SOME OPERATIONAL LIMITATIONS OF THE NAASRA ROUGHNESS METER

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EXECUTIVE SUMMARY

Road roughness is one of the most significant indicators of pavement condition. It is used in New Zealand both as a network management tool to indicate the effectiveness of roading expenditure and as a project evaluation tool in justifying road improvements.

In New Zealand, road roughness has traditionally been measured by the National Association of Australian State Roading Authority (NAASRA) roughness meter. This meter was originally designed to be operated at a constant speed of 80 km/h but operational limitations mean that a wide range of survey speed, as well as accelerating and decelerating (braking), are experienced.

This project investigates the effects of three variables:

1. low speeds;
2. acceleration and deceleration; and
3. tortuous alignment

on the determination of the true roughness level of a pavement section.

The research, initiated in the early 1990s, has concluded that a poor correlation exists between the low speed (less than 50 km/h) response of the meter and the true roughness level. Acceleration and deceleration from or to a stop can also have a significant effect which is site-dependent. Tortuous alignment can also contribute mainly through the use of low speeds in these manoeuvres.

The conclusions are that where the same vehicle is being used on network surveys for determination of trend, then the above effects may not be significant. However, for project evaluation where the true level of roughness is required, operational limitations which restrict the speed of the vehicle can result in significant errors.

Recommendations

1. The use of the NAASRA roughness meter is phased out for use especially in urban areas and replaced with instruments that are not speed sensitive.

2. Until other measuring instruments are generally available, a sensitivity analysis is performed in a project evaluation to determine if the speed error associated with the roughness measurement is significant in the determination of the project benefit/cost ratio.

ABSTRACT

The National Association of Australian State Roading Authority (NAASRA) roughness meter is often required to be operated at low speeds, with acceleration and deceleration from and to a standing start, and through a tortuous pavement alignment.

This project investigates the effect of these operational limitations on the determination of the true roughness level. It concludes that operational limitations which restrict the speed of the survey vehicle have a significant effect on the determination of the true roughness. The implications for the determination of trends in a network survey and for project evaluation are discussed.

1. INTRODUCTION

Road roughness is one of the most significant indicators of pavement condition. It is used in New Zealand both as a road network management tool to indicate the effectiveness of roading expenditure, and as a project evaluation tool in justifying road improvements.

Transit New Zealand and most local authorities now perform a yearly road roughness survey, the results of which are incorporated into the RAMM pavement management system. The RAMM system is then used to indicate pavement sections that require treatment, and the overall yearly changes in roughness level is used as a check on the effectiveness of roading expenditure.

The accuracy of the measurement of road roughness can therefore have a significant effect on both the prioritising of roading improvements and in determining the effectiveness of expenditure.

In New Zealand, road roughness has traditionally been measured by the National Association of Australian State Roading Authority (NAASRA) roughness meter. This meter is mounted in a test vehicle directly over the centre of the rear axle. It operates by summing the vertical displacement of the rear axle relative to the vehicle body as the vehicle is driven along the road.

A total displacement of 15.2 mm is recorded by the meter as one count. The roughness of a pavement section is reported as NAASRA counts/km. The higher the number of counts the rougher the pavement.

As the vertical displacement of the rear axle is a function of the pavement geometry, vehicle suspension characteristics and vehicle speed, the reporting of roughness has been standardised at 80 km/h, and originally all vehicles were calibrated against a standard vehicle held by the Australian Road Research Board (ARRB).

The internationally accepted measure of roughness is the International Roughness Index (IRI). This statistic is derived from the response of a theoretical wheel and suspension traversing a measured pavement profile at 80 km/h. The pavement profile is obtained either by direct measurement using a rod and level, or more quickly using non-contact sensors such as a laser profilometer.

To obtain a more robust standard than the ARRB "standard vehicle", a relationship between the IRI and the NAASRA roughness has been developed. This has allowed roughness measuring vehicles to be calibrated from measured road profiles rather than requiring comparative runs made in Australia with the standard vehicle. A regression equation is developed between the vehicle counts (referred to as raw counts) and the true roughness.

As the standard roughness measurement is based on 80 km/h, surveys should be performed at this speed to obtain the greatest accuracy. It is operationally impossible to maintain this speed over a network, and thus calibration is performed over a 50-80 km/h speed range. However, in many situations, both urban and rural, it is impossible to maintain a steady speed in the 50-80 km/h range, and lower speeds are often used.

To investigate the effect of speed and other operational constraints on the accuracy of the NAASRA roughness meter, this project was initiated in the early 1990s. Three factors were identified for research:

1. low speed response;
2. effect of accelerating and decelerating; and
3. effect of a tortuous route.

This report gives the results and discusses the implications for road roughness surveys.

2. LOW SPEED RESPONSE

To investigate the low speed response of the NAASRA roughness meter, a straight flat section of pavement in the Wairarapa was selected that covered a range of roughnesses of 30 to 180 NAASRA counts/km.

The test strip is 4.5 km long and runs were performed in each direction. This gave a total length of 9 km.

Survey runs were performed at 20, 30, 40, 70, 80 and 100 km/h. Ten runs were performed at each speed. Roughness was recorded at 100 m intervals, giving a total of 90 test sections.

The "true" roughness of each section was determined from the 80 km/h calibration equation after the calibration state of the vehicle had been verified.

Table 1 gives the mean of the 10 test runs at each speed, where the NAASRA roughness for each section is taken from the 80 km/h runs and each direction is indicated by an increasing (Table 1a) or decreasing (Table 1b) run.

Figures 1 to 6 give the relationship between the NAASRA roughness for each 100 m strip and the mean raw counts recorded. The Figures also include the 95 percentile prediction limits. This is the range in which the NAASRA counts could fall when calculated from an individual survey run. For example, where the survey speed is 30 km/h and the raw counts were 9, the true roughness could be between 52 and 98 counts/km (Figure 2) at the 95 percentile confidence. However, at 70 km/h the range of the 9 raw counts is 87 to 101 from Figure 5.

Table 2 gives the summary of linear regressions performed for each speed. As the section "true" roughness was calculated from the 80 km/h runs, no regression is given.

It is obvious from the Figures and reflected in the correlation coefficient that the spread of values increases as the speed decreases. This spread is not reflected in the repeatability of the test runs where the range in raw counts for the 10 runs at different speeds were similar.

The slope and constant of the regression equations are shown as a function of the test speed in Figures 7 and 8. Although there appears to be a smooth relationship between speed and slope of the regression, there is an abrupt change occurring in the value of the constant at 30 km/h. The error of estimate of the constant is such that the constant's value is not significantly different from the projected value of the trend from the other runs, i.e. 2. A best fit straight line fit through the 30-100 km/h data is shown in Figure 9.

Figure 1. Relationship of real NAASRA counts to mean raw counts at 20 km/h.

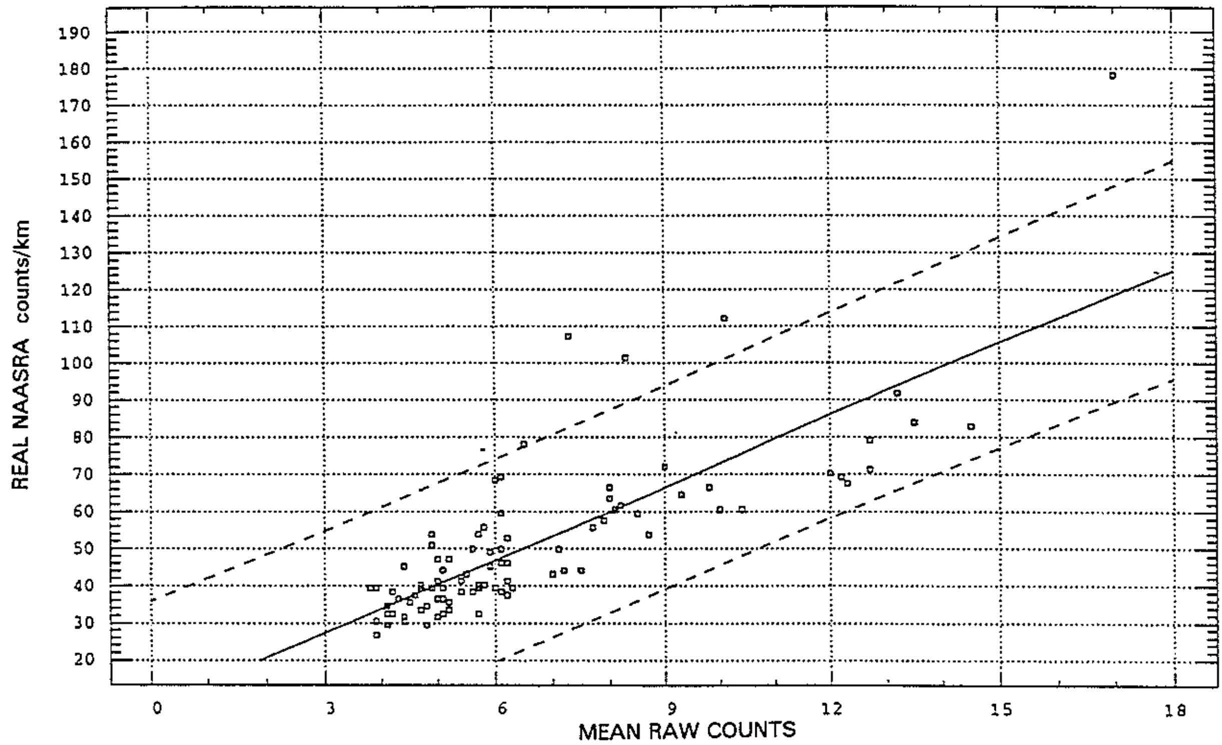


Figure 2. Relationship of real NAASRA counts to mean raw counts at 30 km/h.

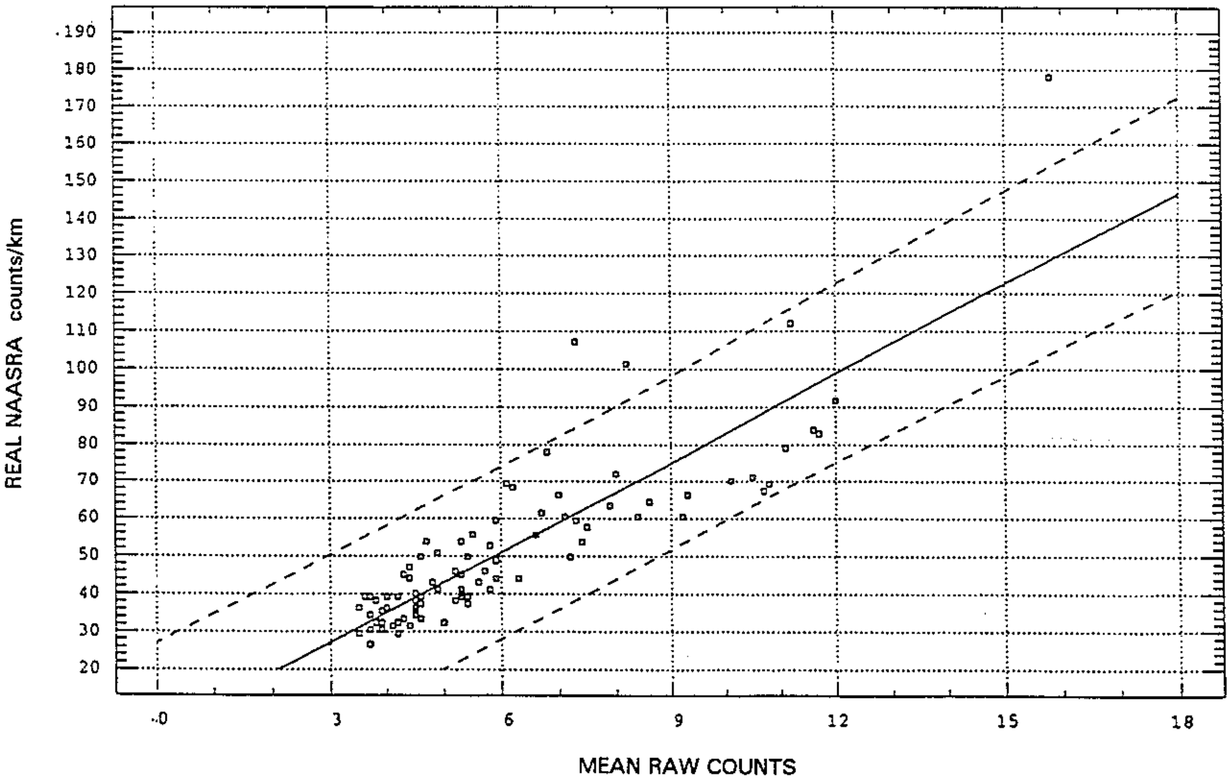


Figure 3. Relationship of real NAASRA counts to mean raw counts at 40 km/h.

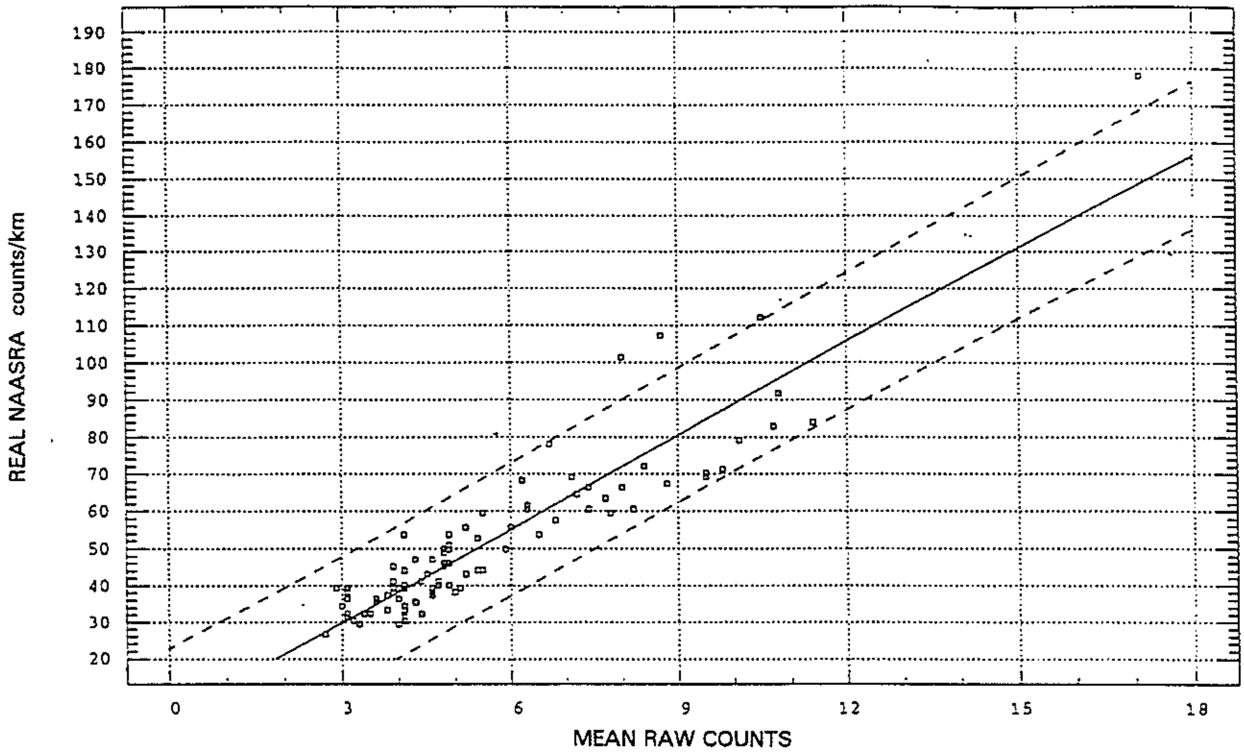


Figure 4. Relationship of real NAASRA counts to mean raw counts at 50 km/h.

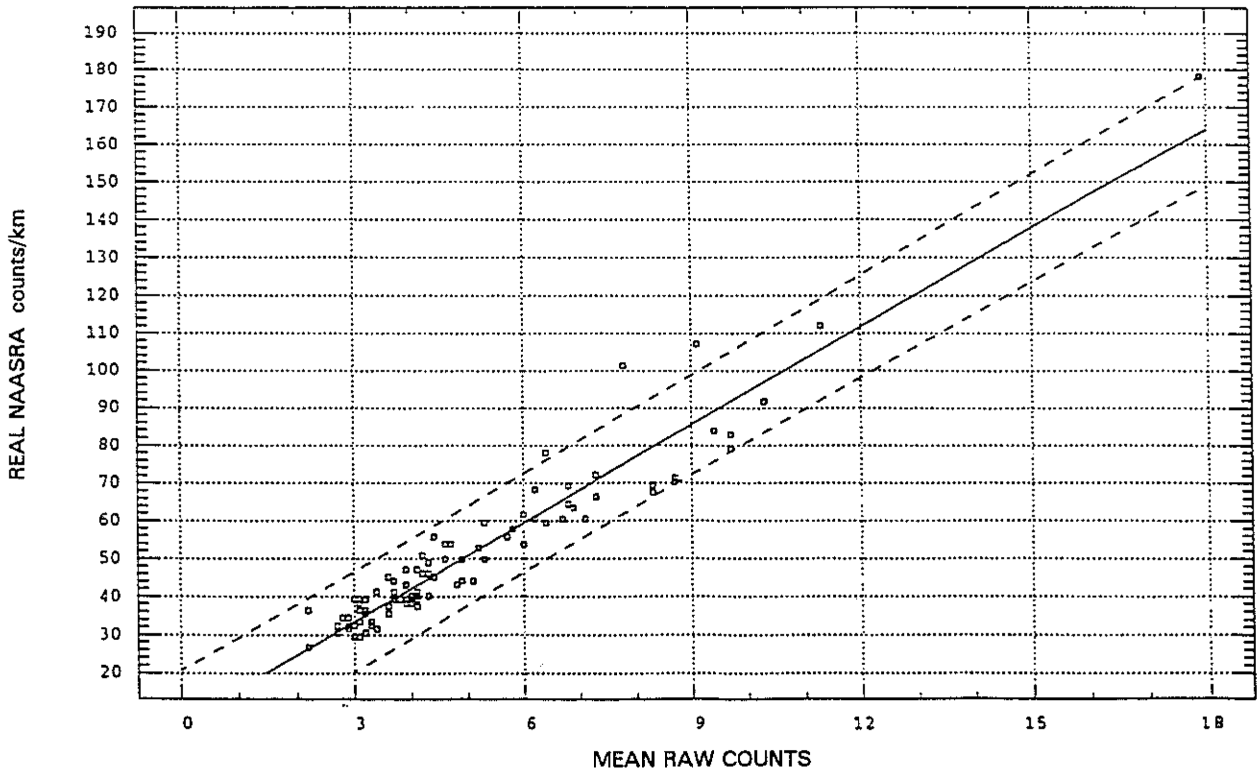


Figure 5. Relationship of real NAASRA counts to mean raw counts at 70 km/h.

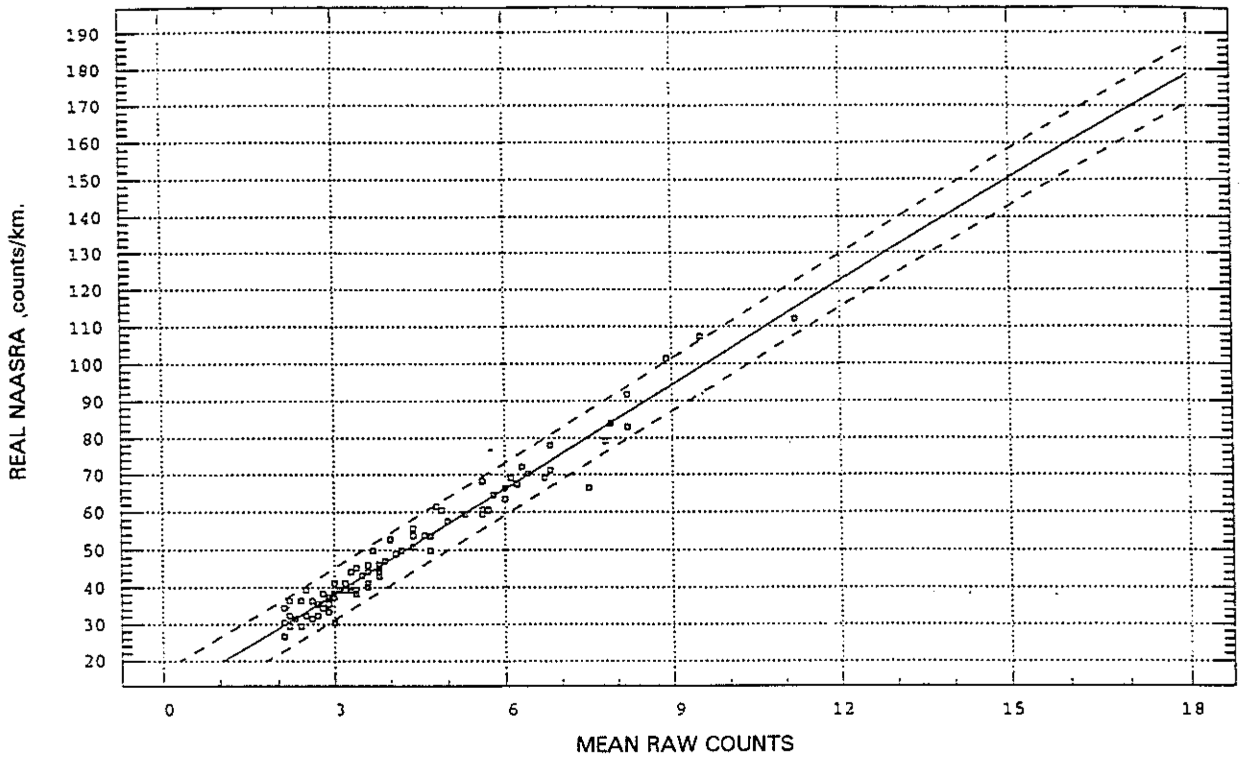


Figure 6. Relationship of real NAASRA counts to mean raw counts at 100 km/h.

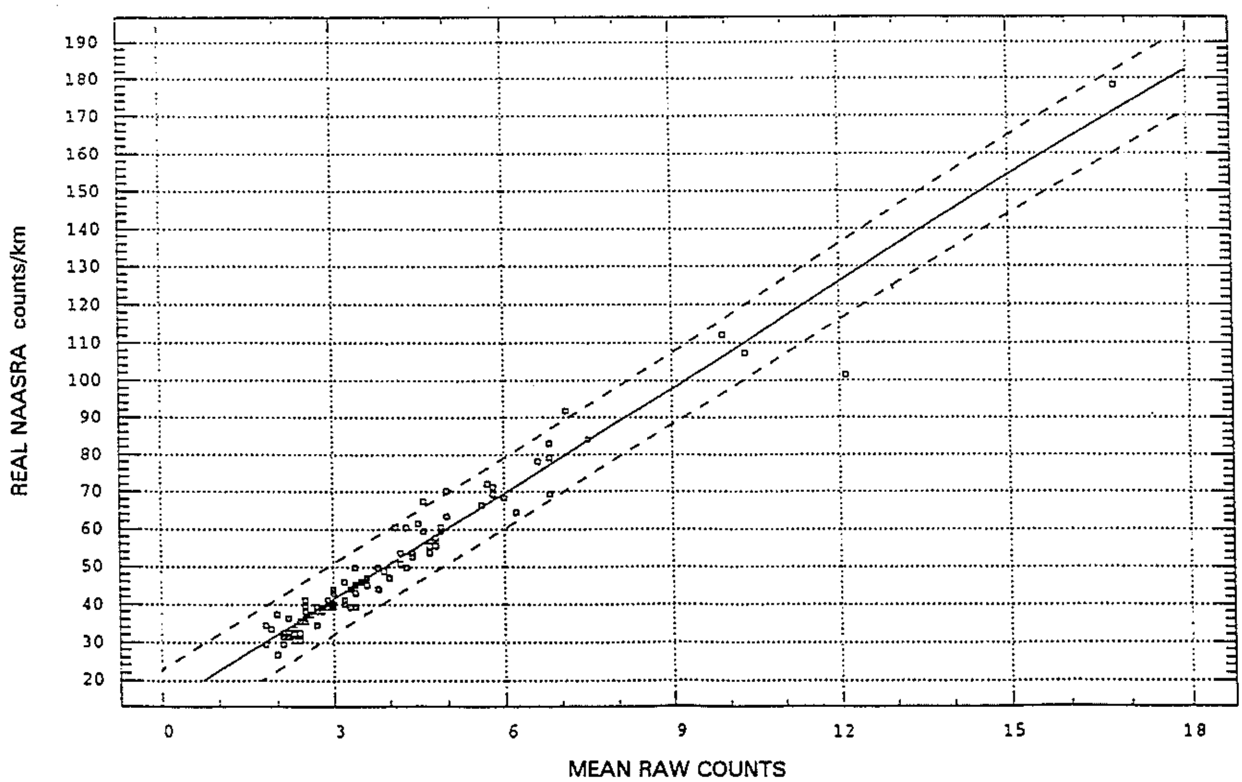


Table 1a. Summary of results at different speeds: mean of 10 runs (increasing direction).

Distance	Calculated section roughness (NAASRA counts/km)	Raw counts						
		20 km/h	30 km/h	40 km/h	50 km/h	70 km/h	80 km/h	100 km/h
0.1	101.378	8.3	8.2	8.0	7.8	8.9	9.4	12.1
0.2	68.364	6.0	6.2	6.2	6.2	5.6	6.0	6.0
0.3	47.002	5.2	4.4	4.3	3.9	3.9	3.8	3.6
0.4	44.089	5.1	4.4	4.1	3.7	3.3	3.5	3.8
0.5	39.234	4.9	4.0	4.0	4.1	3.4	3.0	3.4
0.6	32.437	4.1	3.8	3.1	2.9	2.2	2.3	2.4
0.7	36.321	4.3	3.5	3.1	2.2	2.2	2.7	2.2
0.8	49.915	5.6	4.6	4.9	4.9	4.7	4.1	4.3
0.9	39.234	3.9	3.6	2.9	3.0	3.0	3.0	3.3
1.0	26.611	3.9	3.7	2.7	2.2	2.1	1.7	2.0
1.1	31.466	4.4	4.1	3.1	2.9	2.3	2.2	2.2
1.2	30.495	3.9	3.9	3.2	2.7	2.1	2.1	2.4
1.3	78.074	6.5	6.8	6.7	6.4	6.8	7.0	6.6
1.4	112.059	10.1	11.2	10.5	11.3	11.2	10.5	9.9
1.5	178.087	17.0	15.8	17.1	17.9	18.1	17.3	16.8
1.6	59.625	6.1	5.9	5.5	5.3	5.3	5.1	4.9
1.7	52.828	6.2	5.8	5.4	5.2	4.0	4.4	4.4
1.8	57.683	7.9	7.5	6.8	5.8	5.0	4.9	4.8
1.9	49.915	7.1	7.2	5.9	5.3	4.2	4.1	3.8
2.0	66.422	9.8	9.3	8.0	7.3	6.0	5.8	5.6
2.1	69.335	12.2	10.8	9.5	8.3	6.7	6.1	5.8
2.2	83.900	13.5	11.6	11.4	9.4	7.9	7.6	7.5
2.3	79.045	12.7	11.1	10.1	9.7	7.8	7.1	6.8
2.4	70.306	12.0	10.1	9.5	8.7	6.4	6.2	5.0
2.5	53.799	8.7	7.4	6.5	6.0	4.7	4.5	4.7
2.6	63.509	8.0	7.9	7.7	6.9	6.0	5.5	5.0
2.7	55.741	7.7	6.6	6.0	5.7	4.4	4.7	4.8
2.8	45.060	5.9	5.3	4.8	4.4	3.8	3.6	3.4
2.9	40.205	5.8	5.3	4.9	4.3	3.6	3.1	2.9
3.0	39.234	5.7	5.3	5.1	4.0	3.1	3.0	3.0
3.1	72.248	9.0	8.0	8.4	7.3	6.3	6.4	5.7
3.2	29.523	4.1	3.5	3.3	3.0	2.4	2.0	2.1
3.3	36.321	5.0	4.0	3.6	3.2	2.4	2.7	2.2
3.4	30.495	4.4	3.7	4.1	3.2	3.0	2.1	2.3
3.5	32.437	5.1	4.2	3.5	3.0	2.7	2.3	2.3
3.6	36.321	5.1	4.5	4.0	3.1	2.6	2.7	2.5
3.7	44.089	7.2	5.9	5.4	5.1	3.8	3.5	3.0
3.8	43.118	5.5	4.8	4.5	3.9	3.5	3.4	3.4
3.9	39.234	6.0	5.4	3.9	4.1	3.3	3.0	2.9
4.0	39.234	6.3	5.3	4.6	3.9	3.2	3.0	2.7
4.1	37.292	4.6	4.6	3.8	3.6	2.9	2.8	2.6
4.2	46.031	6.2	5.2	4.8	4.3	3.8	3.7	3.5
4.3	38.263	6.1	5.2	5.0	4.0	3.4	2.9	2.8
4.4	46.031	6.1	5.7	4.9	4.2	3.6	3.7	3.2
4.5	38.263	5.6	5.2	4.6	4.0	3.4	2.9	2.8

Table 1b. Summary of results at different speeds: mean of 10 runs (decreasing direction).

Distance	Calculated section roughness (NAASRA counts/km)	Raw counts						
		20 km/h	30 km/h	40 km/h	50 km/h	70 km/h	80 km/h	100 km/h
0.1	41.176	5.0	5.3	3.9	3.7	3.0	3.2	2.5
0.2	33.408	4.7	4.3	3.8	3.3	2.9	2.4	2.3
0.3	39.234	4.9	4.6	4.1	3.8	3.3	3.0	2.8
0.4	37.292	6.2	5.4	4.6	4.1	3.0	2.8	2.0
0.5	39.234	4.7	4.6	4.0	3.7	3.3	3.0	2.5
0.6	35.350	4.5	3.9	3.6	3.2	2.7	2.6	2.5
0.7	35.350	5.2	4.5	4.3	3.6	2.9	2.6	2.4
0.8	32.437	5.7	5.0	4.4	3.3	2.7	2.3	2.2
0.9	44.089	7.5	6.3	5.5	4.9	3.6	3.5	3.3
1.0	43.118	7.0	5.6	5.2	4.8	3.8	3.4	3.0
1.1	32.437	4.2	3.9	3.4	2.7	2.5	2.3	2.1
1.2	29.524	4.8	4.2	4.0	3.1	2.2	2.0	1.8
1.3	33.408	5.2	4.6	4.1	3.1	2.9	2.4	1.9
1.4	38.263	5.4	4.5	3.9	3.9	2.8	2.9	2.5
1.5	31.466	5.0	4.4	4.1	3.4	2.6	2.2	2.1
1.6	59.625	8.5	7.3	7.8	6.4	5.6	5.1	4.6
1.7	48.944	5.9	5.9	4.8	4.3	4.1	4.0	3.9
1.8	41.176	5.4	4.9	4.7	3.4	3.2	3.2	3.2
1.9	34.379	4.8	4.5	4.1	2.8	2.1	2.5	1.8
2.0	40.205	5.7	5.3	4.7	4.1	3.3	3.1	3.2
2.1	64.480	9.3	8.6	7.2	6.8	5.8	5.6	6.2
2.2	60.596	10.4	9.2	8.2	7.1	5.6	5.2	4.3
2.3	67.393	12.3	10.7	8.8	8.3	6.2	5.9	4.6
2.4	91.668	13.2	12.0	10.8	10.3	8.2	8.4	7.1
2.5	82.929	14.5	11.7	10.7	9.7	8.2	7.5	6.8
2.6	71.277	12.7	10.5	9.8	8.7	6.8	6.3	5.8
2.7	60.596	10.0	8.4	7.4	6.7	5.7	5.2	4.9
2.8	60.596	8.1	7.1	6.3	6.2	4.9	5.2	4.1
2.9	61.567	8.2	6.7	6.3	6.0	4.8	5.3	4.5
3.0	49.915	6.1	5.4	4.8	4.6	3.7	4.1	3.4
3.1	41.176	6.2	5.8	4.4	4.1	3.6	3.2	2.9
3.2	66.422	8.0	7.0	7.4	7.3	7.5	5.8	5.6
3.3	107.204	7.3	7.3	8.7	9.1	9.5	10.0	10.3
3.4	69.335	6.1	6.1	7.1	6.8	6.1	6.1	6.8
3.5	50.886	4.9	4.9	4.9	4.2	4.4	4.2	4.2
3.6	40.205	4.7	4.5	4.1	4.0	3.6	3.1	3.0
3.7	45.060	4.4	4.3	3.9	3.6	3.4	3.6	3.6
3.8	39.234	3.8	3.7	3.1	3.1	2.5	3.0	2.9
3.9	55.741	5.8	5.5	5.2	4.4	4.4	4.7	4.7
4.0	34.379	4.1	3.7	3.0	2.9	2.8	2.5	2.7
4.1	38.263	4.2	3.8	3.1	3.1	3.0	2.9	2.7
4.2	.39.234	5.1	4.2	4.1	3.2	3.2	3.0	3.0
4.3	53.799	4.9	4.7	4.1	4.7	4.4	4.5	4.2
4.4	47.002	5.0	4.4	4.6	4.1	3.9	3.8	4.0
4.5	53.799	5.7	5.3	4.9	4.6	4.6	4.5	4.4

Table 2. Summary of linear regressions.

20 km/h		**50 km/h**	
Regression Output:		Regression Output:	
Constant	7.640699	Constant	7.210130
Standard error of Y estimate	13.61466	Standard error of Y estimate	6.543669
R squared	0.636875	R squared	0.916114
No. of observations	90	No. of observations	90
Degrees of freedom	88	Degrees of freedom	88
X coefficient(s)	6.531173	X coefficient(s)	8.708706
Standard error of coefficient	0.525715	Standard error of coefficient	0.280917
30 km/h		**70 km/h**	
Regression Output:		Regression Output:	
Constant	3.214728	Constant	10.02248
Standard error of Y estimate	11.49286	Standard error of Y estimate	3.480250
R squared	0.741239	R squared	0.976271
No. of observations	90	No. of observations	90
Degrees of freedom	88	Degrees of freedom	88
X coefficient(s)	7.970310	X coefficient(s)	9.367614
Standard error of coefficient	0.501999	Standard error of coefficient	0.155680
40 km/h		**100 km/h**	
Regression Output:		Regression Output:	
Constant	4.471497	Constant	13.16688
Standard error of Y estimate	8.918458	Standard error of Y estimate	4.702375
R squared	0.844180	R squared	0.956681
No. of observations	90	No. of observations	90
Degrees of freedom	88	Degrees of freedom	88
X coefficient(s)	8.439477	X coefficient(s)	9.403122
Standard error of coefficient	0.386515	Standard error of coefficient	0.213297

Figure 7. Effect of survey speed on regression equation constant.

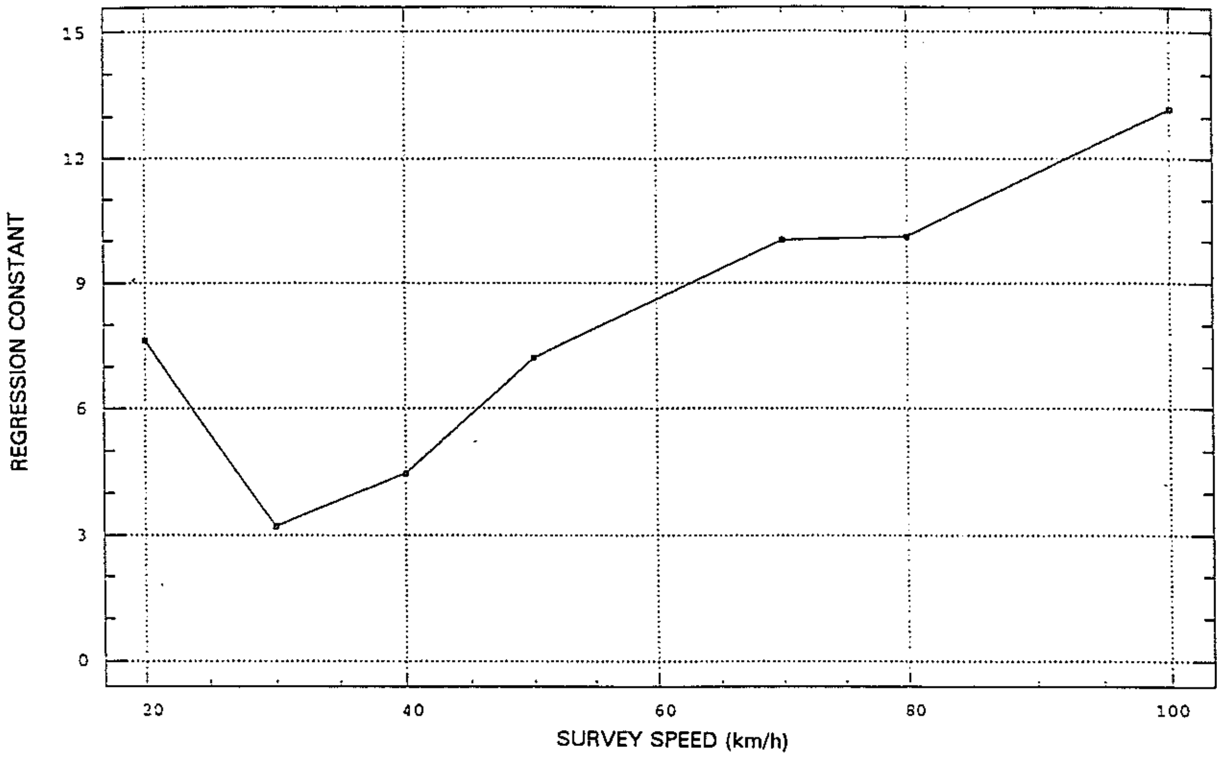


Figure 8. Effect of survey speed on slope of regression.

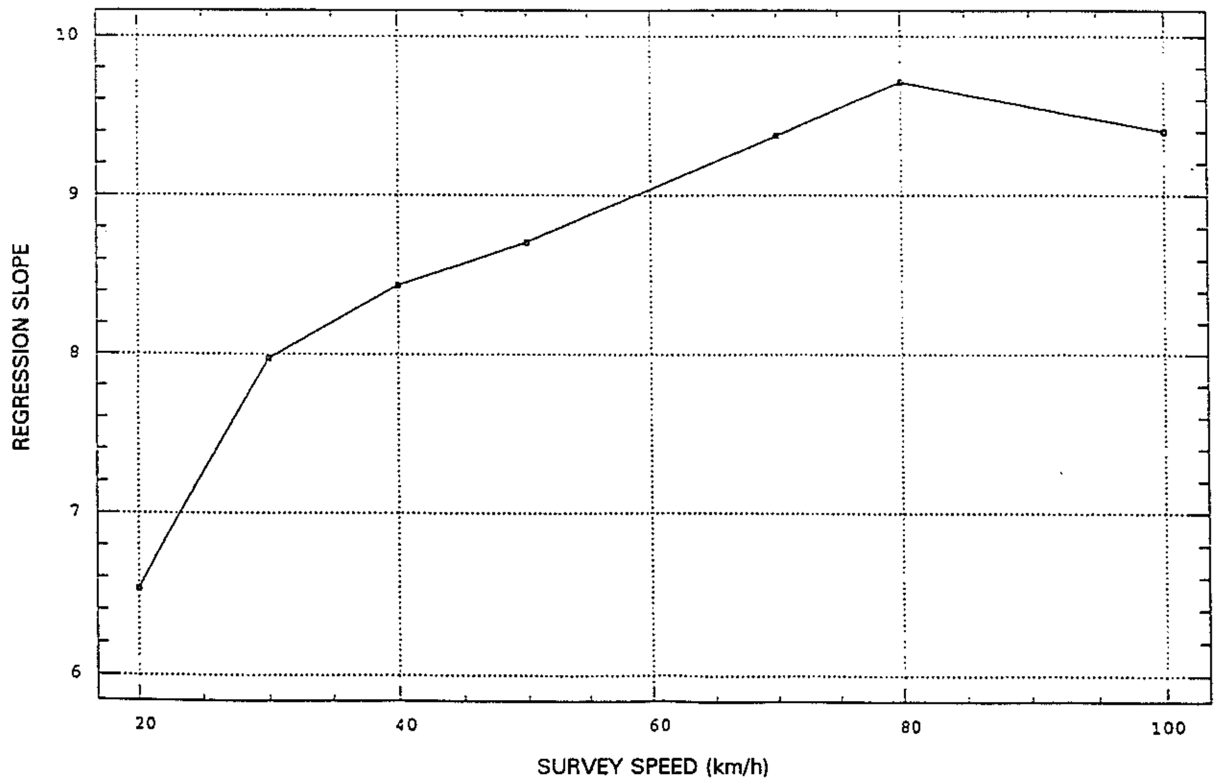
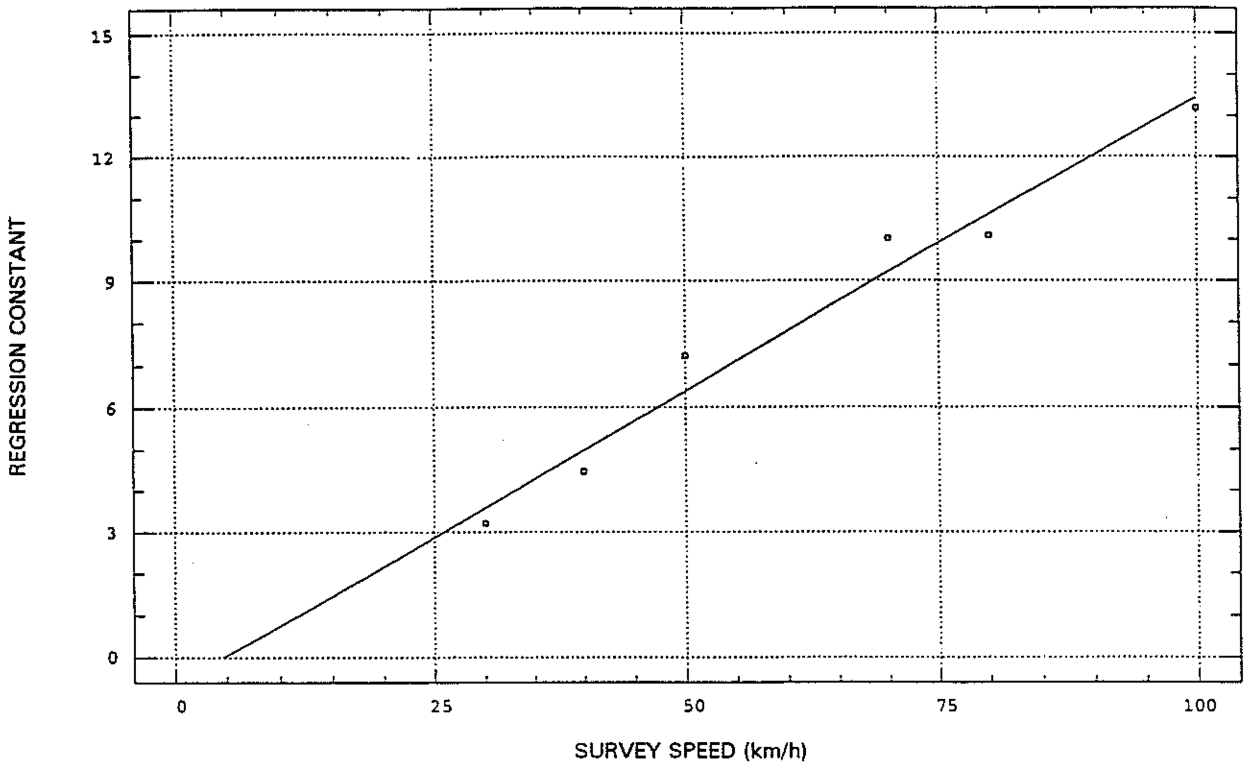


Figure 9. Straight line regression of constant (without 20 km/h).



It therefore appears that the basic relationship between the raw counts and NAASRA counts hold in the speed range of 20-100 km/h. It is not surprising that the spread of results increases the more the speed differs from 80 km/h, as responses of both the vehicle springs and the shock absorbers will be affected by speed.

The response of the vehicle to different speeds is not consistent. For example, one section with a NAASRA roughness of 54 counts/km (4.3 decreasing) had average raw counts ranging between 4.2 and 4.9 over the 20-100 km/h; on another section of 54 counts/km (2.5 increasing) the counts varied from 8.7 to 4.5. There does appear to be a general trend for the counts to increase as the speed decreases. This is not a function of high levels of roughness as the trend is not evident in the roughest section where counts ranged from 15.8 to 18.1, but the highest and lowest were at 70 and 30 km/h respectively.

3. EFFECT OF ACCELERATING & DECELERATING

Three 100 m sections of the test strip used for the low speed response investigation were selected, based on that data (see Section 2 of this report). The sections were selected to represent a range of roughness.

On each 100 m section 10 runs were performed with the vehicle accelerating and ten runs with it decelerating. For the accelerating runs the vehicle began from a standing start and accelerated smoothly up to 50 km/h. This speed was attained well inside the 100 m distance.

In the decelerating runs the same test sections were run in the same direction starting from 50 km/h and stopping at the end of the 100 m.

The results are given in Table 3 (p.19), together with the average speed attained over the 100 m test section. Although the average speeds for the accelerating and decelerating runs were similar, a greater difference exists between the raw counts for the smoother sections.

Although consistent raw counts were obtained for the 10 runs, the difference between the accelerating and decelerating runs are significantly different for test sections 1 and 2. For test section 3 the means are not significantly different.

Table 4 summarises the raw count mean data, together with the constant speed results for each of the road test sections. The NAASRA roughness calculated from the 40 km/h regressions are also given.

Table 4. Comparison of the accelerating and decelerating effect.

Test section	Constant speed (40)		Accelerating		Decelerating		True roughness (counts/km)
	Raw counts	Calculated counts/km	Raw counts	Calculated counts/km	Raw counts	Calculated counts/km	
1	3.4	33	2.2	23	3.5	34	39
2	6.2	57	3.6	35	4.7	44	68
3	17.1	149	16.2	141	16.4	143	178

The "true" NAASRA roughness of these 100 m test sections taken from the 80 km/h runs are 39, 68 and 178 counts/km. For these three test sections, accelerating and decelerating, as well as the constant speed runs, all under-estimate the real value.

Based on the prediction limits as affected by speed given in Section 2 of this report, the acceleration results on test sections 1 and 2 and the deceleration result on test section 2 are outside the 95 percentile limits. Overall, there is no apparent trend and thus the effect of accelerating and decelerating is site-dependent, but can result in an increased error.

Table 3. Accelerating and decelerating tests.

Accelerating test from standing start to 50 km/h over 0.1 km

Section 1 roughness = 39.2 counts/km												
Distance	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Mean	Mean speed
Raw counts	2	2	2	2	3	2	2	3	2	2	2.2	
Speed (km/h)	48	51	39	44	43	37	52	46	49	52		46.1
Section 2 roughness = 68.4 counts/km												
Distance	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Mean	Mean speed
Raw counts	4	3	3	3	4	3	4	4	4	4	3.6	
Speed (km/h)	44	50	49	49	38	39	36	50	51	51		45.7
Section 3 roughness = 178 counts/km												
Distance	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Mean	Mean speed
Raw counts	17	16	16	15	16	16	18	16	16	16	16.2	
Speed (km/h)	44	37	48	49	39	39	44	48	39	35		42.2

Decelerating test from 50 km/h to stop over 0.1 km

Section 1 roughness = 39.2 counts/km												
Distance	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Mean	Mean speed
Raw counts	3	4	3	4	4	3	3	4	3	4	3.5	
Speed (km/h)	38	39	44	38	41	37	37	37	38	40		38.9
Section 2 roughness = 68.4 counts/km												
Distance	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Mean	Mean speed
Raw counts	5	4	5	4	4	5	5	5	5	5	4.7	
Speed (km/h)	44	36	43	43	42	41	40	45	36	42		41.2
Section 3 roughness = 178 counts/km												
Distance	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Mean	Mean speed
Raw counts	16	15	17	16	17	16	16	16	17	18	16.4	
Speed (km/h)	36	39	39	37	40	39	43	43	42	41		39.9

4. EFFECT OF TORTUOUS ROUTES

This part of the project was designed to investigate the effect of bends on the response of the NAASRA roughness meter. Although the displacement between the vehicle body and axle is measured at the centre, the concern is that body roll could significantly affect the results.

Two sections of road were surveyed (Coast Road and Moores Valley Road in Wellington region). On both sections the maximum safe operating speed was approximately 70 km/h. This speed is greater than the driver would normally have used to survey these sections of road. One section was 1.1 km in length and the other 0.6 km. Test results of the three runs performed at three speeds (30, 50, 70 km/h) are given in Table 5 (p.21).

By applying the regression equations from Table 2 to the data, the calculated NAASRA roughness counts for the various speeds shown in Table 6 are obtained.

Table 6. Calculated roughness values for tortuous route tests.

Location	**Speed (km/h)**		
	30	**50**	**70**
	NAASRA counts/km		
Coast Road	79	87	95
Moores Valley	67	63	66

Although the Coast Road section indicates that the roughness is greater at higher speeds, there is little difference on the Moores Valley section. The range of results for the Coast Road section are no greater than what could be expected from the speed-based regression prediction.

Overall, on these two sections the tortuous alignment has not resulted in a variation in roughness that is beyond the effect expected from the difference in the survey speed.

Table 5. Tortuous route tests.

Coast Road tortuous alignment test

Raw NAASRA counts at different speeds											
30 km/h				**50 km/h**				**70 km/h**			
Distance (km)	**Run 1**	**Run 2**	**Run 3**	**Distance (km)**	**Run 1**	**Run 2**	**Run 3**	**Distance (km)**	**Run 1**	**Run 2**	**Run 3**
0.1	10	10	9	0.1	9	9	9	0.1	9	9	9
0.2	9	10	9	0.2	9	10	9	0.2	10	10	10
0.3	7	8	8	0.3	8	7	7	0.3	7	6	7
0.4	10	10	10	0.4	10	10	11	0.4	10	10	10
0.5	13	13	14	0.5	15	13	13	0.5	15	15	13
0.6	12	11	13	0.6	12	13	10	0.6	11	11	13
0.7	7	7	7	0.7	7	7	7	0.7	7	7	6
0.8	9	9	9	0.8	9	9	8	0.8	9	9	9
0.9	11	9	10	0.9	9	9	9	0.9	9	7	7
1.0	8	10	9	1.0	8	8	9	1.0	8	9	8
1.1	8	7	8	1.1	7	7	7	1.1	6	7	8
Mean	9.5	9.5	9.5	Mean	9.4	9.3	9.0	Mean	9.2	9.1	9.1
Overall mean			9.5	Overall mean			9.2	Overall mean			9.13

Moores Valley Road tortuous alignment test

Raw NAASRA counts at different speeds											
30 km/h				**50 km/h**				**70 km/h**			
Distance (km)	**Run 1**	**Run 2**	**Run 3**	**Distance (km)**	**Run 1**	**Run 2**	**Run 3**	**Distance (km)**	**Run 1**	**Run 2**	**Run 3**
0.1	7	8	8	0.1	6	7	6	0.1	5	5	6
0.2	8	8	7	0.2	6	6	5	0.2	5	5	5
0.3	8	9	9	0.3	7	6	7	0.3	7	6	6
0.4	9	9	9	0.4	6	6	6	0.4	6	6	7
0.5	8	9	8	0.5	8	8	8	0.5	8	8	8
0.6	7	7	7	0.6	5	6	6	0.6	5	5	5
Mean	7.8	8.3	8	Mean	6.3	6.5	6.3	Mean	6	5.8	6.2
Overall mean			8.0	Overall mean			6.4	Overall mean			6

5. DISCUSSION

This investigation was commissioned to investigate the effect of three variables on the response of the NAASRA roughness meter. Although it has been shown that significant variation in the calculated NAASRA roughness can be attributed to these variables, the end effect on the manner in which the data are used is the major concern.

In any test method variations do occur. If the error of measurement is not significant in the end use of the data then the test is worthwhile. On the other hand, if the test variability seriously affects the use of the data then either the test requires modification or a greater uncertainty in the use of the data must be accepted.

Road roughness data is used at present in New Zealand for two tasks:

1. to indicate trends in the performance of a network; and
2. as an input into calculating road user costs for project appraisal.

5.1 Network Trends

When roughness data from a network is to be compared from one survey to the next using the same vehicle, it is considered that the variations found in this investigation will not be significant. The basis for this opinion is that lengths of the network where speed is reduced, accelerating or decelerating occur, or is of a tortuous nature will remain basically the same between surveys. Therefore the variations from the real NAASRA value that do occur will be similar for each survey. As the test conditions are constant then statistical comparisons between the overall mean or standard deviation of the total network data will be valid.

If different vehicles are used variations may be significant in that their low speed response, which is a function of their suspension characteristics, could be significantly different.

The extent of the differences will depend on the speed regime of the survey. It would be expected that the greatest differences will occur in urban areas and where the topography restricts the vehicle speed to under 50 km/h.

5.2 Project Appraisal

When roughness data are used for the economic appraisal of a roading project the accuracy of sections of a network database are more critical. Road user costs calculated in an economic appraisal are a function of roughness level and traffic volume. On higher traffic volume roads a small change in roughness level can indicate a substantial change in road user costs.

5. *Discussion*

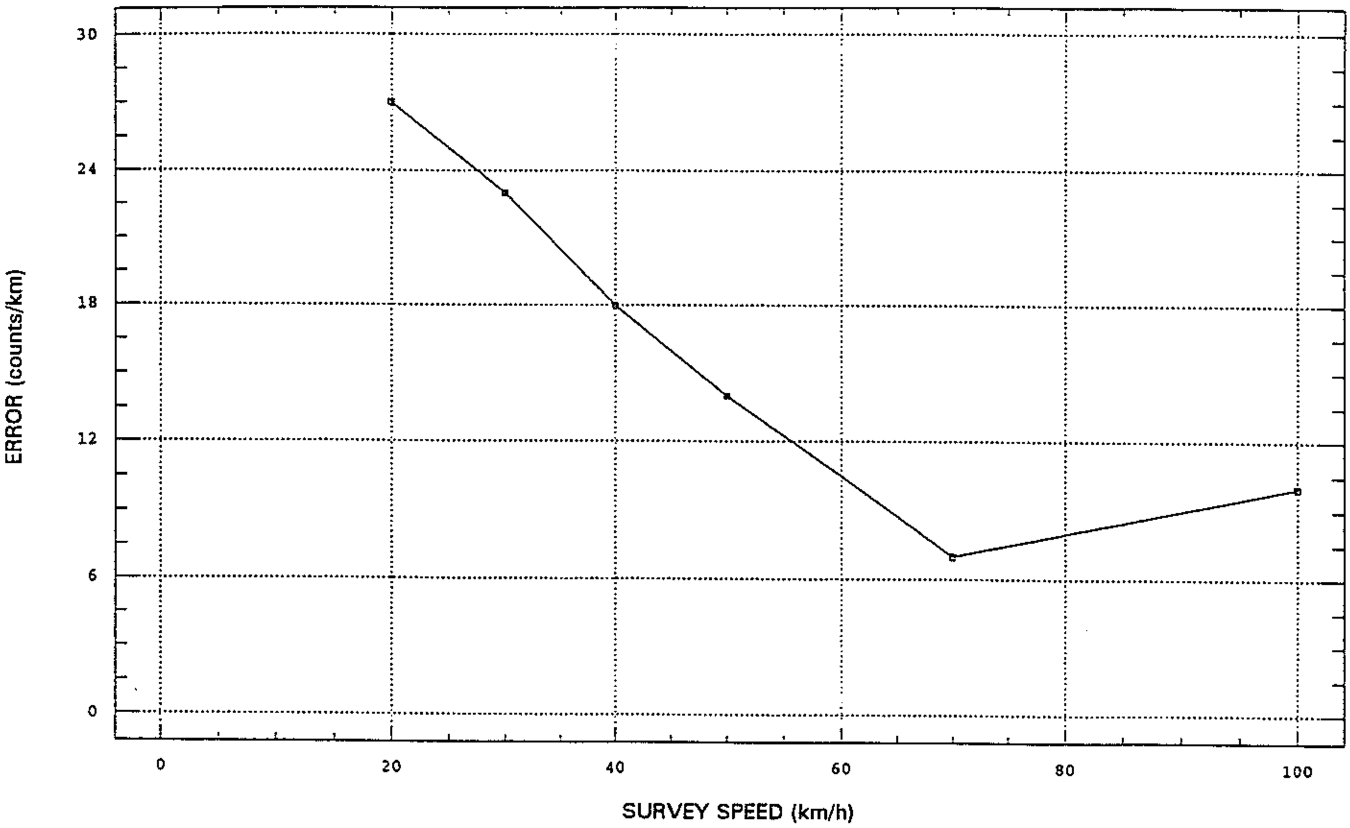
This investigation has shown that low vehicle speeds can lead to very significant errors in the derived NAASRA roughness. This variation can be either over or under the true value. Errors associated with accelerating or decelerating can also contribute significant error, but any cornering effects are less significant.

The effect of the inherent variations in roughness measurements can result in errors in the resulting benefit/cost ratio, as defined in the Transit New Zealand (1991) *Project Evaluation Manual*. A sensitivity analysis needs to be performed to determine this effect on a project by project basis.

The prediction limits associated with performing the survey at a speed other than 80 km/h give an estimate of the error associated with speed that can occur. Inspection of Figures 1 to 6 indicates that the 95% prediction limits in this investigation are close to being parallel to the regression line, i.e. the error is a constant rather than a percentage of the roughness value.

Figure 10 shows the relationship between this error and the survey speed. It shows that the roughness of a pavement section could differ from the real value by ±25 NAASRA counts at 20 km/h which drops to ±7 NAASRA counts at 70 km/h. This possible error is associated only with the survey speed and does not include factors such as vehicle calibration, driver effects, acceleration or topography.

Figure 10. Prediction error as a function of speed.



6. CONCLUSIONS

This investigation into three facets of the operation of the NAASRA roughness meter:

1. effect of low speeds;
2. effect of accelerating/decelerating; and
3. effect of tortuous alignment.

It has shown that the effect of low speed is the most significant, and that the vehicle response at low speed does not appear to allow a robust correlation with NAASRA roughness.

For network surveys, especially using the same vehicle, these three effects are not expected to significantly affect an analysis of trends as the effects will tend to be constant for each survey of the same road network.

For project evaluation, the effect of low speeds (especially below 50 km/h) can result in significant errors in determining the true roughness level.

7. RECOMMENDATIONS

This research project has demonstrated that significant errors in road roughness measurement can result when the NAASRA roughness meter is operated at low speeds. These errors are such that, especially in urban areas, the output from the instrument is unsuitable for input into the project evaluation methodology.

The recommendations are that:

1. For network assessment, the use of this instrument is phased out in urban areas, and also in rural areas where the topography results in significant lengths of roads being surveyed at a speed of less than 50 km/h.
2. For project evaluation both the survey speed and the roughness value are used, with the results presented in this report, to perform a sensitivity analysis to determine the robustness of the benefit/cost ratio.
3. Instruments sensitive to survey speed, e.g. laser profilometers, are used wherever possible.