Pavement Management Services (PMS) have been involved with the management of the Transit New Zealand (TNZ) Performance Specified Maintenance Contract (PSMC) 001 from its commencement on the 1st of January 1999. With a term of ten years, this contract was the first of its type to operate within New Zealand and the PARMMS® Road Manager pavement management system supplied by PMS has been used to predict pavement performance from the early stages of the tender submission until the present day. The PARMMS® Road Manager pavement management system and experience within the TNZ PSMC 001 contract are used to examine the Challenge Case Study.

Analysis Methodology

Segmentation

The first step of any network-level pavement analysis requires that the network be divided into relatively homogeneous segments based on inventory and pavement condition. Cumulative Sum or Difference techniques are usually employed to locate the break points for these segments. Ullidtz (Ullidtz 1998), Chapter 15, *Uniform subsections* pp 173-176 provides a useful introduction to the methodology. To this end it is the intended that a dynamic segmentation module be included in the next release of the PARMMS Pavement Management System.

The summarised form of the data provided for the case study does not allow for further segmentation to be undertaken but given the range of segment lengths (from 30 metres to over 200 km) it is recommended that this be carried out. A large segment that represents a significant proportion of the network should be of particular concern as the condition of this an segment will influence the budget available for other segments, possibly leading to difficulties balancing treatments across the network as a whole.

It is to be expected that the segmentation specified by the case study will increase budget requirements over the alternative segmentation methodology that we have outlined.

Synchronisation

An examination of the information provided for the case study reveals that the most recent data available is from 2002. Assuming that the analysis is to commence from the current year, it is apparent that the data supplied is two years out of date. PARMMS deals with this scenario in a routine manner during its "Synchronisation" phase; projecting traffic growth at the specified growth rate and deteriorating pavement condition in accordance with HDM IV models to produce an initial condition for the analysis.

Intervention Levels

Decision trees or matrices are used within PARMMS to allow intervention or trigger levels to be used for various treatments. In the current version of PARMMS the "Classification" and "Resolution" Matrices represent the decision- level components. A formatted version of the Classification Matrix and Resolution Matrix indicating the intervention levels employed for various treatments are presented in Figure 1 and
Figure 2 respectively.

Network	Distress Factor	Distress Level	Recommended Treatment	Next Decision
Interurban	Roughness	<=70	No treatment	Rut Depth
		>70 and <=240	Redesign	
		>240	Reconstruction	Resolution Matrix
	Rut Depth	<=12	No treatment	Structural Cracking
		>12	Redesign	
	Structural Cracking	<=5	Structural Patching	Resolution Matrix
		>5	Redesign	
Rural	Roughness	<=70	No treatment	Rut Depth
		>70 and <=240	Redesign	
		>240	Reconstruction	Resolution Matrix
	Rut Depth	<15	No treatment	Structural Cracking
		>15	Redesign	
	Structural Cracking	<=5	Structural Patching	Resolution Matrix
		>5	Redesign	

Figure 1 Classification matrix

Classification Matrix Instruction	AC Ovrelay Deficiency (mm)	Roughness (NRMC)	Network	Rut Depth (mm)	Texture Depth (mm)	Structural Cracking (%)	Seal Age Maximum Exceeded	Treatment
Do nothing							FALSE	Do Nothing
							TRUE	Bituminous surface
Strutural patching								Stuctural patching
Redesign	<=35	<=85	Interurban	<=12		<=2		Stuctural patching
						>2		35mm AC Inter
							TRUE	Bituminous surface
				>12				80mm AC Inter
			Rural	<=15	<=1			Bituminous surface
					>1	<=2		Do Nothing
						>2		35mm AC Rural
							TRUE	Bituminous surface
				>15				80mm AC Rural
		>85 and <=160	Interurban					80mm AC Inter
			Rural					80mm AC Rural
		>160	Interurban					Reconstruction Inter
			Rural					Reconstruction Rural
	>35 and <=80		Interurban					80mm AC Inter
			Rural					80mm AC Rural
	>80		Interurban					Reconstruction Inter
			Rural					Reconstruction Rural
Reconstruct			Interurban					Reconstruction Inter
			Rural					Reconstruction Rural

Figure 2 Resolution matrix

Many of the intervention levels are drawn directly from the case study specifications, others from experience within the pavement management environment.
The philosophy behind the selection of treatments in the resolution matrix was to avoid the higher level of future routine and periodic maintenance by selecting only structurally adequate treatments in each category. For instance if Austroads overlay requirements call for at least 80mm of AC overlay it is considered counter productive to install a 35mm non structural AC overlay.

Ideal Strategy

PARMMS examines the case of an unconstrained budget during the "Ideal Strategy" phase of its operation. During this phase a variety of treatment options are examined within a Whole of Life Cost (WOLC) framework to determine the ideal treatment for each segment of the network, including a "Do Nothing", "Routine Maintenance" and a list of user defined treatments. The factors affecting the selection of a treatment include the cost of the initial treatment and the cost of future treatments accruing as a result of the initial treatment over the analysis period (20 years in this case). Treatment costs and work effects will have significant influence during this phase.

HDM IV models are employed by PARMMS to deteriorate segments between treatments, the rate of deterioration being adjusted to suit local conditions via a set of calibration coefficients. The values used for the case study analysis are based on those supplied and the nearly twenty years of calibration experience within Pavement Management Services. It has been decided that separate calibration coefficients for Interurban and Rural environments is difficult to justify and a single set of coefficients has been used as listed in
Table 1.

Table 1 Calibration coefficients

Deterioration Model	Calibration Factor	Value
Wet/Dry Season SNP Ratio	Kf	1
Drainage Factor	Kddf	1.0 (No effects)
All Structural Cracking – Initiation	Kcia	1.1
Wide Structural Cracking – Initiation	Kciw	1.1
All Structural Cracking – Progression	Kcpa	0.3
Wide Structural Cracking – Progression	Kcpw	0.3
Rutting – Initial Densification	Krid	0.5
Rutting – Structural Deterioration	Krpd	1.3
Ravelling – Initiation	Kvi	2
Ravelling – Progression	Kvp	0.5
Pothole – Initiation	Kpi	2
Pothole – Progression	Kpp	0.25
Edge Break	Keb	1
Roughness – Environmental Coefficient	Kgm	0.023
Roughness – SNPK	Ksnpk	1
Roughness – Progression	Kgp	0.8
Texture Depth – Progression	Ktd	1
Skid Resistance	Ksfc	1
Skid Resistance – Speed Effects	Ksfcs	1

The level of structural deficiency is detected in pavement via Austroads (Austroads 1992) empirical relationships, using either the granular or bituminous overlay recommendations depending on the surface type. To this end the surface type is tracked by PARMMS throughout the analysis period.

Optimisation

Budget constraints are introduced during the "Optimisation" phase of PARMMS operation and the allocation of budget will depend largely on the strategy or priorities adopted by the pavement manager. For instance it is possible to favour structural improvement over surfacing or attempt a more balanced strategy by improving roughness. Other strategies include the use of a Pavement Condition Index (PCI) that combines individual condition indices in a weighted function.

Output

Output from PARMMS includes a variety of reports (including user defined) and graphical presentations, although the budget tables (MS Access format) are the most likely source of information for customised analysis. Figure 3 indicates the distribution of roughness over the analysis period for our preferred strategy using roughness and structural cracking as priorities at a budget level of $60 Million.

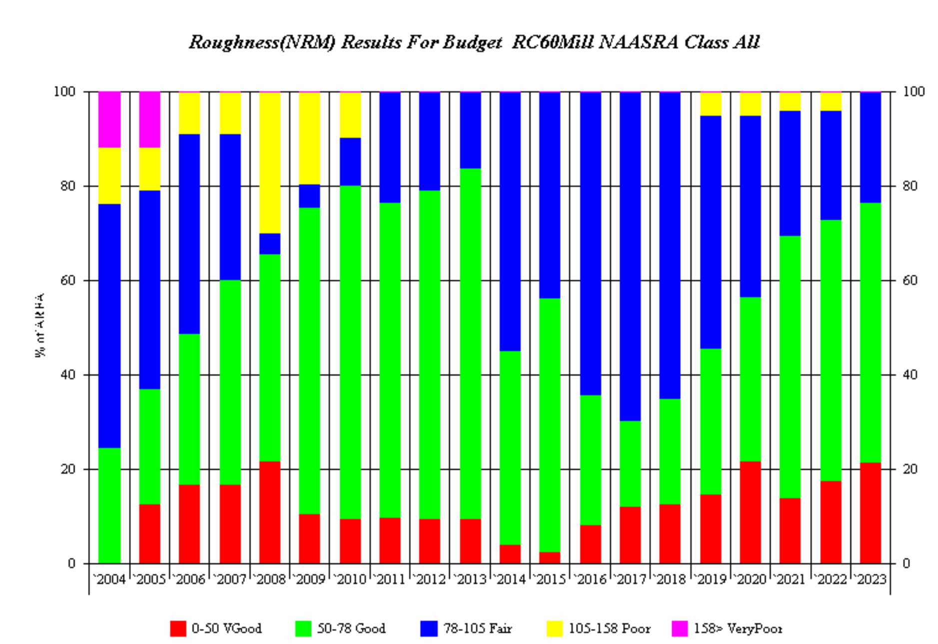

Figure 3 Roughness distribution

The classifications of roughness in Figure 3 are based on case study thresholds but are similar to values that would be used within the PSMC 001 contract. It is clear that the proportion of the network in the Very Good to Good categories have been expanded while Fair has been reduced and Poor to Very Poor eliminated without entering a period where Poor or Very Poor roughness predominate. This is an acceptable outcome.

Constrained Budget

A combined Roughness and Traffic strategy has been developed in response to the case study imperative: "All existing sections in poor or very poor condition and carrying more than 7,500 vehicles per day should be treated within the first three years of the proposed works programme." We will compare this Roughness and Traffic strategy with two alternatives; Roughness improvement alone and treatment of Roughness and Cracking.

We are given a two study budgets, $200 million and $300 million over 20 years, or $10 million and $15 million per annum respectively.

In the analysis budgets have been identified with abbreviations as indicated in
Table 2.

Table 2 Strategy / budget abbreviations

Strategy	Budget	Abbreviation
Roughness and Traffic (Case Study Imperative)	$ 10 million	RA10
	$ 15 million	RA15
Roughness	$ 10 million	R10
	$ 15 million	R15
Roughness and Cracking	$ 10 million	RC10
	$ 15 million	RC15

With a budget of $10 million it is predicted that the average network roughness will rise over the analysis period as indicated in Figure 4.

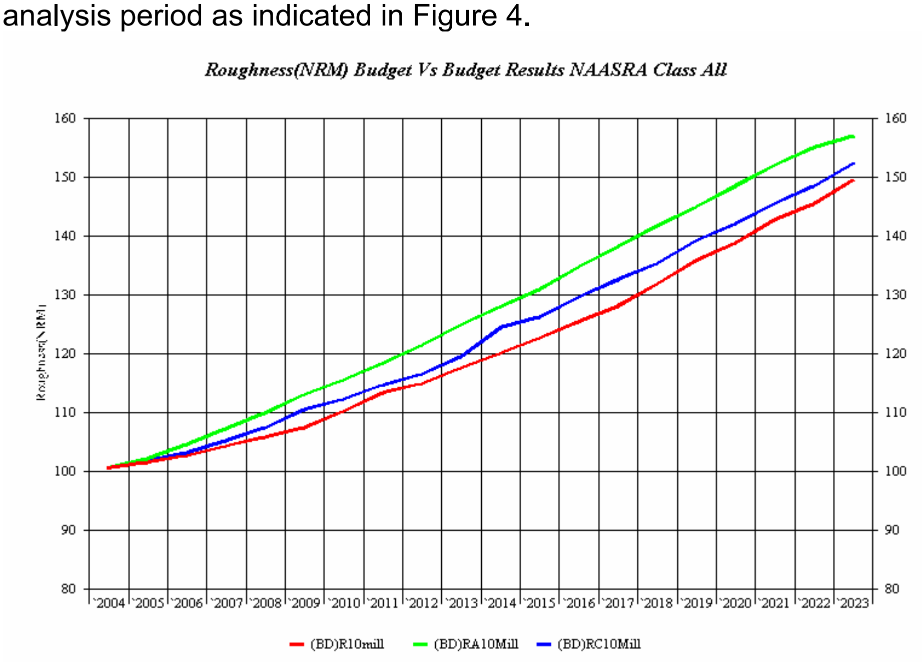

Figure 4 Roughness $10 million

Figure 5 indicates that a budget of $15 million improves roughness slightly but the prudence of the Roughness and Traffic strategy remains doubtful.

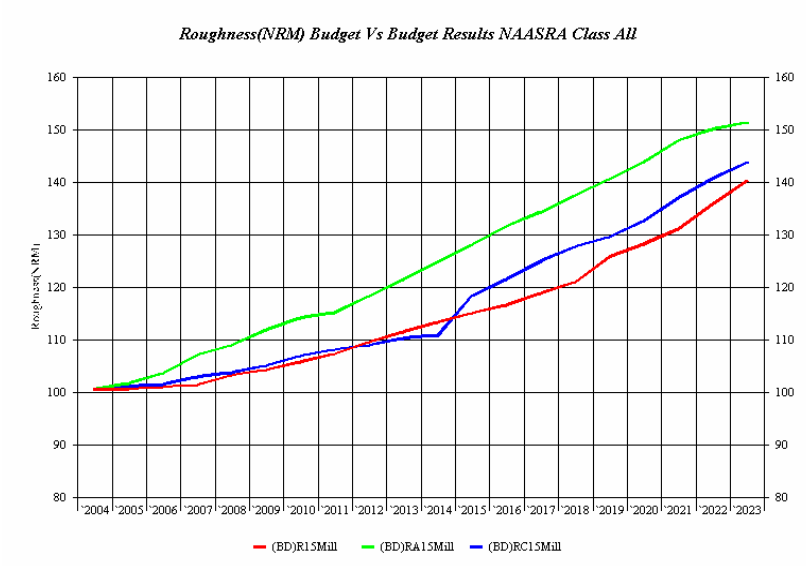

Figure 5 Roughness $15 million

The roughness prediction for the roughness and cracking improvement strategy is slightly higher than that for the strategy for improvement of roughness alone but this should be no surprise as some of the budget that would have been used for roughness improvement is now being used to target cracking. An intervention or trigger level of 12 to 15 mm has been specified for rut depth and this is reflected to a small extent in Figure 6 that indicates the average network rut depth predicted from the various strategies and budgets.

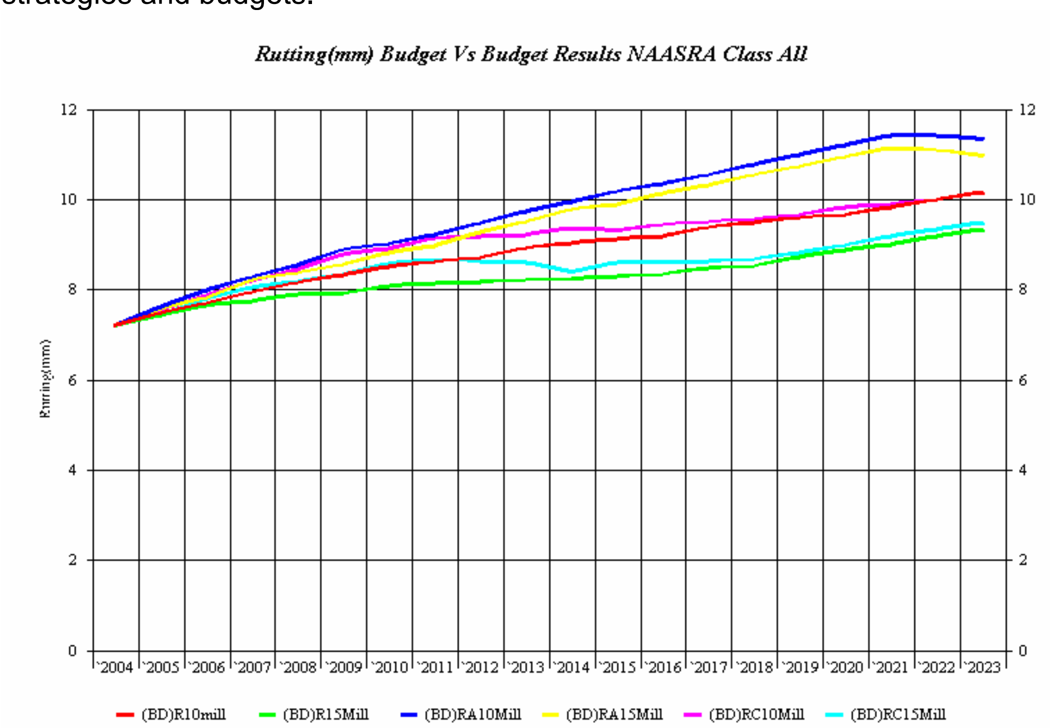

Figure 6 Rut Depth

Although the rut depth for most strategies and budgets is similar it is apparent that the Roughness and Cracking strategy on the lower budget of $10 million forces the use of treatments that have a slightly greater impact on rut depth.

It is sufficient to note that all options considered predict a reduction of average pothole patching on the network as indicated in Figure 7. Pothole patching is thus a non-critical condition.

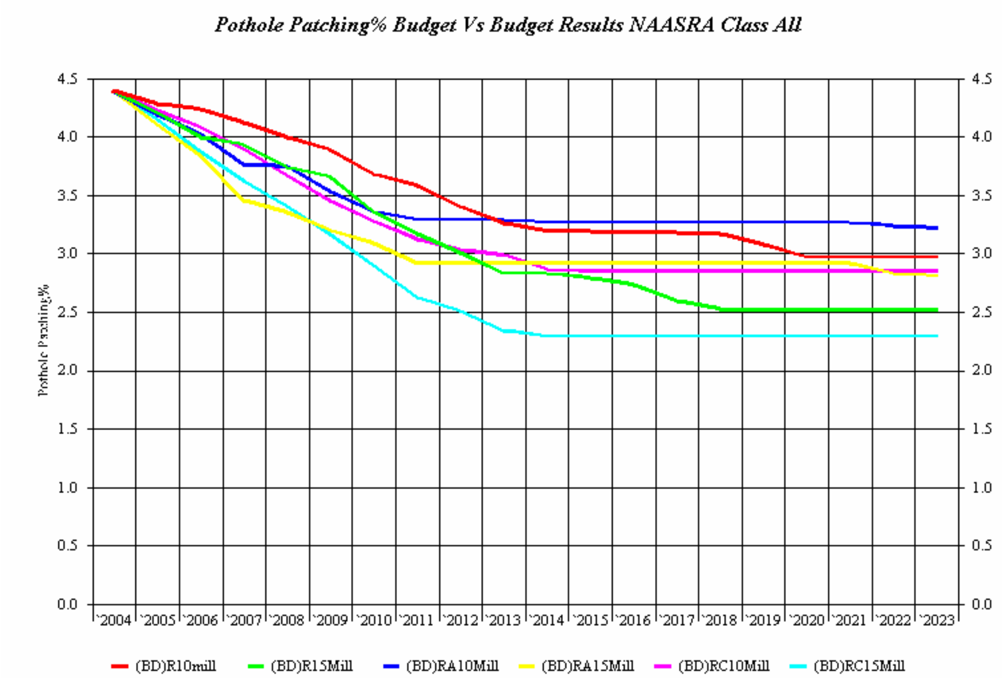

Figure 7 Pothole patching

In the case of structural cracking the prediction of Figure 8 indicates that the most effective strategy involves the treatment of roughness and cracking as a priority.

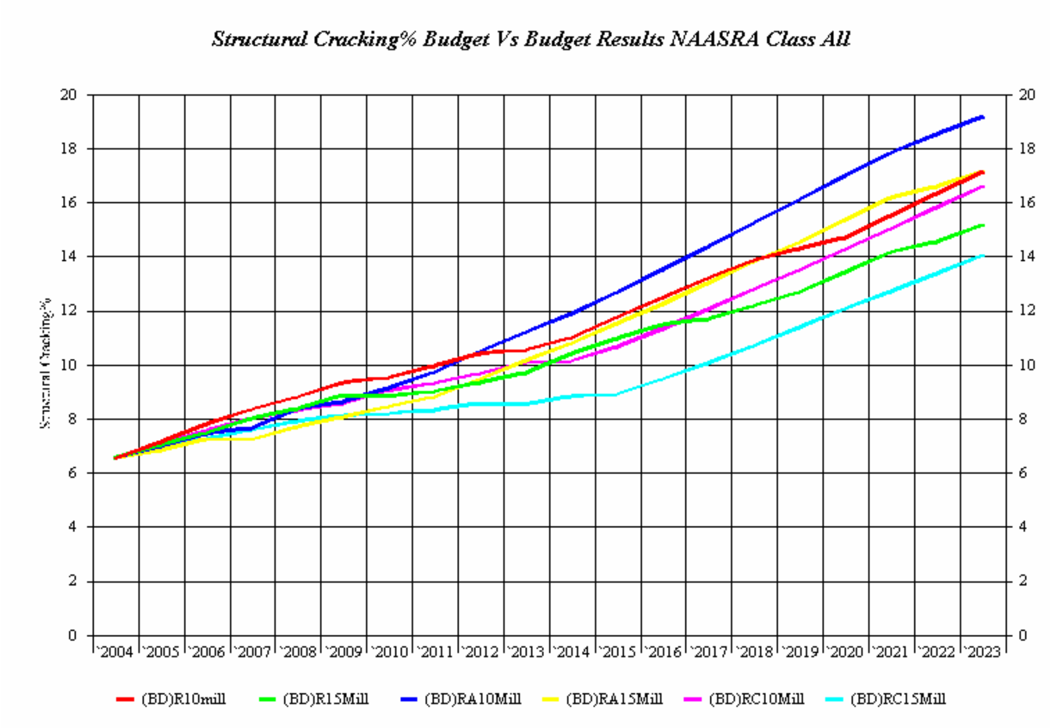

Figure 8 Structural cracking

The prediction for environmental cracking shown in Figure 9 is very similar to that for Structural Cracking and again the most effective strategy involves the treatment of roughness and cracking as a priority.

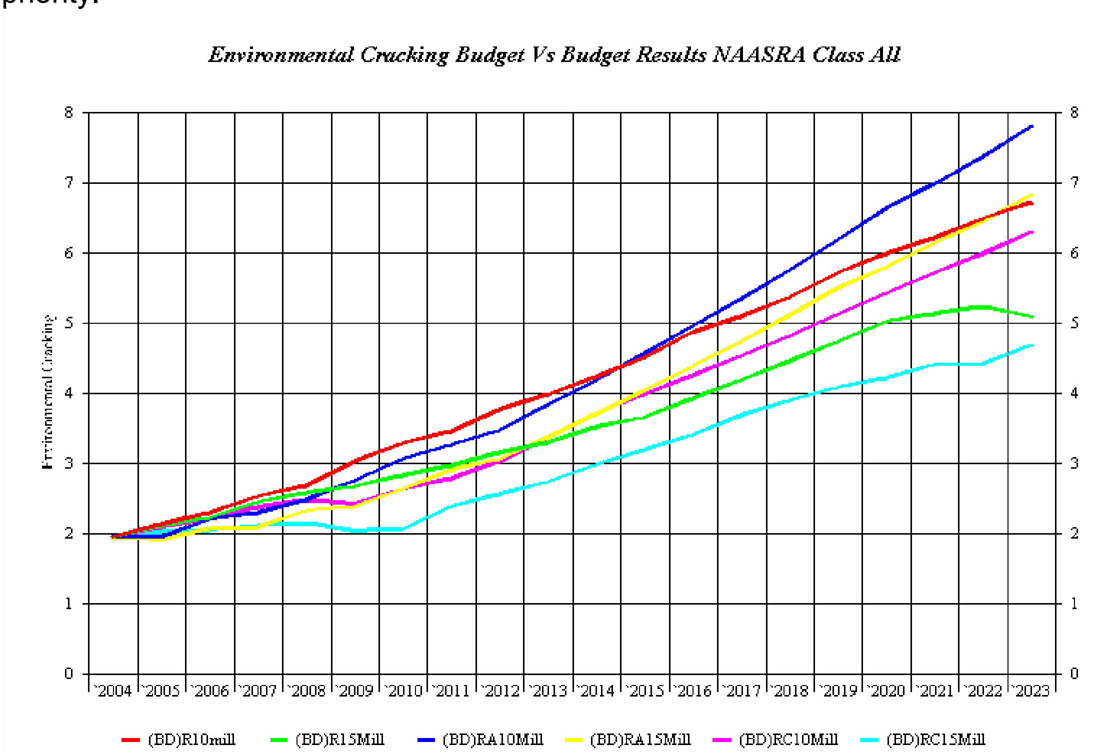

Figure 9 Environmental cracking

As expected the prediction for ravelling in Figure 10, as for structural and environmental cracking, again suggests that the most effective strategy involves the treatment of roughness and cracking as a priority

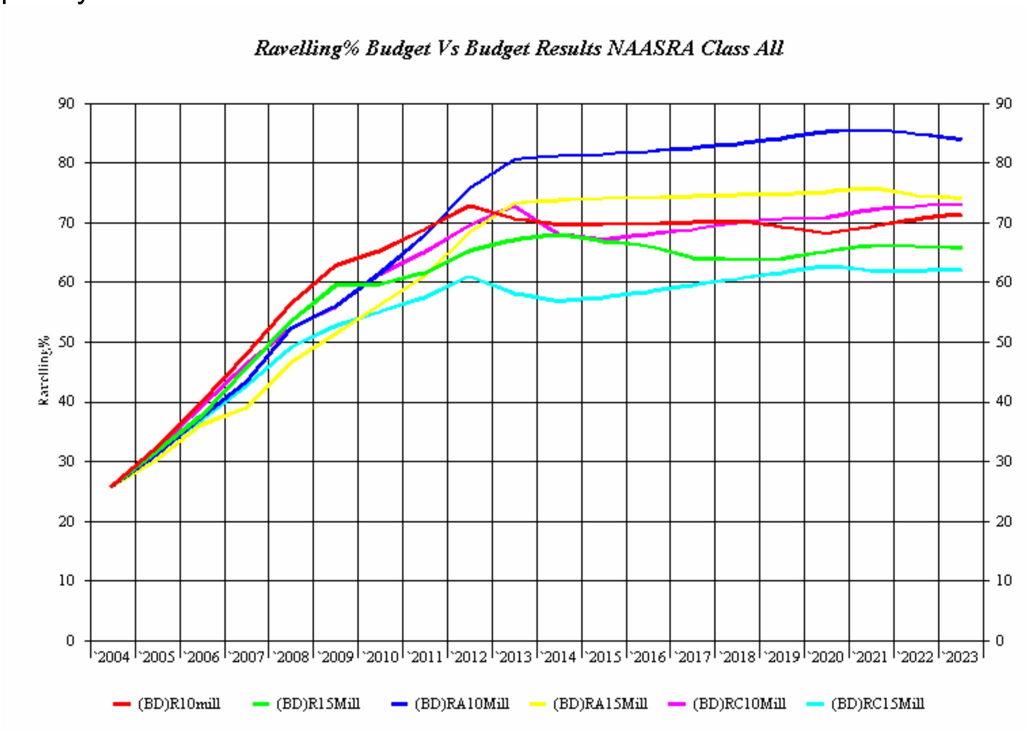

Figure 10 Ravelling

As for pothole patching, it is sufficient to note that all options considered predict a reduction of average potholes on the network as indicated in Figure 11. Potholes are thus a non-critical condition.

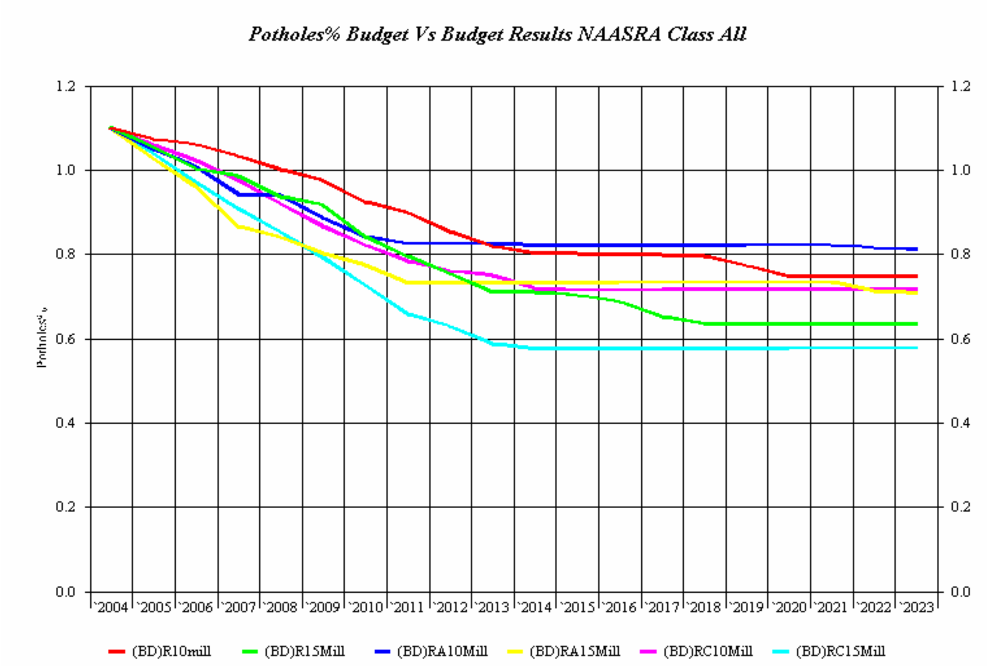

Figure 11 Potholes

It is clear that a decision needs to be made on which strategy best represents stakeholder priorities and the perception of the network by the public. It can be seen that for a given budget the Roughness and Traffic strategy consistently resulted in a poorer average network condition by the end of the analysis period.

Sensitivity to Budget Variations

The analysis has shown that neither of the budgets recommended by the study was able to reduce average network roughness below the initial level of 100 NRMC (3.8 IRI). In fact it has been found that an annual budget of approximately $60 Million is required to reduce average network roughness to acceptable levels by the end of the analysis period as indicated by the Roughness and Traffic strategy in Figure 12.

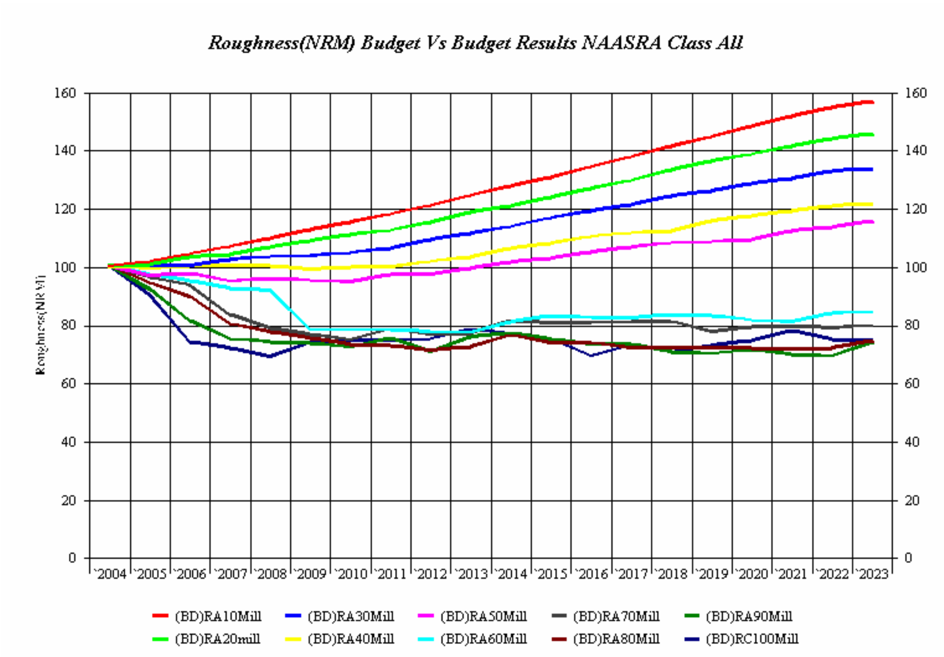

Figure 12 Roughness by budget

A significant gap occurs in the roughness at the end of the analysis period and this is true of all strategies because a significant segment within the network has been treated with a budget of $60 Million that could not have been treated with a budget of say $50 Million. There is also the suggestion in Figure 12 that the network either side of this gap has a different budget sensitivity.

It is difficult to assign meaning to sensitivities at the end of the analysis period when large segments such as R-2LS-H-VP-6-12yrs (297.35 km in length) exist. Additionally the rural network contains seven other segments in excess of 100k in length. When any of these is treated a significant change will occur in the average network condition and sensitivity measurements will contain a large variance. It is in fact very difficult to obtain an average network roughness between 85 and 100 NRMC (3.3 and 3.8 IRI) at the end of the analysis period because of this effect and a very high sensitivity will be recorded in this range.

Let the sensitivity ***S*** of dependent variable ***y*** with respect to independent variable ***x*** be defined as the relative change in ***y*** with respect to the relative change in ***x***:

$$S = \frac{\left(\frac{\Delta y}{y}\right)}{\left(\frac{\Delta x}{x}\right)}$$

Equation 1

or if ***y*** can be expressed as a continuous function of ***x***

$$S = \frac{x}{y} \times \frac{\delta y}{\delta x}$$

Equation 2

Using the definition of Equation 1 we can calculate the results shown in Table 3.

Table 3 Roughness sensitivity

Budget ($ Millions)	Strategy		
	Roughness	Roughness and Traffic	Roughness and Structural Cracking
15	-0.2	-0.1	-0.2
25	-0.1	-0.2	-0.1
35	-0.4	-0.3	-0.5
45	-0.6	-0.3	-0.3
55	-1.5	-1.7	-2.0
65	-0.3	-0.4	0.2
75	-0.2	-0.7	0.2
85	0.7	-0.3	-0.5
95	-0.8	0.1	0.2

The graphical equivalent of the above Table 3 is shown in Figure 13.

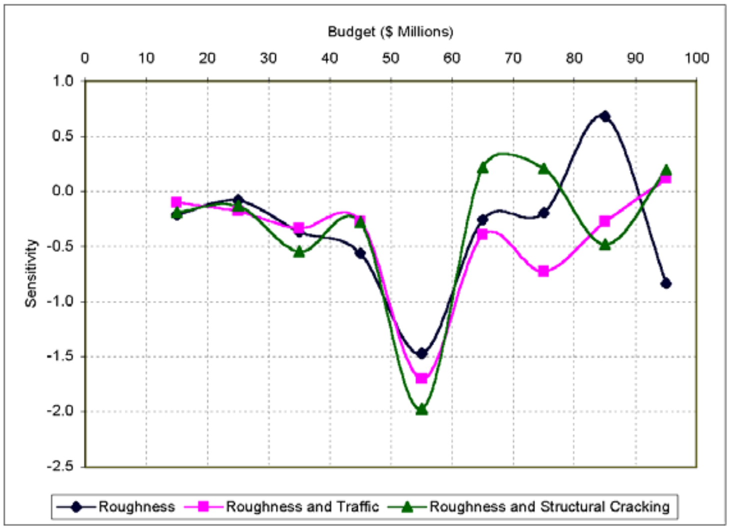

Figure 13 Roughness sensitivity

Figure 13 clearly indicates that sensitivity increases significantly (in an absolute sense) between $50 Million and $60 Million, near budget values that allow large segments of the network to be treated and this is the case.

The rut depth sensitivity is presented in
Figure 14.

Figure 14 Rut depth sensitivity

The Structural Cracking sensitivity is presented in
Figure 15.

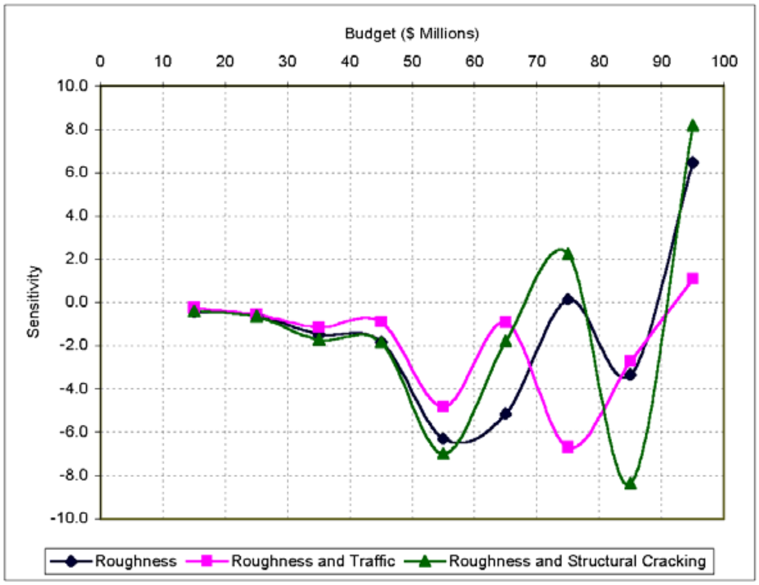

Figure 15 Structural cracking sensitivity

Similar sensitivity characteristics can be demonstrated for a wide variety of condition parameters. It is evident that sensitivity of the various strategies is are largely coherent up to a budget level of between $50 Million and $60 Million, beyond which a divergence in the sensitivities appears to take place.

A $60 Million budget has a split of expenditure between Interurban and Rural networks that varies throughout the analysis period as indicated in
Figure 16.

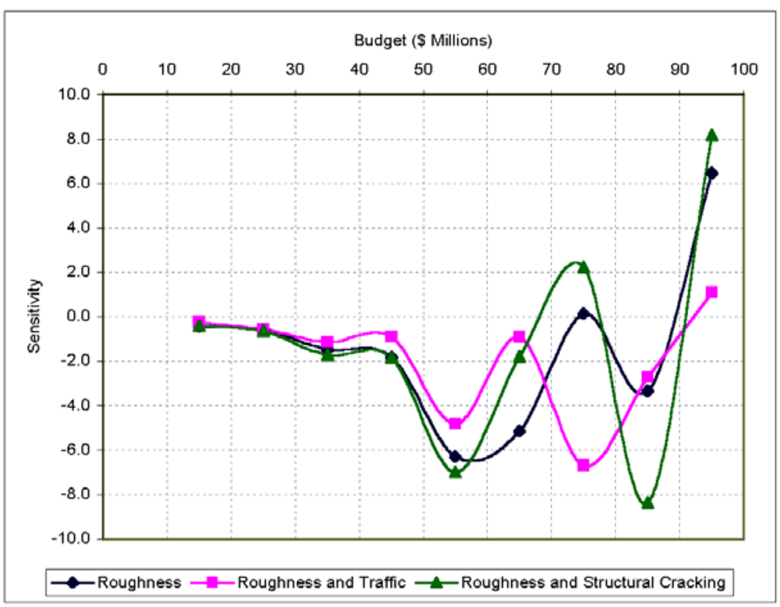

Figure 16 Interurban rural split

It can be seen that the split of Interurban / Rural expenditure will vary by year depending on the strategy employed. The average split will be a function of the condition of respective network segments and their area, however it can be concluded that the Rural network will absorb the greater proportion of funding for most strategies.

Roughness Thresholds
As indicated previously acceptable roughness thresholds are generally in the range 80 to 90 NRMC (3.1 to 3.4 IRI) and this tends to correspond to the threshold at which heavy vehicles are considered to experience roughness related vehicle operating costs. As demonstrated earlier (Figure 4, Figure 5 & Figure 12) the case study budgets would not be capable of reducing roughness to this level. Instead a budget of the order of $60 Million is required although some small reduction on this figure may be possible by pursuing a roughness reduction strategy without reference to deference to traffic levels, although ravelling appears to be quite high within the network and it is inadvisable to ignore this by selecting a roughness only improvement strategy.

Committed Works
The case study includes routine drainage works with a unit cost of $1,000/km/year. Given that the network consists of 2508.29 km of road we can calculate that approximate $2.5 Million will be subtracted from the annual budget for drainage works. Having examined the sensitivity of various condition parameters as a function of the budget we can compute the effects of this budget reduction. From
Table 3 we have a list of sensitivities and if we were to subtract $2.5 Million from a Roughness and Traffic strategy budget of $55 Million with a sensitivity of 1.7 (a high sensitivity budget) is clear that we would forfeit 2.5/55*1.7 = 0.077 NRMC or 0.003 IRI if committed drainage works were subtracted from the budget. Similar calculations are possible for various other parameters.

Usually in the case of committed treatments the work effects of those treatments also need to be taken into account. For instance drainage works will slow the progression of rutting, beam deflection, etc. and this should be taken into account to counter the loss of funding for direct pavement treatments. Particular care needs to be taken to ensure that committed works do not affect the level of a critical budget, that is, one that lies, near a region of high sensitivity where a slight decrease in budget could result in a very large segment remaining untreated. For instance its is known that if a Roughness and Traffic strategy budget of $60 Million is reduced by 2.5 Million to allow for drainage works the average network roughness at the end of the analysis period will rise from 85 to 116 NRMC (3.3 to 4.4 IRI). Clearly sufficient margin needs to be allowed in the budget for critical works to proceed.

Assumptions and Policy Decisions
PARMMS makes the assumption that treatments can be carried out within a single construction season (year). The case study clearly presents segments, particularly within the Rural network, that would take a single work crew 10 years or more to complete. Projects of this magnitude could prove difficult to resource. The simplest solution is to break these large segments into lengths suitable for a single construction season (no more than 8 to 9 kilometres in length). As previously explained these breaks should be determined in a way that will result in each segment having approximate homogeneity in terms of its structure, ancillary structures and condition indices. In terms of condition indices, rut depth, base and subgrade modulus have been found to be useful, roughness less so. On closer examination it is likely to be found that treatment on portions of large segments can be deferred, even where average roughness for the entire segment is high.

Bituminous surfacing and 35mm AC treatments are not suitable treatments for excessive rut depth and the works effects for these have been set to ensure that they are not used for this purpose.
Although the case study suggests the use of a roughness and traffic based strategy for the elimination of high roughness segments within the first three years, a higher effectiveness in terms of the condition

at the end of the analysis period, for alternative strategies has been demonstrated. Additionally a the high initial level of ravelling if ignored would lead to unacceptable levels of ravelling if anything other than a balanced strategy were adopted. Our recommendation would therefore be to employ a strategy aimed at simultaneously reducing roughness and structural cracking.

Decision Support Classification

Table 4 indicates which Framework Characteristics (Robertson 2002) are present within the PARMMS Road Manager pavement management system as operated within Transit New Zealand Performance Specified Maintenance Contract 001.

Table 4 Framework characteristics

Framework Characteristic		
Primary	**Secondary**	**Present**
Supports the Management Functions	Planning	
	Programming	●
	Preparation	
	Operations	
	Policy research	●
Manage and present road asset data (past & current inventory, traffic, condition, work done, expenditure)	Tabular data structure	●
	Geospatial data structure	
Prepare network performance assessments	Asset state	●
	Financial	●
	User impact	
	Value for money	
Calibrated predictive modelling capabilities	Road / bridge deterioration	●
	Vehicle fleet performance	
	Effects of works	●
	Effects on road users	
	Social / environmental effects	
Scope of investment type	Network level	●
	Project level	●
	Developing new road system elements	
	Maintaining existing road system elements	●
	Upgrading existing road system elements	●
Comparison of investment alternatives	Economic costs and benefits	●
	Non-monetary costs and benefits	
Assess investment impacts over asset life cycles		
Provide measures of investment effectiveness	Economic	●
	Social	
	Environmental	
Select investments from competing alternative candidates	Prioritised list	●
	Optimum selection within financial / performance constraints	
	Optimum selection on multiple criteria (eg economic, social, environmental)	
Analyse the sensitivity of outputs to change in inputs		
Analyse the risk of investments achieving desired outcomes		

Decision Support Level: **3.5**

As indicated at the bottom of
Table 4 PARMMS operates with a Decision Support Level (DSL) of between 3 and 4.

Multi-Period Rationing

It has been demonstrated that a single-period rationing budget of $60 Million is required to bring roughness values down to level that could be regarded as acceptable by community standards. However, it will also be noticed that roughness continues to fall further, to the point that we could say that expenditure is excessive in the latter portion of the analysis period. This situation arises because very large segments in the rural portion of the network require a minimum budget to treat, and once treated budget levels could be relaxed. Clearly it would be advantageous if the budget could be varied throughout the analysis period to suit the contingencies at any particular point in time.

Consider the case of a roughness and cracking strategy single period versus multi-period budget as shown in Figure 17. Here the single-period $60 Million budget (lower plot) passes through the region of acceptability, say 80 to 90 NRMC (3.2 to 3.6 IRI) and ultimately results in a roughness below 70 NRMC (2.8 IRI). The upper plot uses a variable budget to redirect the roughness into the region of acceptability.

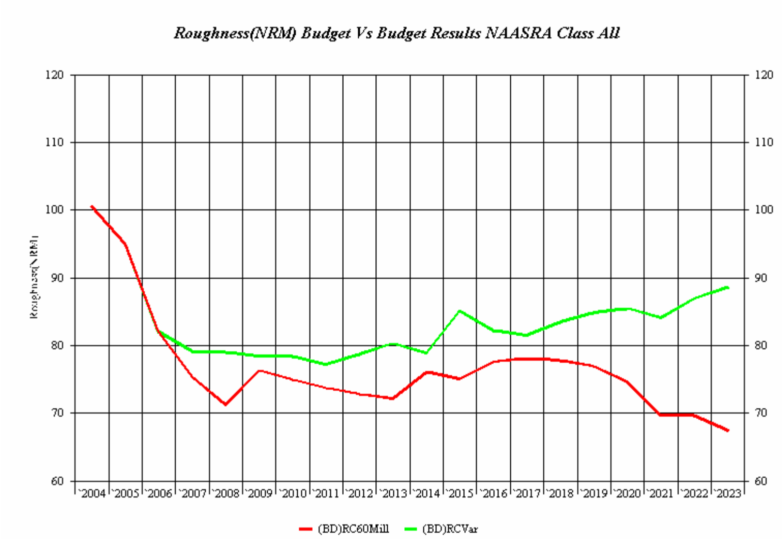

Figure 17: Single versus multi-period rationing

The amount saved by allowing multi-period rationing in this instance is calculated in
Table 5. Here it is obvious that savings of the order of $500 Million dollars are possible over the analysis period or approximately 40% of the single-period budget.

Table 5 Single versus multi-period savings

Year	Expenditure	
	RC060	RCVar
2004	$59,985,698	$59,985,698
2005	$59,983,363	$59,983,363
2006	$59,985,031	$24,978,468
2007	$59,943,941	$24,976,533
2008	$59,921,069	$24,992,583
2009	$59,991,103	$24,990,464
2010	$59,722,582	$24,979,781
2011	$59,789,829	$24,987,429
2012	$59,395,103	$24,981,929
2013	$41,342,340	$29,972,659
2014	$59,801,905	$29,787,820
2015	$59,419,646	$39,961,598
2016	$59,634,191	$39,978,728
2017	$59,768,705	$34,896,275
2018	$59,944,500	$34,946,237
2019	$59,987,390	$34,930,634
2020	$59,948,477	$34,966,069
2021	$59,984,851	$44,903,910
2022	$59,947,905	$44,001,502
Total	$1,118,497,629	$663,201,680
Difference	$455,295,949	41%

Implicit in the above analysis is the assumption that the budget variations in the range of $25 Million to $60 Million can be accommodated through normal funding arrangements and will not attract extraordinary short-term finance costs. Additionally the availability of plant and labour to meet the highly variable workload implied by the multi-period budget runs counter to resource levelling initiatives commonly encountered in this area. It is quite possible that the additional cost of attracting the appropriate level resourcing to those periods of high expenditure will significantly reduce or even eliminate any potential cost savings associated with the multi-period budget. A much closer examination of local resource capabilities is therefore required if expenditure beyond a single-period budget is being contemplated.

It is worthwhile to note that the latest version of PARMMS would be particularly useful in this area in that it supports both resource levelling and year-by-year budget adjustment while simultaneously displaying the effects on future pavement condition.

The Forward Works Programme (FWP) for the multi-period budget can be examined in terms of the treatment length as in
Table 6

Table 6 Treatment lengths

Network	Year	Total Length	Heavy Patching	Bituminous surface	35mm AC	80mm AC	Reconstruction
Interurban	2004	93,500		1,720		91,750	30
	2005	3,480			3,480		
	2006	90,800		1,840		88,960	
	2007	32,060	1,180	4,450	16,350	10,080	
	2008	31,480		12,880	5,430	13,170	
	2009	103,110	36,460			66,650	
	2010	63,490	24,170	34,310		5,010	
	2011	66,140	66,140				
	2012	85,990				85,990	
	2013	15,520	14,040	1,480			
	2014	420,660	357,050	25,190		38,420	
	2015	162,690	142,820	13,970		5,900	
	2016	93,810	63,390	26,940		3,480	
	2017	100,730	42,480			58,250	
	2018	190,550	67,630	85,990		36,930	
	2019	307,280	168,290	33,680		105,310	
	2020	74,070				74,070	
	2021	282,520	262,870			19,650	
	2022	226,650	199,030			27,620	
Total		2,444,530	1,445,550	242,450	25,260	731,240	30
%		100%	59%	10%	1%	30%	0%
Rural	2004	220,180		2,820		214,750	2,610
	2005	300,940		290		3,160	297,490
	2006	41,260	11,590			29,670	
	2007	149,510	690	8,160	55,850	83,650	1,160
	2008	208,700		114,290		94,410	
	2009	116,700	1,990		114,710		
	2010	161,730	50,670			85,270	25,790
	2011	323,080	60,750	145,980		116,350	
	2012	520,590	520,300			290	
	2013	287,540	119,730	630	11,590	155,590	
	2014	636,040	526,620	6,260	8,850	47,270	47,040
	2015	323,130	102,470	600	760	219,300	
	2016	279,420	690	46,620	30,270	201,840	
	2017	590,630	452,170		59,090	79,370	
	2018	444,840	138,460	168,770	22,900	114,710	
	2019	233,410	137,610		79,580	16,220	
	2020	233,780		47,040	184,330	2,410	
	2021	530,460	282,540		47,270	200,650	
	2022	445,750	247,920			197,830	
Total		6,047,690	2,654,200	541,460	615,200	1,862,740	374,090
%		100%	44%	9%	10%	31%	6%

From a treatment length point of view it can be seen from
Table 6 that the majority of treatments carried out within the network centre around routine maintenance (Heavy Patching) and 80mm AC Overlays although the amount of routine maintenance in the interurban network is higher than that in the rural network where substantial treatments such as reconstruction are more common.

The Forward Works Programme (FWP) for the multi-period budget can also be examined in terms of the treatment cost as in
Table 7.

Table 7 Treatment costs

Network	Year	Total Cost ($)	Heavy Patching	Bituminous surface	35mm AC	80mm AC	Reconstruction
Interurban	2004	20,447,644		43,860		20,387,584	16,200
	2005	452,606			452,606		
	2006	19,842,792		40,296		19,802,496	
	2007	3,768,167	3,225	89,046	1,554,224	2,121,672	
	2008	3,761,866		343,122	558,740	2,860,004	
	2009	15,148,544	269,036			14,879,508	
	2010	1,889,273	136,682	744,675		1,007,916	
	2011	767,299	767,299				
	2012	18,611,684				18,611,684	
	2013	133,551	91,101	42,450			
	2014	11,154,425	2,720,878	571,959		7,861,588	
	2015	1,555,602	3,145	335,241		1,217,216	
	2016	1,567,778	67,123	595,443		905,212	
	2017	13,611,574	14,354			13,597,220	
	2018	9,726,589		1,994,109		7,732,480	
	2019	23,641,462		730,518		22,910,944	
	2020	16,772,364				16,772,364	
	2021	4,336,971	213,971			4,123,000	
	2022	5,893,496				5,893,496	
Total		173,083,687	4,286,814	5,530,719	2,565,570	160,684,384	16,200
%		100%	2%	3%	1%	93%	0%
Rural	2004	39,538,054		66,156		38,907,568	564,330
	2005	59,530,757		8,499		692,048	58,830,210
	2006	5,135,676	9,884			5,125,792	
	2007	21,208,366	1,703	169,401	5,440,932	15,355,340	240,990
	2008	21,230,717		2,186,181		19,044,536	
	2009	9,841,920	13,570		9,828,350		
	2010	23,089,720	176,484			17,830,036	5,083,200
	2011	24,218,727	256,793	2,671,434		21,290,500	
	2012	6,370,245	6,290,921			79,324	
	2013	29,835,979	918,657	14,742	1,064,420	27,838,160	
	2014	18,585,652	1,175,611	126,339	860,958	8,153,124	8,269,620
	2015	38,360,289		14,625	90,972	38,254,692	
	2016	38,354,812	654	966,402	2,642,528	34,745,228	
	2017	21,258,942	178,456		5,451,642	15,628,844	
	2018	25,190,139		3,443,127	2,090,312	19,656,700	
	2019	11,248,594			8,145,130	3,103,464	
	2020	18,149,554		826,962	16,833,040	489,552	
	2021	40,510,912	90,042		4,076,562	36,344,308	
	2022	38,047,884				38,047,884	
Total		489,706,939	9,112,775	10,493,868	56,524,846	340,587,100	72,988,350
%		100%	2%	2%	12%	70%	15%

From a treatment cost point of view it can be seen from
Table 7 that the majority of expenditure centres around 80mm AC Overlays. In terms of cost only minor expenditure is recorded against routine maintenance and bituminous surfacing. A more diverse range of treatments has been selected within the rural network where expenditure on 35mm AC overlays and reconstruction are significantly higher than for the interurban network.

The Appendix A contains a portion of the Programme of Works report produced by PARMMS.

Conclusion

The Roughness and Traffic strategy developed in response to the case study imperative for treating pavements in a poor condition and with high traffic in the first three years has been compared with two alternative strategies and found wanting in terms of the condition of the pavement at the end of the analysis period.

Of the alternative strategies, that involving the prioritisation of roughness and structural cracking was seen to give the best overall pavement condition at the end of the analysis period but since the end does not justify the means the roughness distribution over this period was also examined and was found not to have intervals that could be considered unacceptable.

A single-period budget of approximately $60 Million was considered necessary to bring the network to a community acceptable level of roughness without allowing ravelling to elevate to unacceptable levels and this appears to be supported by all strategies considered.

The split in expenditure between Interurban and Rural networks has been demonstrated to vary over the analysis period but generally the Rural network will require the greater portion of expenditure, reflecting its average condition and extent.

It is expected that closer attention to segmentation methodologies on this network would reduce the budget required to bring performance to satisfactory levels within the analysis period.
An examination of the possibility of using multi-period rationing suggests that total savings of approximately $500 Million over the analysis period could be achieved, this amounts to a saving of about 40% of the single-period budget. However, without further details of local financial and resourcing capabilities the full extent of savings remains uncertain.

The pavement condition and benefit/cost of treatments in the rural network has resulted in a more diverse range of treatments being applied than in the interurban network.

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APPENDICES

Appendix A
PARMMS Programme of Works (Portion)

SEGMENT	2004	2005	2006	2007	2008	2009	2010	2011
I-2LS-H-F-<6yrs					80mm AC Inter	Heavy patching		Bituminous surface
I-2LS-H-F-12+yrs				80mm AC Inter	Heavy patching	Heavy patching		80mm AC Inter
I-2LS-H-F-6-12yrs				80mm AC Inter	Heavy patching	Bituminous surface	Heavy patching	80mm AC Inter
I-2LS-H-G-<6yrs					Bituminous surface	Bituminous surface	Bituminous surface	Bituminous surface
I-2LS-H-G-12+yrs			35mm AC Inter		Heavy patching	Heavy patching		80mm AC Inter
I-2LS-H-G-6-12yrs				Bituminous surface	Bituminous surface	Bituminous surface	Heavy patching	80mm AC Inter
I-2LS-H-P-<6yrs					80mm AC Inter	Heavy patching	Bituminous surface	Bituminous surface
I-2LS-H-P-12+yrs	80mm AC Inter				Heavy patching	Bituminous surface	Heavy patching	
I-2LS-H-P-6-12yrs			80mm AC Inter		Heavy patching	Bituminous surface	Heavy patching	
I-2LS-M-F-<6yrs					80mm AC Inter	Heavy patching	Bituminous surface	Bituminous surface
I-2LS-M-F-6-12yrs	80mm AC Inter				Heavy patching	Bituminous surface	Heavy patching	80mm AC Inter
I-2LS-M-G-<6yrs					Bituminous surface	Bituminous surface		80mm AC Inter
I-2LS-M-G-12+yrs		35mm AC Inter			Heavy patching	Heavy patching		80mm AC Inter
I-2LS-M-G-6-12yrs	Bituminous surface				Bituminous surface	Bituminous surface	Heavy patching	80mm AC Inter
I-2LS-M-P-<6yrs				80mm AC Inter	Heavy patching	Bituminous surface	Bituminous surface	Bituminous surface
I-2LS-M-P-6-12yrs	80mm AC Inter				Heavy patching	Bituminous surface	Heavy patching	80mm AC Inter
I-2LS-VH-F-<6yrs					80mm AC Inter	Heavy patching		Bituminous surface
I-2LS-VH-F-12+yrs	80mm AC Inter				Heavy patching	Bituminous surface	Heavy patching	
I-2LS-VH-F-6-12yrs			80mm AC Inter		Heavy patching	Bituminous surface	Heavy patching	80mm AC Inter
I-2LS-VH-G-<6yrs					80mm AC Inter	Heavy patching	Bituminous surface	Bituminous surface
I-2LS-VH-G-12+yrs				35mm AC Inter	Heavy patching	Heavy patching		80mm AC Inter
I-2LS-VH-G-6-12yrs				Bituminous surface	Bituminous surface	Bituminous surface	Heavy patching	80mm AC Inter
I-2LS-VH-P-<6yrs					80mm AC Inter	Heavy patching	Bituminous surface	Bituminous surface
I-2LS-VH-P-12+yrs	80mm AC Inter				Heavy patching	Bituminous surface	Heavy patching	80mm AC Inter
I-2LS-VH-P-6-12yrs	80mm AC Inter				Heavy patching	Bituminous surface	Heavy patching	80mm AC Inter
I-2LS-VH-VP-<6yrs	Reconstruction Inter				Heavy patching	Bituminous surface	Bituminous surface	Bituminous surface
R-2LS-H-F-<6yrs						80mm AC Rural	Heavy patching	Bituminous surface
R-2LS-H-F-12+yrs	80mm AC Rural				Heavy patching			
R-2LS-H-F-6-12yrs			80mm AC Rural		Heavy patching	Bituminous surface		
R-2LS-H-G-<6yrs					Bituminous surface	Bituminous surface		Bituminous surface
R-2LS-H-G-12+yrs				35mm AC Rural	Heavy patching			
R-2LS-H-G-6-12yrs				Bituminous surface	Bituminous surface			
R-2LS-H-P-<6yrs						80mm AC Rural	Heavy patching	Bituminous surface
R-2LS-H-P-12+yrs			80mm AC Rural		Heavy patching			
R-2LS-H-P-6-12yrs				80mm AC Rural	Heavy patching	Bituminous surface		
R-2LS-H-VP-<6yrs	Reconstruction Rural				Heavy patching		Bituminous surface	Bituminous surface
R-2LS-H-VP-12+yrs				Reconstruction Rural	Heavy patching			
R-2LS-H-VP-6-12yrs		Reconstruction Rural			Heavy patching		Bituminous surface	
R-2LS-L-F-<6yrs							80mm AC Rural	Heavy patching
R-2LS-L-F-12+yrs			80mm AC Rural		Heavy patching	Bituminous surface		
R-2LS-L-F-6-12yrs				80mm AC Rural	Heavy patching		Bituminous surface	
R-2LS-L-G-<6yrs					Bituminous surface	Bituminous surface		80mm AC Rural
R-2LS-L-G-12+yrs				35mm AC Rural	Heavy patching			
R-2LS-L-G-6-12yrs				Bituminous surface				
R-2LS-L-P-<6yrs					80mm AC Rural	Heavy patching	Bituminous surface	Bituminous surface
R-2LS-L-P-12+yrs	80mm AC Rural				Heavy patching	Bituminous surface		
R-2LS-L-P-6-12yrs	80mm AC Rural				Heavy patching	Bituminous surface		
R-2LS-L-VP-<6yrs				Reconstruction Rural	Heavy patching	Bituminous surface	Bituminous surface	Bituminous surface
R-2LS-L-VP-6-12yr	Reconstruction Rural				Heavy patching	Bituminous surface		
R-2LS-M-F-<6yrs					80mm AC Rural	Heavy patching	Bituminous surface	Bituminous surface
R-2LS-M-F-12+yrs			80mm AC Rural		Heavy patching			
R-2LS-M-F-6-12yrs				80mm AC Rural	Heavy patching	Bituminous surface		
R-2LS-M-G-<6yrs				Bituminous surface		Bituminous surface	Bituminous surface	Bituminous surface
R-2LS-M-G-12+yrs			35mm AC Rural		Heavy patching			
R-2LS-M-G-6-12yrs			Bituminous surface		Bituminous surface			
R-2LS-M-P-<6yrs					80mm AC Rural	Heavy patching	Bituminous surface	Bituminous surface
R-2LS-M-P-12+yrs				80mm AC Rural	Heavy patching	Bituminous surface		
R-2LS-M-P-6-12yrs		80mm AC Rural			Heavy patching	Bituminous surface		
R-2LS-M-VP-<6yrs					Reconstruction Rural	Heavy patching	Bituminous surface	Bituminous surface
R-2LS-M-VP-12+yr	Reconstruction Rural				Heavy patching			
R-2LS-M-VP-6-12y	Reconstruction Rural				Heavy patching	Bituminous surface		
R-2LS-VH-F-<6yrs					80mm AC Rural	Heavy patching	Bituminous surface	Bituminous surface
R-2LS-VH-F-12+yrs					80mm AC Rural	Heavy patching	Bituminous surface	