface information for the ground or obstacles. Assumptions or generalisations could be used where only basic information is available for the modelled situation (or where no information is available). Each acoustician using the NORD2000 method may follow a different approach leading to difficulty in achieving reproducible results.	The CNOSSOS-EU method expects some complex input information, including the metrological data and surface information for the ground or obstacles. Assumptions or generalisations could be used where only basic information is available for the modelled situation (or where no information is available). Each acoustician using the CNOSSOS-EU method may follow a different approach leading to difficulty in achieving reproducible results.	The absence of chip seal surfaces within the in-built surfaces is noted. Prior to TNM 3.0, supplementary guidance on the application of the TNM method was prepared to assist in accurate, consistent, and efficient use of the method. It is not known whether this guidance remains valid for TNM 3.0.
	Support				
15	**Latest revision:** When was the method developed or most recently reviewed and/or revised?	The CRTN method was published in 1988 and additional advice given in 2008 and 2011 by the UK Highways. Agency.	NORD2000 was released in 2006.	Directive (EU) 2015/996 was the first and latest release of the CNOSSOS-EU method. Further releases are expected as development work continues.	TNM 3.0 was released in 2020.
		Negative.	**Neutral.**	**Slight negative:** the method may be still evolving.	**Neutral.**

		CRTN	Nord2000	CNOSSOS-EU	TNM 3.0
16	**Local validation**: Is there guidance or precedent for validating the method for New Zealand application?	The CRTN method is currently the method most commonly used in New Zealand. It has been formally validated in 1994 for New Zealand application.	No known guidance or precedent for validation of the model for New Zealand application. The method includes potential of correction for road surfaces, air temperature, ageing, and country (Denmark, Finland, Norway, Sweden), so there is potential for the method to be validated for New Zealand.	The method is fundamentally strong at localisation, having been developed and adopted across the EU.	No known validation of TNM 3.0 for New Zealand application. Previous versions of the TNM method have some limited use in New Zealand. There is guidance on how to take measurements suitable for TNM validation. (The TNM method is used in some Australian states.)
		Positive.	**Slight positive.**	**Slight positive.**	**Neutral.**
17	**Documentation:** Does the method have full documentation (in English) and database available?	Full documentation for the CRTN method is available. Where CRTN is non-specific in its handling of situations, software platforms develop their own interpretations and methods. These may be explicitly stated in the software documentation or can be considered Intellectual Property and not shared.	A NORD2000 user manual is available. The method is intended to be applied through software platforms. Software platforms develop their own interpretations and methods. These may be explicitly stated in the software documentation or can be considered Intellectual Property and not shared.	The method has been well documented by project partners. As the method is new and subject to further development, more documentation will follow.	User and technical manuals are freely available. TNM 3.0 was released in 2020 with updated user and technical manuals available. Information supporting earlier versions of the TNM method remains available and sometimes it can be unclear whether the information remains valid for all TNM versions or has been superseded.
		Neutral.	**Neutral.**	**Neutral.**	**Neutral.**

		CRTN	Nord2000	CNOSSOS-EU	TNM 3.0
18	**Documentation:** Are the method's underlying equations or relationships available?	The CRTN method equations and tables are published. Where CRTN is non-specific in its handling of situations, software platforms develop their own interpretations and methods. These may be explicitly stated in the software documentation or can be considered Intellectual Property and not shared.	Equations are available in the NORD2000 users' guide and background reports.	The equations for this method are publicly available.	The equations for TNM 3.0 are publicly available.
		Slight negative.	**Positive.**	**Positive.**	**Positive.**
19	**Support**: Is there support readily available for learning the method or troubleshooting? (May be formal support or "common" support through wide usage of the method?)	CRTN is widely used in NZ and there is a body of expertise here now. Some level of support is available through software platform providers.	While the NORD200 method has support documentation, it is intended to be applied through software platforms The method is used in Nordic countries so support is assumed available through contacting users there or through software platforms.	There is current activity across Europe implementing the CNOSSOS-EU method and an increasing body of publications.	The method is implemented throughout the US and many states have their own implementation guidance.
		Positive.	**Slight negative.**	**Neutral.**	**Neutral.**

		CRTN	Nord2000	CNOSSOS-EU	TNM 3.0
	Compatibility				
20	**Adaptability**: Is the method constrained to the region/context from which it originated? Are there vehicle fleet, road characteristics, legislative requirements embedded in the method that may affect its use in New Zealand?	The CRTN method was designed for UK usage and based on measurements from UK in the 1970s and 1980s. The method seems readily adaptable for usage in other contexts due to its simplicity and openness.	The Nordic countries make use of rougher-textured road surfaces similar to those in New Zealand. The NORD2000 method is adapted for use across the Nordic countries, suggesting it is also readily adaptable for New Zealand.	The CNOSSOS-EU method is designed to be adopted and adapted by various countries across Europe, suggesting it is also readily adaptable for New Zealand. The method provides for vehicle types and road surfaces representative of those in New Zealand.	The TNM method does not natively represent chip seal road surfaces, the most common road surface type in New Zealand. The method is adopted in states across the US but "adaptation" of the method appears limited.
		Positive: noting re-validation of the method could be done to ensure the method continues accurately represent New Zealand conditions.	**Neutral:** guidance may exist that is suitable for adapting the method for a New Zealand context.	**Slight positive:** guidance likely exists that is suitable for adapting the method for a New Zealand context.	**Negative:** the assumptions and adaptability of the TNM method are unclear with respect to the New Zealand context.
21	**Local indices:** Does the method output indices relevant to New Zealand requirements or have established conversions for indices relevant to New Zealand requirements? Can other indices be derived from the method?	The native CRTN method calculates $L_{10(1h)}$ and $L_{10(18h)}$ noise levels. These indices have been related to other indices, such as $L_{Aeq(24h)}$ and L_{den}.	The NORD2000 method parameters can be inputted on an hour-by-hour basis so the method can calculate many indices such as L_{Aeq}, L_{Aday}, $L_{Aevening}$, L_{Anight}, and L_{Aden}.	The CNOSSOS-EU method parameters can be inputted on an hour-by-hour basis so the method can calculate many indices such as L_{Aeq}, L_{Aday}, $L_{Aevening}$, L_{Anight}, and L_{Aden}.	The TNM 3.0 method parameters can be inputted on an hour-by-hour basis so the method can calculate many indices such as L_{Aeq}, L_{Aday}, $L_{Aevening}$, L_{Anight}, and L_{Aden}. Indices such as L_{A10} and L_{A50} are used in some noise limits across the US and the TNM 3.0 method calculates these.
		Slight negative: ideally the method would natively calculate the $L_{Aeq(24h)}$ index commonly used in New Zealand road-traffic noise assessments (or other indices that may be adopted in the future).	**Slight positive:** all indices possibly relevant to New Zealand now or in the future can be calculated. Indices such as L_{A10} and L_{A50} should be readily calculable.	**Slight positive:** all indices possibly relevant to New Zealand now or in the future can be calculated. Indices such as L_{A10} and L_{A50} should be readily calculable.	**Slight positive:** all indices possibly relevant to New Zealand now or in the future can be calculated.

		CRTN	Nord2000	CNOSSOS-EU	TNM 3.0
22	**Other noise sources:** Does the method integrate with methods for noise from other modes/sources? Such as rail noise or wind turbines.	A Calculation for Rail Noise (CRN) method exists, developed similarly to the CRTN method. There is no information in the CRTN method regarding integration with the CRN method.	The propagation model is separate from the road-noise source model. Nordic methods are available for noise sources such as air traffic, wind turbines, and rail traffic.	CNOSSOS-EU can model road traffic, rail, aircraft, and industrial noise.	FHWA, the sponsor of the TNM method, is responsible for road-traffic noise only. Integration with noise models for other modes is unknown.
		Neutral.	**Positive.**	**Positive.**	**Neutral.**
23	**Other effects:** Does the method integrate with methods for other environmental effects, such as vibration or air quality?	No integration found.	No integration found.	No integration found.	No integration found.
		Neutral.	**Neutral.**	**Neutral.**	**Neutral.**
24	**Spatial mapping:** How compatible is the method with spatial mapping?	Software platforms develop their own spatial mapping implementation of the CRTN method. The interpretations and methods used may be explained in the software documentation or considered Intellectual Property and not shared.	Software platforms develop their own spatial mapping implementation of the NORD2000 method. The interpretations and methods used may be explained in the software documentation or considered Intellectual Property and not shared.	The CNOSSOS-EU method was developed in response to the END/2002 requirement for spatial noise mapping, and can perform that task.	The TNM 3.0 method's native software does spatial mapping.
		Slight negative.	**Slight negative.**	**Neutral.**	**Neutral.**
25	**Software:** Does the method have its own software or are there multiple software providers?	The CRTN method was designed for manual implementation and is now provided through multiple software platforms.	The NORD2000 method is intended to be applied through software platforms and there are multiple providers.	The CNOSSOS-EU method is intended to be applied through software platforms and there are multiple providers.	The TNM 3.0 method has native software and is also provided through multiple software platforms.
		Neutral.	**Neutral.**	**Neutral.**	**Slight positive.**

		CRTN	Nord2000	CNOSSOS-EU	TNM 3.0
26	**Online calculator:** Can basic calculations with the method be expressed in a way useful for non-experts, like the existing NZTA road-traffic noise calculator?	The CRTN method was designed for manual implementation. The Waka Kotahi NZ Transport Agency existing road-traffic noise calculator helps users both experienced and inexperienced with noise assessment.	The NORD2000 method was designed for computer implementation but equations are available so it would be possible, with assumptions and caveats, to produce a simplified calculation tool for basic situations.	The CNOSSOS-EU method was designed for computer implementation but equations are available so it would be possible, with assumptions and caveats, to produce a simplified calculation tool for basic situations.	A “low volume road tool” version of the TNM method already exists, probably with assumptions and caveats compared with the full TNM 3.0 method as designed for computer implementation.
		Positive: the current Waka Kotahi NZ Transport Agency online tool is well-used.	**Neutral:** the algorithms are complex and may not lend themselves to simplification.	**Neutral:** the algorithms are complex and may not lend themselves to simplification.	**Slight positive.**

4. Commentary

The CRTN method appears to be performing adequately as the road-traffic noise calculation method most commonly used in New Zealand. Notably, the software platform SoundPLAN is very often used with the CRTN method for road-traffic noise assessments of larger roading projects in New Zealand and typically the maximum calculation distance used is only about 200 metres from roadside.

The other road-traffic calculation methods evaluated in this project contain technical advancements and manage complexity the CRTN method was not designed for.

- Software platforms are used to implement road-traffic noise calculation methods. Where the method is not explicit in its handling of situations, the software platforms develop their own interpretations and methods.

  For CRTN it is likely that software platforms add considerably to the original method. This has a positive effect on extending application of the method and effectively adding capability to CRTN to be more like capabilities of NORD2000, CNOSSOS-EU, and TNM 3.0.

  However, reproducibility of CRTN between software platforms may be compromised, given its reliance on interpretations and methods of the software platforms. By example, implementation of CRTN through SoundPLAN may calculate noise levels different from manual calculations using CRTN or implementation of CRTN through a different software platform.
- Additional input requirements are implied by the complexity offered by methods such as NORD2000, CNOSSOS-EU, and TNM 3.0, for example hour-by-hour traffic flows or statistical data on wind flows. Appropriate New Zealand data may not be readily available, requiring the acoustician to make decisions and assumptions to fulfil the input requirements. This may affect the noise level calculations and compromise review or reproducibility of calculations between acousticians. New Zealand guidance on fulfilling input requirements could resolve the issues but would need to be comprehensive and may be a substantial undertaking.

For now, New Zealand may choose to proceed with CRTN as the most commonly used road-traffic noise calculation method.

- In the UK, a discussion like the topic of this project is underway. A British Standards Institute committee is considering the need for, and potential scope of, a new standard for calculating noise levels outdoors. Road-traffic noise and rail noise are the initial focus with the potential for expansion to other noise sources. The committee has acknowledged a completely new method would likely take years to develop. The committee is considering adoption of a different noise calculation method such as CNOSSOS-EU, and considering continuing or adapting current use of the CRTN method.
- Australia does not appear to have a coordinated discussion regarding road-traffic noise calculation methods. The CRTN method (with local procedures) is used in Australia and the TNM method is used in some states.

If New Zealand proceeds with the CRTN method:

- Re-validation of the CRTN method for New Zealand application should be considered.

  Validation of the CRTN method for New Zealand application dates from 1994 and 1999. Road surfaces and vehicle types have changed since then, and the distances over which it is applied have increased.
- Other methods may be used to complement the CRTN method.

  The NORD2000 method or the CNOSSOS-EU method may be used to complement the CRTN method, so road-traffic noise assessment could generally continue using the CRTN method but the other methods would be used in a research capacity to provide corrections or add interpretation to the CRTN method calculations.

Intersections and roundabouts are an example. CRTN makes no adjustments for such flow interruptions but other methods do calculate these effects. There may be potential for a research project to use the NORD200 method or CNOSSOS-EU method alongside the CRTN method to develop rules or factors for adjusting noise levels calculated with the CRTN method to be more representative of actual road-traffic noise levels.

The effect of wind on road-traffic noise assessment is an issue often raised by submitters to consenting processes. The CRTN method uses a constant assumption about wind but specific wind conditions can be input to other methods. There may be potential for a research project to use the NORD2000 method or CNOSSOS-EU method alongside the CRTN method to develop “tolerances” to put around noise levels calculated with the CRTN method to represent how actual road-traffic noise levels may fluctuate with wind conditions.

If New Zealand was to adopt a method other than the CRTN method, either the NORD2000 method or CNOSSOS-EU method appear options to investigate. CNOSSOS-EU will have wide adoption throughout Europe once it is fully developed. The NORD2000 method and CNOSSOS-EU method appear more readily adaptable to New Zealand application than the TNM 3.0 method.