ICMP Challenge
Pavement Condition and Budget Report
Example Road Authority

Sullivan; B.W. and Erskine J.P.

Pavement Management Services

Synopsis

Pavement Management Services was requested as part of the 6th International Conference of Managing Pavements, to produce a recommended forward works program and the budget requirements to maintain an existing road network in acceptable condition.

The results of previous: structural, visual and serviceability condition surveys of the network conducted in 2002, were supplied to Pavement Management Services for use in the analysis. Overall the network appears to be in reasonable condition with relatively low roughness, structural cracking and rutting, however there are concerning levels of ravelling. A closer examination of the results indicate that optimal maintenance strategies may not have been always been followed with some of the sections of the network which have had recent surface treatments exhibiting high levels of surface deficiencies considering their age. For this reason the treatment selection process adopted in the forward works program assessment has included structural assessment of the current pavement, to limit this accordance in the future.

The network definition supplied by the Authority included sections of pavement in excess of 200km. Clearly, this length of pavement is significantly greater than any maintenance treatment and not appropriate for pavement management. It is strongly recommended that future surveys be conducted with accompanying linear referencing system, to allow for more advance methods of pavement management, such as dynamic segmentation. Given that the yearly budget was $10-15,000,000, sections with lengths greater than 100km were broken into equivalent sections of less than 100km so all treatments could be accommodated in a single years budget.

To produce a forwards works program the data collected was modeled using the PARMMS® Road Manager Pavement Management Systems with budget levels of $10,000,000 and 15,000,000 per year, over fifteen years, with 4 prioritization/optimization procedures:

1. Roughness and cracking ranking method
2. Treating all failed pavements, then optimizing on roughness
3. Economic optimization on roughness
4. Treating all failed pavements, then minimize routine maintenance costs

Of the four methods, the recommended treatment philosophy is to: Firstly, treat all failed pavements, and then optimizing the remaining sections based on roughness improvement. Using this philosophy the recommended budget level required to maintain network condition is $10,000,000 per year.

This report is a design tool to be used by the Authority for budgetary issues concerned with the pavement network and to provide a summary of the current condition of the network. The works program produced is theoretical and still needs to be placed in effective works packages, with accompanying resource leveling. This should be undertaken in consultation with Pavement Management Services, using the Road Manager resource leveling tool, so effective Key Performance indicators, and budget levels can be established.

N.B. While Road Manager can use IRI, the standard in Australia and New Zealand is still NAASRA counts and was therefore used in this analysis.

Table of Contents

Page

CHAPTER 1. INTRODUCTION AND OBJECTIVES

1.1 Background

Pavement Management Services was requested as part of the 6th International Conference of Managing Pavements to provide a comprehensive fifteen-year forward maintenance program.

The visual, roughness and structural condition of the network was based on previous condition surveys undertaken by the Authority in 2002.

The previously collected data was analysed and incorporated into the PARMMS® Road Manager Pavement Management Systems. To produce five different works programs and their accompanying condition profiles to select the optimum combination.

1.2 Objective

The objective of this report was to examine the condition of all roads within the Authorities network produce a comprehensive fifteen-year forward maintenance program.

1.3 Scope of Work

The scope of work covered

- Assessment of previously collected condition data.
- Synchronization of historical data to the current year.
- The production of a fifteen-year forward maintenance plan.
- Recommendation for maintenance priorities, based on an assessment of risk.

CHAPTER 2. METHOD

2.1 Decision Support Level

The PARMMS® Road Manager Pavement Management System has been developed over the past 25 years in Australia and New Zealand, with the latest version being used in this analysis. The models used in the system are based on calibration of LTPP data collected in both Australia and New Zealand over the previous 20 years. The flowing Table, Table 2-1, indicates the Framework Characteristics [2], which are present within the latest version of the PARMMS Road Manager pavement management system.

Table 2-1 Decision Support Level

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: **4.0**

As indicated, PARMMS Road Manager operates with a Decision Support Level (DSL) of between 2- 5 with an overall rating of 4.

2.2 Existing Pavement Evaluation

2.2.1 Classification of Road/Footpath Sections

The road network comprises a total of 71 “representative” road sections, covering two road classes, and varying traffic use, surface age and condition, which is shown in Table 2-2, following. The rural roads (R) span most traffic and condition categories. Inter-urban roads (I) are represented on the medium to very highly trafficked roads. All roads are two-lane two-way single carriageways.

Table 2-2 Characteristics of the road network

ROUGHNESS (M/KM IRI)	SURFACE AGE < 6 YEARS				SURFACE AGE 6 – 12 YEARS				SURFACE AGE > 12 YEARS			
	Traffic Volume[1]											
	L	M	H	VH	L	M	H	VH	L	M	H	VH
Good (< 3)	R	I/R	I/R	I/R	R	I/R	I/R	I/R	R	I/R	I/R	I/R
Fair (3 – 4)	R	I/R	I/R	I/R	R	I/R	I/R	I/R	R	R	I/R	I/R
Poor (4 – 6)	R	I/R	I/R	I/R	R	I/R	I/R	I/R	R	R	I/R	I/R
Very Poor (> 6)	R	R	R	I	R	R	R	R	-	R	R	-

In developing a pavement management strategy, 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. The current version of Road Manager includes a dynamic segmentation module to allow sections to be divided into relatively uniform pavement sub sections.

However, the summarised form of the data provided for this analysis does not allow for further segmentation to be undertaken and has a range of segment lengths (from 30 metres to over 200 km). 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.

Clearly, these lengths of pavement are significantly greater than any maintenance treatment and not appropriate for pavement management. It is strongly recommended that future surveys be conducted with accompanying linear referencing system, to allow for more advance methods of pavement management, such as dynamic segmentation. Given that the yearly budget is $10-15,000,000, sections with lengths greater than 100km were broken into equivalent sections of less than 100km so they would not consume more than an entire years budget and could be considered.

2.2.2 Traffic Calculations

Traffic count information was provided by the Authority as a classified traffic count survey undertaken in 2002. This data was used to derive an Annual Average Daily Traffic (AADT), % Commercial vehicles and ESAL figure, in accordance with the Austroads Pavement Design Guide [1], with was used as the design traffic loading for modeling purposes within Road Manager.

2.3 Forward Maintenance Program

2.3.1 Pavement Treatments

The appropriate and applicable preventive, corrective and rehabilitation maintenance options considered in the analysis were determined in conjunction with the Authority and are shown following in Table 2-3.

Table 2-3 Pavement Treatments

TREATMENT	TYPICAL LIVES (YRS)	MAXIMUM APPLICABLE ROUGHNESS (M/KM IRI)	UNIT COST

Routine crack sealing	-	-	$20/m^2$
Routine structural patching	-	-	$65/m^2$
Routine pothole patching	-	-	$15/m^2$
Routine edge repairs	-	-	$9/m^2$
Bituminous surface dressing, initial & reseals	10 – 15	6	$3/m^2$
Thin asphalt surfacing (35 mm AC)	8 – 12	6	$14/m^2$
Structural overlay (80 mm AC)	> 15	8	$28/m^2$
Pavement Reconstruction - Inter-urban 200 mm Granular and 50 mm AC	> 15	No limit	$45/m^2$
Pavement Reconstruction – Rural 150 mm Granular and DBST	> 15	No limit	$30/m^2$

2.3.2 Intervention Levels

To allow investigation as to which treatment would be applicable once the pavement has reached a determined serviceability level, intervention levels were derived that would indicate the minimum condition when maintenance would be undertaken. These levels are set out in Table 2-4 following, for the appropriate pavement condition and compared to the average current condition to assist in the interpretation of these levels:

N.B. While Road Manager can use IRI, the standard in Australia and New Zealand is still NAASRA counts and was therefore used in this analysis.

Table 2-4 Intervention Levels PARMMS® Road Manager

PAVEMENT CONDITION	URBAN	RURAL	AVERAGE
Roughness	70	80	102
Cracking	5	7	5.8
Rutting	10	12	7.2

2.3.3 Treatment Selection

The treatment selection processes used in this analysis, in the Road Manager software is a two-phase analysis. The first phase is a broad classification of the pavement based on pavement condition data, referred to as Classification. The second a more detailed “resolution” of the required treatment, based on both the pavement condition and the attributes of the pavement.

2.3.3.1 Classification

In this process the current condition of the pavement is used to determine an appropriate level of treatment. For example, less than 5% of structural cracking on a road may be acceptable and this condition would be ignored for the current year. If there is between 5% and 30% structural cracking it is recommended to undertake “heavy patching”. For over 30% the reason for the distress would be determined, this is the “redesign” action of the resolution phase. Table 2-5, following shows the classification matrix used in this analysis, derived in conjunction with the authority.

Table 2-5 Classification Matrix

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	

If a section has no characteristics exceeding the minimum intervention levels, the section will be sent to the *No Treatment* area of the resolution matrix.

2.3.3.2 Resolution

This phase uses a series of decision trees in order to obtain a treatment suitable to repair, maintain or reconstruct the current condition of the pavement section. The treatment can be based on a combination of both the condition and attributes of the pavement, such as: roughness, rut depth, traffic class, surface type, kerb height, overlay requirement, curvature function, geographical conditions, skid resistance parameters and surface life. The careful process of combining the desired factors allows the system to define the treatment selection process, with the process being flexible and tailored to the Client's practices and pavement conditions, creating an expert system.

The following figure, figure 2-6, shows the resolution matrix used in this analysis to determining what, if any, treatment will be applied to a given section. The resolution matrix is read from left to right with a particular treatment being applied only if all criteria in the particular row are satisfied.

Table 2-6 Resolution Matrix

TREAT CLASS	AC OLAY REQUIRED	ROUGHNESS	URBAN RURAL	RUTTING	TEXTURE	MAX SURF LIFE	CRACKING	ASSOCIATED TREAT	TREATMENT
						<Max			NO TREATMENT
Do Nothing						>Max			Seal
Heavy Patch									Structural Patching
							<2		Structural Patching
						<Max	>2		Seal
				<12		>Max			Seal
			Urban	>12					Thin Asphalt Surface U
					<1				Seal
							<2		NO TREATMENT
						<Max	>2		Seal
				<15	>1	>Max			Seal
		<85	Rural	>15					Thin Asphalt Surface R
			Urban						Thin Asphalt Surface U
		85-160	Rural						Thin Asphalt Surface R
			Urban						Structural Overlay U
	<35	>160	Rural						Structural Overlay R
			Urban						Structural Overlay U
	35-80		Rural						Structural Overlay R
			Urban						Recon Urban
Redesign	>80		Rural						Recon Rural
			Urban						Recon Urban
Reconstruction			Rural						Recon Rural

The resolution matrix used in the analysis was developed in conjunction with the Authority.

2.3.4 Works Effects

Post resolution adjustment, or the resetting of condition data after a treatment, is required so that decisions for future years can be made on the basis of defensible data. What the adjustment does is modify the condition of the pavement so that it reflects the predicted condition after performing a certain treatment.

Table 2-7 following, shows the works effects models used for all years in the analysis, for each treatment.

Table 2-7 Works Effects Models, Reset Values

	ROUGHNESS IMPROVMENT			RESET		STRUCTURAL IMPOVEMENT
TREATMENT	%	FIXED	MIN RESET	RUTTING	SURFACE	
Crack Sealing	0	0	0	No	No	N/A

	ROUGHNESS IMPROVMENT			RESET		STRUCTURAL IMPOVEMENT
TREATMENT	%	FIXED	MIN RESET	RUTTIN G	SURFAC E	
Reconstruction (Urban)	0	Unlimited	40	Yes	Yes	Granular
Heavy Patching	0	0	0	No	No	N/A
Reconstruction (Rural)	0	Unlimited	50	Yes	Yes	Granular
Pothole Patching	0	0	0	No	No	N/A
Thin AC Overlay 35mm	5	50	40	Yes	Yes	Asphalt
Routine	0	-1	40	No	No	N/A
AC Overlay 80mm (Rural)	0	Unlimited	45	Yes	Yes	Asphalt
Bituminous Surface	2	2	50	No	Yes	N/A
AC Overlay 80mm (Urban)	0	Unlimited	45	Yes	Yes	Asphalt

2.3.5 Model Calibration

As currently no Long Term Pavement Performance sites exist for the Authority, global calibration factors were used, shown in Table 2-8, based on a desktop calibration of the Authority and Pavement Management Services LTPP sites. *N.B. some of the models in the Road Manager System are not HDM(IV) model so equivalent calibrations were used*.

Table 2-8 Model Calibration Factors

DETERIORATION MODEL	CALIBRATION FACTOR	VALUE
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
Roughness – Environmental Coefficient	Kgm	0.023
Roughness	Ksnpk	1
Roughness – Progression	Kgp	0.8
Texture Depth – Progression	Ktd	1
Skid Resistance	Ksfc	1

2.3.6 Prioritisation/Optimization

In real world situations budgets are constrained and priorities need to be set in spending the available budget. In Road Manager several methods are available to set priorities:

1. Ranking the pavement (pure or partitioned) in order of worst to best condition.
2. Economic optimization to maximize benefits (rutting, cracking, structural deficit, roughness for a given budget.
3. Failure Plane analysis, to weigh up functional and serviceability failure and determine which sections of pavement have failed.

4. Minimizing routine maintenance cost.

So the budget can be more efficiently allocated. The money will then be spent on the worst sections, or highest priority section in preference to lower priorities, thus bringing the overall network to a higher standard.

In the analysis undertaken 4 possible optimization methods where used in order to meet the needs of the Authority, for the management of the road network. The funding is allocated to sections with the highest priority until the cumulative cost does not exceed the current budget total. The four methods used are:

1. Order Roughness in decreasing bins of 50 and then sort on level of cracking
2. Treat all sections failed pavements, then optimizing on roughness
3. Economic optimization on roughness only
4. Treat all areas of failed pavements, then minimize routine maintenance costs

2.3.6.1 Failure Plane

In real world situations pavements do not fail by roughness, rutting or cracking alone but by a combination of all three. The failure plane approach used in Road Manager weighs up a 4 dimensional failure plane to determine when a pavement has failed, like the real thought process used in management. What this approach does is sets the level at which an authority defines a pavement as failing using: roughness, rutting and cracking (or area of defects) for each traffic class of road. The figure following Figure 2-1, shows the failure plane used in this analysis, sections are defined as failing when they fall bellow the surface and are then defined as in need of immediate attention.

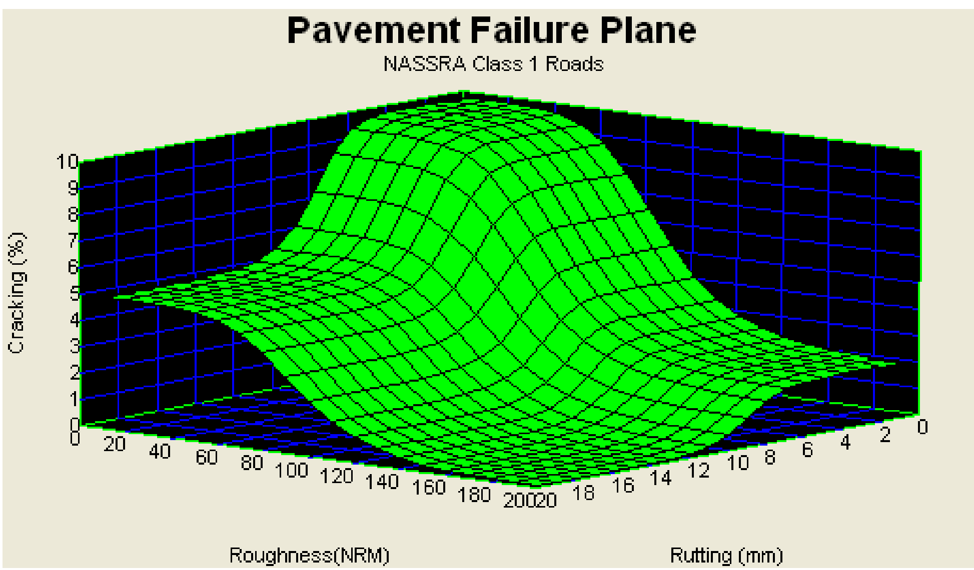

Figure 2-1"Fuzzy" Failure Plane

2.3.7 Budget Level

The Authority allocated an annual budget of $10,000,000 to the upkeep of the paths. An alternative budget of 15,000,000pa has also suggested by the authority.

2.4 Data Synchronization

The PARMMS® Road Manager system is capable of accepting input data on a cyclic basis, where a portion of the network is tested and evaluated in one year and another portion in another year. This could extend over several years. As a result, there will be age discrepancies between the data sets for different pavement sections.

Because the pavement section’s data maybe collected over an extended period of time, the information necessary to compute the pavement sections’ maintenance strategy is out of synchronization. Thus there is a preliminary activity to bring this material into synchronization before the optimum redesign treatment can be identified.

The systems will deteriorate the pavement section factors in accordance with accepted deterioration models and the time interval between the pavement section’s test date and the study’s start date.

After the pavement factors have been deteriorated using the appropriate deterioration models, all factors are in synchronization with the study start date (2004). At this point further analysis and decisions identify the optimum redesign treatment for the applicable scenario and study period.

2.5 Committed Works

As part of the their requirements the Authority whished to assess the effect of treating all existing sections classified as being in “poor” or “very poor” condition and carrying more than 7,500 vehicles per day within the first three years of the proposed works program.

As part of any pavement management system needs to incorporate user requirements, this was completed regardless, for all optimization strategies.

CHAPTER 3. PAVEMENT CONDITION RESULTS

3.1 Implications to the Network

Using the results of the synchronized data from the provided surveys, the average condition statistics of the network are reported in Table 3-1 following.

Table 3-1 Road Network Statistics

	NETWORK AVERAGE
Roughness (NRM)	102
Rut Depth (mm)	7.2
Fatigue Cracking (%)	5.8
Ravelling (%)	20
Structural	
Subgrade CBR (%)	10
Beam (mm)	0.44

The identification of raveling which provides an indication of the age of the wearing course reveals a network that is need of resurfacing, with 20% of the network affected by stone loss. Left unchecked from current levels the wearing course will continue to degrade and lead to further surface deficiencies and a loss of impermeability resulting in a more critical deterioration of the pavement structurally. This will result in drastically increased requirements for routine maintenance as well as more intensive rehabilitation options to treat structural deficiencies as a result of moisture ingress. Currently approximately 6% of the network is affected by structural cracking which while not high does indicate some structural deficiencies, which may related to the high level of raveling.

Roughness or serviceability indicates the pavement network is in a fair condition, with a network average of 102NRM and 23% of the network with a roughness greater than 120NRM. This is somewhat high considering the average age of the network is only 8 yrs and only 20% of the network with a roughness less than 70NRM. Rutting on the network is currently 7.2mm and while not high need to be maintained.

4.1 Budget Level Required

Figure 4-1 following shows the output of the ranking sort (roughness and cracking) on the predicted network outcome for both cracking and roughness. What the figure clearly shows is that a budget level of $15,000,000pa produces significant improvements in the network condition, for both cracking and roughness. While ideally, this would be preferable, it is not practical and a budget level of $10,000,000 maintains network condition, therefore this is the recommended budget level.

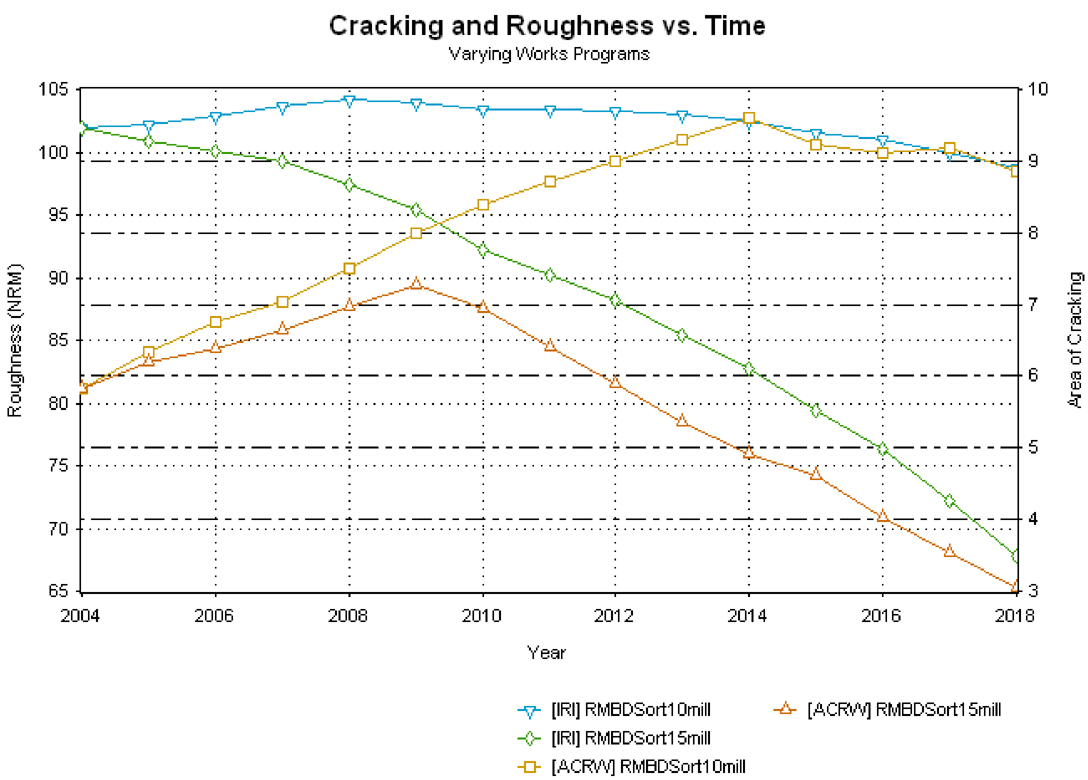

Figure 4-1 Roughness/Cracking Vs Budget Level

4.2 Prioritization Method

4.2.1 Roughness

Figure 4-2, following shows the predicted network condition for the 4 different priority methods. As should be expected the greatest improvement is from the economic optimization on roughness, however all optimization methods will maintain overall network condition, with little difference between the remaining three methods. This suggests that any method is capable of maintaining current network condition.

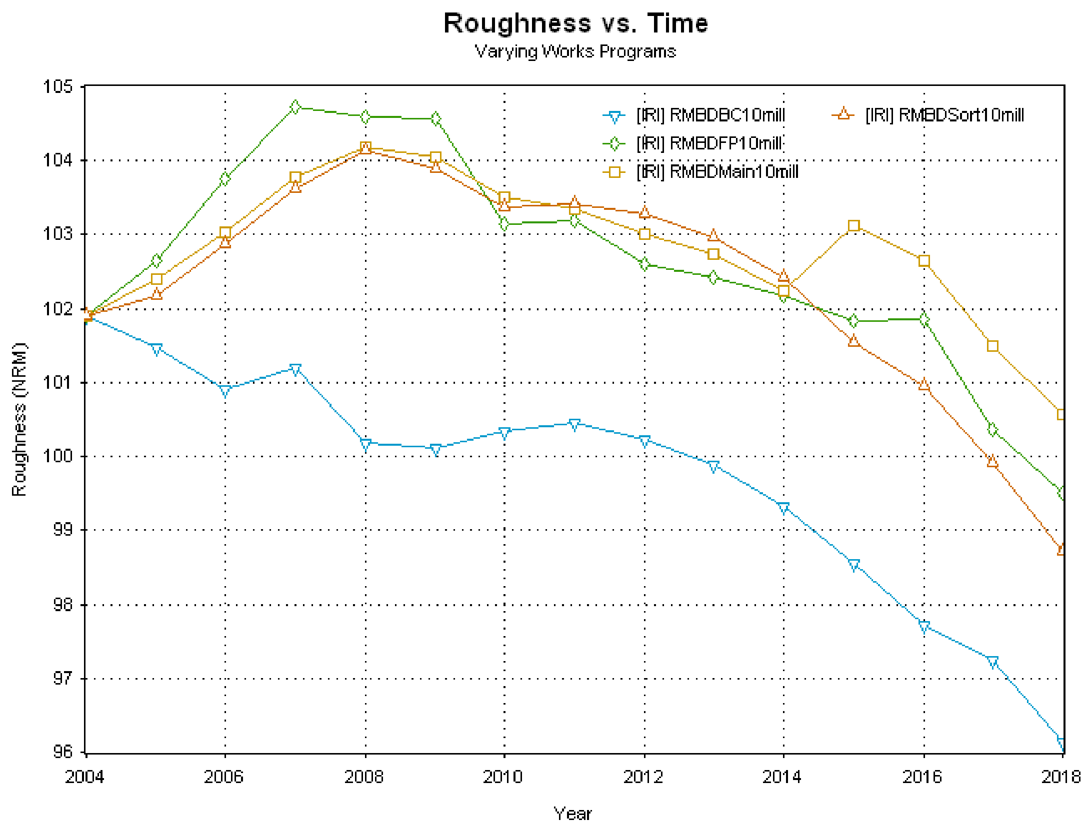

Figure 4-2 Roughness Various Works Programs

What the results imply is that if the network had significant roughness deficiencies, which it does not, the economic optimization would be preferable other wise all other methods are just as acceptable.

4.2.2 Structural Cracking

Figure 4-3 following, shows the predicted network condition for the four-prioritization methods employed. What is shown in the figure is that only the failure plane analysis maintains the network at its current condition, with all other budget allowing some level of deterioration, with up-to 4% with the sort method.

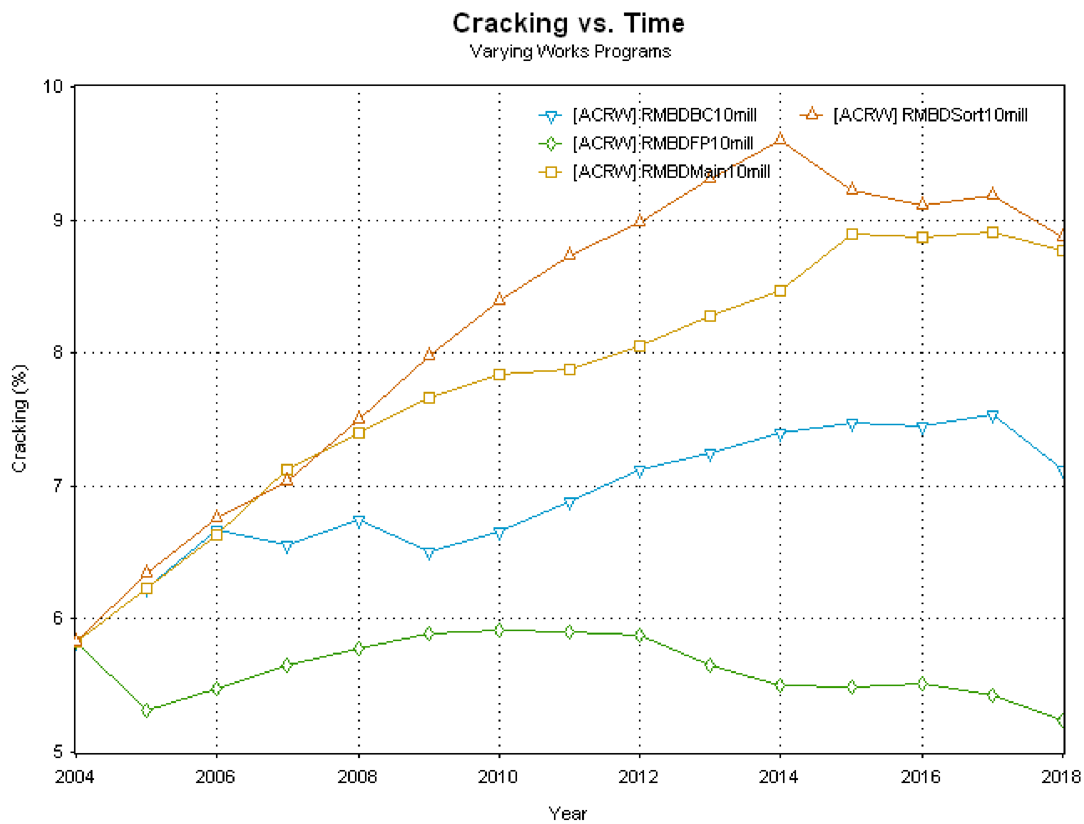

Figure 4-3 Cracking for Various Works Programs

What the results imply is all optimization methods bar the failure plane analysis fail to maintain the current network condition and thus the failure plane is preferable.

4.2.3 Rutting

Figure 4-4 following, shows the predicted network condition for rutting, for the four-prioritization methods employed. The figure shows that the sort method produces the best outcome for rutting, however the difference between all methods is only 1mm indicating all methods can maintain rutting below the intervention levels.

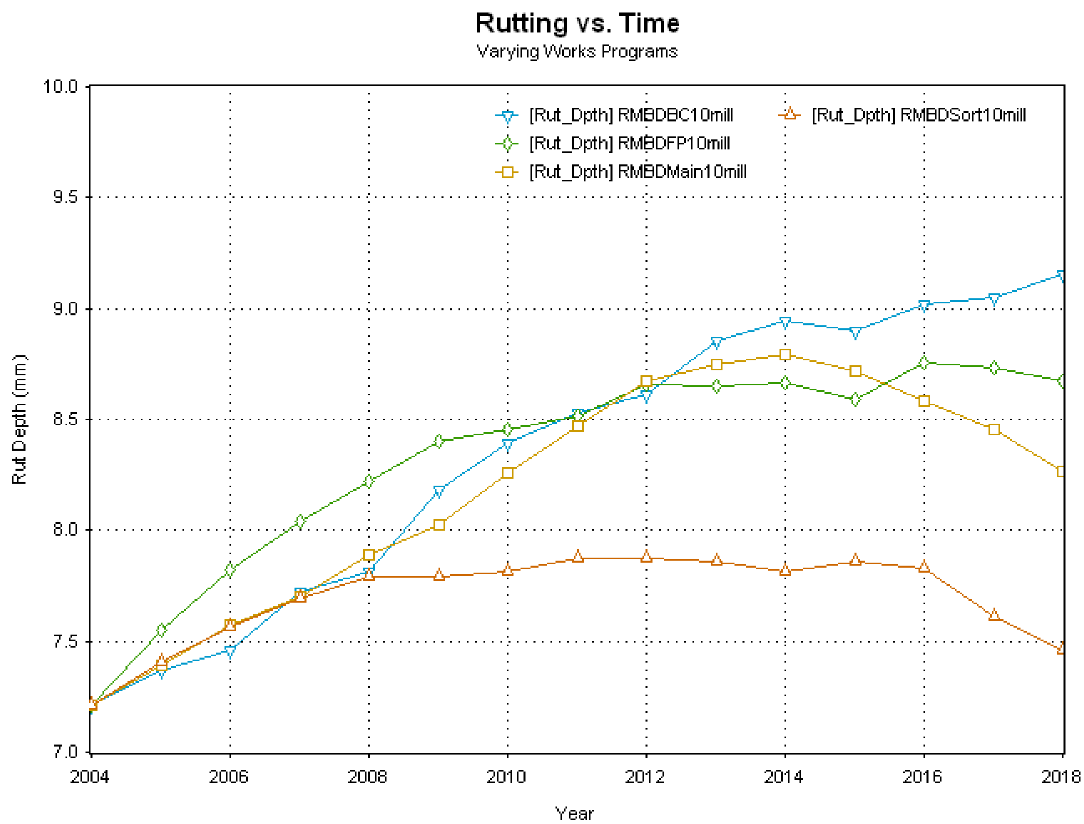

Figure 4-4 Rutting for Various Works Programs

What the results imply is all optimization will maintain the rutting at acceptable levels although rutting was not targeted and all prioritization methods are acceptable.

4.3 Recommended Budget and Optimization Method

Of the four-optimization methods, the recommended treatment philosophy is to: treating all failed pavements, then optimizing the remaining sections based on roughness improvement as this strategy will maintain network condition in terms of cracking, roughness and rutting. While all other optimization methods maintain roughness they do allow cracking to accelerate.

Using this philosophy the recommended budget level required to maintain network condition is 10,000,000 per year.

CHAPTER 5. CONCLUSIONS

Overall the network appears to be in reasonable condition with relatively low roughness, structural cracking and rutting, however there are concerning levels of ravelling. A closer examination of the results indicate that optimal maintenance strategies may not have been always been followed with some of the sections of the network which have had recent surface treatments exhibiting high levels of surface deficiencies considering their age. For this reason the treatment selection process adopted in the forward works program assessment has included structural assessment of the current pavement, to limit this accordance in the future.

The network definition supplied by the Authority included sections of pavement in excess of 200km. Clearly, this length of pavement is significantly greater than any maintenance treatment and not appropriate for pavement management. It is strongly recommended that future surveys be conducted with accompanying linear referencing system, to allow for more advance methods of pavement management, such as dynamic segmentation. Given that the yearly budget was $10-15,000,000, sections with lengths greater than 100km were broken into equivalent sections of less than 100km so all treatments could be accommodated in a single years budget.

To produce a forwards works program the data collected was modeled using the PARMMS® Road Manager Pavement Management Systems with budget levels of $10,000,000 and 15,000,000 per year, over fifteen years, with 4 prioritization-optimization procedures:

1. Roughness and cracking ranking method
2. Treating all failed pavements, then optimizing on roughness
3. Economic optimization on roughness
4. Treating all failed pavements, then minimize routine maintenance costs

Of the four methods, the recommended treatment philosophy is to: Firstly, treat all failed pavements, and then optimizing the remaining sections based on roughness improvement. Using this philosophy the recommended budget level required to maintain network condition is $10,000,000 per year.

References

1. Austroads Pavement Design "A Guide to the Structural Design of Road Pavements", Kelvin Press, Manly Vale N.S.W., 1992.

2. Robertson, N F (2002), "An Investment Decision Framework for Road Asset Management", Queensland Department of Main Roads

3. PMS-TP1-002(1,4) "PCM Visual Only, Pavement Management Services, Sydney, 1998.

Author Bios

Bevan Sullivan

Bevan Sullivan joined Pavement Management Services in 1996 following service with The Australian Defence Forces and completion of his BE degree. He initially served for two years as Pavement Management's "Implant Engineer" to the RTA – Transfield Services Performance Specified Maintenance Contract. Following this position Bevan implemented the Pavement Management Engineering methodology to Transit New Zealand's PSMC in the North Island of New Zealand and TNC 4 in association with Macmahon contractors in Western Australia.

Following a visit to Australia in 1999 by Prof Mathew Witczak, Bevan was invited to to study under the Professor at Arizona State University with his research into the Superpave Simple Performance Test for Asphalt Mixtures and AASHTO Pavement Design guide. This he undertook, not only introducing new asphalt technology but gaining a highly awarded Master of Science degree in Civil Engineering.

Since returning to Pavement Management Bevan has been promoted to Principal Engineer and is responsible for Research and Development and the overseeing of all engineering undertaken by Pavement Management Services. As part of this role he has been responsible for the development of the latest version of the Road Manager software, which was used in the analysis.

James Erskine

James Erskine joined Pavement Management Services in 199 after gaining his BE in Civil Engineering from the University of Wollongong in 1999. Since that time James has worked as an implant engineer in the Queensland Main Roads Department and as Pavement Management Services project engineer for Queensland.

James Erskine currently employed as a Senior Pavement Engineer with Pavement Management Services, Australia. His responsibilities include the development of road maintenance programs using PARMMS Road Manager and other software packages; design of road maintenance and rehabilitation works and reporting of network condition assessments.

James currently develops over 20 pavement management strategies on a yearly basis for local government authorities and private enterprises throughout Australia.