VALIDATION OF L_{eq} MODELS FOR ROAD NOISE ASSESSMENT IN NEW ZEALAND

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EXECUTIVE SUMMARY

Introduction

Models that can accurately predict the noise level from road traffic are a necessary part of evaluating the effects of proposed roading projects. Accuracy is important, as the results influence the provision made for noise mitigation, and many resource consents now require a noise performance standard to be met when a road is in operation.

At present (1999), the Calculation of Road Traffic Noise model (CRTN) is the main model used in New Zealand. This model was validated for New Zealand use in Transit New Zealand Research Report No. 28, *Traffic Noise from Uninterrupted Traffic Flows*. However, CRTN uses the noise index L_{10} (18 hour) which excludes traffic late at night, and the L_{10} (18 hour) index is an ad hoc rather than a true scientific unit.

The equivalent noise level (symbol L_{eq}) is a form of average noise level. For traffic, it is used in the form of a 24-hour average value (L_{eq} (24 hour)). It is the continuous sound which has the same energy as all the instantaneous and fluctuating sounds over a time period.

Several models which use the L_{eq} (24 hour) index were evaluated in this study. These models were from Scandinavia (the Nordic model), France (CETUR model), and the USA (FHWA model). A modified CRTN model was also trialled, as well as a simplified version of CETUR. The CRTN L_{10} (18 hour) model was included to provide a benchmark of performance.

All these models are similar in form. There is a base noise level, usually the L_{eq} value of a single vehicle, with separate values for trucks and for cars. This base level is then modified for speed and for traffic volume. The influence of road gradient is usually included. The base noise level will be for a point near the roadway, e.g. 10 m from the centreline.

Measurements made at any other distance need to allow for the drop-off in noise with distance and for the increased drop-off over soft ground. The length of the road segment causing the noise is included by an expression which incorporates the angle subtended by the ends of the segment at the receiver.

Method

This evaluation was undertaken in 1998 by first making detailed measurements of noise levels and of traffic volumes, including the percentage of heavy traffic on a hour-by-hour basis over a full 24-hour period at each of 20 sites in the Wellington region. The sites selected included a range of speeds (50 to 100km/h), traffic volumes (2,000 to 30,000 ADT), and surface types (friction course and chipseal), as shown in the table below.

Measurements were made over the period February to April 1998 in fine conditions with low wind.

Road Type	Speed (km/h)	Road Surface	No. of Sites	Typical Daily Traffic Volumes
Motorway	100	Friction course	3	30,000
Highway, high % heavy vehicles	100	Chipseal	6	3000 - 12,000
Highway, low % heavy vehicles	100	Chipseal	4	1000 - 20,000
Urban arterial	70	Friction course	1	20,000
	70	Chipseal	3	6000 - 30,000
Urban street	50	Chipseal	3	2000 - 14,000

In fitting the models, one major influence was the corrections made to the noise level to account for the road surface. At speeds of between 40 and 70 km/h the mean source of traffic noise changes from engine noise at low speeds to tyre/road interaction noise at higher speeds. Three of the models, Nordic, CRTN (New Zealand) and CRTN (UK), have corrections for road surface. The table below shows the average correction for each of the site groups in this study.

Site Group	Model Type		
	Nordic	CRTN (UK)	CRTN (NZ)
Motorway	–2.0	–3.5	–2.5
Highway, high % heavy vehicles	–0.3	–0.25	+3.7
Highways, heavy vehicles 3-6%	–0.25	–0.5	+2.1
Urban arterial (site 18 excluded)	0	–0.6	+1.4
Site 18	–1.0	–3.5	–3.8
Street	–0.3	–1.0	+0.5

While the surface correction for the Nordic and CRTN (UK) models (excluding friction course surfaces) are similar, the correction for CRTN is substantially greater and always more positive (i.e. the reading is increased). There is a major discrepancy between corrections for the Nordic model, which decrease with increasing volumes of heavy traffic, and the CRTN (NZ) which increases with increasing heavy traffic volume.

The first model fitted was the CRTN (NZ) to L_{10} (18 hour). This was to establish a benchmark for accuracy against which the other models could be compared.

Of the 20 sites, the CRTN (NZ) predicted eight sites within ±1 dBA, 15 sites within ±2 dBA, 18 sites within ±2.5 dBA, and 20 sites within ±3 dBA.

The sites which gave the most inaccurate predictions were the open highways with chipseal surfaces, and it appears that the surface corrections are a significant factor in causing over-predictions at these sites.

Fitting the L_{eq} models to the measured data gave the results shown in the table below, which shows the number of sites of the 20 which were within a specific range of the measured value.

Model	±1 dBA	±2 dBA	±2.5 dBA	±3 dBA
CRTN (UK)	6	12	17	18
CRTN (NZ)	8	15	18	20
Nordic	11	20	20	20
CETUR (detailed)	4	13	16	17
CETUR (simplified)	3	8	10	12
FHWA	7	12	13	15

The Nordic model gives the best fit, with all sites within ±2 dBA. It appears to be able to better accommodate variables in the site layout than the other models, and to have the more accurate adjustments for road surface effects.

The CRTN (NZ) model as a L_{eq}-type model gives a reasonable performance which is equal to that achieved by L_{10} (18 hour). Its inaccuracies in prediction seem to lie within its modified surface correction factors. These, while more appropriate than the UK correction factors, appear to over-correct for highways with chipseal surfaces.

The other two models (CETUR and FHWA) gave only moderate prediction accuracy, with just 13 and 12 sites respectively being predicted within ±2 dBA.

In comparison to the Nordic model, the CETUR and FHWA are the poorer performers. These models have no road surface corrections, and this particularly gives errors on the friction course surfaces. Both of these models simplify the site layout effects.

The most unreliable site type for predictions for all the models is the 100 km/h highway with chipseal surfaces and high heavy traffic volumes. This carries over, to a lesser extent, to highways with low heavy traffic volumes. Only Nordic and CRTN are satisfactory on motorways with friction course surfaces, and all models are reasonable on urban streets and arterials.

CRTN (NZ) (L_{10}) is unreliable where vehicle flows are less than 50 vehicles per hour, and on the sites in this study it was unreliable for less than 100 vehicles per hour. An analysis of the ability of the models to predict accurately at low traffic volumes showed that CRTN (NZ) (L_{eq}) and the Nordic model could predict equally as well for 1 hour traffic flows of 30 vehicles per hour and less, as they could for volumes greater than 100 vehicles per hour.

Unusually, the CETUR and FHWA were more consistent at the lower traffic volumes rather than the higher volumes.

Conclusions
The Nordic model provides accurate prediction of noise levels (within ±2 dBA) for typical New Zealand highways and urban roads in an open environment.

The next most reliable model is CRTN, when it is used to predict L_{eq} directly by reducing the model constants by 3 dBA, rather than first predicting L_{10}. However, this CRTN model does, however, need improved surface corrections to be developed.

The CETUR and FHWA appear to over-simplify ground effects, and not make sufficient allowance for road surface effects to give accurate predictions.

When used to predict L_{eq} (1 hour), the Nordic and the CRTN (NZ) models will give highly indicative values, even where the hourly traffic volumes are 10 or less.

Recommendations

- The Nordic model can be adopted in New Zealand in its current form for determining L_{eq} (24 hour) noise levels for substantially free-flowing traffic.

- Surface correction effects should be further investigated, as these are a major source of variability in traffic noise from roads. The extent of noise reduction from friction course in 70 km/h speed areas is a particular area requiring study, as models are under-predicting noise in this situation.

ABSTRACT

An evaluation of models which predict noise levels from road traffic in terms of the L_{eq} (24-hour) index was undertaken in 1998 by comparing predicted levels with noise levels measured at 20 sites. These sites included motorways, highways, urban arterials and urban streets in New Zealand.

Three main L_{eq} models were evaluated: the Nordic, the FHWA, and the CETUR models. In addition, the CRTN model was included as a L_{eq}-type model with both UK and New Zealand road surface corrections, and a simplified version of CETUR.

The Nordic model was able to correctly predict noise levels within ±2 dBA at all 20 sites. CRTN was able to predict L_{eq} (24 hour) to the same level of accuracy as L_{10} (18 hour), and predicted 15 sites. The CETUR and FHWA models were less successful, with only 65% correct predictions.

The L_{eq} models could give strongly indicative predictions (80% successful) for traffic flows as low as 10 vehicles per hour or less.

For successful prediction, accurate account needs to be taken of road surface effects on noise levels.

1. INTRODUCTION

The model most commonly used to predict road traffic noise in New Zealand is the Calculation of Road Traffic Noise model (CRTN), originally prepared in the United Kingdom (UK) by the Welsh Office of the Department of Transport. This model has been validated for use in Australia and in New Zealand with minor modifications. In New Zealand, additional modifications were prepared to correct for the effects of road surface.

The CRTN model predicts noise in terms of a noise index L_{10} (18 hour). L_{10} (18 hour) is the arithmetic sum of the noise level exceeded for 10% of the time in each hour of the 18 hours between 6.00 am and 12 pm midnight. The index is a purely empirical measure and is not a scientific term. It also has inadequacies. For example, in excluding the hours 12 midnight to 6.00 am, it can exclude the effects of heavy night-time traffic on those routes exposed to overnight truck movements.

The calculation of L_{10} cannot be applied to low traffic flows. Corrections must be applied to L_{10} (1 hour) for flows less than 200 vehicles per hour, and the measure becomes unreliable below flows of 50 vehicles per hour. The use of empirical noise indices is being replaced by the use of true scientific indices, such as the equivalent sound level L_{eq}. The Transit New Zealand *Guidelines for the Management of Road Traffic Noise – State Highway Improvements*, published as a draft in 1994, use L_{eq} (24 hour) as the noise index for road traffic. However, at this stage in New Zealand, L_{eq}(24 hour) needs to be estimated from L_{10} (18 hour) using the relationship L_{10} (18 hour) – 3 dBA = Leq (24 hour). This is slightly different from the relationship used in Australia of L_{10} (18 hour) – 3.5 dBA = L_{eq} (24 hour).

Previous studies (TNZ 1997) and Cenek (1978) had undertaken an evaluation of three L_{eq} models, namely the Nordic, the simplified CETUR model, and the FHWA model. These studies also included an evaluation of CRTN when used as a prediction model of L_{eq}. These evaluations had all used data obtained from 15 sites which were selected from the 100 sites used for the evaluation of the CRTN (L_{10}) model. While this analysis indicated a useful level of accuracy, the database had deficiencies as it had not been gathered with a view to validating L_{eq} type models.

In this current validation (1998), data on traffic flow, noise levels and site details were gathered as specifically required for input into these models.

2. MODELS FOR EVALUATION

Three models formed the main part of this evaluation: the Nordic model, the CETUR model (Detailed) and the FHWA model. Three further models were also included. These were the CETUR model (Simplified) and the CRTN model in two forms, one with the UK surface corrections and the other with the surface corrections for New Zealand developed during the validation of the L_{10} model.

Usually, CRTN would be regarded as a L_{10} model. L_{eq} is determined by first determining L_{10}, then subtracting 3 dBA to give L_{eq}. CRTN is regarded as inaccurate in predicting L_{10} for less than 50 vehicles per hour (vph), and the evidence gathered in this study supports this view. However, while L_{10}(predicted) is a poor match to L_{10} (measured), L_{10} (predicted) – 3 dBA is quite a good match to L_{eq} (measured). The equation for L_{10} (predicted) contains the constant 42.2. The expression $L_{10} - 3$ reduces this constant effectively to 39.2, a number very similar to the base levels of noise used in the other equations.

All the models have a common form. They assume that a road is a line source of traffic noise. The noise level is the sum of:

- a base level which has been established empirically,
- adjustments for volume of vehicles, and the number of heavy vehicles,
- adjustments for road gradient,
- adjustments for road surface type (some models only),
- corrections for noise reduction with distance,
- additional corrections for ground effects,
- corrections for angle of view (or segment angle).

The manner in which these adjustments are made, and the factors that are considered, vary among the models. Differences in performance are probably more related to the detail of how the corrections are determined rather than in the models' more general structure. In all of the models, except the detailed CETUR method, the factors can be determined by equations or by nomograms (graphs showing the relationships between the noise level and the input parameters, such as speed, number of vehicles and so on). For the detailed CETUR method, the underlying equations are not stated and the nomograms must be used.

The classification of vehicles differs for each model:

- The Nordic and CETUR models use two classes only: light vehicles and heavy vehicles (those with gross weight more than 3.5 tonnes).
- The CRTN model uses two classes: light vehicles and heavy vehicles (those with unladen weight greater than 2.5 tonnes).
- The FHWA uses three classes: light (two-axled and four-wheeled vehicles usually less than 4.5 tonnes), medium (two-axled six-wheeled vehicles usually between 4.5 tonnes and 12 tonnes), and heavy (three or more axles and a gross weight greater than 12 tonnes).

The CRTN model classes as trucks those vehicles with an unladen weight of 2.5 tonnes. The noise contribution of heavy vehicles is included in the same correction factor as mean vehicle speed.

The Nordic, FHWA and CRTN models further increase the noise level generated with an expression for road gradient, but consider only increasing gradient. In the CETUR model, the gradient factor is included in the base noise level selected. The CETUR model is the most detailed in this respect, as it includes a base noise value for cars and trucks on level surface, increasing gradient, and decreasing gradient, and for four modes of flow - accelerating, decelerating, free flow, and bunched (platoon-type) flow.

All models predict noise for a reference point near to the road edge:

- For the Nordic the position is 10 m from the centreline of the road.
- For FHWA it is a point 15 m from the centre of the lane under consideration.
- For CETUR it is a position 30 m from the road 'bed' and 10 m in the air. The CETUR model also assumes a road shape. So, for example, a two-lane road consists of two lanes totalling 7 m of a road bed of 12 m total width.
- For CRTN it is 10 m from the nearside carriageway.

All four models then deal with noise attenuation with distance. First, as a hard ground decrease (usually a 3 dBA decrease per doubling of distance), then with an additional modification for soft ground. The Nordic model considers the intervening ground in some detail in terms of the relative height of the source, ground and receiver. The FHWA model considers the intervening ground only in broad terms and detailed features of the terrain are not considered.

The CETUR model has a number of nomograms to cover the different ground configurations. However, these are broad-banded so that they too become over-simplified. For example, a single road when level, or elevated, or depressed by up to 2.5 m, is considered by the one nomogram. CRTN includes corrections for soft ground which are based on the average propagation height.

Each model reduces the noise for locations where the road segment subtends an angle less than180 ° by the similar expression log (θ/180). For the Nordic and FHWA models, both the perpendicular distance to the road and the distance to the midpoint of the road segment are used in the calculation.

All models contain factors to account for barriers and screens, but in this evaluation sites were selected to avoid these effects as the aim was to assess the noise generation rather than the noise attenuation parts of the model.

Two of the models (Nordic and CRTN) contain corrections for the road surface, and two do not (CETUR and FHWA). The effect of these surface corrections is discussed in Section 3 of this report.

3. CORRECTIONS TO MODELS

As stated in Section 2 of this report, some of the models contained corrections for the road surface type and some did not. Fitting the models to the measured data highlighted the fact that the road surface correction applied is probably the most critical factor in determining whether a model is sufficiently accurate.

Neither the detailed CETUR model nor the FHWA model contain road surface corrections. The simplified CETUR model contains road surface factors within other parameters, such as heavy vehicles and road gradient, because the heavy vehicle equivalence factor is selected, among other things, on the basis of road type (such as urban street, motorway, and so on).

The Nordic model has an annex of road surface corrections which may be used, if desired, in conjunction with the model. These corrections are expressed as ± an integer (whole number), usually between ±2, selected from a table which shows corrections to be applied for a range of heavy traffic percentages and vehicle speeds. For some specialist surfaces, the corrections could be either +5 or –5 dBA.

The CRTN model (UK version) also has road surface corrections. In this UK version, the correction is expressed solely in terms of texture depth when speeds are greater than 75 km/h. Where speeds are less than 75 km/h, 1 dBA is deducted for impervious surfaces. For pervious surfaces, 3.5 dBA is deducted for all speeds. In practice, most corrections will be within the range +2 and –3.5 dBA.

The CRTN (UK) corrections have been modified for use in New Zealand by Barnes et al. (1994). The correction is:

$$1.65\log\left(\frac{\text{heavy vehicle percentage}}{\text{ratio of medium : heavy vehicles}}\right)+5.57C\left[0.77-\log\left(\frac{\text{sand circle reading}}{\text{speed}}\right)\right]-3.4X$$

Where C and X = 1 and 0 (for chipseal), or 0 and 1 (for friction course) respectively.

The ratio of medium to heavy vehicles is constrained to a maximum of 10. However, certain traffic mixes in this current study were found to give corrections of +7.5 or –5 dBA or greater. Therefore, corrections related to road surface effects have been further constrained to within ±4.0 dBA.

Both the Nordic and CRTN corrections have been applied to all of the models to see if a better fit of measured to predicted data could be obtained. In addition, both the New Zealand and UK corrections to CRTN were applied to the use of CRTN for L_{10} (18 hour) and L_{eq} (24 hour). It was found that the best fits were obtained for the Nordic corrections applied to the Nordic, the detailed CETUR and the FHWA models, and for either of the CRTN UK or New Zealand corrections applied to the CRTN model.

Table 3.1 below lists the surface correction used for each site. The New Zealand correction to CRTN is shown as a range as it is related to variables such as speed, heavy vehicle percentages, and ratio of medium/heavy to very heavy vehicles, so the correction to be applied varies hourly as these parameters also vary.

The Nordic and CRTN corrections applied are, to some extent, contradictory. The Nordic corrections applied tend to become smaller if greater than zero, or more negative if less than zero, as heavy traffic percentages increase. The CRTN model surface correction tends to increase as the heavy vehicle percentages increase, and is strongly influenced by the medium/heavy vehicle to very heavy vehicle ratio. The CRTN (UK) correction lies between these first two and is independent of the heavy vehicle contribution.

Table 3.1 Corrections to be applied for road surface type.

Site No.		Correction for Road Surface to be Applied to Models		
		Nordic	CRTN (UK)	CRTN (NZ)
1	Mazengarb Road	0	–1.0	0.8 to 1.5
2	Te Moana Road	–1	–1.0	0.3 to 2.0
3	SH2, Kaitoke	–1	–0.2	3.0 to 4.0
4	SH2, Birchville	–1	–1.6	0.3 to 2.6
5	Adelaide Road	0	–1.0	–0.6 to 1.8
6	Days Bay	–1	–1.0	–1.0 to 0.6
7	Ruahine Street	0	–0.3	0 to 1.9
8	SH2, Greytown	0	+0.2	3.2 to 4.0
10	SH53, Featherston	–1	–1.0	1.1 to 3.3
11	SH1, Tawa	–2	–3.5	–0.6 to –3.4
12	SH1, Paekakariki	–1	–0.3	3.5 to 4.0
13	SH57, Levin South	0	–0.9	2.3 to 4.0
14	SH57, Levin North	0	+0.1	4.0
15	SH1, Levin North	0	–0.4	4.0
16	SH1, Linden	–2	–3.5	–1.1 to –3.1
17	SH2, Belmont	–2	–3.5	0 to –3.5
18	Wainuiomata	–1	–3.5	–3.4 to –4.0
19	SH58, Judgeford	0	+0.1	2.0 to 4.0
20	SH2, Moonshine	+1	+0.5	3.1 to 4.0
21	Eastern Hutt Road	+1	+0.6	1.7 to 2.8

4. METHOD

Twenty sites were selected for the evaluation. These are shown in Table 3.1 (site 9 had to be abandoned and was replaced by site 13).

Table 4.1 Characteristics of the sites used for the evaluation of the models.

Road Type	Speed (km/h)	No. of Lanes	Road Surface	No. of Sites	Sites
Motorway	100	4	Friction course	3	11,16,17
Major highway	100	2	Chipseal	6	3,4,12,15,19,20
Secondary highway	100	2	Chipseal	4	8,10,13,14
Urban arterial	70	4	Friction course	1	18
Urban arterial	70	4	Chipseal	1	21
Urban arterial	70	2	Chipseal	2	2,7
Urban street	50	2	Chipseal	3	1,5,6

At each site, simultaneous measurements were made of noise levels, as 1-hourly L_{eq} level (with a main sound level meter and a backup meter), with traffic volume and speed recorded as 15-minute averages. The traffic counters were located about 50 m away from the noise meters to prevent the extra noise from the counters being traversed. Traffic measurements were made using the 20 NAASRA classifications. These were later consolidated to give light, medium and heavy vehicle counts.

Both noise and traffic measurements were made over the full 24-hour period. The study was undertaken during the period February to April 1998. Measurements were undertaken on days when conditions were fine with low wind. The sites were attended in daylight hours and the instruments were secured for overnight readings.

Measurement positions were nearly always more than 15 m from the nearest traffic lane. This was to ensure that the FHWA model could be applied. This caused some complications as it increased the number of ground attenuation factors that needed to be considered, especially on several sites where the road was slightly raised relative to the surrounding terrain. Measurement height was 1.2 m above the ground.

5. FITTING MODELS TO DATA

5.1 Traffic Measurements

Table 5.1 shows a summary of the traffic records obtained for each site. The table shows the total vehicle volumes, the percentage that were heavy trucks, and the ratio of medium/heavy to very heavy vehicles. The table indicates how the percentage of heavy trucks varies over the 24-hour day. This is significant, as on some routes the percentage of heavy vehicles can increase to nearly 50% of the total vehicles, while on others it can drop to almost zero. The table also shows the total number of vehicles at the site, expressed as number of hours, for which a given flow was achieved.

Table 5.1 Summary of traffic results.

Site No.		Total vpd	Heavy Traffic Characteristics					No. of Hours for which Total Vehicle Flow is				
			% Medium & Heavy	Ratio Medium : Heavy	24-hour Profile of Flow (% heavy and medium)							
					Day	Evening	Late Night	<10	10-30	21-50	51-100	>100
1	Mazengarb Rd	2443	3.9	6.2	6	2	0	6	1	2	2	13
2	Te Moana Rd	6360	3.8	10.0	5	1	0	4	2	-	1	17
3	SH2 Kaitoke	3382	12.1	2.4	14	4	30	2	3	2	3	14
4	SH2 Birchville	10154	4.3	3.5	5	2	10	-	2	1	3	18
5	Adelaide Rd	14097	4.3	10.0	5	2	9	-	-	1	4	19
6	Days Bay	7383	4.6	20.0	5	2	10	3	2	1	1	17
7	Ruahine Street	33632	2.9	7.7	4	2	5	-	-	-	1	23
8	SH2 Greytown	7054	10.5	3.2	11	6	20	1	4	1	2	16
10	SH53 Featherston	1673	5.7	3.6	8	2	1	6	3	1	5	9
11	SH1 Tawa	33787	5.5	2.5	6	3	20	-	-	-	-	24
12	SH1 Paekakariki	19794	8.9	2.3	8	7	40	-	-	2	3	19
13	SH57 Levin S	4267	8.3	2.6	8	7	30	1	5	1	3	14
14	SH57 Levin N	4834	13.5	2.8	13	16	50	2	3	2	4	13
15	SH1 Levin N	9523	13.8	2.0	11	20	45	-	-	1	5	18
16	SH1 Linden	35385	6.0	2.5	6	5	20	-	-	-	-	24
17	SH2 Belmont	31117	6.2	4.0	7	5	20	-	-	-	2	22
18	Wainuiomata	20605	2.4	12.5	3	2	2	-	-	-	2	22
19	SH58 Judgeford	10959	5.6	3.3	6	2	14	1	4	-	2	17
20	SH2 Moonshine	20523	6.0	5.0	7	3	16	-	2	2	1	19
21	Eastern Hutt Rd	18421	5.5	9.0	7	2	12	-	-	4	1	19
	Total Hours	-	-	-	-	-	-	26	31	21	45	357

vpd - vehicles per day

The results show that traffic flows range from about 1600 to 35,000 vehicles per day. Heavy traffic percentages average 3% to 14%, but late at night can be as high as 50%. The table also shows that 16% of the 1-hour traffic flows are less than 50, the level at which CRTN L_{10} (1 hour) predictions are unreliable, and that 26% of the 1 hour traffic flows are less than 100. Low-flow corrections need to be applied to CRTN for flows between 50 and 200 vehicles.

5.2 Applying the CRTN (L_{10}) Model

Table 5.2 shows the L_{10} (18 hour) measurements and how this differs from the noise level for the 20 trial sites when predicted with the CRTN L_{10} model using the measured input data. Applying the normal criteria – that the prediction needs to be within ±2 dBA of the measured value – Table 5.2 shows that five sites (4, 10, 12, 13 and 18) exceed these criteria. For three of these sites the degree by which the ±2 dBA is exceeded is minor, being no more than 0.2 dBA greater than 2, but for sites 12 and 18 the degree exceeded is significant at 1.0 and 1.5 dBA respectively. Table 5.2 shows that for all of these five sites the surface correction is large, especially when compared to the surface corrections for other models.

Table 5.3 shows an analysis of the number of 1-hour correct predictions for five different hourly traffic volumes. It shows the L_{10} (1 hour) is unreliable at less than 50 vehicles per hour, as was expected, but even at high volumes it is not completely reliable. Table 5.3 also shows results for this same analysis but with the five failed sites removed to avoid biasing the data. Performance is still poor for less than 50 vehicles per hour, but improves significantly for the higher traffic volumes.

Table 5.2 L_{10} (18 hour) measurements and predictions for trial sites (applying CRTN with New Zealand surface correction).

Site No.	Measured Noise Level	Model Prediction* (dBA)	Site No.	Measured Noise Level	Model Prediction* (dBA)
1	55.7	+1.4	12	67.4	+3.0
2	60.5	−0.3	13	65.3	+2.2
3	66.5	+0.3	14	69.0	+0.6
4	65.3	+2.2	15	70.0	+1.7
5	67.6	−1.4	16	67.0	+0.8
6	63.9	−0.4	17	65.7	−0.3
7	69.5	−0.2	18	66.2	−3.5
8	69.0	+0.5	19	74.0	−0.2
10	57.8	+2.1	20	75.0	−1.6
11	68.7	−0.9	21	67.5	−1.1

* Predicted level – measured level.

Table 5.3 Percentage of L_{10} (1 hour) predictions agreeing within ±2 dBA for trial sites.

Hourly traffic flow (vpd)	<10	10-30	31-50	51-100	>100
Percentage (%) of agreements	8	0	19	33	71
Percentage (%) of agreements with five failed sites removed	5	0	25	52	84

5.3 Applying the L_{eq} Models

Table 5.4 shows the match of the models to measured values as the difference (predicted – measured) for the Nordic, CETUR (detailed), simplified CETUR, FHWA and CRTN (UK and NZ) models. CRTN has two versions, one with the UK surface corrections and the second with New Zealand surface corrections. In addition, Nordic surface corrections have been added to the CETUR and FHWA models.

The accuracy of each model is shown in the final column as the number of predictions within ±2 dBA. The Nordic model has accurately predicted all 20 sites. The CRTN with New Zealand surface corrections has predicted 15 out of the 20 sites, which is an improvement on the performance of the same model with the UK surface correction of only 12 sites. More significantly, the CRTN model (UK) is failing by under-prediction, whereas the CRTN (NZ) generally fails in over-prediction. There is a consistent trend of a 3-4 dBA difference between the predicted level from the two models.

With the exception of site 18, a friction course surface where the average speed is 70 km/h, the two CRTN versions fail at different sites. The CRTN (UK) fails at sites 3, 7, 8, 14, 18 and 20, whereas the CRTN (NZ) fails at sites 4, 12, 13, 15 and 18. Site 18 highlights the inappropriateness of assigning large noise reductions to New Zealand friction course in speed zones of about 70 km/h. Also of interest is that the L_{10} version of CRTN (NZ) fails at four of the same sites as the L_{eq} version of CRTN (NZ); the common sites being 4, 12, 13 and 18.

The Nordic model generally has road surface corrections a little less than midway between those of CRTN (UK) and CRTN (NZ), and has successfully predicted all 20 sites. However, replacing the CRTN corrections with the Nordic corrections gave no improvement, with predictions falling outside ±2 dBA for sites 7, 8, 14, 19 and 20. The last four of these sites are of the same type, namely rural highways with a large chipseal surface and significant volumes of heavy traffic. Predicted/measured levels for site 18, Wainuiomata, are now in agreement, confirming that the smaller noise reduction of −1 dBA for a low-speed friction course site is more appropriate.

Accurate surface corrections appear to be necessary for accurate predictions with noise models. Those of CRTN (UK) appear too low for New Zealand chipseal with significant heavy traffic, whereas those of CRTN (NZ) appear to be too high on this same type of site. The corrections of the Nordic model, while appropriate for that model, give under-predictions if used with the CRTN model.

Table 5.4 Extent that noise models over-predict (+ve) or under-predict (–ve) for six models at the 20 sites.

Site Type	Motorway 100 km/h Friction Course			Highway 100 km/h Chipseal, Heavy Vehicles 8-14%						Highway 100 km/h Chipseal Heavy Vehicles 4-6%				Urban Arterial 70 km/h				Urban Street 50 km/h			Total Sites Within ±2 dBA
Site No.	11	16	17	3	8	12	13	14	15	4	10	19	20	2	7	18	21	1	5	6	
Measured Level	65.2	63.6	62.1	62.2	64.7	63.7	61.1	64.0	65.6	61.0	56.1	69.8	70.8	56.1	66.2	62.4	62.1	52.8	64.1	66.2	
CRTN (UK)	1.2	–0.5	–0.6	–2.6	–2.1	0.8	–1.2	–2.5	–1.6	0.2	–1.8	–2.1	–4.0	–1.3	–2.3	–3.1	0.0	–1.5	–1.4	–0.2	12
CRTN (NZ)	–0.8	–1.4	0.0	1.4	1.6	3.1	2.9	1.3	2.7	3.1	0.9	–1.5	0.9	0.6	–0.5	–3.4	1.8	1.5	–1.8	0.4	15
Nordic	–0.2	–0.5	0.2	0.9	1.2	–0.7	1.9	1.0	2.0	1.6	0.0	0.0	1.6	1.6	0.2	–1.0	1.2	–1.4	–1.4	0.9	20
CETUR(D)	4.9	6.0	6.7	–0.4	0.1	0.6	2.6	0.8	1.1	2.0	2.0	–2.5	–1.2	1.9	0.7	2.4	2.4	1.1	–1.5	1.3	13
FHWA	3.3	5.7	7.0	0.7	1.3	3.2	2.6	1.9	3.0	3.8	2.2	–1.8	–1.2	0.3	–0.9	1.0	1.0	0.2	–1.6	0.7	12
CETUR(S)	2.9	5.0	6.2	0.7	1.2	1.3	3.5	1.0	1.5	5.7	3.5	1.5	–0.3	3.9	1.2	4.0	3.3	–2.1	–2.2	2.9	8

5.3.1 Predicted/Measured Values Without Surface Correction

Table 5.5 shows noise predictions of the 20 sites for the four models with all surface corrections removed. This shows the Nordic model giving accurate predictions at 15 sites compared to 10-12 sites for the other three models. This improved performance of the Nordic model is believed to be attributable to its better treatment of the intervening ground between source and receiver.

The Nordic model is based on establishing the relative height of source and receiver above the dominant portion of the ground, which is referred to as the place of reflection. This placement is more detailed than CRTN, which considers only the average height of propagation over all intervening ground. CETUR does consider ground effects at some length but over-simplifies so that terrains are grouped. For example, the main group for which all effects are treated as the same includes roads elevated 2.5 m to roads depressed by 2.5 m, so that noise effects are over-stated. The model considers this treatment is justified in that errors, if they occur, will generally be an over-prediction. This over-prediction is borne out by Table 5.5. The FHWA model also tends to over-simplify the intervening ground and again this has mainly resulted in over-predictions.

Table 5.5 Predicted/measured values for four models without any surface corrections.

Site and Description		Without Correction			
		Nordic	CETUR	FHWA	CRTN
1	Mazengarb Road	−1.4	+1.1	+0.2	−0.5
2	Te Moana Road	+2.6	+1.9	+0.3	−0.3
3	SH2, Kaitoke	+1.9	−0.4	+0.7	+2.8
4	SH2, Birchville	+2.6	+2.0	+3.8	+1.8
5	Adelaide Road	−1.4	−1.6	−3.7	+0.4
6	Days Bay	+1.9	+1.3	+0.7	+0.8
7	Ruahine Street	−1.2	+0.7	−0.9	−2.6
8	SH2, Greytown	+1.2	+0.1	+1.3	−2.3
10	SH53, Featherston	+1.0	+2.0	+2.2	−0.8
11	SH1, Tawa	+2.1	+4.9	+3.3	+2.7
12	SH1, Paekakariki	+0.3	+1.6	+3.2	−0.5
13	SH57, Levin South	+1.9	+2.6	+2.6	−0.3
14	SH57, Levin North	+1.0	+0.8	+1.9	−2.3
15	SH1, Levin North	+2.0	+1.1	+3.0	−1.2
16	SH1, Linden	+1.5	+6.0	+5.7	+1.0
17	SH2, Belmont	+1.8	+6.7	+7.0	+2.9
18	Wainuiomata	0.0	+2.4	+0.5	+0.4
19	SH58, Judgeford	0.0	−2.5	−1.8	−2.2
20	SH2, Moonshine	+0.6	−1.2	−1.2	−4.5
21	Eastern Hutt Road	+0.2	+2.4	+1.0	−2.7

Both the CETUR and the FHWA models gave reasonable results on the majority of sites. The CETUR model has performed well on the urban sites. Adding the surface corrections gave no overall improvement, though it did change the order of sites for which successful predictions were made. Table 5.5 shows that for the uncorrected levels, sites 11, 16 and 17 showed the largest departures. The differences can be expected in that these are all friction course sites. This, coupled with the fact that the measurement location is lower than the road on sites 16 and 17, increases ground effects. However, it is an inadequacy of the model that it does not account for these effects.

The FHWA model has over-predicted on several of the chipseal highway sites with significant heavy traffic. However, its main failings are again on the friction course sites (such as sites 16 and 17) where ground effects are probably also significant.

5.3.2 Accuracy of Models at Predicting L_{eq} (1 hour)

Table 5.6 shows the number of hours out of the total 24 hours when the models agreed within ±2 dBA of the measurement, and the percentage of accurate predictions for each type of site. The CRTN (both UK and NZ) and the Nordic have performed well on the motorway sites, but the CETUR and FHWA have performed poorly. This is a reflection of the absence of surface corrections for friction course in these last two models.

On the main highways (high percentage of heavy vehicles) the best reliability is achieved by the Nordic with 75% correct predictions. All the other models achieve only about 50%. This is a combination of the surface correction and heavy vehicle effect. The large texture chipseals on these sites result in more noise being generated, so that models without surface corrections or with low corrections will tend to under-predict, e.g. the CETUR and FHWA do not have surface corrections. However, they appear to have dealt well with the times when heavy traffic percentages are high. Their simplistic treatment of ground effects has probably also partly compensated for the lack of a surface correction. The CRTN (NZ) model has surface corrections that increase with the heavy vehicle percentage, and appear to frequently over-predict.

The difficulties of accounting for the effects of heavy vehicles and texture are highlighted by the group 'highways with 3-6% heavy vehicles'. This third group has sites ranging from very low traffic flow (site 10) to high traffic flow (site 20), yet models give a consistently more reliable prediction than on the second group of sites, which are very similar but with a higher proportion of heavy vehicles.

The models, especially the FHWA and the CETUR, give significantly improved performance on the two groups of urban sites. On these sites, surface corrections are less significant and the nature of the sites are better suited to the more simplified treatment that these two models give to the ground effects.

Site 18 is notable for the complete failure of the CRTN (UK, NZ) and CETUR models. CETUR has no surface correction but fails in over-prediction. CRTN has a large surface correction of –3 to 4 dBA and has failed in over-prediction. This highlights the inappropriateness of expecting large noise reductions from friction course for 70 km/h speed areas.

Table 5.6 Number of hours of total of 24 hours for which models agreed within ±2 dBA of measurement and % totals for site type.

Site Type	Motorway Friction Course				Highway Chipseal, Heavy Vehicles 8-14%							Highway Chipseal, Heavy Vehicles 3-6%					Urban Arterial					Urban Street			
Site No.	11	16	17	% Total	3	8	12	13	14	15	% Total	4	10	19	20	% Total	2	7	18	21	% Total	1	5	6	% Total
Model:																									
CRTN (NZ)	24	24	23	98	17	11	4	13	14	13	50	8	19	15	18	63	21	22	0	18	64	16	21	21	80
CRTN (UK)	24	20	18	86	5	15	23	12	9	12	53	23	14	10	23	73	15	7	1	23	48	12	19	19	69
Nordic	20	22	21	87	23	14	23	17	15	16	75	19	21	24	24	92	21	20	24	24	93	20	21	23	89
CETUR(S)	2	0	0	3	23	14	0	11	11	18	47	0	3	20	2	49	2	23	0	2	28	13	16	10	54
CETUR(D)	1	0	8	13	19	19	1	13	14	18	58	15	16	7	12	60	14	23	8	12	60	17	16	18	71
FHWA	0	0	0	0	18	14	0	9	10	15	46	2	14	13	22	48	21	17	24	22	88	18	4	20	58

CETUR(S) – CETUR simplified
CETUR(D) – CETUR detailed

The final analysis was of the ability of these L_{eq} models to predict for low traffic flows. This analysis is given in Table 5.7, which shows the percentage of successful predictions for 1 hour L_{eq} values for five bands of hourly traffic flow. Compared to the L_{10} model, there is a dramatic improvement in accuracy at traffic volumes less than 50 vehicles per hour. The two most accurate models are the CRTN(NZ) and the Nordic, with the Nordic model being superior in all traffic volume ranges.

It is notable that there is no improvement with increasing traffic volume. For the FHWA and CETUR models, accuracy falls off at the high volume, but this is also a reflection of the number of sites at which these models were inaccurate at the 24-hour level. Both the CRTN(NZ) and Nordic models show a good level of certainty above 10 vehicles per hour, and show that good indicative values can be obtained, even for less than 10 vehicles per hour.

Table 5.7 Analysis of accurate predictions of L_{eq} (1 hour) for given bands of traffic volume.

Model	% Accurate Prediction of L_{eq}(1 hour) for Traffic Volume				
	<10vpd	10-30vpd	31-50vpd	51-100vpd	>100vpd
CRTN (UK)	31	26	62	29	66
CRTN (NZ)	65	81	71	71	62
Nordic	77	94	90	89	84
CETUR	73	77	57	65	48
FHWA	50	71	43	51	50

6. CONCLUSIONS

The Nordic model provides accurate prediction of noise levels (within ±2 dBA) for typical New Zealand highways and urban roads in an open environment. The next most reliable model is CRTN (NZ), when it is used to predict L_{eq} directly by reducing the model constants by 3 dBA rather than first predicting L_{10}. However, this CRTN model needs improved surface corrections to be developed. The CETUR and FHWA models appear to over-simplify ground effects, and make insufficient allowance for road surface effects to give accurate predictions.

When used to predict L_{eq} (1 hour), the Nordic and the CRTN (NZ) models will give highly indicative values, even where the hourly traffic volumes are 10 or less.

Road surface effects on noise levels need to be better defined. A particular case for example is friction course for streets with speeds of 70 km/h or less.

7. RECOMMENDATIONS

- The Nordic model can be adopted in New Zealand in its current form for determining L_{eq} (24 hour) noise levels for substantially free-flowing traffic.

- Surface correction effects should be further investigated, as these are a major source of variability in traffic noise from roads.

- The extent of noise reduction obtained from friction course in 70 km/h speed areas is a particular area requiring study, as models are under-predicting noise in this situation.

8. REFERENCES

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APPENDIX
DETAIL OF MEASUREMENTS, AGREEMENT OF MEASURED AND PREDICTED VALUES, AND AGREEMENT OVER LEVELS OF TRAFFIC FLOWS

The following tables show detail of the measurements made and agreements achieved.

Column 1: shows the number and name of trial site
Column 2: shows the measured (24 hour) level
Column 3: shows the difference between predicted and measured levels for each of the models considered
Column 4: shows the number of hours of the 24-hour total

- for which correct predictions were made (left column); and
- for which predicted levels exceeded measured levels by more than ±2 dBA (right column)

Column 5: is dived into 5 sub-columns. Each sub-column is a band of 1-hour traffic volumes.

For each site, the first row shows the total number of hours at that site for which traffic flow was within each of the five traffic bands. The next six rows show the number of hours in each traffic band for which predictions for each of the models exceeded measured levels by ±2 dBA. The final column lists the models.

Site	Measured	Predicted – Measured	Pass/ Fail		Total No. of Hours of Traffic Volume Within Range and No. of Fails of Model on Hourly Basis					
					≤10	10-30	30-50	50-100	>100	
1 Mazengarb Road					6	1	2	2	13	Total Hours
		+1.6	16	8	1	-	-	-	7	CRTN (NZ)
		–1.5	12	12	5	1	1	2	3	CRTN (UK)
		–0.4	20	4	1	1	1	-	1	Nordic
		+2.1	13	11	2	-	1	1	6	CETUR (S)
		+1.1	17	7	1	-	1	-	5	CETUR (D)
	52.8	+0.2	18	6	3	-	1	-	2	FHWA
2 Te Moana Road					4	2	-	1	17	Total Hours
		+0.6	21	3	2	-	-	-	1	CRTN (NZ)
		–1.3	15	9	3	1	-	1	4	CRTN (UK)
		+0.6	21	3	2	-	-	-	1	Nordic
		+3.9	2	22	3	2	-	1	16	CETUR (S)
		+1.9	14	10	2	-	-	-	8	CETUR (D)
	56.1	+0.3	21	3	2	-	-	-	1	FHWA
3 SH2, Kaitoke					2	3	2	3	14	Total Hours
		+1.4	17	7	1	-	-	1	5	CRTN (NZ)
		–2.6	5	19	1	3	2	3	10	CRTN (UK)
		+0.9	23	1	-	-	-	-	1	Nordic
		+0.7	23	1	-	1	-	-	-	CETUR (S)
		–0.4	19	5	-	2	1	2	-	CETUR (D)
	62.2	+0.7	-		2	1	1	1	1	FHWA
4 SH2, Birchville					-	2	1	3	18	Total Hours
		+3.1	8	16	-	2	1	1	12	CRTN (NZ)
		+0.2	23	1	-	-	-	1	-	CRTN (UK)
		+1.6	19	5	-	-	-	-	5	Nordic
		+5.7	0	23	-	1	2	3	18	CETUR (S)
		+2.0	15	9	-	-	-	-	9	CETUR (D)
	61.0	+3.8	2	22	-	-	2	3	18	FHWA
5 Adelaide Road, Wellington					-	-	1	4	19	Total Hours
		–1.8	21	3	-	-	-	1	2	CRTN (NZ)
		–1.4	19	5	-	-	-	3	2	CRTN (UK)
		–1.4	21	3	-	-	-	-	3	Nordic
		–2.2	16	8	-	-	1	2	5	CETUR (S)
		–1.6	16	8	-	-	-	2	6	CETUR (D)
	64.1	–3.7	4	20	-	-	1	3	16	FHWA
6 Days Bay					3	2	1	1	17	Total Hours
		+0.4	21	3	-	-	-	1	2	CRTN (NZ)
		–0.2	19	5	1	1	-	1	2	CRTN (UK)
		+0.9	23	1	-	-	-	-	1	Nordic
		+2.9	10	14	1	-	-	-	13	CETUR (S)
		+1.3	18	6	1	1	-	-	4	CETUR (D)
	59.5	+0.7	50	4	1	-	1	-	2	FHWA

Site	Measured	Predicted – Measured	Pass/ Fail		Total No. of Hours of Traffic Volume Within Range and No. of Fails of Model on Hourly Basis					
					≤10	10-30	30-50	50-100	>100	
7 Ruahine Street					-	-	-	1	23	Total Hours
		–0.5	22	2	-	-	-	-	2	CRTN (NZ)
		–2.3	7	17	-	-	-	1	16	CRTN (UK)
		+1.2	20	4	-	-	-	-	4	Nordic
		+1.2	23	1	-	-	-	-	1	CETUR (S)
		+0.7	23	1	-	-	-	-	1	CETUR (D)
	66.2	+0.9	17	7	-	-	-	-	7	FHWA
8 SH2, Greytown					1	4	1	2	16	Total Hours
		+1.6	11	13	1	-	-	1	11	CRTN (NZ)
		–2.1	15	9	1	3	1	1	3	CRTN (UK)
		+1.2	14	10	-	1	-	1	8	Nordic
		+1.2	14	10	-	1	-	1	8	CETUR (S)
		+0.1	19	5	-	1	-	1	3	CETUR (D)
	64.7	+1.3	14	10	1	1	-	2	6	FHWA
10 SH53, Featherston					6	3	1	5	9	Total Hours
		+0.9	19	5	3	-	-	-	2	CRTN (NZ)
		–1.8	14	10	3	1	-	3	3	CRTN (UK)
		0	21	3	3	-	-	-	-	Nordic
		+3.5	3	21	5	3	1	5	8	CETUR (S)
		+2.0	16	8	2	-	-	2	4	CETUR (D)
	56.1	+2.2	14	10	2	1	-	2	5	FHWA
11 SH1, Tawa					-	-	-	-	24	Total Hours
		–0.8	24	0	-	-	-	-	-	CRTN (NZ)
		0	24	0	-	-	-	-	-	CRTN (UK)
		+0.1	20	4	-	-	-	-	4	Nordic
		+4.8	2	22	-	-	-	-	22	CETUR (S)
		+4.9	1	23	-	-	-	-	23	CETUR (D)
	65.2	+3.3	0	24	-	-	-	-	24	FHWA
12 SH1, Paekakariki					-	-	2	3	19	Total Hours
		+3.1	4	20	-	-	1	1	18	CRTN (NZ)
		–0.8	23	1	-	-	-	-	1	CRTN (UK)
		–0.7	23	1	-	-	-	-	1	Nordic
		+3.3	0	24	-	-	2	3	19	CETUR (S)
		+1.6	1	23	-	-	2	3	18	CETUR (D)
	63.7	+3.2	0	24	-	-	2	3	19	FHWA
13 SH57, Levin South					1	5	1	3	14	Total Hours
		+2.9	13	11	-	-	-	-	11	CRTN (NZ)
		–1.2	12	12	1	5	-	3	3	CRTN (UK)
		+1.9	17	7	-	-	-	-	7	Nordic
		+3.5	11	13	-	-	1	1	11	CETUR (S)
		+2.6	13	11	-	-	-	-	11	CETUR (D)
	61.1	+2.6	9	15	1	2	-	2	11	FHWA

Site	Measured	Predicted – Measured	Pass/ Fail		Total No. of Hours of Traffic Volume Within Range and No. of Fails of Model on Hourly Basis					
					≤10	10-30	30-50	50-100	>100	
14 SH57, Levin North					2	3	2	4	13	Total Hours
		+1.3	14	10	-	-	1	2	7	CRTN (NZ)
		−2.5	9	15	2	3	2	4	4	CRTN (UK)
		+1.0	15	9	-	-	1	2	6	Nordic
		+1.0	11	13	1	1	2	2	7	CETUR (S)
		+0.8	14	10	-	-	1	2	7	CETUR (D)
	64.0	+1.9	10	14	1	2	1	1	9	FHWA
15 SH1, Levin North					-	-	1	5	18	Total Hours
		+2.7	13	11	-	-	-	-	11	CRTN (NZ)
		−1.6	12	12	-	-	1	5	6	CRTN (UK)
		+2.0	16	8	-	-	-	-	8	Nordic
		+1.5	18	6	-	-	-	-	6	CETUR (S)
		+1.1	18	6	-	-	-	-	6	CETUR (D)
	65.6	+3.0	5	19	-	-	2	3	14	FHWA
16 SH1, Linden					-	-	-	-	24	Total Hours
		−1.4	24	0	-	-	-	-	-	CRTN (NZ)
		−0.5	20	4	-	-	-	-	4	CRTN (UK)
		−0.5	22	2	-	-	-	-	2	Nordic
		+6.7	0	24	-	-	-	-	24	CETUR (S)
		+6.0	0	24	-	-	-	-	24	CETUR (D)
	63.6	+5.7	0	24	-	-	-	-	24	FHWA
17 SH2, Belmont					-	-	-	2	22	Total Hours
		0	23	1	-	-	-	-	1	CRTN (NZ)
		−0.6	18	6	-	-	-	2	3	CRTN (UK)
		+0.2	21	3	-	-	-	2	1	Nordic
		+8.4	0	24	-	-	-	2	22	CETUR (S)
		+6.7	0	24	-	-	-	1	23	CETUR (D)
	62.1	+7.0	0	24	-	-	-	1	23	FHWA
18 Wainui					-	-	-	2	22	Total Hours
		−3.4	0	24	-	-	-	2	22	CRTN (NZ)
		−3.1	1	23	-	-	-	2	21	CRTN (UK)
		−1.0	24	0	-	-	-	-	-	Nordic
		+4.0	0	24	-	-	-	2	22	CETUR (S)
		+2.4	8	16	-	-	-	1	15	CETUR (D)
	62.4	+0.5	24	0	-	-	-	-	-	FHWA
19 SH58, Judgeford					1	4	-	2	17	Total Hours
		−1.5	15	9	1	3	-	1	4	CRTN (NZ)
		−2.1	10	14	1	3	-	2	8	CRTN (UK)
		0	24	0	-	-	-	-	-	Nordic
			20	4	1	2	-	1	-	CETUR (S)
		−2.5	7	17	1	3	-	1	12	CETUR (D)
	69.8	−1.8	13	11	-	3	-	1	7	FHWA

Site	Measured	Predicted – Measured	Pass/ Fail		Total No. of Hours of Traffic Volume Within Range and No. of Fails of Model on Hourly Basis					
					≤10	10-30	30-50	50-100	>100	
20 River Road					-	2	2	1	19	Total Hours
		–0.9	17	7	-	1	1	1	4	CRTN (NZ)
		–4.0	1	23	-	2	1	1	19	CRTN (UK)
		+1.6	20	4	-	-	-	-	4	Nordic
		–0.3	20	4	-	1	2	1	-	CETUR (S)
		–1.2	16	8	-	-	2	1	5	CETUR (D)
	70.8	–1.2	17	7	-	-	-	-	7	FHWA
21 Stokes Valley					-	-	4	1	19	Total Hours
		+1.8	18	6	-	-	1	-	14	CRTN (NZ)
		0	23	1	-	-	-	-	1	CRTN (UK)
		+1.2	24	0	-	-	-	-	17	Nordic
		+3.3	2	22	-	-	4	1	10	CETUR (S)
		+2.4	12	12	-	-	2	-	1	CETUR (D)
	62.1	+1.0	22	2	-	-	1	-		FHWA
Totals					26	31	21	45	357	

CRTN (NZ) = CRTN with New Zealand road surface corrections
CRTN (UK) = CRTN with UK road surface corrections
CETUR (S) = Simplified CETUR model
CETUR (D) = Detailed CETUR model