REVIEW OF RAMM TREATMENT SELECTION PROCESS FOR STATE HIGHWAYS & LOCAL AUTHORITY ROADS IN NEW ZEALAND

Transfund New Zealand Research Report No. 87

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Auckland, New Zealand

Transfund New Zealand Research Report No. 87

ISBN 0-478-10545-2
ISSN 1174-0574

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Beca Carter Hollings & Ferner Ltd. 1997. Review of RAMM treatment selection process for state highways & local authority roads in New Zealand. *Transfund New Zealand Research Report No. 87.* 98pp.

Keywords: assessment, local authority roads, maintenance, management, New Zealand, pavements, pavement management, RAMM, roads, selection, state highways, treatment

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ABBREVIATIONS & ACRONYMS

AC	Asphaltic concrete
B/C	Benefit/cost (ratio)
CCI	Construction cost index
FC	Friction course
FYRR	First year rate of return
LA	Local authority
m	metres
maint.	maintenance
NAASRA	National Association of Australian State Road Authorities
PV	Present value
R&R	Rip and remake
RAMM	Road assessment and maintenance management system
RCA	Road controlling authority
RDC	Rotorua District Council
SCRIM	Sideways-force coefficient routine investigation machine
SH	State highway
SCT	Shape correction treatment
TNZ	Transit New Zealand
TSF	Thin-surfaced flexible pavements
TSP	Treatment selection process
vpd	Vehicles per day

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ACKNOWLEDGMENTS

The contributions made to this project by the Transit New Zealand (TNZ) staff involved and the TNZ Wanganui Network Management Consultant are acknowledged, and in particular to Mr A.O'Hara of TNZ Wanganui and Mr J.Ryan of the Rotorua District Council for the field assessment work.

EXECUTIVE SUMMARY

1. Introduction

The development of the Road Assessment and Maintenance Management (RAMM) system was initiated in 1985 by a group of New Zealand local authorities who had recognised the need for a system to assist them with the management of their roading asset. This initiative was carried on by Transit New Zealand and has now reached a stage where all local authorities and the New Zealand state highway sector use the RAMM system at various levels to assist them with the formation of their road maintenance policies and road maintenance schedules.

This report documents a review, carried out during 1993/94, of the Treatment Selection Process (TSP) contained within the RAMM system. The review has been an opportunity to draw upon the knowledge and experience gained by the users of the RAMM system for state highways in the Transit New Zealand Wanganui Region and for the local authority roads maintained by the Rotorua District Council.

2. Outputs from TSP in RAMM

At the Regional and District road network levels, the outputs from the TSP contained in the RAMM system have been compared with the road maintenance programmes for the Transit New Zealand Wanganui Region and the Rotorua District Council. The financial outputs from the TSP contained in the RAMM system are also compared with the actual maintenance expenditure on the state highways within the Transit New Zealand Wanganui Region.

At the project level, the site-specific RAMM outputs have been compared with a field assessment for road maintenance needs. These assessments have been made by the Roading Manager for the Wanganui Region for 150 km of state highways, and by the Roading Manager for the Rotorua District Council for 73 km of the Rotorua District road network. The differences in output from the RAMM system and the field assessment made by the Transit New Zealand Roading Manager are identified and commented on.

3. Methodologies

The methodologies of both the TSP and the field assessment are described and the reasons for the differences in outcomes are discussed. These sections of the report are intended to provide a useful guide to users of the RAMM system, assuming a knowledge of New Zealand practices in the maintenance of state highways and local authority roads, to the interpretation and use of the outputs from RAMM when preparing a road maintenance programme, and for assisting with the preparation of major road maintenance schedules.

4. Results

The sensitivity of the TSP to inputs is examined and the results of this examination are used in combination with the comparisons made between RAMM outputs and the field assessment to highlight the strengths and weaknesses of the system in reporting each type of major road maintenance need.

5. Recommendations

Recommendations are made for improvements to both system inputs and analyses to improve the outputs of the TSP. The recommendations from this review are as follows:

- Road condition rating allowable limits of variation should be improved.
- Data from the multi-laser profilometer and SCRIM (Sideways-force coefficient routine investigation machine) vehicle surveys should be used in the TSP.
- The calculation of user benefits should allow for the TSP to access the RAMM traffic loading table.
- Routine pavement maintenance costs should be recorded in RAMM.
- The relationship between routine pavement maintenance costs and RAMM-reported routine pavement maintenance costs should be investigated.
- The TSP model to predict future maintenance costs should be improved with the development of a family of pavement maintenance cost-prediction curves.
- The TSP model to predict future surface treatment life cycles should be improved.
- World Bank pavement deterioration models should be trialed in New Zealand.
- Roads should be sectioned on the basis of homogenous lengths into treatment sections.
- Sampling of the road for condition should be carried out more frequently than 500 m.
- Reports for surface treatments should include more categories.
- The calculation of a width, and cost, for sections of potential seal widening should be excluded from the TSP.
- The road condition rating procedure should be altered to allow the Roading Manager to set the criteria for the rating of inadequate surface water channels.

ABSTRACT

This report documents a review, carried out during 1993/94, of the Treatment Selection Process (TSP) contained within the RAMM (Road Assessment and Maintenance Management) system. The review draws upon the knowledge and experience gained by the users of RAMM for state highways in the Transit New Zealand Wanganui Region and for local authority roads maintained by the Rotorua District Council. It reviews the performance of the TSP, and identifies differences between the outputs from the TSP with the results of a traditional engineering assessment of road maintenance needs by field assessment. The resulting prediction of road maintenance needs from both types of assessment are compared at the road network level (Regional and District), and also at the project level.

The methodologies of both the TSP and the field assessment are described and the reasons for the differences in outcomes are discussed. These sections of the report are intended to provide a useful guide to users of the RAMM system, assuming a knowledge of New Zealand practices in the maintenance of state highways and local authority roads, to the interpretation and use of the outputs from RAMM when preparing a road maintenance programme, and for assisting with the preparation of major road maintenance schedules. It also provides users with a better understanding of the analyses carried out within the TSP and the sensitivity of the outputs from these analyses to inputs provided by the user. Recommendations are made for improvements to both system inputs and analyses.

1. INTRODUCTION

Transit New Zealand (TNZ) initially introduced the Road Assessment and Maintenance Management (RAMM) software to New Zealand Local Authorities (LAs) in the mid-1980s with a view to assisting them to identify and quantify their major road maintenance needs. Within 12 months of the initial introduction, the system was also incorporated into the broad spectrum of tools used for road maintenance management in the state highway sector. The system was used to standardise methodologies used by both Transit New Zealand Regional offices and the local authorities when establishing their annual road maintenance needs.

The basis of the RAMM system is the storage and analysis of road data in a standard manner. Both the descriptive and condition data for all roads in a network are collected and stored in a proprietary computer database in the manner described in manuals and workshops approved by Transit New Zealand. An algorithm has been designed to analyse the data stored in the database and a computer program has been written to carry out the analysis. The outputs from the computer program are lists of road sections with an indication of the road maintenance treatments required on each section, and the financial costs and benefits of carrying out the maintenance treatment indicated.

The analysis and reporting process is known as the treatment selection process (TSP). The TSP allows the user to set a financial performance level in terms of Benefit/Cost (B/C) ratio above which a shape correction treatment (SCT) is selected. The B/C ratio represents the ratio of benefits (i.e. road user benefits obtained from roughness reduction) to construction costs (i.e. the SCT cost less maintenance savings). If all the SCT selected was actioned by the road controlling authority (RCA) this would limit the roughness of all roads in the network categorised by traffic volume. The B/C ratio chosen is therefore also a de facto functional performance level for the road network.

Historically local authority roading managers relied on an annual field assessment of potential major maintenance sites which was usually carried out by the roading manager or an experienced roading engineer or overseer. The sites inspected were scheduled from information received from the public and from road maintenance gangs who patrolled the roads in the road network to carry out routine maintenance. Records of the age of road surface treatments and local knowledge of the pavement structures and materials were used to assist with the determination of the maintenance treatment required and the timing of such maintenance. In a few local authorities, records of maintenance expenditure were located by road and these were also used to assist with locating potential major road maintenance work.

In the state highway sector, roading managers historically had good road maintenance expenditure records and these were used along with road surface treatment records and an annual field assessment ("walkover" survey) carried out by technical staff to determine the location of major road maintenance sites and to assess the maintenance treatments required. The road maintenance programmes produced from the field assessments were reviewed and adjusted by the roading manager to suit financial resources available.

Before the introduction of the RAMM system the selection of road maintenance sites and the maintenance treatment required was subjective and could be constrained for political reasons if the roading manager was not able to demonstrate the change in the condition of the road network as a consequence of budget changes.

Use of the RAMM system grew rapidly from 1990 until 1994 and has now been implemented as a separate database by each Local Authority and each Transit New Zealand Regional Office for the road network under their control. Many of the users understand the benefits of the TSP and the system is, to a large extent, achieving its goal of enabling Transfund New Zealand as the funding agency to make an equitable assessment of requests for road maintenance funding from all RCAs, and to assess the consequences of the budget levels proposed. In many local authorities the results from the TSP are now the primary input for the initial formation of their annual road maintenance programme at the following two levels.

1. *At the Network Level:*
   A summary report is produced which totals each major maintenance type required to maintain the road network at the chosen performance level. This report can be used as a basis for requests to Transfund New Zealand for road maintenance funds for each regional office. Local authorities can also use the report as a basis for request for road funding from both the Local Authority Council and for subsidy from Transfund New Zealand.

2. *At the Project Level:*
   A report is produced which lists the maintenance treatment selected for each road section in the road network. This report can be used as the initial list of candidate projects which require a technical evaluation for surface treatment, shape correction and drainage. The report is used alongside other traditional inputs such as surface treatment age, bitumen condition and the present quantity of general maintenance required to keep the pavement in an acceptable condition.

Before the TSP was incorporated in the RAMM system in 1989, the results of the TSP were checked against a traditional assessment of maintenance needs for some 40 km of local authority roads and some 100 km of state highways. Reasonable agreement was obtained and was reported in the *Treatment Selection Workshop Manual* published by Transit New Zealand (1990). Subsequent work by many users of the RAMM system has demonstrated consistency between the results of the TSP and maintenance needs determined from traditional field assessment methods. This is especially so for pavement surface treatment requirements.

The research described in this report has provided an opportunity to draw upon the knowledge and experience gained by users of the system in the Transit New Zealand Wanganui region and the Rotorua District Council (RDC) to review the performance of the TSP. The review documented in this report was carried out during 1993/94.

This report is intended to provide Transit New Zealand with an understanding of how effectively the TSP is operating and how it can be improved. The report is also intended to provide a guide to users of the RAMM system, assuming a knowledge of New Zealand practices in maintenance of state highways and local authority roads, to the interpretation and use of the outputs from RAMM when preparing a road maintenance programme, and for assisting with the preparation of major road maintenance schedules.

State highway networks carry more traffic and have a different maintenance regime than do local authority road networks and for this reason this review has been carried out in two parts:

State Highways (SH); and
Local Authority (LA) roads.

2. OBJECTIVE

The objective of this study was to review the reliability of the TSP contained within the RAMM system, when compared to traditionally determined maintenance options, e.g. with regard to:

- The reliability of the TSP in RAMM when predicting, at the network level, the total quantity of each maintenance type required to maintain a road network at a chosen performance level, and the cost of this maintenance.

- The reliability of the TSP when predicting, at the project level, the type, quantity, cost and financial return of the maintenance treatment selected for each road section requiring a major maintenance treatment, i.e. an SCT or a surface treatment.

If appropriate, modifications to improve the efficacy of the TSP have been recommended.

3. SOFTWARE

RAMM Version 2.1a was used for the state highway section of the project and RAMM Version 2.3 was used for the local authority section of the project. The database software used was Informix (SQL) Version 2.1 for the state highway section of the project and Informix (SQL) Version 4.12 was used for the local authority section of the project. The TSP used was for Thin Surfaced Flexible (TSF) pavements and remained unchanged in both versions of RAMM and Informix.

4. DATA

4.1 Road Network Data

A copy of the RAMM system data was obtained for both the Transit New Zealand Wanganui Region and the Rotorua District Council RAMM systems.

4.2 RAMM Road Condition Data

The RAMM system requires the user to divide each road in the network into homogeneous sections. The average length of a road section in the rural environment is approximately 2 km while in the urban environment the average length is approximately 200 m. Road sections which are longer than 800 m are divided into 500 m lengths (i.e. "rating sections") for the purposes of collecting road condition data. The first 50 m of the rating length has the carriageway inspected (i.e. "inspection length") during a condition rating survey to collect road condition data.

4.3 Site Assessment Data

4.3.1 General

After the road roughness and condition rating data have been entered into the RAMM system the TSP program can be run and reports produced. These reports list all of the rating sections that have been selected for a major road maintenance treatment. The roading manager is required to inspect the rating sections reported as requiring a major maintenance and to make an assessment, in the field, of the length and type of treatment required and the priority that the section of road or highway should have in the road maintenance programme. The site inspection and technical assessment referred to in this clause is simply called a "field assessment" throughout the remainder of this report.

4.3.2 Field Assessment Procedure

Each rating section was inspected from the sample of highway or road selected and compared with the RAMM TSP output. An inspection from a slowly moving vehicle was carried out of all rating sections where the TSP had not identified the need for any major maintenance and of those where the roading manager was not aware of any pavement distress. All sections of highway listed for major maintenance from either the TSP or from the Transit New Zealand maintenance programme were inspected on foot. This inspection was used to check the results of the road condition rating and to determine a maintenance treatment based on the following parameters:

- Level of distress showing in the pavement.
- The age of the current surface treatment.
- The quantity and type of maintenance carried out on the pavement in the past two years.
- Local knowledge of the pavement structure and traffic loading.

4.3.3 Sample Size for Field Assessment

Site-specific data for a 28% sample of the state highway network studied in the Transit New Zealand Wanganui Region and a 12% sample of the local authority road network studied in the Rotorua District was obtained from site inspections carried out by the Roading Managers for each of the RCAs. The state highway network and the local authority road network studied and the samples chosen for the field assessments are shown in Figures 4.1 and 4.2.

Figure 4.1 Map of the roads in the Transit New Zealand Wanganui Region and sections of the State Highways selected for field assessment.

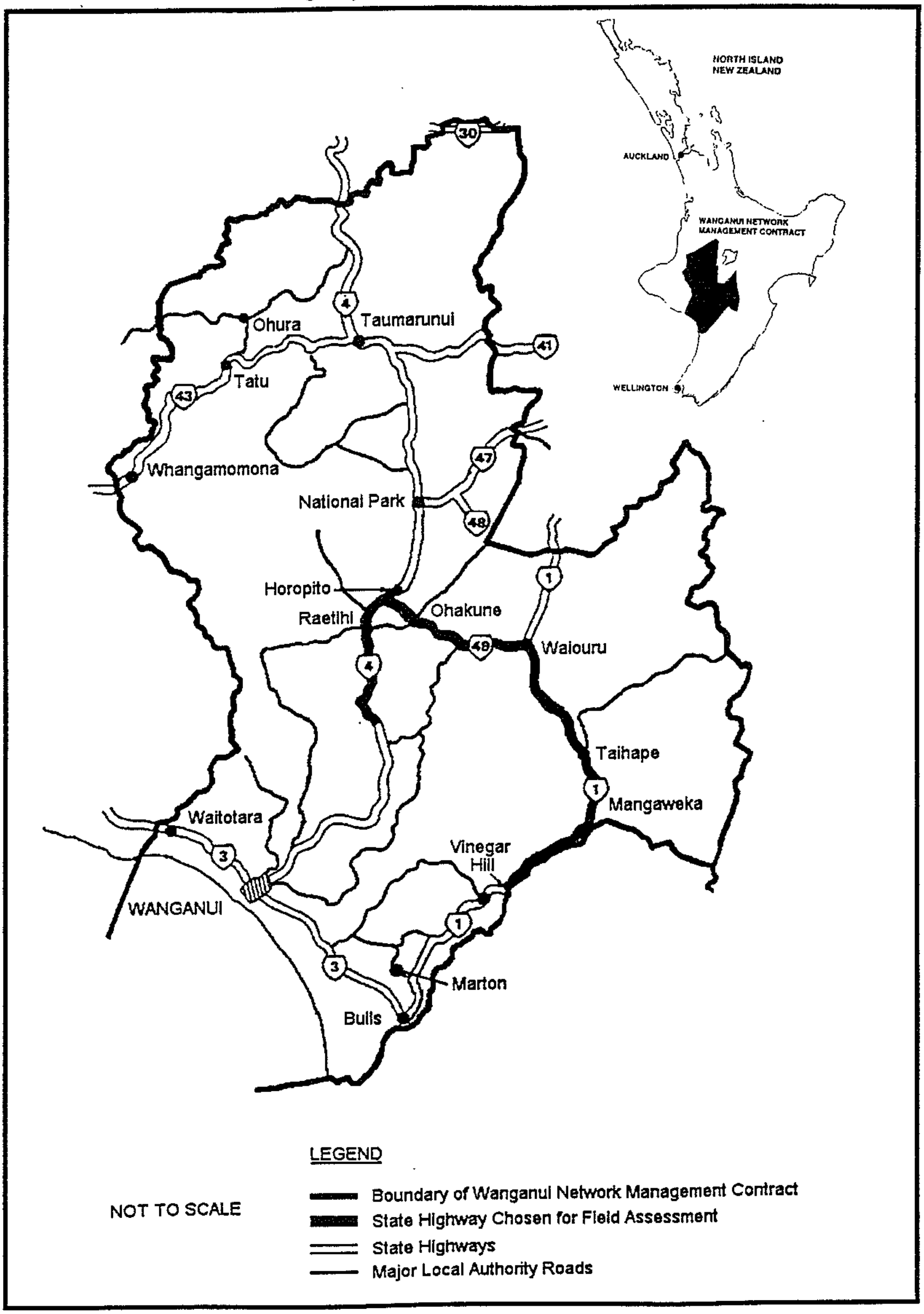
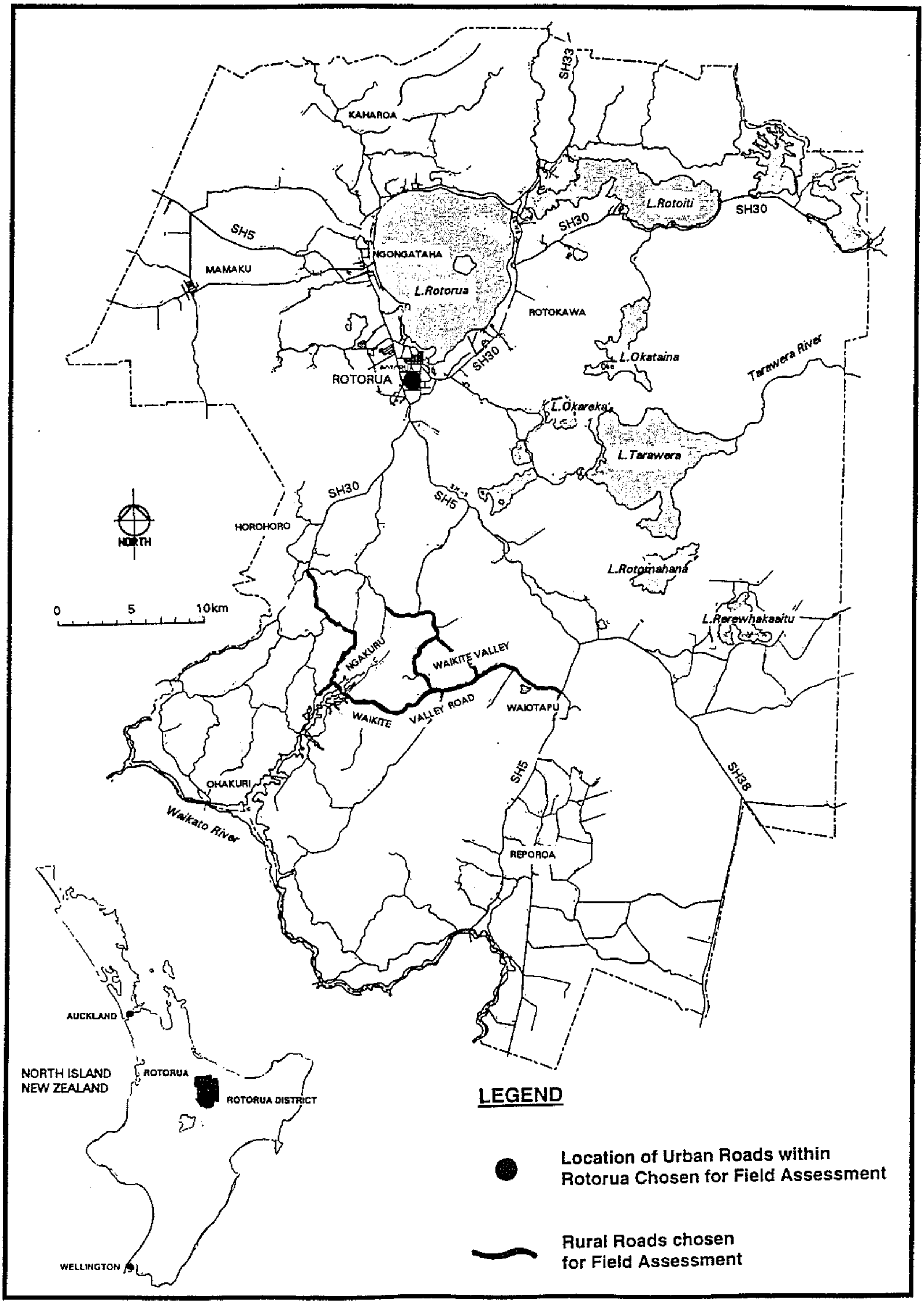


Figure 4.2 Map of roads in the Rotorua District Council and the sections of local authority roads selected for field assessment.



5. SUMMARY OF TREATMENT SELECTION PROCESS

5.1 General

The TSP for thin surfaced flexible pavements has a comprehensive algorithm which was developed to use the data that are available in the RAMM system, to analyse each rating section and to select the most appropriate maintenance treatment. A detailed description of the algorithm is available in the *Treatment Selection Workshop Manual* (Transit New Zealand 1990). The following description of the TSP is a brief summary of the process which should enable the reader of this report to better comprehend the results of the process.

5.2 Calculation of Road Repair Costs

The costs to repair all the faults recorded during the condition rating survey are calculated for each rating section.

5.3 Calculation of Major Maintenance Costs

The costs to undertake major maintenance treatments (area treatments) are calculated for the rating section. The treatments considered are a surface treatment (usually a reseal) or an SCT. The SCT has a cost calculated for a smoothing treatment (little or no strength added to the pavement structure) and a cost calculated for a smoothing treatment which includes strengthening of the pavement.

5.4 Surface Treatment Selection

The selection of a surface treatment is condition responsive. The type and quantity of carriageway faults recorded during the road condition rating, which the TSP responds to for the selection of a surface treatment, are shown in Table 5.1.

5.5 Shape Correction Treatment (SCT) Selection

SCT is divided into the two categories of smoothing and strengthening. A smoothing SCT is designed to smooth the vehicle ride of the road but does not add greatly to the strength of the pavement. A strengthening SCT is designed to both smooth the vehicle ride of the road and improve the strength of the pavement. The improvement to the pavement strength has a higher capital cost than a smoothing SCT but will reduce the future cost of pavement maintenance for a pavement which has inadequate strength before the construction of the SCT.

Table 5.1 Type and quantity of carriageway faults required for the selection of a surface treatment.

Pavement Fault	Treatment Selected: Reseal In Budget	Treatment Selected: Reseal Next Time	Treatment Selected: Reseal Flushed
Alligator cracking	>3% wheelpath length	1-3% wheelpath length	Not applicable
Shoving	>3% wheelpath length	1-3% wheelpath length	Not applicable
Shoving plus Alligator cracking	>3% wheelpath length	1-3% wheelpath length	Not applicable
Potholes plus Pothole patches	> 1 hole per 10m of carriageway	< 1 hole per 10m and > 1 hole per 25m of carriageway	Not applicable
Scabbing	> 25% carriageway area	10-25% carriageway area	Not applicable
Flushing	Not applicable	Not applicable	> 10% wheelpath length for high use > 25% wheelpath length for medium use > 50% wheelpath length for low use

5.5.1 Criteria

Shape Correction is triggered by the following criteria:

- Cost of present maintenance (including a surface treatment if required).
- Present value (PV) of future maintenance.
- Present value of user benefits due if roughness is reduced from an SCT .
- Costs of the SCT construction.

- ***Cost of present maintenance***

The cost of present maintenance is determined from the quantity of faults found in the rating and includes the cost of a surface treatment if the pavement qualifies for a Reseal in the Budget Year.

- ***Present value of future maintenance***

The present value of future maintenance is determined from a mathematical relationship between the surface treatment cycle time and the cost of the surface treatment. This is shown graphically in Figure 5.1. If the condition of the present surface indicates that it is due for a re-surface, the future surface treatment cycle is assumed to equal the number of years that the current surface treatment has survived (i.e. determined from the age of the current surface treatment). The surface treatment life cycle is adjusted downwards if the present condition of the surface is in such a significantly deteriorated state that an earlier re-surfacing the carriageway would have been more economic.

The condition of the drainage is also used to adjust the life cycle where poor drainage is likely to have significantly decreased the life of the surface treatment. Where the present age and condition of the surface indicates a significantly shorter life cycle than listed in Table 5.2, and the drainage is in poor condition, the assumption applied is that the repair of the drainage will restore the future surface treatment life cycle to 80% of that shown in Table 5.2. The TSP is unable to ascertain the condition of the pavement material and therefore this assumption is incorrect if the pavement material is structurally unsound.

If the present surface is in good condition and does not qualify for a re-surfacing treatment the life cycle is taken from the values shown in Table 5.2. The life cycle is then "normalised" to that of a grade 3 chipseal for the calculation of life cycle costs. All present values are determined using a discount rate of 10% and an analysis period of 25 years.

The average life cycle of a surface treatment depends on the type of surface treatment placed and the traffic loadings carried. The TSP makes use of the use code used in RAMM to indicate the traffic loading carried by each road section. The codes used are shown in Table 5.3.

The surface treatment life cycle, after the construction of a smoothing SCT, is adjusted by a small amount to take into account the slight structural benefit of a smoothing treatment. The surface treatment life cycle, after the construction of a strengthening SCT, is based on the assumption that the pavement strength will be adequate for future traffic loading and is therefore derived directly from Table 5.2.

The SCT option by the TSP for the final analysis is the one with the least present value of construction and future maintenance costs.

Table 5.2 Average surface treatment life cycles for New Zealand roads in years.

Surface Treatment Type	**Pavement Use Code**				
	1	2	3	4	5
Friction Course	12	11	10	9	8
Thin Asphaltic Concrete	12	11	10	9	8
Open Graded Emulsion Mix	12	11	10	9	8
Slurry Seal	8	7	6	5	4
Grade 6 Void Fill or Locking Coat	6	5	4	3	2
Grade 5 Texturising Seal or Void Fill	8	7	6	5	4
Grade 4 Reseal or 2nd Coat	12	10	8	7	6
Grade 3 Reseal or 2nd Coat	14	12	10	9	8
Grade 2 Reseal or 2nd Coat	16	14	12	10	9
First Coat Seal (Grade 4)	3	2	1	1	1
Prime and Seal (Grade 4)	10	9	8	7	6
Two Coat Seal (Grade 5/3)	16	14	12	10	9

Figure 5.1 An example of pavement life cycle costs used by the TSP.

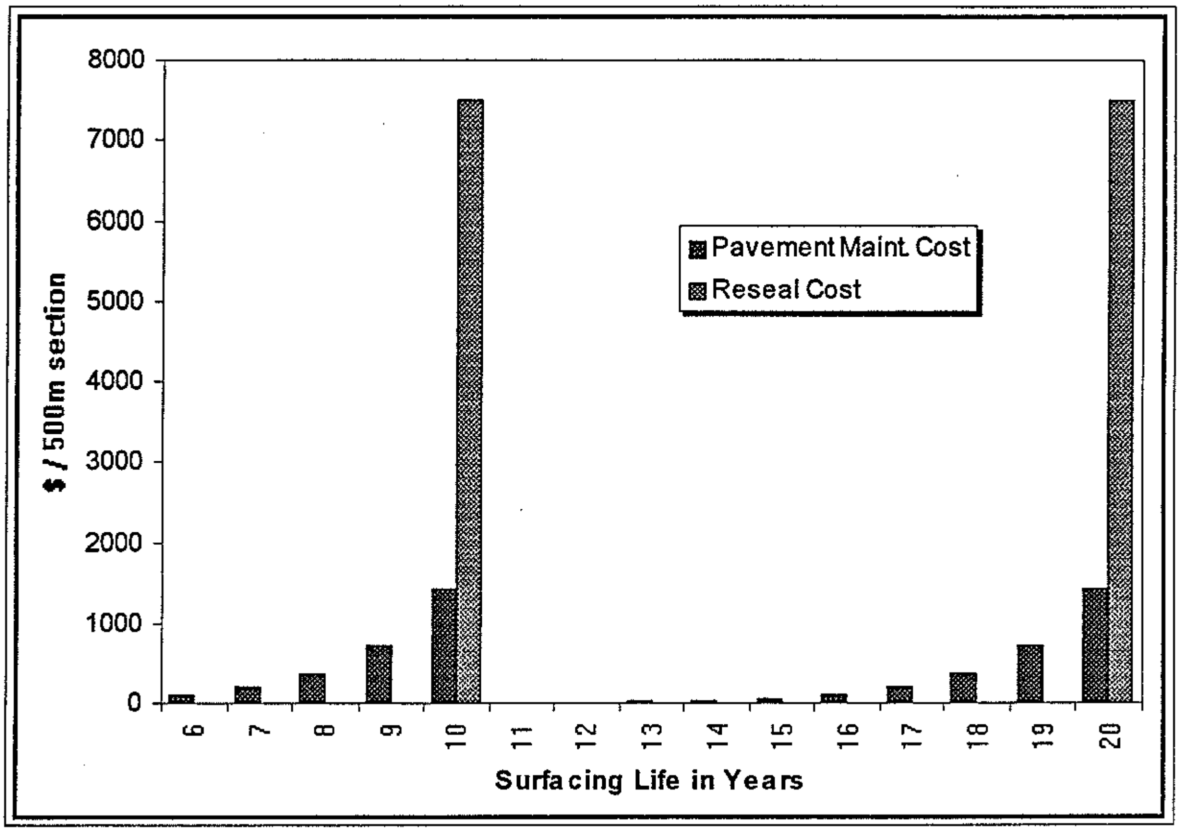


Figure 5.2 Additional user costs related to road roughness by five road types.

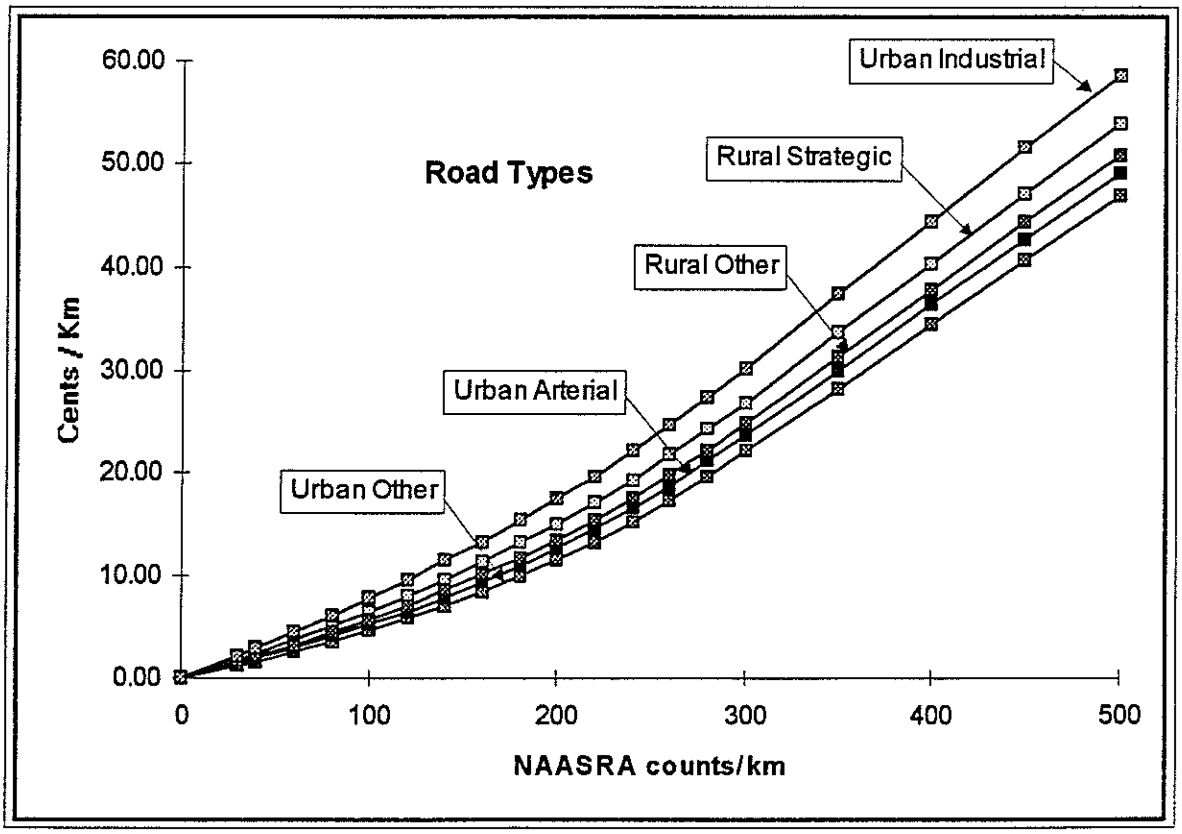


Table 5.3 Use codes applied in the RAMM system to indicate traffic loading.

Use Code	Traffic Volume (vehicles/day)	Traffic Load (equivalent design axles/lane/day)
1	< 100	< 2
2	100 - 500	2 - 5
3	500 - 2,000	5 - 20
4	2,000 - 10,000	20 - 100
5	> 10,000	> 100

- ***Present value of user benefits***

The present value of user benefits arising from the reduction in roughness after an SCT are based on Table A2.15 of the *Project Evaluation Manual Volume 2: Full Procedures* (Transit New Zealand 1991). The "Rural Other" vehicle operating costs were chosen from Table A2.15 and a simple curve was fitted to the values listed in the manual. This curve is shown in Figure 5.2 with the other values for different vehicle mixes indicated by road type.

The roughness value used is the average for the rating section, and the difference in the additional vehicle operating costs between the SCT option and the non-SCT option are assumed to continue for a period of 25 years.

- ***SCT Construction Costs***

The cost of SCT construction is calculated from the unit costs input by the user and the area of pavement to be shape corrected.

The cost of a smoothing SCT is based on the assumption that a granular overlay of 70 mm over the high spots is applied in the rural environment or that a non-structural treatment is applied in the urban environment (e.g. thin asphaltic concrete (AC) overlay, rip and remake (R&R), etc.).

The cost of a strengthening SCT is based on the assumption that a granular overlay of 150 mm is applied in the rural environment or a structural treatment is applied in the urban environment (e.g. structural AC, stabilisation, etc.).

5.5.2 Calculation of B/C Ratio

- ***Calculation of Benefit/Cost (B/C) ratio***

The future life cycle costs for the non-SCT option are calculated using a surface treatment life cycle based on past performance as shown in Figure 5.1. All of the calculated costs are then used to calculate a B/C ratio as follows:

B/C Ratio = PV User Benefits/(PV SCT Option – PV Non-SCT Option)

If the life cycle of the surface treatment for the non-SCT option is very short, the PV of future maintenance for this option will be high and can result in a PV for the non-SCT option greater than that calculated for the SCT option. This causes the above formula to return a negative value and the TSP then gives a default B/C ratio of 100 which should result in the SCT option being the treatment selected.

- ***Cut-off B/C ratio***

The TSP uses a B/C ratio value as a "cut-off" level above which SCT work is required. The B/C ratio value used as a cut-off is selected by the user of the system and is set as a decision factor in the TSP program. If the B/C ratio derived is greater than the cut-off B/C ratio defined by the user, the rating section is reported for an SCT. If not, the rating section is reported for the non-SCT treatment. The B/C ratio is used as the priority indicator for SCT work reported.

Where the treatment selected is a non-SCT, the program calculates the B/C ratio for the maximum roughness value in the rating section and, if this value is greater than the cut-off B/C ratio defined by the user for a SCT, a warning is generated indicating the need for a possible partial SCT.

6. SENSITIVITY OF TREATMENT SELECTION PROCESS TO INPUTS

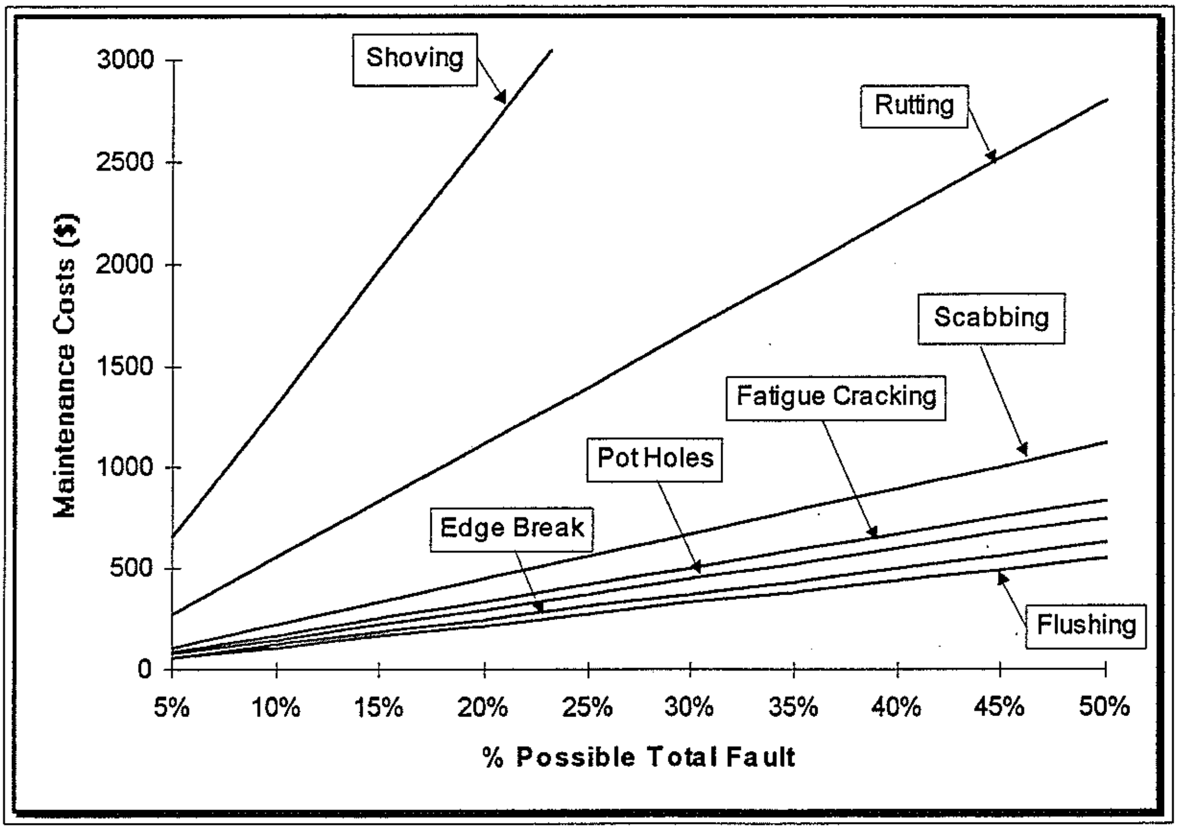
6.1 Maintenance Costs

The calculation of maintenance costs is carried out to enable the reporting of these costs for rating sections selected for "General Maintenance" and for pre-treatment work such as seal preparation. The maintenance costs are also used as an input for the determination of the first year rate of return (FYRR) for carrying out a surface treatment and for the B/C ratio for SCT work.

For the following sensitivity analysis, the cost of repairing each distress type rated was calculated from the maintenance costs given for the Transit New Zealand Wanganui Region rural road maintenance contracts.

The maintenance costs calculated by the TSP were most sensitive to shoving and this is shown in Figure 6.1 below.

Figure 6.1 Sensitivity of maintenance costs calculated by the TSP to pavement faults for state highways in the Transit New Zealand Wanganui Region.



6.2 Surface Treatments

Surface treatments are triggered by pavement faults reported from the road condition rating survey. The type of fault and the level at which each category of surface treatment is triggered is shown in Table 5.1.

Surface treatments selected for structural purposes are based on the presence of structural faults in the pavement surface. The selection of a surface treatment for structural purposes by the TSP was found to be very sensitive to fatigue (alligator) cracking and to shoving in the pavement surface. The FYRR is used to determine the priority of a surface treatment, and the sensitivity of this calculation to road condition rating inputs was checked using a rating section from the Transit New Zealand Wanganui Region database. The rating section chosen had just sufficient fatigue cracking (3%) to trigger a "Reseal in the Budget Year". All other faults recorded in the rating with the exception of the fatigue cracking were set to zero and then each one was individually increased.

The results of the analysis confirmed that rutting, edge break, flushing and longitudinal, transverse and joint cracks had no effect on the FYRR calculated by the TSP for a rating section selected for a surface treatment. The FYRR was found to be sensitive to the remaining carriageway faults of shoving, fatigue cracking, potholes and scabbing, and this sensitivity was demonstrated with the plot of FYRR against the percentage of the possible total for each pavement surface fault as shown in Figure 6.2. The analysis demonstrated that the FYRR calculated by the TSP was most sensitive to shoving.

Surface treatments selected for safety purposes are based on the need to improve the macrotexture of the pavement surface. The fault which indicates the need to improve the surface macrotexture is flushing and the quantity of flushing required to trigger a surface treatment is based on the pavement use code. Sections which qualify for this treatment are reported under "Reseal Flushed". The selection of a surface treatment by the TSP was found to be sensitive to flushing only when the structural distress indicators were very low and traffic volumes were high.

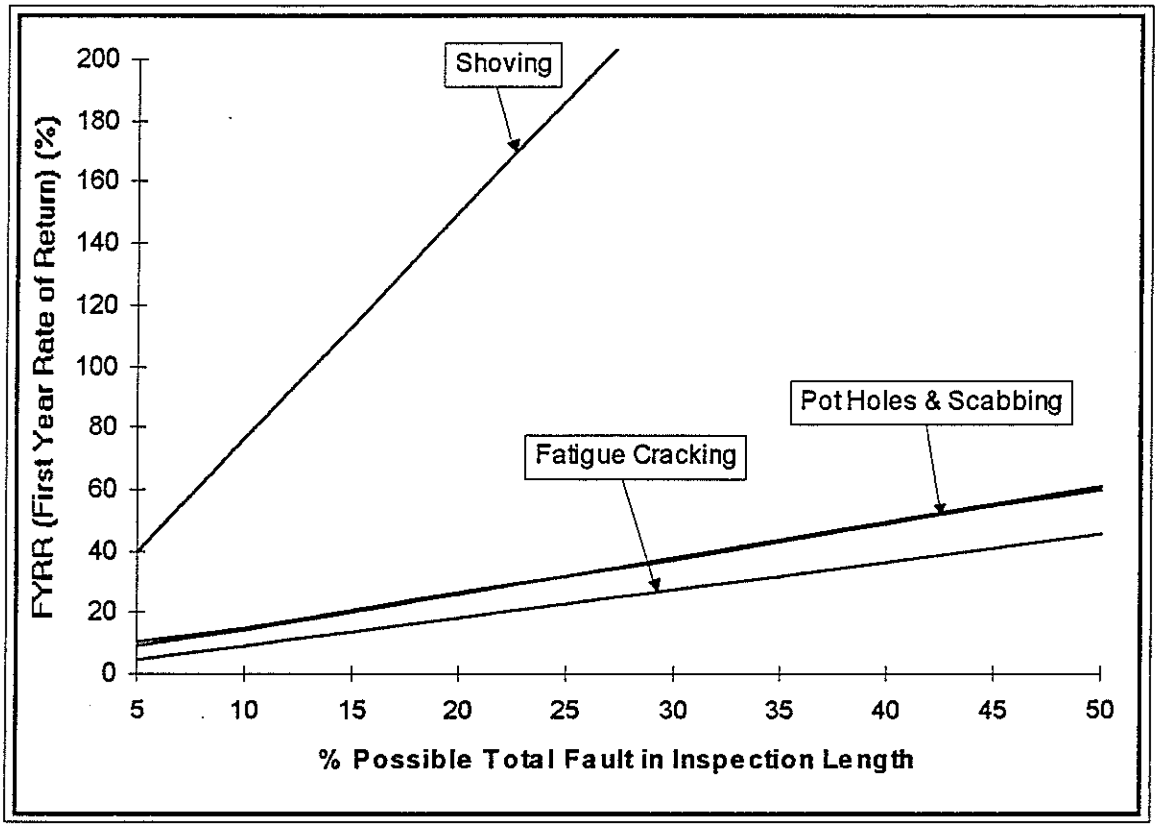
6.3 Shape Correction Treatments

An SCT is selected by the TSP when the B/C ratio calculated for carrying out the work is greater than the cut-off B/C ratio input by the user. The calculated B/C ratio is dependent upon several inputs, as discussed in Section 5.5. Therefore, the sensitivities of the B/C ratio calculated by the TSP were checked against the following inputs:

- The present cost of pavement maintenance (derived from the road condition rating inputs).
- The present value of future maintenance (derived from the surface treatment life cycle).

- The present value of user benefits (derived from the reduction in roughness and traffic volume).
- The cost of the SCT instruction.

Figure 6.2 Sensitivity of FYRR calculated by the TSP to pavement faults for state highways in the Transit New Zealand Wanganui Region.



6.3.1 Sensitivity to Cost of Present Maintenance

The cost of present maintenance is derived from the condition rating inputs and, therefore, the sensitivity of the TSP treatment selection for an SCT was checked against a series of variable road condition rating inputs.

A rating section was chosen from the Transit New Zealand Wanganui Regional Office database which the TSP had selected for a Smoothing SCT. All the rating values were set to zero and the B/C ratio output by the program was checked against each fault by gradually increasing the quantity of the individual faults. The rating section chosen had the following characteristics:

- Length of 500 m and width 6.8 m,
- Traffic flow of 1460 vehicles per day (vpd),
- Average surface roughness of 121 NAASRA counts/km,

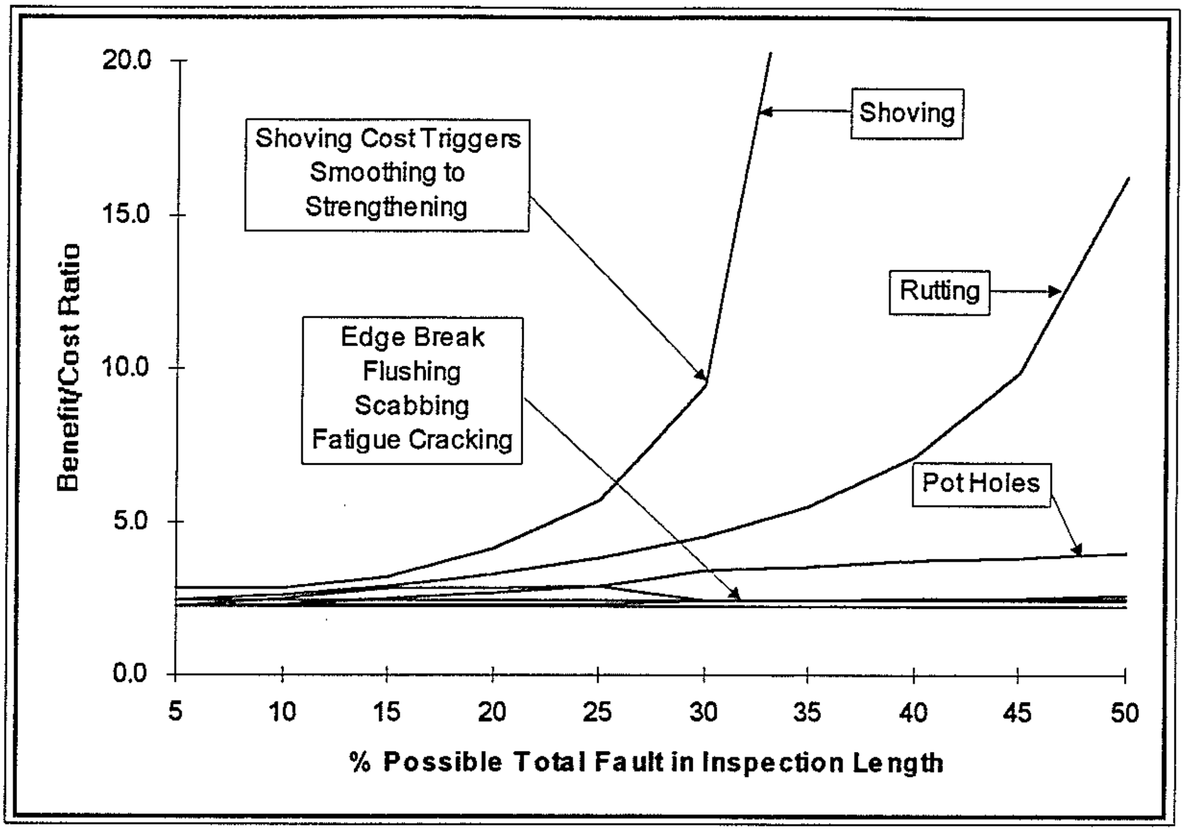
- No faults recorded for the surface water channels,
- An October 1984 Grade 3 chipseal showing fatigue cracking, scabbing and holes.

The total possible length, for faults measured by length, was calculated as 200 m (four wheelpaths for the 50 m inspection length). The total possible area, for faults measured by area, was calculated as 340 m^2 and the total possible number of holes was estimated as 60 in the inspection length.

The resulting B/C ratios indicated that the process was sensitive to shoving and rutting but only if large quantities of each fault were recorded. To have a significant effect on the B/C ratio, the quantity of shoving required was greater than 25% of the wheelpath length and for rutting greater than 40% of the wheelpath length, as shown in Figure 6.3.

In practice this high number of faults was not recorded in many rating. In the Wanganui database only one rating section had more than 25% shoving recorded, and no rating sections had more than 40% rutting recorded.

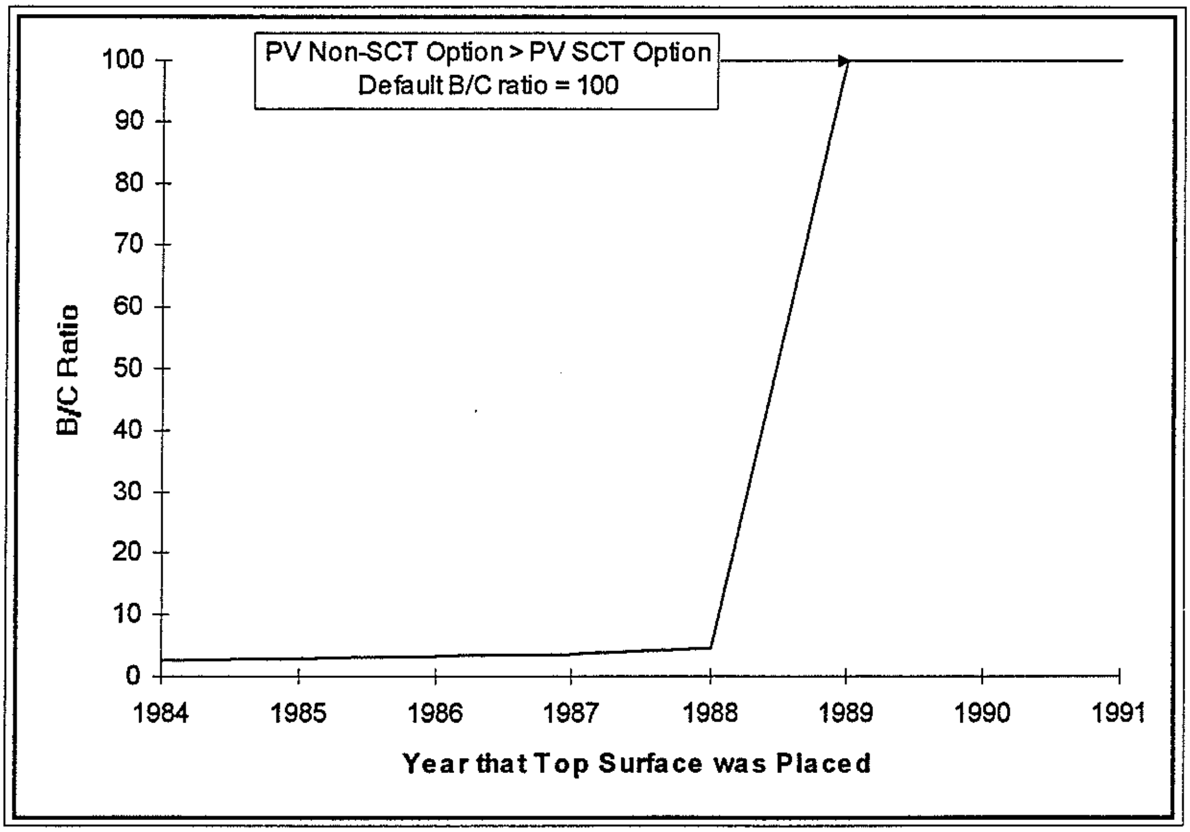
Figure 6.3 Sensitivity of the B/C ratio calculated by the TSP to pavement faults for state highways in the Transit New Zealand Wanganui Region.



6.3.2 Sensitivity to Present Value of Future Maintenance

The life cycle costs for the pavement are estimated in the TSP, as described in Section 5.5. The PV of future maintenance and surface treatments is based on the surface treatment life cycle which is estimated from the past life span of the present surface treatment with adjustment for current drainage and surface treatment conditions. For these reasons the rating section chosen for the sensitivity analysis was the one used in Section 6.3.1 above and the life span of the present surface treatment was adjusted over a period of years. These results are shown in Figure 6.4.

Figure 6.4 Sensitivity of the B/C ratio to the life cycle of a present road surface treatment.



The PV of maintenance (reseals, seal preparation and general maintenance between reseals), is considered a negative cost and is subtracted from the SCT cost as part of the B/C ratio formula (see Section 5.5). If the PV of the non-SCT option exceeds the SCT option, the formula returns a negative value. This is not considered appropriate and therefore the TSP sets a value of 100, which is the cause of the sudden step in the graph shown in Figure 6.4.

The method used for the calculation of the B/C ratio means that the B/C ratio becomes highly sensitive to the PV of the future maintenance costs when the PV of both the present and future maintenance (non-SCT option) approaches or exceeds the PV of the SCT option. For the rating section used in this analysis, the point of sensitivity is reached when the estimated life cycle of the surface treatment is less than three years.

In essence, roads which have low roughness values and/or low vehicle flows, have low vehicle operating costs. This creates the situation shown in Figure 6.4 whereby little change occurs in the B/C ratio value until the PV of maintenance costs approaches the PV of the SCT cost.

The conclusion is that outcomes from the B/C ratio formula are highly sensitive to the frequency of surface treatments and the cost of general maintenance between the surface treatments (see Figure 5.1), as these costs influence the cost of each surface treatment cycle and will therefore alter the point at which the PV of the maintenance costs approaches the PV of the SCT costs. This confirms that the rate of change of future maintenance costs, which is estimated by roading managers when calculating the B/C ratio for a SCT project, is probably the greatest reason for the differences found in project level assessments. These differences occur when comparing RAMM outputs with the roading manager's calculations, and when comparing results between different roading managers.

6.3.3 Sensitivity to Present Value of User Benefits

The PV of user benefits arise from the reduction of vehicle operating costs caused by the reduction in roughness after an SCT has been undertaken. The user benefits are therefore dependent upon the number of vehicles per day (vpd), the mix of vehicles using the road, the present roughness for the rating section, and the roughness value (measured in NAASRA counts/km) achieved after an SCT.

The B/C ratio values calculated by the TSP were checked against the inputs of traffic flow and present roughness. The target roughness value after an SCT was set at 60 NAASRA counts/km. Another comparison was made to check the influence of pavement condition by carrying out a set of calculations where the pavement was in good condition (from the rating survey) and where the pavement was in poor condition.

The pavement in good condition had zero pavement distress, whereas the pavement in poor condition had high distress levels for shoving, rutting, scabbing, cracking, flushing and holes. The distress levels were at a levels which, in practice, would be towards upper end of the spectrum for these types of fault.

The results from these calculations indicate that the B/C ratio calculated from the TSP is more sensitive to the reduction in road roughness and the traffic flow (vpd) than any other input. This is shown in Figures 6.5 and 6.6.

Figure 6.5 Sensitivity of the B/C ratio to traffic flow (less than 5,000 vpd) and pavement roughness (NAASRA counts/km).

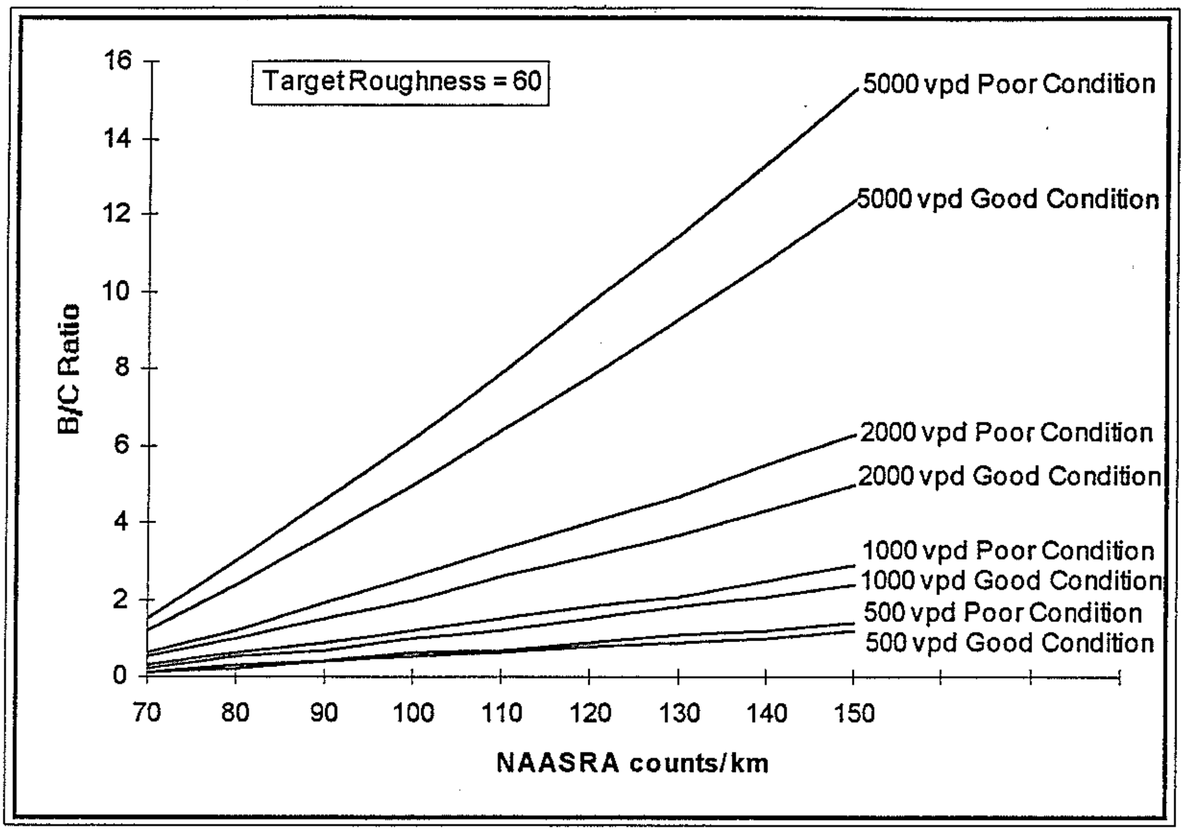


Figure 6.6 Sensitivity of the B/C ratio to traffic flow (more than 5,000 vpd) and pavement roughness (NAASRA counts/km).

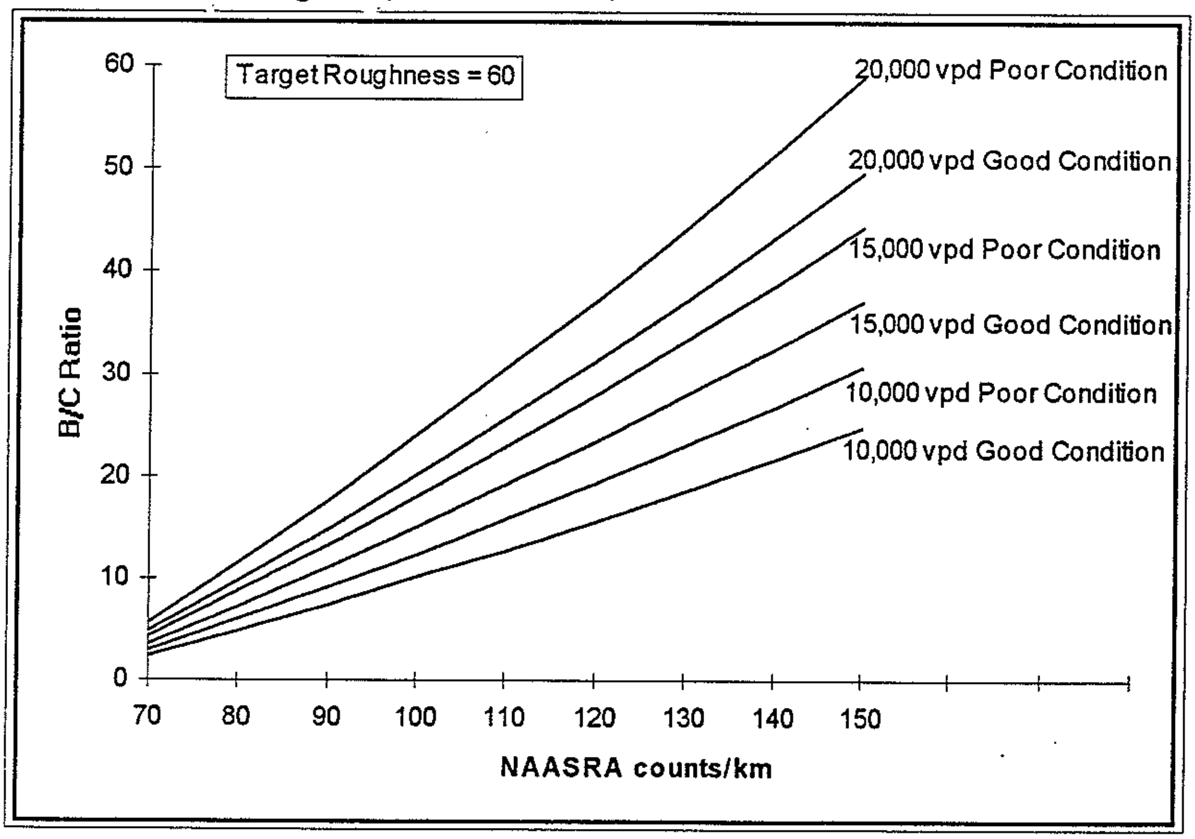


Figure 6.7 Sensitivity of the B/C ratio to user benefits by road type.

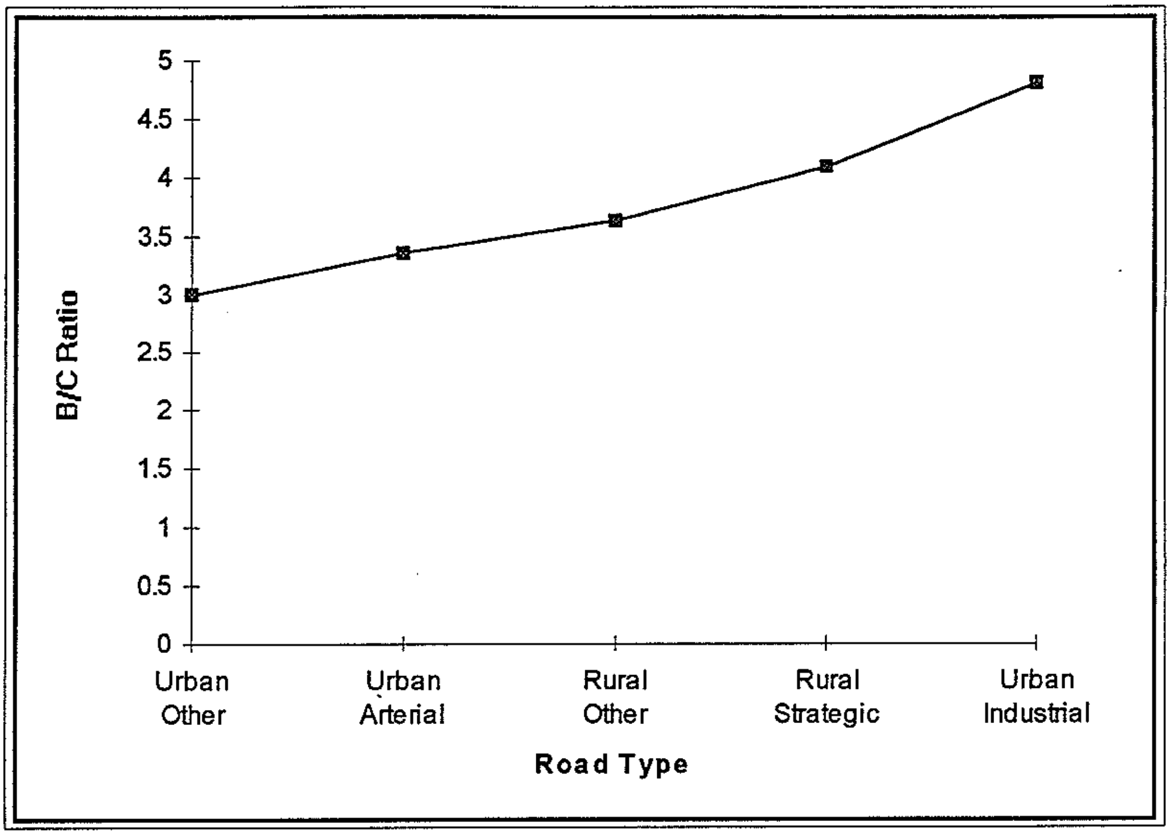
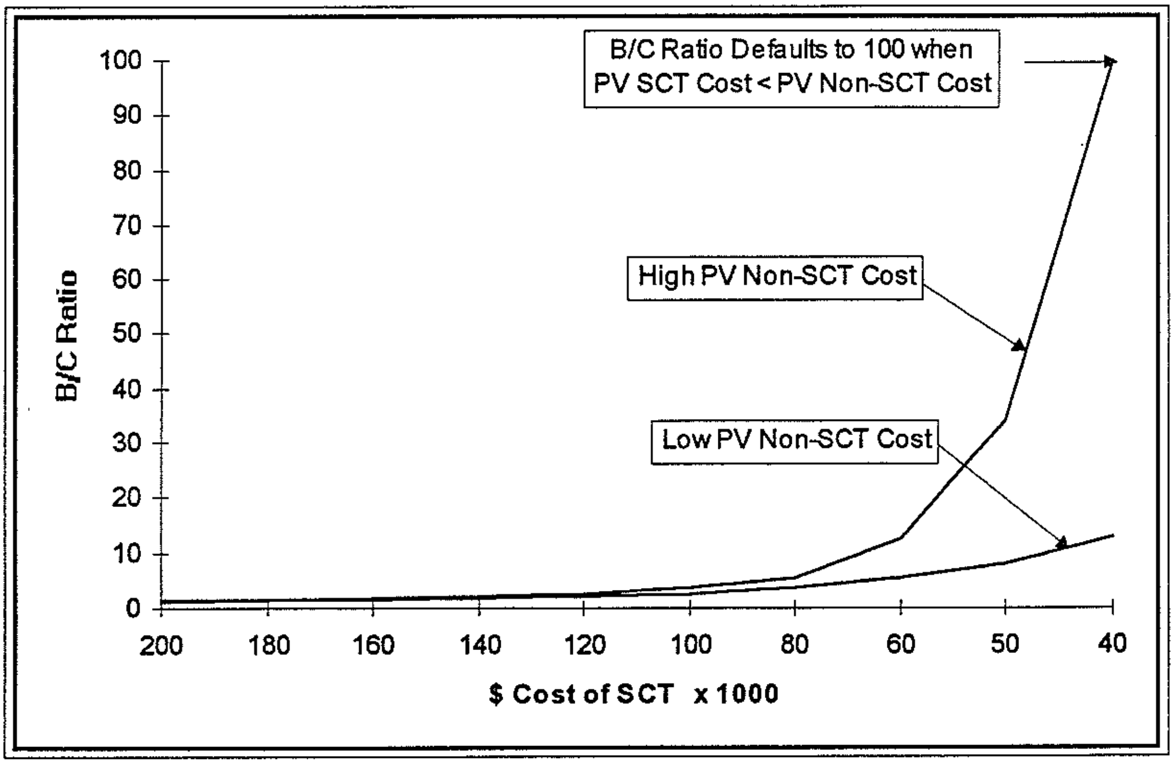


Figure 6.8 Sensitivity of the B/C ratio to the construction cost of an SCT.



The B/C ratio, calculated by the TSP for an SCT, is directly proportional to the value of the user benefits derived from that treatment. Using the additional vehicle operating costs created by a roughness value of 150 NAASRA counts/km, the B/C ratio was calculated for a rating section using the different vehicle mixes estimated for each road type, as described in the Transit New Zealand *Project Evaluation Manual, Volume 2: Full Procedures* (1991). The roughness value after a SCT was taken as 75 NAASRA counts/km. The comparison between the vehicle mixes is shown in Figure 6.7 which demonstrates that vehicle mix does have a significant effect on the calculated B/C ratio. At present, differing vehicle mixes are not catered for in the TSP.

6.3.4 Sensitivity to the SCT Construction Cost

The rating section used for this analysis was the same as the one used in Section 6.3.1 where its characteristics are listed. The construction cost of the SCT was made to range from $40,000/km to $200,000/km, and the date of the seal was set at 01 October 1984 and also at 01 October 1987, to vary the PV of the non-SCT cost. The resulting values are shown in Figure 6.8, and demonstrate that the B/C ratio calculated for an SCT is sensitive to construction cost, especially when the non-SCT cost becomes high as a proportion of the SCT cost.

7. TREATMENT SELECTION PROCESS FOR STATE HIGHWAYS

7.1 State Highway Network Studied

The state highway network studied comprised most of the Transit New Zealand Wanganui Region state highway network and no local authority roads were included. The network consisted of 561.3 km of highway which was managed by Works Consultancy under contract to Transit New Zealand as the Wanganui Network Maintenance Management Consultants (see Figure 4.1).

7.2 Basis of Treatment Selection Analysis

7.2.1 General

The road condition information was obtained from the condition rating survey carried out during October 1992 and the road roughness survey carried out during September 1992. The length of road analysed was 561 km.

7.2.2 Target Roughness Values

The target roughness value used to represent the road roughness after an SCT was 65 NAASRA counts/km for urban and rural roads. This value was determined from the results of the roughness survey on the sections of first and second coat seals that had been placed during the preceding two years.

7.2.3 Unit Costs

The unit costs used in the TSP were supplied as part of the RAMM data and were dated 30 September 1991. The costs reported from the TSP were updated to the 30 September 1992 with the use of the construction cost index (CCI).

7.2.4 B/C Ratio Values Used to Select an SCT

The cut-off B/C ratio for selecting an SCT was set at 4.0 for the initial analysis and a subsequent analysis was undertaken at a cut-off B/C ratio of 8.0. The B/C ratio of 4.0 was chosen because it was the level at which the Transit New Zealand Roading Manager considered that a site inspection of the section of road selected for an SCT was warranted. Furthermore, Transit New Zealand policy in 1992/93 was to fund all SCT projects with a B/C ratio greater than 4.0. The B/C ratio of 8.0 was the level at which the length of highway reported for SCT by the RAMM system corresponded approximately with the length of SCT work carried out annually (1992/93 - 1993/94) on the Transit New Zealand Wanganui Region state highway network.

7.2.5 Data Integrity

The RAMM software includes programs (audit reports) which analyse the database for accuracy and report any data which are considered to be erroneous. Other programs included in the RAMM software (pre-treatment validation reports) analyse the database for completeness and report any data required for the TSP which are missing. Both sets of programs were run on the Transit New Zealand Wanganui Region RAMM database and the reports produced indicated that the database was sound and well maintained.

7.3 Network Level Results From TSP

7.3.1 Effect of Cut-off B/C Ratio for Reporting an SCT

A summary of the results from the TSP with cut-off B/C ratios of 4.0 and 8.0 set as decision factors for selecting an SCT is presented in Tables 7.1 and 7.2.

Table 7.1 State highway regional network level results using a cut-off B/C ratio of 4.0 for selecting SCT.

Target Roughness for Urban = 65, Rural = 65 Construction Cost Index Date = 30 Sept 1992								
Area Treatment	Length (km)	% of SH	Treatment Cost $	Treatment Ave.$/km	Maint. Cost $	Maint. Ave.$/km	Drainage Cost $	Drainage Ave.$/km
General Maint.	383.20	68.3	0	0	528,064	1,378	1,032,319	2,694
Reseal (Flushed)	38.83	6.9	0	0	41,359	1,065	105,423	2,715
Reseal Next Time	63.76	11.4	0	0	420,559	6,596	146,518	2,298
Reseal in Budget	60.30	10.7	1,858,469	30,820	410,884	6,814	166,562	2,762
SCT - Smoothing	8.78	1.6	988,501	112,586	7,893	899	7,557	861
SCT - Strengthen	6.43	1.1	993,142	154,454	0	0	320	50
Total	561.3	100.0	3,840,112	-	1,408,759	2,510	1,458,699	2,599

Table 7.2 State highway regional network level results using a cut-off B/C ratio of 8.0 for selecting SCT.

Target Roughness for Urban = 65, Rural = 65 Construction Cost Index Date = 30 Sept 1992								
Area Treatment	Length (km)	% of SH	Treatment Cost $	Treatment Ave.$/km	Maint. Cost $	Maint. Ave.$/km	Drainage Cost $	Drainage Ave.$/km
General Maint.	385.06	68.6	0	0	530,203	1,377	1,036,642	2,692
Reseal (Flushed)	38.94	6.9	0	0	41,546	1,067	105,774	2,716
Reseal Next Time	63.95	11.4	0	0	422,493	6,607	147,003	2,299
Reseal in Budget	62.20	11.1	1,927,369	30,987	437,803	7,039	176,491	2,837
SCT - Smoothing	4.72	0.8	526,039	111,686	7,336	1,558	1,666	354
SCT - Strengthen	6.43	1.1	993,142	154,454	0	0	320	50
Total	561.30	100.0	3,446,550	-	1,439,381	2,564	1,467,896	2,615

The results presented in Tables 7.1 and 7.2 above demonstrate how the increase from 4.0 to 8.0 in the cut-off B/C ratio as a decision factor for SCT reduces the quantity of SCT (Smoothing) reported from 8.78 km to 4.72 km. The quantity of SCT

(Strengthening) has not altered because the sections of road reported for this treatment all have a B/C ratio above 8.0.

The quantity of Reseal in Budget has increased from 60.3 km to 62.2 km and General Maintenance has increased from 383.2 km to 385.06 km, which indicates that approximately 50% of the pavements not reported for an SCT at the higher cut-off B/C ratio, still require a surface treatment if they do not require an SCT.

The total treatment cost reported in Tables 7.1 and 7.2 decreased approximately 10% with the increase in the cut-off B/C ratio from 4.0 to 8.0 as a decision factor for SCT. This demonstrates the relatively high cost of SCT compared with other treatment costs.

7.3.2 RAMM Results v Transit New Zealand Land Transport Programme at Network Level

7.3.2.1 Comparison of maintenance treatment lengths

A comparison of the total of each major maintenance reported from the TSP (cut-off B/C ratio = 4.0) against the total of each major maintenance in the road maintenance programme for Transit New Zealand Wanganui Region is shown in Table 7.3 and Figure 7.1. With the exception of SCT, agreement between the Transit New Zealand programme and the Treatment Selection lengths reported from RAMM is generally good.

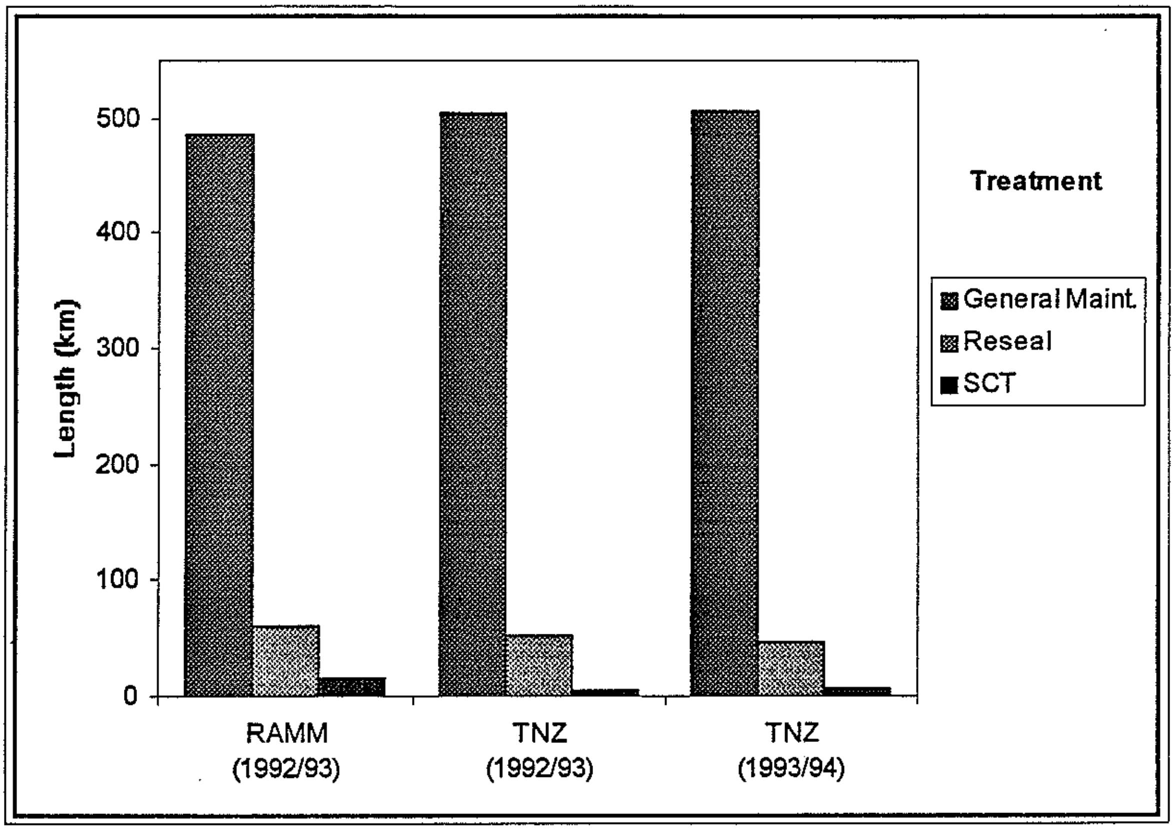
A cut-off B/C ratio decision factor of 10.0 apparently gave a better correlation between the RAMM-predicted SCT requirements and the actual Transit New Zealand programme, than did a cut-off B/C ratio of 8.0. However, many of the SCTs reported to be needed for the heavily trafficked urban pavements in Wanganui were not considered to be practical maintenance options. From inspection of the sites reported for SCT in urban Wanganui, and the associated RAMM data, these road sections had little obvious pavement distress and only moderate roughness (i.e. average roughness values of 90 - 110 NAASRA counts/km). The traffic counts were sufficiently high, however, to generate significant user benefits which therefore resulted in the pavement being reported for an SCT. An inspection of these pavements showed that the moderate roughness counts resulted primarily because they are situated in an urban environment.

The roads in an urban environment often have poor road surface shape because of the presence of service covers, service trenches and a multiplicity of intersections. Roughness measurements in urban areas also reflect a greater variation in vehicle speed related to braking and acceleration. All these factors combine to give higher average roughness values for roads in an urban environment compared with rural roads. In many urban situations where the RAMM system reports the need for an SCT based on small reductions in roughness and a high traffic volume, a smoothing treatment would be unlikely to achieve the average target roughness for urban SCT because of the urban environment.

Table 7.3 Comparison of lengths of each maintenance type selected by the RAMM TSP (cut-off B/C ratio = 4.0) with those from the Transit New Zealand Wanganui Region Land Transport Programme.

RAMM (B/C 4.0)		**TNZ (1992/93)**		**TNZ (1993/94)**	
Treatment Type	**Length (km)**	**Treatment Type**	**Length (km)**	**Treatment Type**	**Length (km)**
General Maint.	383.20	General Maint.	505.51	General Maint.	506.80
Reseal (Flushed)	38.83				
Reseal Next Time	63.76				
Total Maintenance	485.79	Total Maintenance	505.51	Total Maintenance	506.80
Reseal in Budget	60.30	Reseal	43.50	Reseal	39.30
		2nd Coat	7.80	2nd Coat	7.60
Total Reseal	60.30	Total Reseal	51.30	Total Reseal	46.90
Smoothing	8.78				
Strengthening	6.43	SCT	4.49	SCT	7.60
Total SCT	15.21	Total SCT	4.49	Total SCT	7.60
TOTAL	**561.30**		**561.30**		**561.3**

Figure 7.1 Comparison of lengths of each maintenance type selected by the RAMM TSP (cut-off B/C ratio = 4.0) with those from the Transit New Zealand Wanganui Region Land Transport Programme.



After deducting the length of urban roads repórted by RAMM for an SCT, but which could not be justified on inspection, the quantities of maintenance reported at a cut-off B/C ratio decision factor value of 8.0 gave a good correlation with the Transit New Zealand Wanganui Region road maintenance programme. This result was at variance with the Transit New Zealand 1992/93 policy which required SCT work to be programmed if a B/C ratio above 4.0 could be achieved. However, the sections of road identified for an SCT by the RAMM system at a B/C ratio above 4.0 often did not yield such high B/C ratios when the calculation was based on more detailed site data and carried out in accordance with the *Project Evaluation Manual, Volume 1: Simplified Procedures* (Transit New Zealand 1991). This was primarily because the capital cost of an SCT was higher than that predicted by RAMM. The reasons for this difference are discussed in Section 7.3.2.2 (SCT).

Second coat seals are normally dealt with outside the TSP contained within the RAMM system and originally these were not intended to be included in the comparison. However, the site inspections revealed that the condition rating had detected faults in the first coat seals and the TSP had therefore selected these for a reseal. For this reason second coat seals were included in the comparison.

7.3.2.2 Comparison of costs of maintenance reported

The actual expenditure on road maintenance was obtained from Transit New Zealand's records of maintenance costs for state highways within the Wanganui Network Maintenance Management Contract for the 1991/92 financial year. Expenditures recorded were compared with the RAMM predictions as shown in Table 7.4 and Figure 7.2 (p.38). In general the match between the two sets of data was good with the exception of drainage and SCT.

- ***Shape Correction Treatment***

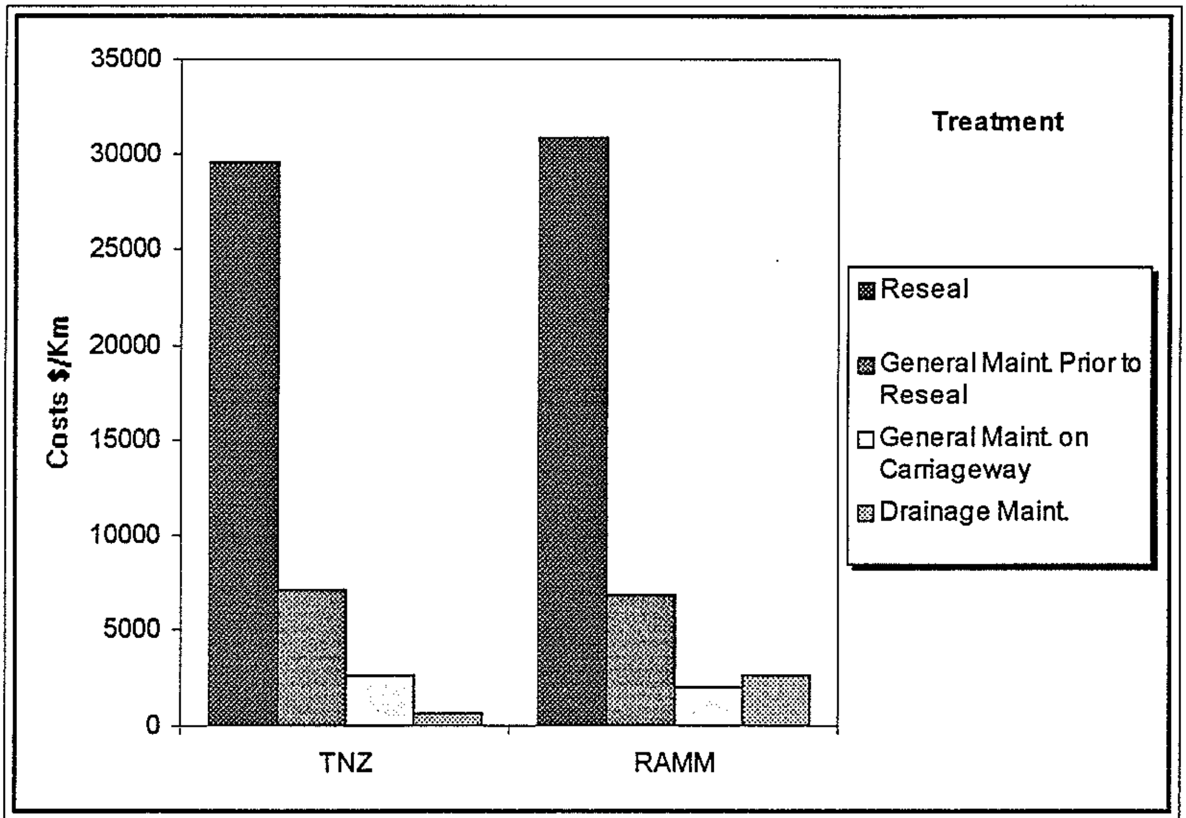
Transit New Zealand policy allows for improvement work to be carried out to the road (e.g. seal widening) at the same time as an SCT is undertaken, providing the cost of the improvements does not exceed 30% of the total project cost. The objective of an SCT is to provide improved ride characteristics for the road user and, because the improvements are usually not related to this objective, no attempt is made in the TSP to include such work in the calculation of a B/C ratio for an SCT.

The opportunity is usually taken by Transit New Zealand Roading Managers to maximise improvements to the road network when an SCT is carried out. The non-SCT improvements add to the expenditure on SCT work but do not usually contribute greatly to the user benefits (e.g. seal widening has an approximate average B/C ratio of 1.0). However, when improvements are carried out in conjunction with an SCT, Transit New Zealand policy requires the cost of the improvements to be included in the calculation of the B/C ratio for the project. The effect of this policy is to increase the capital cost of an SCT project where improvements are included and therefore to reduce the B/C ratio.

Table 7.4 Comparison of Transit New Zealand actual expenditure for 1991/92 with RAMM predicted costs (cut-off B/C Ratio = 4.0).

Maintenance Type	Length (km)	TNZ Expenditure $	TNZ Expenditure $/km	RAMM Cost($)/km Cut-off B/C ratio=4.0
Reseal	44.1	1,301,500	29,512	30,820
General maint. before reseal	44.1	317,095	7,190	6,814
General maint. on carriageway	514.0	1,366,627	2,659	2,038
Drainage maint.	558.0	373,820	670	2,599
SCT (Strengthen)	4.5	851,000	189,111	154,454

Figure 7.2 Comparison of Transit New Zealand actual expenditure for 1991/92 with RAMM-predicted costs (cut-off B/C ratio = 4.0).



The difference between the actual expenditure and RAMM-predicted costs for an SCT is related to the 58% of the SCT programme for 1992/93 which included widening of the carriageway. The associated extra cost of the improvement work has caused an overall decrease in the B/C ratio obtained for SCT work when compared with the B/C ratios calculated by the TSP. Hence, the difference in the predicted length of road requiring a SCT which RAMM predicts has a B/C ratio better than 4.0

when compared with the length on the Transit New Zealand programme with a B/C ratio better than 4.0.

The comparison is not made for SCT in Figure 7.2 because of the effects of including seal widening when undertaking an SCT.

- ***Reseals***

The average expenditure versus RAMM-predicted costs for reseals compared favourably, although a significant variation in the expenditure per kilometre between sealing sites was demonstrated, as shown in Figure 7.3. This variation was almost entirely related to the difference in carriageway widths.

- ***General Maintenance of Carriageway***

General maintenance is the category of work which is not considered as a major maintenance and includes such activities as pothole patching, digout patching, crack sealing, surface-water channel cleaning, culvert cleaning, vegetation control, re-painting road markings, etc. RAMM reports the predicted general maintenance costs in two categories:

- Carriageway repairs (does not include re-painting markings, cleaning litter, etc.).
- Surface-water channel repairs (does include shoulder maintenance but does not include vegetation control, cleaning culverts, replacing marker posts, etc.)

The comparisons made between the TSP and actual expenditure for general maintenance are based on the type of repairs reported by the TSP and do not include the routine cyclic maintenance such as vegetation control, cleaning culverts, etc.

The network was divided into 15 areas based on road maintenance contract areas. The average expenditure for general maintenance per kilometre of highway was obtained for each of the 15 maintenance contract areas from the Transit New Zealand Network Maintenance Management Consultant.

The expenditure for carriageway repairs required for seal preparation closely matched that predicted by the TSP for roads requiring a reseal in the budget year and was added to the average maintenance expenditure for those sections of highway which had required a reseal during 1992/93.

The expenditure/km for carriageway repairs in each area of highway network ranged widely from $150.00/km to $5,600.00/km as shown in Figure 7.4. However, when the carriageway general maintenance expenditure was averaged it correlated reasonably well to the average carriageway general maintenance costs predicted by the TSP. The actual average expenditure for carriageway general maintenance was 11% higher than that predicted by the TSP. However, when the reseal preparation costs were removed from consideration, the difference between carriageway general maintenance expenditure and the costs reported by the TSP was 30%. This difference would seem appropriate given that maintenance is an ongoing requirement whereas the rating only captured a "snapshot" of the maintenance need.

Figure 7.3 Actual reseal expenditure for the sections of state highway in the Transit New Zealand Wanganui Region sealed in 1991/92.

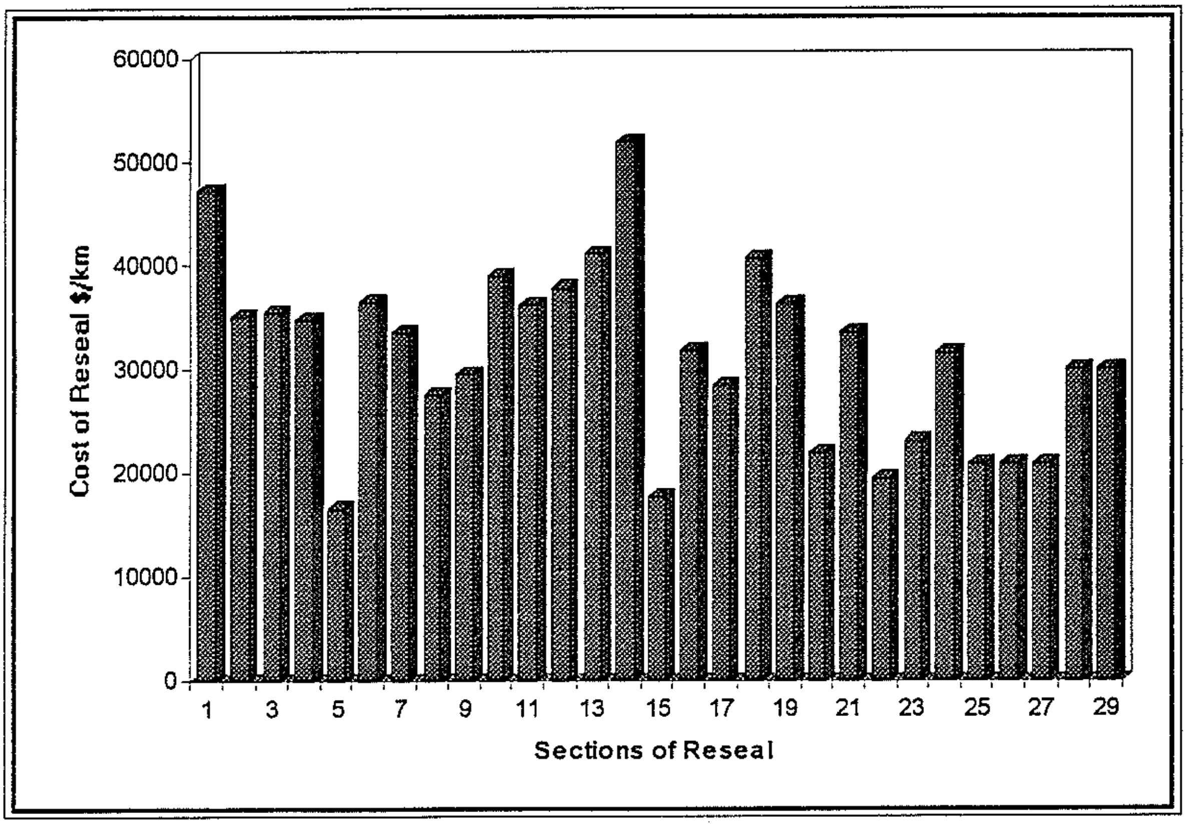
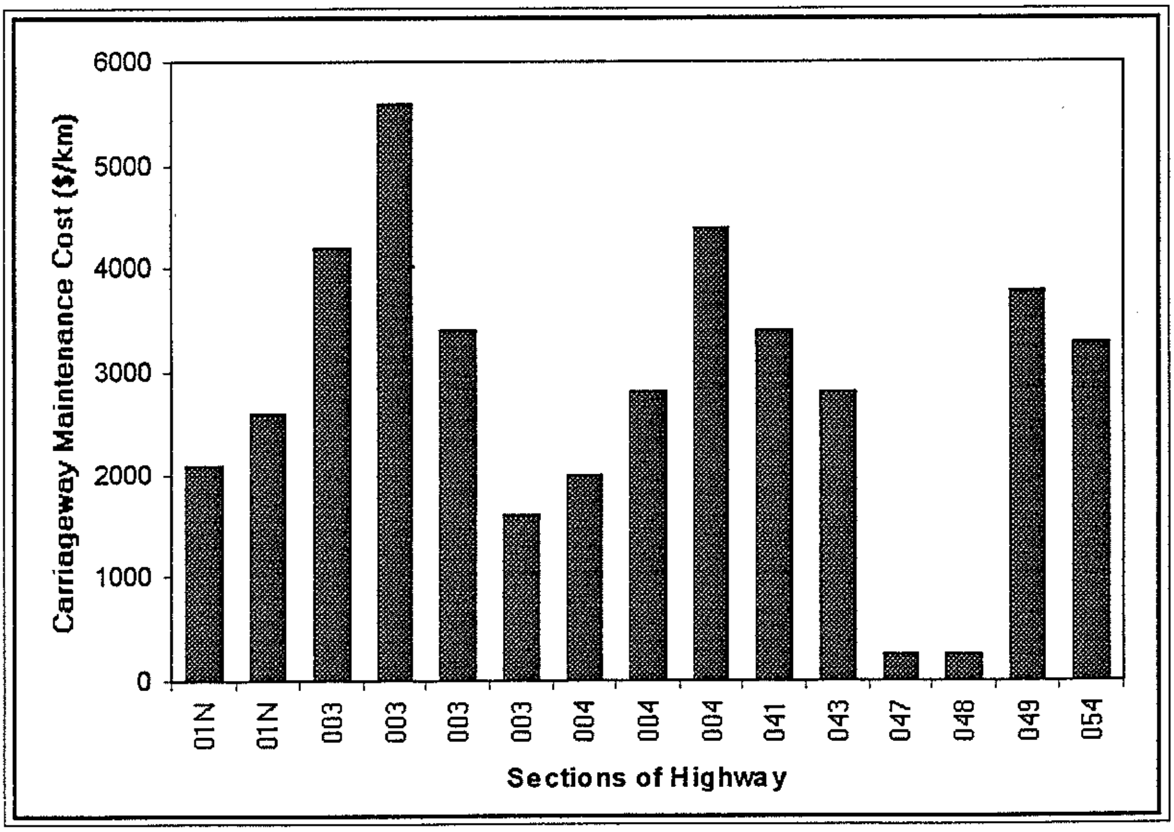


Figure 7.4 Average carriageway maintenance expenditure for 15 different areas of state highway in the Transit New Zealand Wanganui Region.



- ***Drainage Maintenance***

Drainage maintenance reported from the TSP includes all work required to allow surface water to flow off the carriageway, over the road shoulder into the surface water channel constructed alongside the road, and to flow along the channel to an outlet or culvert. The channel alongside the road can be constructed by cutting an open channel in the earth (earth surface-water channel) or can be constructed from concrete, asphaltic concrete or chipseal (surfaced surface-water channels). The costs predicted from the TSP and the expenditures with which they are compared in this review do not include drainage maintenance work such as cleaning or replacing culverts or placing subsoil drains, etc.

The difference in drainage maintenance expenditure compared with the RAMM prediction is primarily related to the difference in the standards used in the RAMM condition rating survey, compared with the standard used in the Transit New Zealand Wanganui Region to schedule drainage maintenance and improvement work. The condition rating manual defines an adequate earth surface-water channel as one which is 400 mm in depth from the edge of the seal, whereas a lesser depth would seem to be acceptable in terms of the practical requirements on many of the state highways in the Transit New Zealand Wanganui Region. The rating survey identified 27% of the total length of earth surface-water channel as being inadequate and this has resulted in the predicted high maintenance costs for drainage maintenance.

- ***Seal Widening***

No attempt has been made to analyse the predicted need or the costs predicted by the TSP for seal widening. The reason for this is that any attempt by the TSP to predict a suitable width for seal widening will be inaccurate because the TSP cannot model site conditions. At best the TSP outputs for this type of work should simply be considered an indication that seal widening may be required.

7.4 Project Level Results from TSP

7.4.1 Field Assessment

A sample of the road network was inspected with the Roading Manager from the Transit New Zealand Wanganui Regional Office. The purpose of this exercise was to obtain an assessment of the road maintenance needs of a typical section of the highway network and to compare this assessment with the results from the TSP used in RAMM. A requirement of this project was that the assessment was to be made by local Transit New Zealand regional staff and was to take into account any local knowledge of pavement behaviour.

7.4.2 Selection of Samples

The sections of state highway selected for the field assessment were as follows:

- SH1N from Reference Station 728 to Route Position 801/14.86
- SH4 from Reference Station 140 to Route Position 158/17.12
- SH49 from Reference Station 0 to Route Position 29/6.76

To assist with the field assessment, reports from the RAMM system were generated to provide the following data for the road network:

- Road Surface treatment data
- Road Condition Rating data
- Road Roughness data
- Treatment Selection results for each Rating Section

7.4.3 Suitability of Sample

The TSP outputs for the sample of state highways selected for the field assessment were compared with the TSP outputs for the total Transit New Zealand Wanganui Regional state highway network. The results are shown in Table 7.5 and Figure 7.5. This comparison ensured that the sample sections of state highway selected were typical of the full network under study, in that the sections had similar proportions of the total length reported from the TSP for each major maintenance type.

7.4.4 Comparison of Project Level Assessment with TSP Results

The field assessment found the road condition rating report had accurately reflected the faults found on the carriageway within the inspection length and along the length of the surface-water channels. The base information for the TSP was therefore deemed to be of good quality.

The field assessment of maintenance needs and those reported from the TSP for the sample of state highways are summarised and compared in Appendix 1. This comparison shows that, at the project level, there is often a difference in the maintenance type, quantity and priority assessed by the Roading Manager when compared with TSP outputs. However, the method of sampling used for the road rating (10% of carriageway length) caused the TSP to report very few sites which required a reseal or SCT. The quantity scheduled from the field assessment for a reseal or SCT by the Roading Manager which was not reported from the TSP for field validation, was only 3.82 km or 2.5% of the road length inspected.

The over-statement of maintenance need on some sites was balanced by the under-statement of maintenance need on other sites. In general some type of pavement maintenance was almost always needed on all sites reported by the TSP.

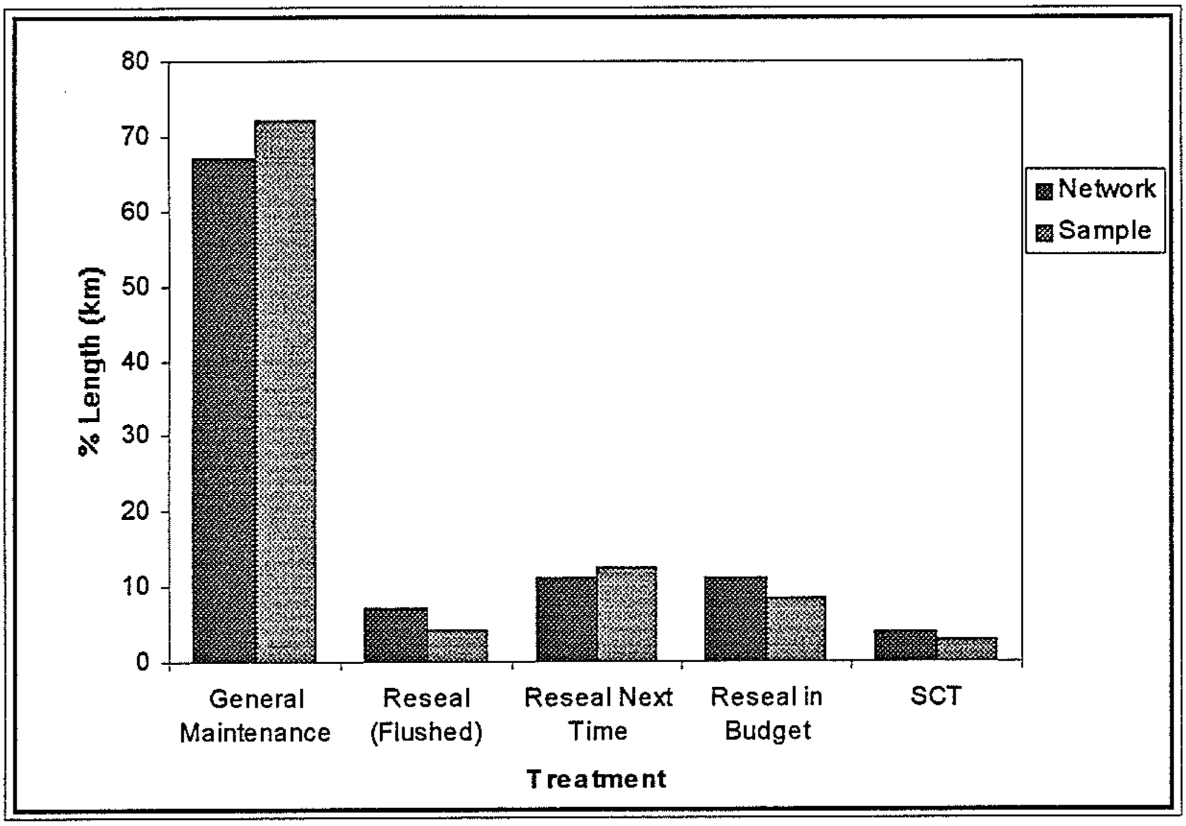
7.4.5 Comparison of Aggregated Project Level Results

When the aggregation of the project level results was considered purely on a technical basis (i.e. unrestrained budget), the field assessment gave a total quantity of maintenance similar to the TSP. However, once budget restraint was applied by the Roading Manager, the programming or timing of the work was quite different with regard to the surface treatment requirements. This result was not found to be the same when the comparison was made at the network level and demonstrated how project level assessments could vary quite markedly between those produced by the TSP and those of the Roading Manager within different sections of a road network and yet still give a similar result at the network level. The comparison of results is shown in Table 7.6 and Figure 7.6.

Table 7.5 TSP outputs for the selected sample compared with the TSP outputs for the state highway network for the Transit New Zealand Wanganui Region.

Treatment	**Network (cut-off B/C ratio = 4.0)**		**Sample (cut-off B/C ratio = 4.0)**	
	Length (km)	%	Length (km)	%
General Maintenance	383.21	68.3	110.62	71.2
Reseal (Flushed)	38.83	6.9	8.04	5.2
Reseal Next Time	63.76	11.4	18.85	12.1
Reseal in Budget	60.30	10.7	13.49	8.7
Shape Correction	15.21	2.7	4.44	2.8
Total	561.31	100.0	155.44	100.0

Figure 7.5 TSP outputs for the selected sample compared with the TSP outputs for the state highway network for the Transit New Zealand Wanganui Region.



7.4.6 Comparison of General Maintenance Results

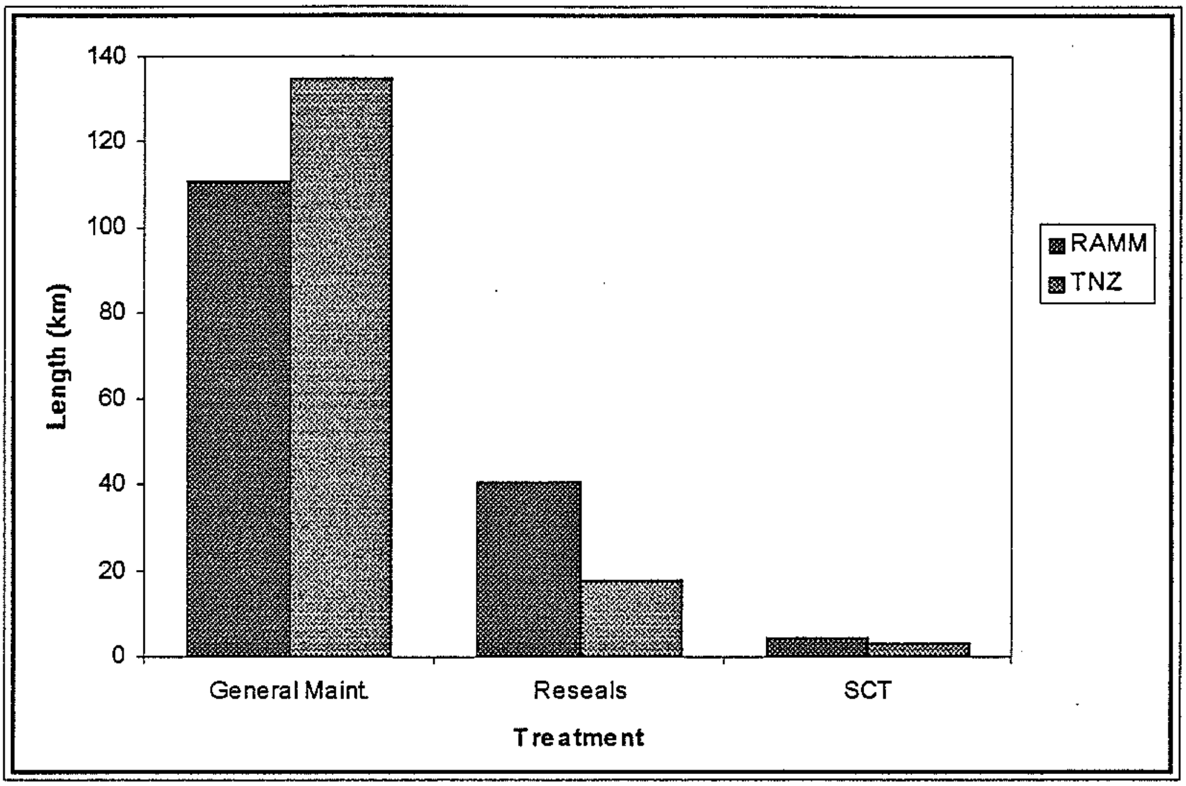
During the inspection of each rating section it was observed that the routine maintenance which had been carried out within the previous few months had corrected the rating faults recorded during the October 1992 road condition rating survey. The quantity of each maintenance repair correlated well with the quantity of each fault found during the rating survey (e.g. the quantity of alligator cracking closely matched the quantity of skin patching for crack sealing, and the quantity of shoving closely matched the quantity of digout patching observed).

Table 7.6 TSP outputs compared with results of the field assessment carried out by Transit New Zealand Wanganui Region Roading Manager for the state highway sample.

RAMM (B/C 4.0)		**TNZ assessment**	
Treatment	**Length**	**Treatment**	**Length**
General Maint.	110.62	Routine Maint.	91.38
		Special Maint.	13.03
		Routine Maint. (Reseal 1994/96)	30.39
Total Maintenance	110.62	Total Maintenance	134.80
Reseal in Budget (1992/93)	13.49	1992/93 Reseal	6.20
Reseal Next Time (1993/94)	18.85	1993/94 Reseal	6.99
Reseal (Flushed)	8.04	1993/94 Locking Coat *	4.55
Reseal	40.38	Reseal	17.74
Strengthen (1992/93)	1.50	SCT (1992/93)	1.80
Smoothing (1992/93)	2.94	SCT (1993/94)	1.10
Total SCT	4.44	Total SCT	2.90
Total Inspected	**155.44**	**Total Inspected**	**155.44**

* These Locking Coat seals were identified as necessary because premature excessive chip loss had occurred from the 1990/91 and 1991/92 reseals.

Figure 7.6 TSP outputs compared with results of the field assessment carried out by Transit New Zealand Wanganui Region Roading Manager for the state highway sample.



The RAMM system is only able to use road condition information at a certain point in time to calculate the routine maintenance need. Over the period of a year the quantity of routine general maintenance required on the carriageway would be greater than that reported from the RAMM system, because gradual deterioration continues after the road condition rating survey.

7.4.7 Comparison of Surface Treatment Results

7.4.7.1 General

The five sites reported by field assessment for a surface treatment but not reported by the RAMM TSP are listed in Table 7.7 (p.46), and those reported by the RAMM TSP for a surface treatment but not by the field assessment are listed in Table 7.8 (p.46).

From the 85 sites listed for a surface treatment by RAMM, 27 sites (Table 7.8) were not scheduled in the field assessment for an area treatment. However, from these 27 sites, 24 sites did require a specific carriageway maintenance such as crack sealing, digouts or partial surface treatment with a locking coat to halt chip loss.

7.4.7.2 Discussion

Comment on the reason why the Roading Manager chose a particular treatment is given in Table 7.8. This table also demonstrates how important it is to report these sections as most of them required maintenance and many required monitoring because of their poor performance at time of assessment.

- ***Trigger Values***

The trigger values for selecting a surface treatment are set very low (see Table 5.1) in respect to all the carriageway faults, with the exception of scabbing and flushing. Yet the Roading Manager disagreed with very of the few rating sections reported for a surface treatment triggered by faults other than scabbing. Sections excluded for a surface treatment during the field assessment had been triggered by scabbing that was occurring prematurely. The Roading Manager preferred to try and hold these relatively recent reseals by treatment with repair techniques rather than with another seal coat. This decision appeared to be related primarily to budget restraint.

Four of the five sites not reported by RAMM, but which were selected in the field assessment for a surface treatment, had a void fill seal that was four to six years old. The standard practice in the Wanganui Region is to place a reseal where a texturising/void fill seal exceeds four to six years of age because a very thin binder film is used with void fill seals. The fifth section not reported by RAMM was a 1983 grade 3 reseal which was starting to show its age but did not have enough faults for the RAMM TSP system to trigger the selection of a surface treatment. The Roading Manager considered that it should be resealed because it could undergo rapid deterioration if it was left to get too old.

Table 7.7 Sites reported by the field assessment for a surface treatment but not reported by the RAMM TSP.

Reference Station	Start (km)	End (km)	Field Assessment Treatment	Comments
49/29	0.00	1.20	Reseal 92/93	1988 Grade 5 Texturising seal
01N/780	8.80	9.80	Reseal 92/93	1987 Grade 5 Void Fill
01N/780	7.44	7.84	Reseal 93/94	1989 Grade 5 Void Fill
4/140	0.00	0.32	Reseal 93/94	1988 Grade 5 Texturising seal
01N/780	14.60	15.50	Reseal 92/93	1983 Grade 3 Reseal

Table 7.8 Sites reported by RAMM TSP for a surface treatment but not reported by the field assessment.

RAMM TSP (Cut-off B/C ratio = 4.0)				TNZ Field Assessment	
Reference Station	Start (km)	End (km)	Treatment Selected	Treatment Selected	Comments
01N/756	9.39	9.89	Reseal (Flushed)	Do Nothing	Inspection length not typical of rating length
01N/780	1.16	2.18	Reseal (Flushed)	Do Nothing	Flushing on seal joins
01N/768	3.38	3.88	Reseal Next Time	Do Nothing	Inspection length not typical of rating length
004/148	0.00	0.13	Reseal in Budget	Crack Seal	(Observe) 1988 reseal starting to crack
004/148	0.56	0.69	Reseal Next Time	Crack Seal	(Observe) 1988 reseal starting to crack
049/0	3.00	3.50	Reseal in Budget	Crack Seal	(Observe) Reseal 3-4 years if more cracks
01N/756	11.00	11.79	Reseal Next Time	Heavy Maint.	Localised shoving in inspection
01N/728	0.32	0.82	Reseal in Budget	Partial Texturise	Premature scabbing 90/91 reseal
01N/728	0.82	1.32	Reseal Next Time	Partial Texturise	Premature scabbing 91/92 reseal
01N/780	18.51	19.01	Reseal Next Time	Partial Texturise	Premature scab sh. & centre 91/92 reseal
049/29	1.64	2.14	Reseal Next Time	Partial Texturise	Premature scabbing 1991/92 reseal
049/29	2.64	3.10	Reseal Next Time	Partial Texturise	Lock coat 2m wide on centre full length
01N/728 Off Ramp	0.00	0.11	Reseal Next Time	Repair Scabbing	–
01N/741	0.00	0.50	Reseal in Budget	Repair Scabbing	Inspection length not typical of rating length
01N/756	7.58	8.08	Reseal Next Time	Repair Scabbing	Localised scabbing in inspection length
01N/780	5.04	5.54	Reseal Next Time	Repair Scabbing	Premature scabbing on centreline from
01N/780	6.04	6.54	Reseal Next Time	Repair Scabbing	1991/92 reseal
01N/801	4.45	4.95	Reseal Next Time	Repair Scabbing	Premature scabbing on shoulder and centreline from 1990/91 reseal
01N/801	8.79	9.29	Reseal Next Time	Repair Scabbing	Scabbing on shoulder widening
01N/801	9.79	10.76	Reseal Next Time	Repair Scabbing	Scabbing on shoulder widening
004/148	9.30	9.80	Reseal Next Time	Repair Scabbing	{Premature scabbing on 1990/91 and
004/158	15.62	16.12	Reseal in Budget	Repair Scabbing	{1991/92 reseals on sections of SH4
004/158	9.65	10.15	Reseal Next Time	Repair Scabbing	{R/S 004/148 and R/S 004/158: if chip
004/158	11.15	11.65	Reseal in Budget	Repair Scabbing	{loss continues over winter consider a full
004/158	11.65	12.15	Reseal Next Time	Repair Scabbing	{locking coat
004/158	15.12	15.62	Reseal Next Time	Repair Scabbing	–
049/29	5.10	5.60	Reseal Next Time	Repair Scabbing	Premature scabbing 1991/92 reseal

- ***Section Lengths***

Major road maintenance is carried out over lengths (treatment lengths), which usually coincide with previous surface treatment or SCT lengths. The RAMM TSP carries out an analysis for each rating section (approximately 500 m length) and selects the most appropriate treatment for that section of road (see Section 4.2 in this report). The rating sections seldom coincide with treatment lengths and there are usually several rating sections in a single treatment length. A rating section may also span a very short treatment length.

The Roading Manager has to inspect the rating sections reported for a major maintenance treatment and assess the priority and treatment type for the treatment length. In regard to surface treatments in particular, the assessed treatment length may incorporate rating sections not reported for a major maintenance treatment, into a treatment length. This situation often leads to longer lengths being scheduled for a surface treatment than the aggregate of the rating sections reported as requiring a surface treatment for reference station length of highway.

The extra length of surface treatment scheduled during the field assessment usually compensates for the rating sections reported from the RAMM TSP as requiring a surface treatment, but which were not included as sites needing a surface treatment during the field assessment. Therefore the total length scheduled for a surface treatment by the Roading Manager for the road or highway network, usually closely matches the total length of surface treatment reported from RAMM.

Greater accuracy in determining treatment lengths could be obtained from the RAMM system if faults were monitored on a continuous basis or sampled more frequently. The sectioning of the road could then be based on the condition state into which the road falls, rather than on standard rating lengths. This type of sectioning (dynamic segmentation) would yield more accurate project level results from the TSP.

- ***Priorities***

The priorities given to the work by the Transit New Zealand Roading Manager resulted in a four year programme of surface treatments. The TSP results indicated that the quantity of work scheduled by the Roading Manager should be programmed over a two year period. This difference in programming of surface treatment work would normally indicate, for the sample of highway inspected, that the trigger levels set in the RAMM system give higher priorities than those given by the traditional field assessment. However, the desired regime for surface treatments on state highways is that, on average, 10% of the highways receive a surface treatment each year. If this quantity of surface treatment (plus the locking coat surface treatments for roads with premature chip loss) could have been scheduled for the sample of highway inspected, an approximate match would have been made with the RAMM-predicted programme.

A possible reason that 10% of the highways were not scheduled for a surface treatment in the sample length was that the Roading Manager had viewed the sample in perspective with the total road network. His decision was that other sections of the network had greater need for surface treatments than did the sample section at the time of the field assessment. However, at many sites visited in the sample section, he would have preferred to carry out the work sooner than scheduled if funding had allowed.

- ***Deferral of Priorities***

In general, the sections of road chosen for deferral of maintenance were those which did not have structural faults but which suffered from premature chip loss or flushing. This situation may be adequate to protect the structural integrity of the pavements but may compromise safety because the scabbed of flushed surface could not provide adequate macrotexture and skid resistance. It is now possible to provide high quality surface texture and skid resistance data, from the high speed data capture and SCRIM surveys. This information should be stored in the RAMM system and then can be used to trigger a reaction to pavement surfaces which are inadequate from a safety viewpoint.

- ***Second Coat Seals***

Second coat seals are dealt with outside the RAMM system and the timing of the second coat is usually a set period of time (normally 1 to 3 years), with small adjustments determined by the success of the SCT and the traffic loading sustained by the pavement. The first coat seal has a thin bitumen film thickness and any deterioration of the first coat is likely to be rapid. Therefore the second coat is better applied before the first coat begins to deteriorate. This same principle is applied by Transit New Zealand Wanganui Regional Office to void fill seals.

7.4.8 Comparison of SCT Results

7.4.8.1 General

A summary of the results for SCT is shown in Tables 7.9 and 7.10 (p.49). From the ten sites reported for an SCT by RAMM, five were selected for an SCT during the field assessment. Of the remaining five sites, two were selected for a surface treatment and three required specific general maintenance. Three other sites were identified by the Roading Manager to require an SCT, all of which had been reported by the RAMM system as requiring a surface treatment. From these three sites, two had warnings indicated in the RAMM report for a partial SCT.

7.4.8.2 Discussion

In general, SCT was chosen during the field assessment where pavement failure had occurred and maintenance costs had been (or were expected to be) excessive. In some cases an associated higher roughness value was also recorded. No sites were chosen for smoothing only to overcome excessive roughness. The mode of pavement failure was primarily shallow shear. Failure from rutting was not predominant.

Table 7.9 Sites with agreement between RAMM and the field assessment for SCT.

Site			**RAMM-predicted (B/C ratio = 4.0)**			**TNZ Assessment**	
Ref. Station	Start (km)	End (km)	Treatment	Prior.	U/R	Field Assessment	Comments
01N/741	5.93	6.43	Smoothing	4.4	R	SCT (1992/93)	Strengthening
01N/741	7.43	7.78	Smoothing	5.2	R	SCT (1992/93)	Strengthening
01N/741	10.73	11.23	Smoothing	4.7	R	Smooth 93/94	Plus widening
049/29	3.10	3.60	Smoothing	4.6	R	SCT with imp.93/94	
049/29	3.60	4.10	Strengthening	100	R	SCT with imp.93/94	

U/R = Urban/Rural; imp. = improvements

Table 7.10 Sites without agreement between RAMM and the field assessment for SCT.

Site			**RAMM-predicted (B/C ratio = 4.0)**			**TNZ Assessment**	
Ref. Station	Start (km)	End (km)	Treatment	Prior.	U/R	Field Assessment	Comments
01N/741	4.93	5.43	Strengthening	100	R	Reseal 92/93	Heavy maint. - reseal to even texture
01N/741	6.43	6.93	Reseal in Budget	116.9	R	SCT (1992/93)	Strengthening (partial smoothing B/C= 12.7)
01N/756	0.00	0.09	Smoothing	100	U	Maintain	Pavement sound and not too rough; some potholes in 91/92 reseal
01N/756	8.08	8.58	Smoothing	100	R	Heavy Maint.	(Observe) 100m cracked and rutted; possible short SCT
01N/801	2.95	3.95	Reseal Next Time	0	R	Strength 94/95	Excessive heavy maint. past 3 years (partial smoothing B/C = 4.9)
01N/801	14.36	14.86	Reseal Next Time	0	R	SCT 1993/94	–
004/148	8.80	9.30	Strengthening	100	R	Repair scabbing	(Observe) Premature cracking and scabbing in 91/92 reseal
049/11	6.40	6.90	Smoothing	100	R	Reseal 95/96	Short sections of maintenance SCT required
049/29	6.26	6.76	Reseal in Budget	116.9	R	SCT 94/95	Short section SCT required 2-3 years out

U/R = Urban/Rural

Six sites were reported by RAMM to require an SCT with a B/C ratio of 100. The high calculated future maintenance costs for these sites are related to the present surface treatments which have only attained a short life before beginning to crack or show holes. The Roading Manager scheduled only one of these for an SCT and determined that the others only needed heavy maintenance and/or surface treatment. On two sites he agreed that short sections of strengthening would be required which would be undertaken as heavy maintenance (e.g. digout patching). He based his decisions on his knowledge of the historical structural performance of the pavements and the historic maintenance costs. This information was not stored in the RAMM database at the time of the field assessment.

The premature fatigue cracking observed in some of these pavements indicated excessive deflections under present traffic loading and the technical need for a strengthening treatment. However, because of budget constraint, these pavements will not be strengthened for some years but instead are being vigilantly maintained by crack sealing and by digout patching until the pavements become too costly to maintain. This maintenance strategy tends to retard the roughness progression of the pavements, particularly where the patching is of a high quality.

The pavement maintenance strategy observed in the Transit New Zealand Wanganui Region requires vigilance with pavement maintenance if "blow up" situations are to be avoided. Given that general maintenance of the pavement cannot be deferred, the ability to identify when maintenance costs are becoming or will become excessive is needed. It is most cost-effective to carry out an SCT just prior to a pavement undergoing a significant and continuing increase in maintenance costs. However, the model used in RAMM to predict future maintenance costs is inadequate in respect to structurally inadequate pavements.

Improvements could be made to the model if historic maintenance costs, pavement condition data and pavement structural data were included as inputs, and the carriageway was segmented on the basis of surface condition, surface type, traffic load and maintenance costs. This could be followed by more extensive research to achieve further improvement to the maintenance cost model in the TSP, or by including in the TSP calibrated models, such as those developed by the World Bank. Such research or the inclusion of the World Bank models would require the recording of historic maintenance activities and an assessment of pavement structural performance in the RAMM system.

Another approach could be to estimate historic maintenance effort by measuring large patches. At present the RAMM condition rating does not require this to be done because of the difficulty which arises when an attempt is made to estimate the type of pavement failure which caused the patch to be placed.

In some sections (particularly urban), traffic counts are high and the sections require only a moderate reduction in roughness before the RAMM TSP triggers the selection of an SCT. This scenario has been discussed in Section 7.3.2.1 in this report.

7.4.9 Comparison of Surface-Water Channel Results

The field assessment indicated that the road condition rating surveys had correctly identified surface-water channel deficiencies as described in the road condition rating manual. The RAMM-estimated cost to correct the surface-water channel deficiencies for each rating section was greater than what was generally being allocated for this type of work. In many cases this was related to the standard depth of 400 mm set in the rating as being required for an "adequate" surface-water channel. Often site restrictions or subgrade conditions did not require this standard, and examples of this were evident on SH4 where 30% of the surface-water channels are rated as inadequate but, because of the topography, would probably never be altered.

8. TREATMENT SELECTION PROCESS FOR LOCAL AUTHORITY ROADS

8.1 Local Authority Road Network Studied

The road network studied was that comprised of all the local authority roads in the Rotorua District Council (RDC) area. No state highways were included. The road network consisted of 614 km of road which was managed by the RDC (Figure 4.2).

8.2 Basis of Treatment Selection Analysis

8.2.1 General

The road condition information used was obtained from the condition rating survey carried out during May 1992 and from the road roughness survey carried out during June 1992. The length of road analysed was 614 km.

8.2.2 Target Roughness Values

The target roughness value used for determining road roughness after an SCT was 110 NAASRA counts/km for urban roads and 73 NAASRA counts/km for rural roads. These values were determined from the results of the roughness survey on the sections of first and second coat seals that had been placed during the preceding two years.

In an urban environment the higher road roughness after SCT often results from poor road surface shape because of the presence of service covers, and a multiplicity of intersections. Roughness of roads in urban areas are also subject to a greater variation in vehicle speed related to braking and acceleration. All these factors combine to give higher average roughness values for roads in an urban environment compared with those for rural roads.

8.2.3 Unit Costs

The unit costs used in the TSP were supplied with the RDC RAMM database and were dated 30 March 1992. The costs reported from the TSP were updated to the 30 September 1992 with the use of the construction cost index (CCI).

8.2.4 B/C Ratio Values Used to Select an SCT

The cut-off B/C ratio for selecting an SCT was set at 2.0 for the initial analysis and subsequent analyses was undertaken at B/C ratios of 4.0 and 8.0. The B/C ratio of 2.0 was chosen for the initial analysis because it was the level at which the Local Authority Roading Manager considered that a site inspection of the section of road reported was warranted. The B/C ratio of 8.0 was the level at which the length of road reported for SCT by the RAMM system corresponded approximately with the length of SCT work programmed for the 1992/93 season.

8.2.5 Data Integrity

A database audit was carried out using the standard RAMM audit reports. The audit reports indicated that the database was sound and well maintained.

8.3 Network Level Results from TSP

8.3.1 Effect of Cut-off B/C Ratio for Reporting an SCT

A summary of the results from the TSP with cut-off B/C Ratios for SCT of 2.0, 4.0 and 8.0 is presented in Tables 8.1, 8.2 and 8.3. The results presented in these tables demonstrate how the increase from 2.0 to 8.0 in the cut-off B/C ratio as a decision factor for SCT reduces the quantity of SCT (Smoothing) from 11.75 km to 2.53 km.

The quantity of Reseal in Budget has increased from 55.93 km to 59.46 km and General Maintenance has increased from 493.81 km to 497.92 km. This indicates that approximately 55% of the pavements not reported for an SCT at the higher cut-off B/C ratio still require a surface treatment if they do not receive an SCT.

The quantity of SCT (Strengthening) is zero which indicates the TSP has not calculated a high present value of future maintenance costs for any rating section analysed.

The total treatment cost reported in Tables 8.1 and 8.3 decreased approximately 32% with the increase in the cut-off B/C ratio from 2.0 to 8.0. This demonstrates the relatively high cost of SCT compared with other treatment costs.

8.3.2 RAMM Results v Rotorua District Council Land Transport Programme at Network Level

8.3.2.1 Comparison of maintenance treatment lengths

A comparison of the results from the TSP (Cut-off B/C ratio 8.0 for SCT) against those for the RDC Land Transport Programme is shown in Table 8.4 and Figure 8.1.

Second coat seals are dealt with outside the RAMM system TSP. The quantity of second coat seals programmed should approximate the annual length of first coat seal placed. An analysis of the surface treatment records in RAMM showed approximately 10 km of first coat seal had been placed annually for the 1991/92 and 1990/91 seasons. The quantity of second coat seal programmed for the 1992/93 season was 10.8 km which correlated well with the quantity of first coat seals placed each year.

The length of reseal placed each year was approximately 25% less than that predicted by the RAMM system. This length was determined from field inspections carried out by the Roading Manager and took into account pavement condition, seal age and surface texture. The large quantity of SCT and second coat seals placed in 1991/92 was to eliminate a backlog of work which had accrued before that time.

Table 8.1 Local authority road network level results using a cut-off B/C ratio of 2.0 for selecting SCT.

Target Roughness for Urban = 110, Rural = 73 **Construction Cost Index Date = 30 Sept 1992**								
Area Treatment	Length (km)	% Road N/work	Treatment Cost $	Treatment Ave. $/km	Maint. Cost $	Maint. Ave.$/km	Drainage Cost $	Drainage Ave.$/km
Gen. Maint.	493.81	80.4	$0	$0	$241,191	$490	$709,967	$1,440
Reseal (Flushed)	0.50	0.1	$0	$0	$0	$0	$72	$140
Reseal Next Time	52.18	8.5	$0	$0	$194,641	$3,730	$77,550	$1,490
Reseal in Budget	55.93	9.1	$1,231,796	$22,030	$137,391	$2,460	$757,169	$13,540
SCT - Smoothing	11.75	1.9	$1,045,870	$89,010	$0	$0	$111,205	$946
SCT - Strengthen	0.00	0.0	$0	$0	$0	$0	$0	$0
Total	614.17	100.0	$2,277,666		$573,223	$933	$1,655,963	$2,696

Table 8.2 Local authority road network level results using a cut-off B/C ratio of 4.0 for selecting SCT.

Target Roughness for Urban = 110, Rural = 73 **Construction Cost Index Date = 30 Sept 1992**								
Area Treatment	Length (km)	% Road N/work	Treatment Cost $	Treatment Ave.$/km	Maint. Cost $	Maint. Ave.$/km	Drainage Cost $	Drainage Ave.$/km
Gen. Maint.	497.92	81.1	$0	$0	$250,212	$500	$735,096	$1,480
Reseal (Flushed)	0.50	0.1	$0	$0	$0	$0	$75	$150
Reseal Next Time	53.38	8.7	$0	$0	$212,819	$3,990	$81,031	$1,520
Reseal in Budget	58.47	9.5	$1,341,325	$22,940	$158,512	$2,710	$813,236	$13,910
SCT - Smoothing	3.90	0.6	$349,547	$89,700	$0	$0	$28,188	$7,230
SCT - Strengthen	0.00	0.0	$0	$0	$0	$0	$0	$0
Total	614.17	100.0	$1,690,872		$621,543	$1,012	$1,657,62 6	$2,699

Table 8.3 Local authority road network level results using a cut-off B/C ratio of 8.0 for selecting SCT.

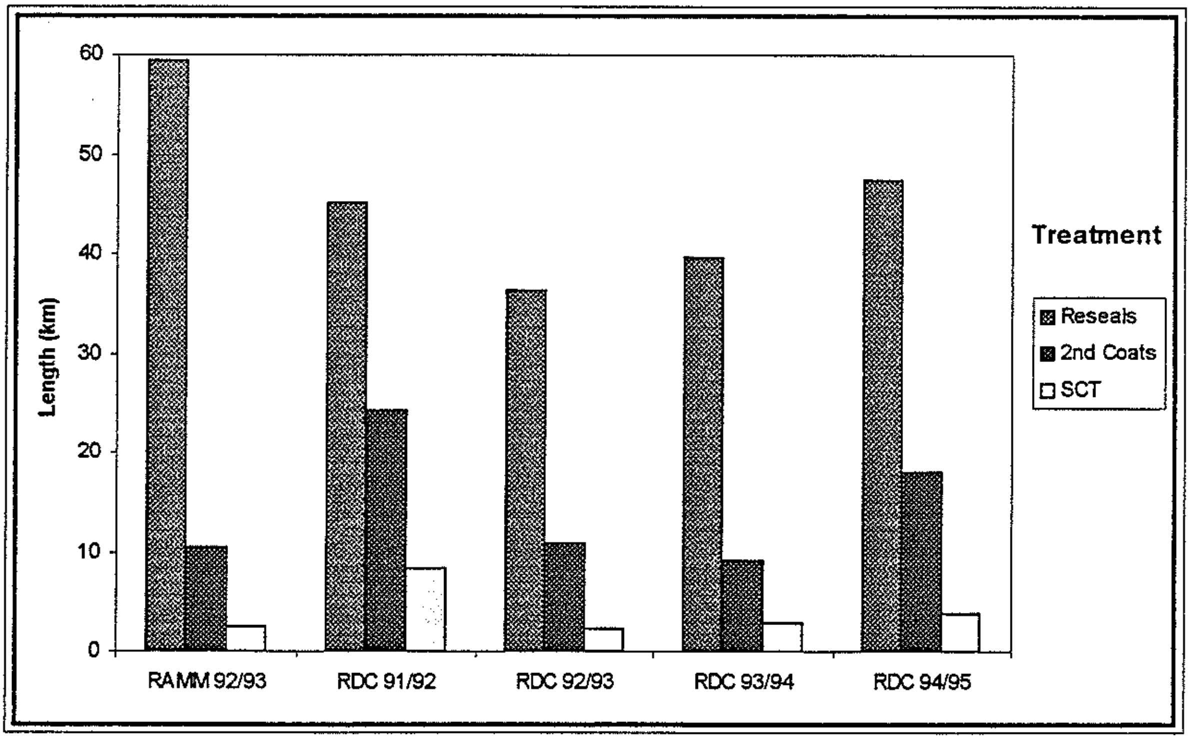
Target Roughness for Urban = 110, Rural = 73 **Construction Cost Index Date = 30 Sept 1992**								
Area Treatment	Length (km)	% Road N/work	Treatment Cost $	Treatment Ave.$/km	Maint. Cost $	Maint. Ave.$/km	Drainage Cost $	Drainage Ave.$/km
Gen. Maint.	497.92	81.1	$0	$0	$250,212	$500	$735,096	$1,480
Reseal (Flushed)	0.50	0.1	$0	$0	$0	$0	$75	$150
Reseal Next Time	53.76	8.7	$0	$0	$214,209	$3,980	$81,235	$1.510
Reseal in Budget	59.46	9.7	$1,369,605	$23,030	$169,343	$2,850	$830,577	$13,970
SCT - Smoothing	2.53	0.4	$175,856	$69,480	$0	$0	$3,077	$1,220
SCT - Strengthen	0.00	0	$0	$0	$0	$0	$0	$0
Total	614.17	100.0	$1,545,461		$633,764	$1,032	$1,650,060	$2,687

N/work = network; Ave. = average; Gen.Maint. = General maintenance

Table 8.4 Comparison of lengths of each maintenance type obtained from the RAMM TSP (cut-off B/C ratio = 8.0) with those from the RDC Land Transport Programme.

RAMM (B/C 8.0) 1992/93 Treatment	**Length** km	**RDC** Treatment	**91/92** km	**92/93** km	**93/94** km	**94/95** km
General Maint.	487.52	Gen. Maint.	536.47	564.54	562.27	544.97
Reseal (Flushed)	0.50					
Reseal Next Time	53.76					
Total Maint.	541.78	Total Maint.	536.47	564.54	562.27	544.97
Reseal in Budget	59.46	Reseal	45.00	36.44	39.70	47.30
Second Coat Seals	10.40	2nd Coat	24.30	10.82	9.20	18.10
Total Reseal	69.86	Total Reseal	69.30	47.26	48.90	65.40
Smoothing	2.53					
Strengthening	0.00	SCT	8.40	2.37	3.00	3.80
Total SCT	2.53	Total SCT	8.40	2.37	3.00	3.80
TOTAL	614.17		614.17	614.17	614.17	614.17

Figure 8.1 Comparison of lengths of each maintenance type obtained from the RAMM TSP (cut-off B/C ratio = 8.0) with those from the RDC Land Transport Programme.



8.3.2.2 Comparison of costs of maintenance

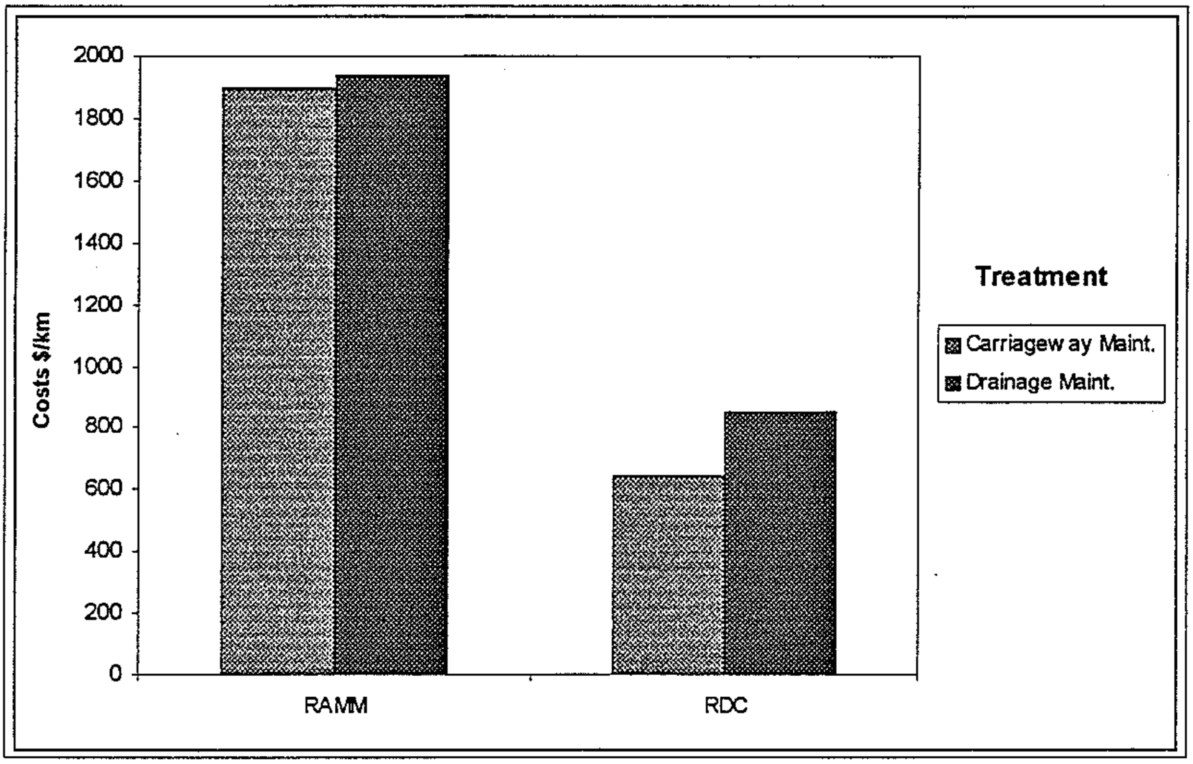
RDC advised that the surface treatment costs/km calculated by the RAMM system were a good indication on average of the costs/km to carry out surface treatment work. It was noted that in recent years contract costs had fluctuated significantly.

In most cases the SCT costs calculated by RAMM were lower than actual expenditure because other improvements were normally carried out with the SCT work at the same time. The expenditure for routine general maintenance work could not be obtained accurately for each category of maintenance but estimates were made from RDC's expenditure records. These estimates are compared with the RAMM-predicted costs in Table 8.5 and Figure 8.2.

Table 8.5 Comparison of RDC's estimated expenditure (1992/93) with RAMM-predicted cost (cut-off B/C ratio = 8.0).

Maintenance Type	RDC expenditure $/km	RAMM (cut-off B/C ratio = 8.0) cost $/km
Carriageway general maintenance	640	1,032
Drainage maintenance	851	2,687

Figure 8.2 Comparison of RDC's estimated expenditure (1992/93) with RAMM-predicted cost (cut-off B/C ratio = 8.0).



For both carriageway and drainage general maintenance the RAMM-predicted costs are two to three times the estimated expenditure. RAMM reports the maintenance required to repair all faults recorded during the road condition rating survey. The difference between the RAMM-reported general maintenance costs and the RDC-estimated expenditure indicates that the routine general maintenance budget in RDC is constrained and all pavement faults detected will not always be repaired.

The difference in drainage maintenance expenditure compared with the RAMM prediction is because of the influence of the pumice subgrades occurring in the RDC. Because pumice soils are very free draining, the depths of surface-water channels are not so important. The RAMM road condition rating survey requires that an adequate earth surface-water channel is 300 mm in depth from the edge of the seal, whereas it would seem that a lesser depth is acceptable in terms of the practical requirements on approximately 50% of the roads that are pumice based in Rotorua District.

8.4 Project Level Results from TSP

8.4.1 Field Assessment

A sample of the road network was inspected with the Roading Manager from the RDC during November 1993. The purpose of this exercise was to obtain an assessment of the road maintenance needs of a typical section of the local authority road network, and to compare this assessment with the results from the TSP. A requirement of this project was that the assessment was to be made by local authority staff and was to take into account any local knowledge of pavement behaviour.

8.4.2 Selection of Samples

The sections of road network selected for the field assessment were as follows:

- Urban: Sub-area 5 of the urban City area - 23.8 km,
- Rural: Ngakuru area - 49.3 km.

To assist with the field assessment, reports from the RAMM system were generated to provide the following data for the road network:

- Road Surface Treatment data,
- Road Condition Rating data,
- Road Roughness data,
- Treatment Selection results for each Rating Section.

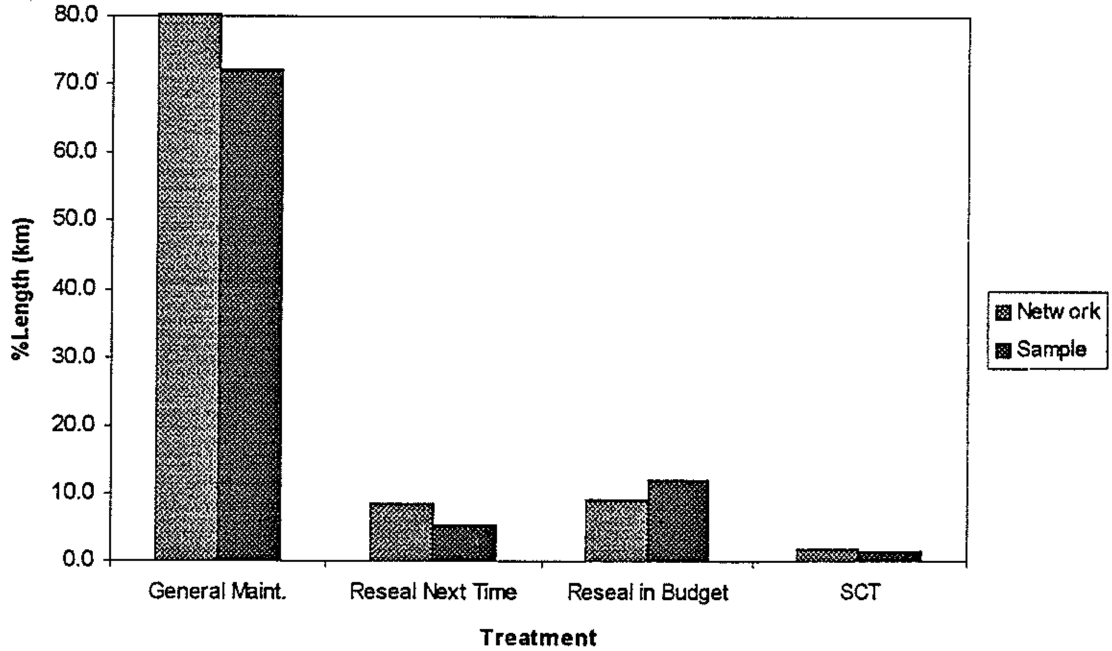
8.4.3 Suitability of Sample

The RAMM outputs for the sample of road network chosen for the field inspection are compared with those for the total local authority road network and are shown in Table 8.6 and Figure 8.3. This comparison demonstrates that the sample of road chosen was typical of the full local authority network in that it had similar proportions of the total length reported from the TSP for each major maintenance type.

Table 8.6 TSP outputs for local authority road sample selected compared with TSP outputs for the RDC road network.

Treatment	Network (cut-off B/C ratio = 2.0)		Sample (cut-off B/C ratio = 2.0)	
	Length (km)	%	Length (km)	%
General Maintenance	493.81	80.4	54.37	75.0
Reseal (Flushed)	0.50	0.1	0	0
Reseal Next Time	52.18	8.5	7.28	10.0
Reseal in Budget	55.93	9.1	9.68	13.4
Shape Correction	11.75	1.9	1.15	1.6
Total	614.17	100.0	72.48	100.0

Figure 8.3 TSP outputs for local authority road sample selected, compared with TSP outputs for the RDC road network.



8.4.4 Comparison of Project Level Assessment with TSP Results

The field assessment found the road condition rating report had accurately reflected the faults found on the carriageway within the inspection length and along the length of the surface-water channels for all but one rating section. The base information for the TSP was therefore deemed to be of good quality.

The field assessment of maintenance needs and those reported from the RAMM system are summarised and compared in Appendix 2. This comparison shows that, at the project level, there is sometimes a difference in the maintenance type, quantity and priority assessed by the Roading Manager when compared with TSP outputs.

However, the method of sampling used for the road rating (10% of carriageway length) caused the TSP to miss selecting only very few sites for a surface treatment or an SCT. The length of road not selected because of the sampling technique used in the road condition rating was 2.15 km or 3% of the length inspected. The total quantity scheduled for a surface treatment or an SCT by the Roading Manager which was not flagged in the RAMM treatment selection outputs for field validation was 9.82 km or 13% of the road length inspected. Most of this length was scheduled for a surface treatment during the field assessment to provide a uniform road surface after trenching work or to waterproof a bitumen-deficient plant mix overlay.

The over-statement of maintenance need on some sites was balanced by the under-statement of maintenance need on other sites. In general some type of pavement maintenance was almost always needed on all sites reported by the TSP.

8.4.5 Comparison of Aggregated Project Level Results

The aggregation of the project level results shows a favourable comparison with the traditional assessment with the exception of the SCT category. The comparison of results is shown in Table 8.7 and Figure 8.4 (p.59).

8.4.6 Comparison of General Maintenance Results

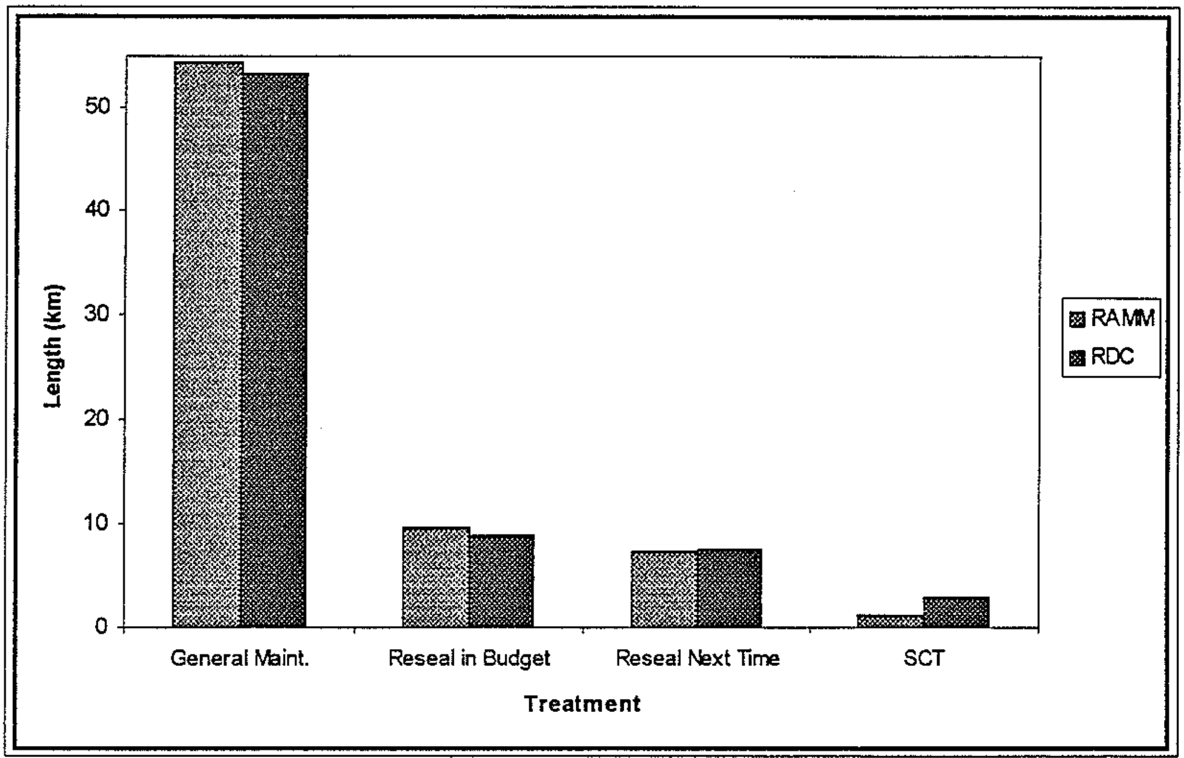
The differences on a site-by-site basis between the RAMM-predicted maintenance projects and those determined during the field assessment are shown in Table 8.8. The Roading Manager scheduled five sites for general maintenance from the 32 sites which had been reported by the RAMM system for a surface treatment. The reason for these differences was mainly because the inspection length was not typical of the rating length. In one section the rating surveyor appeared to have over-stated the quantity of cracking. From these five sites excluded for an area treatment, one site required a heavy maintenance treatment.

When inspecting each rating section, routine maintenance was found to have been carried out to correct the serious pavement faults recorded during the May 1992 road condition rating survey. The quantity of maintenance repairs observed was not at a level that attempted to repair all the minor faults found during the rating survey (e.g. minor alligator cracking, scabbing and edge break). This was in contrast with the state highway assessments where the majority of the faults found during the road condition rating had been repaired. However, the level of maintenance found during the RDC assessments was in keeping with the author's experience in regard to the maintenance of local authority roads carrying relatively low traffic volumes. This observation helps to explain why the RAMM-reported routine general maintenance costs were higher than the carriageway routine general maintenance expenditure, as shown in Table 8.5.

Table 8.7 TSP outputs compared with results of the field assessment carried out by RDC Roading Manager for the sample of local authority roads selected.

RAMM (B/C ratio = 2.0)		**RDC Assessment**	
Treatment	Length (km)	Treatment	Length (km)
General Maint.	54.37	Routine Maint. Special Maint. Routine Maint. (Reseal 95/97)	46.15 0.87 6.29
Total Maintenance	54.37	Total Maintenance	53.31
Reseal in Budget (1992/93) Reseal Next Time (1993/94)	9.68 7.28	1992/93 Reseal 1993/94 Reseal	8.81 7.52
Total Reseal (1992/94)	16.96	Total Reseal (1992/94)	16.33
Smooth (1992/93)	1.15	SCT (1992/93) SCT (1994/95)	0.59 2.25
Total SCT	1.15	Total SCT	2.84
Total	72.48	**Total**	72.48

Figure 8.4 TSP outputs compared with results of the field assessment carried out by the RDC Roading Manager for the sample of selected local authority roads.



8.4.7 Comparison of Surface Treatment Results

Comments on the reason why both the RAMM system and the Roading Manager chose a particular treatment are given in Table 8.8. This table also demonstrates how important it is that all sections reported are inspected in the field by the Roading Manager after the TSP has been used, because most of them required maintenance of some type.

- ***Reasons for Differences between TSP and RDC Field Assessment Outputs***

Twenty six rating section sites identified by the Roading Manager for a surface treatment were also selected by the TSP for a surface treatment. Nineteen sites identified by the Roading Manager for a surface treatment were selected by the TSP for general maintenance. The rating sections were chosen for a surface treatment by the RDC Roading Manager for the following reasons:

- Four sections had extensive trenching carried out in the past two years to place new services, and the Roading Manager was keen to resurface these road sections to improve waterproofing and to provide a more even surface texture.

- Seven sections were scheduled for a surface treatment because they were part of a seal length that required a reseal, and they needed to be re-surfaced to maintain rational lengths of seal.

- Three sections had previously had a smoothing SCT with a plant mix material which was deficient in binder. The seal coat was scheduled to improve waterproofing and prevent premature deterioration of the surface.

- Five sections which had only a few faults were chosen because of the age of the seal. Three of these had a void fill seal over five years old. The Roading Manager considered that these sections should be resealed because they could rapidly deteriorate if they were left to get too old.

- ***Section Lengths***

All treatments are reported by the RAMM system in rating section lengths which have an average value of 500 m for rural roads. In reality, the length requiring a treatment is usually the length of the previous surface treatment or SCT. The Roading Manager has to decide from a field inspection the priority and treatment type for the "treatment length", only part of which may have been reported for a treatment in rating sections. Therefore, the field assessment often resulted in longer lengths of surface treatment being scheduled for each site when compared with the length reported by the TSP.

The total quantities of surface treatment scheduled for the sample of road network considered by both the TSP and the field assessment were in good agreement. The good correlation at the network level was achieved because the extra length of surface treatment scheduled during the field assessment at many sites, usually compensated for the rating sections reported from the RAMM TSP as requiring a surface treatment, but they were not included as sites needing a surface treatment during the field assessment.

- ***Priorities***

The priorities given to surface treatments by the Roading Manager resulted in work being programmed for three years, with most work falling into the first two years. This compared favourably with the two-year predicted programme of work from the TSP.

- ***Second Coat Seals***

Second coat seals are dealt with outside the RAMM TSP and the timing of the second coat is usually a set period of time (normally 1 to 3 years after the first coat), with adjustments determined by the success of the SCT and the traffic loading sustained by the pavement.

Table 8.8 Differences between sites assessed by RAMM and by RDC Field Assessment.

Road Name	**Start (m)**	**End (m)**	**RAMM (cut-off B/C=2)**	**RDC**	**Comments**
CARLTON St	0	400	Gen. Maintenance	Reseal 1992/93	Too little binder in plant mix SCT
CARNOT St	182	433	Gen. Maintenance	Reseal 1993/94	Advanced due to service openings for new housing
CLINKARD Ave	0	779	Reseal Next Time	General Maint.	Alligator cracking from rating not apparent
CORBETT Rd	4000	4500	Reseal Next Time	General Maint.	Localised Maintenance - Inspection not typical
DEVON St	0	560	Smooth/g overlay	Reseal 1992/93	Heavy Maint.+Level (SCT preferred if finance avail.)
DUNCAN St	0	327	Gen. Maintenance	Reseal 1992/93	Too little binder in plant mix SCT
EASON St	0	249	Reseal Next Time	Reseal 1995/96	Old Grade 5 seal with minor cracking & scabbing
GREY St	0	341	Gen. Maintenance	Reseal 1993/94	Advanced due to service openings
GREY St	341	593	Gen. Maintenance	Reseal 1993/95	Advanced due to service openings
HEREWINI St	0	251	Gen. Maintenance	Reseal 1993/94	Minor cracking, kerb & service trench repairs
HOLLAND St	0	341	Gen. Maintenance	Reseal 1993/94	To maintain a rational seal length with adjacent section
HOSSACK Rd	4170	4670	Reseal in Budget	General Maint.	Crack seal - Inspection not typical
KOWHAI St	0	279	Gen. Maintenance	Reseal 1994/95	10 yr old Grade 5 seal with some longitudinal cracks
MCLEAN St	0	287	Gen. Maintenance	Reseal 1992/93	Due to age
RANOLF St	1291	1716	Gen. Maintenance	Reseal 1993/94	Due to age
ROBERTSON St	342	594	Gen. Maintenance	Reseal 1993/95	To maintain a rational seal length with adjacent section
SEDDON St	0	592	Reseal Next Time	Reseal 1996/97	No obvious reason for difference
SUMNER St	0	345	Gen. Maintenance	Reseal 1993/94	To maintain a rational seal length with adjacent section
TILSLEY St	341	572	Gen. Maintenance	Reseal 1993/94	To maintain a rational seal length with adjacent section
TOKO St	0	249	Gen. Maintenance	Reseal 1993/94	Old Grade 5 seal and some cracking
WAIKAUKAU Rd	500	2000	Gen. Maintenance	Reseal 1992/93	To maintain a rational seal length with adjacent section
WAIKITE V. Rd	3000	3870	Reseal Next Time	Heavy Maint.	Digouts + Drainage + Sections of maintenance seal
WAIKITE V. Rd	4500	5870	Gen. Maintenance	SCT	}Shoving, cracking, rutting missed by rating inspection
WAIKITE V. Rd	5870	6370	Reseal in Budget	SCT	}lengths; combination of faults and historic high
WAIKITE V. Rd	6370	6750	Gen. Maintenance	SCT	} maint. costs reason for selection of an SCT by RDC
WHIRINAKI V. Rd	1000	1500	Gen. Maintenance	Reseal 1993/94	To maintain a rational seal length with adjacent section
WHIRINAKI V. Rd	2500	3940	Gen. Maintenance	Reseal 1993/94	To maintain a rational seal length with adjacent section
WHIRINAKI V. Rd	5940	6100	Reseal in Budget	General Maint.	Inspection not typical
WYLIE St	0	402	Gen. Maintenance	Reseal 1992/93	Too little binder in plant mix SCT

8.4.8 Comparison of SCT Results

From the two sites reported for an SCT by the TSP, one was selected for an SCT during the field assessment. The second site was selected for a surface treatment preceded by heavy maintenance and localised levelling. The Roading Manager would have preferred to have carried out an SCT but was unable to do so because of budget constraint.

A section of Waikite Valley Road (Figure 4.2) comprising four rating sections, was identified by the Roading Manager as requiring an SCT. Only one of these rating sections was selected by the TSP for a surface treatment with the other three being reported for general maintenance. From these three sites, two were flagged in the RAMM report for a partial SCT.

The Waikite Valley Road SCT section was chosen during the field assessment because it had pavement failure and historically high maintenance costs. Parts of this section had high roughness values, which gave rise to two of the rating sections being flagged by the TSP for a partial SCT. The road condition rating inspection lengths had missed the most deteriorated sections of the pavement which exhibited shoving, rutting and cracking. The uphill side of the section also had several short sections of maintenance seal placed over the past 10 years, to try and halt the pavement deterioration and surface macrotexture problems. These faults appeared to have been aggravated by the traction forces of the trucks climbing the steep grade. None of this information was available to the TSP and the only indication in the RAMM outputs of the pavement problems encountered was the reseal selection for one rating section and the indications for partial SCT for the other two sections.

The Roading Manager observed that in urban situations with high traffic counts, the TSP reported a greater need for SCT, whereas in the lower trafficked rural areas most sections scheduled by the Roading Manager for an SCT were reported by the TSP as merely needing a surface treatment.

A B/C analysis was carried out on the Waikite Valley Road section scheduled for an SCT using the *Project Evaluation Manual - Simplified Procedures* (Transit New Zealand 1991). This was done to test for consistency between the two systems. The analysis using the *Project Evaluation Manual* was carried out over the full length of 2250 m, whereas the RAMM system split the nominated length into four rating sections. The details regarding the section chosen for the SCT are on the following page.

A spreadsheet was used to carry out the calculations required by the *Project Evaluation Manual* and is shown as Appendix 3. The future periodic maintenance costs were based on an estimate made of the maintenance work requirement at the time of the inspection and the surface treatment life cycles achieved since 1980. The unit costs for the maintenance work were kept consistent with those supplied in the RDC RAMM system.

Details of SCT Section on Waikite Valley Road, Rotorua District

Road Name:	Waikite Valley Road
Start Displacement:	4500 m
End Displacement:	6750 m
AADT:	400 vehicles per day
Pavement Type:	Thin Surfaced Flexible (Chipseal surface)
Pavement Condition:	Sections showed severe alligator cracking with associated shoving and rutting. Significant lengths of the uphill side had flushed surfaces and significant patching from previous heavy maintenance. Some corrugations were apparent on the uphill lane.
Do Minimum:	Digout shoved areas and replace basecourse (approx. 5% of pavement), fill depressions and ruts by localised levelling and reseal (approx. 10% of pavement). As judged from past seal life, future heavy maintenance, similar to observed needs, followed by a reseal was estimated to be required every 6 years for a grade 3 chipseal, with an intermediate texturising seal of 2 years duration.
SCT Option:	Rip and remake pavement and add a significant depth of make-up material (average 100 mm) to strengthen the pavement. The cost of this option was estimated at $15.00/m^2$ or $108,000/km, which included a first coat seal. Future maintenance costs were based on a second coat grade 3 seal being placed at 2 years, and a surface treatment cycle time of 10 years for a grade 3 chipseal, and 3 years for a grade 5 texturising chipseal.

Surface History:	4500m - 5600m	1980	First Coat Seal Grade 4
		1981	Second Coat Seal Grade 3
		1987	Reseal Grade 4
	5600m - 6200m	1989	Reseal Grade 4
	6200m - 6800m	1988	Reseal Grade 4

Present Roughness:	4870m - 5370m	132	average NAASRA counts/km
	5370m - 5870m	89	average NAASRA counts/km
	5870m - 6370m	110	average NAASRA counts/km
	6370m - 6800m	71	average NAASRA counts/km
Overall	4870m - 6800m	102	average NAASRA counts/km

Roughness after SCT:	73 NAASRA counts/km
Traffic Mix:	Rural Other
Date Inspected:	03 November 1993
Base Date:	01 July 1996
Time Zero:	01 July 1996

The TSP allows the user to interact with the program and replace intermediate values used in the calculation of the B/C ratio. These intermediate values include capital and maintenance costs of the treatment options and the present value of future maintenance for each option. The present and future maintenance costs/km were calculated using the procedure recommended in the *Project Evaluation Manual.* These values were used to update the intermediate costs in the TSP for all four rating sections within the section of Waikite Valley Road nominated for an SCT. The resulting B/C ratios are shown in Table 8.9.

Table 8.9 Comparison of B/C ratios obtained from RAMM with those from the *Project Evaluation Manual* (PEM).

Start Displ. (m)	**End Displ. (m)**	**RAMM B/C Ratio (Default values)**	**RAMM B/C Ratio (Site Values)**	**PEM B/C Ratio**
4500	6750	N.A.	N.A.	7.1
4870	5370	0.8	154.8	N.A.
5370	5870	0.2	5.8	N.A.
5870	6370	0.8	22.8	N.A.
6370	6800	0.0	7.2	N.A.

Displ. = displacement; N.A. = not applicable

8.4.9 Comparison of Drainage Results

The estimated cost of the work reported for each rating section was greater than the 1993/94 allocation for this work. In many cases this was related to the standard depth of 300 mm, set in the rating, being required for an "adequate" surface-water channel, whereas areas with a free draining pumice subgrade did not require this standard. In general, extensive drainage maintenance was carried out only before a surface treatment. Between surface treatments, surface-water channels were maintained by simply freeing any major blockages.

9. CONCLUSIONS

9.1 Network Level Outputs

9.1.1 Surface Treatments

For the state highways that have been reviewed, the total quantity of surface treatments reported by the TSP at the network level was similar to the quantities scheduled in the Land Transport Programme.

For the local authority roads that have been reviewed, the network level outputs for surface treatments from the TSP are approximately 25% less than the quantity scheduled in the RDC 1991/92 Land Transport Programme. This discrepancy resulted from the difference in the timing of the surface treatment recommended by the RDC Roading Manager compared with the TSP. The RDC Roading Manager recommended a surface treatment be carried out one year later than the TSP for many of the sections considered in the field assessment.

9.1.2 Shape Correction Treatments

Network level outputs for SCT could be made to correlate well with the Land Transport Programme for both the State Highway and Local Authority sectors by simply raising or lowering the cut-off B/C ratio value until the length of SCT reported matches the scheduled programme length. In both sectors a cut-off B/C ratio of 8.0 to 10.0 gave a similar length of SCT to the length scheduled in the Land Transport Programme. However, much of the length reported by the TSP was located in the urban areas and was driven by high traffic volumes which generate high user benefits for roads which, although riding somewhat rough, were not incurring high maintenance costs. The need for SCT work on the low trafficked highways and roads was, in many cases, not reported because the TSP cannot calculate future maintenance costs in the correct order of magnitude for pavements which are weak and require continued heavy maintenance.

The B/C ratio calculated by the TSP for the sections of road and highway selected for an SCT did not correlate well with the Land Transport Programme. This poor correlation is related partly to the policy of allowing improvements to be carried out during an SCT. Improvements such as seal widening, when considered by themselves as a project, often have a low B/C ratio. When the improvements are incorporated in an SCT project they have the effect of increasing the capital cost of the project without providing many benefits, and therefore the B/C ratio is lowered, thus making a difference with the RAMM output.

Short sections that could possibly qualify for an SCT are only identified as a warning where the maximum roughness value in a rating section yields a B/C ratio above the cut-off value. The warning is displayed on TSP outputs for sections selected for a surface treatment or general maintenance, and these short sections of potential SCT are not reported as part of the network level outputs from the TSP. This reduces the accuracy of the network level quantity of SCT reported by the TSP.

The network level outputs from the TSP depend heavily on the ability of the RAMM system to carry out an accurate analysis at the project level. This is not possible at present and hence the lack of correlation between the RAMM system and the traditional field assessment is primarily related to the simplicity of some of the inputs for the selection of an SCT by the TSP. Improvements to inputs need to be addressed urgently, because new tools such as the High Speed Data Capture Vehicle and the SCRIM machine are now available.

Greater accuracy in detecting faults and determining treatment lengths could be obtained from the TSP if faults were monitored on a continuous basis or sampled more frequently. The sectioning of the road should be based on the condition state into which the road falls, rather than on standard rating lengths. This resulting sectioning of highways and roads (i.e. dynamic segmentation) would yield more accurate project level results from the TSP.

9.1.3 Routine Pavement Maintenance Cost

The ability of the RAMM system to predict the annual required budget for "on carriageway" pavement maintenance is restricted because the road condition rating provides only a "snapshot" of the pavement condition at a certain point in time. If accurate maintenance costs were to be stored in the RAMM system it should be possible, in the future, to research this data and determine the relationship between the RAMM TSP prediction of routine general maintenance and the actual cost.

The TSP assumes that all carriageway faults detected during the road condition rating survey will be repaired by routine general maintenance within the following financial year. This assumption was shown to be at variance with maintenance practice in both the State Highway and Local Authority sectors where the TSP estimated the need for routine general maintenance to be either too high or too low depending on the "on carriageway" routine maintenance regime required for the traffic volumes and subsoil conditions.

9.1.4 Drainage Maintenance Cost

Drainage maintenance requirements differed throughout the State Highway and Local Authority sectors, especially in the rural environment. At present the system requires that all earth surface-water channels which have a depth less than 400 mm on state highways, and less than 300 mm on local authority roads, to be recorded during the road condition survey. The recorded surface-water channels are reported for drainage maintenance. Reliance is placed on inspections of all reported sites to determine where it is necessary to carry out maintenance work. This procedure makes the TSP less able to accurately predict the drainage maintenance needed at the network level. If the present system of rating earth surface-water channels is to remain, the TSP may never be able to accurately forecast the drainage maintenance requirement at the network level.

The considerable effort required to collect the rating data for the surface-water channels must therefore be questioned. A valid simplification could possibly be made if the method used for collecting this data was made similar to that used for the unsealed road condition rating.

A possible improvement for predicting drainage maintenance would be to include a user-defined "flag" for those roads or areas of the road network where, if favourable soil conditions allow, drainage standards do not need to meet those specified in the road condition rating procedures.

9.1.5 Seal Widening

The accurate prediction of seal widening need from the TSP is not feasible with the inputs currently available.

9.2 Project Level Outputs

9.2.1 Surface Treatments

The rating sections reported for a surface treatment appeared to be well targeted, and many required a specific maintenance treatment even though a surface treatment was not required. The priorities determined from the field inspection were not as high as those determined by the TSP, but this in part appeared related to budget restraint rather than for any technical reason.

- ***Trigger Levels***

The field assessment results indicated that the trigger levels set in the TSP resulted in the reporting of more sites for a surface treatment than was scheduled from the field assessment. However, if the trigger levels were set higher, rating sections which require attention may not be reported for a surface treatment.

- ***Section Lengths***

The field assessment often resulted in longer lengths of surface treatment being scheduled for each site when compared with the length reported by the TSP. However, the total quantities of surface treatment scheduled for the total road network by both the TSP and the field assessment were in good agreement. The good correlation at the network level was achieved because the extra length of surface treatment scheduled during the field assessment, at many sites, usually compensated for the rating sections reported from the RAMM TSP as requiring a surface treatment. However they were not included as sites needing a surface treatment during the field assessment.

- ***Second Coat, Texturising and Void Fill Seals***

The RAMM system currently does not report the need for second coat seals unless the first coat is showing signs of distress at the time of the road condition rating. This is often past the optimum time to apply the second seal and most normal maintenance practices have a relatively fixed period of time in which they require a second coat seal to be placed. Texturising and void fill seals often also fall in this category when they are part of a planned two stage (Texturise/Reseal or Void Fill/Reseal) process. Both texturising and first coat seals could be catered for within the TSP by allowing the user to define the time period before placing the next surface treatment. Then these sections could be reported when either the time limit has been reached, or if the road condition rating indicates sufficient distress to require a surface treatment.

- ***Locking Coat Seals***

It would be desirable to have sections which need a "Locking Coat" seal separated from the other sections of surface treatment that are reported. The selection of a "Locking Coat" treatment could be triggered by a rating section which has had a recent surface treatment and which is exhibiting significant scabbing or stripping.

- ***Road Condition Rating***

The sensitivity analysis showed the selection of surface treatment treatments to be sensitive to pavement condition rating inputs, and that any improvement in the accuracy of measurement for cracking, shoving, potholes and scabbing would benefit the process. From quality assurance checks carried out on many road rating projects, the limits of variation allowed for carriageway defects may possibly be tightened, with the exception of scabbing and flushing. The limits of these defects are more difficult to define than other carriageway defects.

The road condition rating is carried out over a 10% sample of the pavement in the rural environment, and over approximately a 25% sample in the urban environment. A 100% sample would obviously improve outputs from the TSP but this is economically unattractive if carried out manually. Also a 100% survey sample would still not be able to locate a concentrated section of faults within a rating section.

A significant improvement could be made to the outputs from the TSP at the project level by sampling more frequently during the road condition rating surveys (e.g. for 20 m every 100 m). This increased frequency would eliminate the need to continuously rate the surface-water channels and would make it possible to segment the carriageway into lengths of relatively uniform condition (i.e. dynamic segmentation). The cost of the increase in sampling frequency should not increase road condition rating costs greatly because the increase in work effort related to the rating of the carriageway should be offset by the decrease in effort related to the surface-water channels.

- ***Data Collection***

The development of vehicle-mounted data collection devices which continuously sample the carriageway are presently being used to collect data for faults such as rutting, shoving, flushing and skid resistance. The data collected continuously by mechanical devices should assist with the dynamic segmentation of roads. This segmentation would provide data inputs to the TSP that enable sections of pavement to be identified which may be deficient from a safety viewpoint and are currently not being addressed.

9.2.2 Shape Correction Treatments

The analyses used in the TSP appear to be soundly based at the project level and they represent Transfund New Zealand policy on the financial justification for this type of road maintenance. However, the selection of SCTs is sensitive to many of the inputs. At present the inputs available to the program do not allow accurate outputs at the project level. In particular, the TSP cannot accurately predict an SCT where it is the most cost-effective maintenance option, irrespective of user benefits.

The inputs to the TSP can be altered at the project (site-specific) level. The inputs which can be altered are the capital cost, maintenance cost and future maintenance cost of a specific rating section. However, if more accurate predictions are required with the first pass of the TSP, the inputs would need to be refined and the life cycle cost model improved. The inputs which require improvement are discussed below.

- *User Benefits*

The sensitivity analysis showed that the TSP is sensitive to road user benefits resulting from the reduction in road roughness after an SCT. RAMM presently requires users to categorise road sections based on the environment (urban and rural) and pavement loading (traffic volume). This categorisation could be used in the TSP to improve the calculation of user benefits by estimating a suitable vehicle mix for each rating section rather than using a single vehicle mix for all rating sections.

A further improvement could be made by measuring the actual vehicle mix on all the high use roads with the use of classified traffic counters. The results of such surveys could be used directly to determine the vehicle mix for a road and therefore better determine the user benefits from an SCT.

This review has shown that the selection of an SCT can be misleading in an urban, high traffic volume environment. Road users will tolerate a higher level of road roughness in the urban environment where vehicle speeds are low in comparison to rural highways. Therefore, roading managers were reluctant to schedule an SCT for urban highways where the pavement was sound even though an SCT was selected by the TSP based on user benefits derived from high traffic volumes and a small reduction in roughness.

- *Capital Costs of SCT*

The TSP determines the capital cost of an SCT for the average situation but is unable to take into account site variations related to the local topography, pavement or subgrade conditions. Unless the topography of each section of highway is recorded in the RAMM system, the problem of trying to accurately calculate the capital costs of an SCT within the TSP will remain.

- *Present Pavement Maintenance Cost*

Because the selection of an SCT by the TSP is sensitive to the present cost of pavement maintenance where large quantities of shoving and rutting were present, outcomes at the project level would be improved significantly if the sections of road to be analysed were in a uniform condition. The TSP uses road condition rating results from a sample of the rating length, and an average of continuous measurements made for the full rating length (e.g. roughness). The results of the sampling and averaging process have been shown, from the field inspection, to frequently give an inaccurate indication of the quantity of faults to be found in a sub-section of the rating length and this has been confirmed by the results from the High Speed Data Capture trial. More frequent sampling or the continuous measurement of the pavement condition would improve the ability of the TSP to more accurately select sections for an SCT.

- ***Future Pavement Maintenance Costs***

The cost of future pavement maintenance has a significant effect on determining the need for an SCT, especially where traffic volumes are below 1,000 vpd. The present model used by the TSP is simplistic and relies heavily on the surface treatment cycle time estimated from the road condition rating and the age of the surface treatment.

Quite commonly, roading managers now use the immediate past carriageway maintenance costs to estimate the future maintenance costs for the non-SCT option. However, recent analyses carried out on pavement maintenance costs for state highways show that the immediate past maintenance costs can be misleading if the pavement has been returned to a sound condition after maintenance.

Maintenance costs usually rise again more quickly for repaired pavements than do those which have been recently rehabilitated. However, the actual amount of future maintenance required is difficult to predict and this difficulty leads to large differences in the outcomes from financial analyses for an SCT between different roading managers, and between roading managers and the TSP.

The prediction of future pavement maintenance costs could be improved by researching some typical maintenance costs for both local authority roads and state highways, and producing life cycle times and cost curves which are typical for pavements in a range of condition states. The parameters to be used by the TSP, to determine which of the three curves to use for each section of road, would need to be researched and established, and should incorporate the use of maintenance cost data. These data should in future be stored in RAMM. Very likely the life cycle times and cost curves would be significantly influenced by the quantity of shoving and rutting measured or repaired in the past three years, and the age and traffic loading of the pavement. A further refinement would be to reduce the amount of improvement in the future surface treatment life cycle assumed by the TSP after improving the drainage.

In the longer term a pavement deterioration model should be adopted, or considered for development, that is similar to the World Bank HDM 111. This model could be used to estimate the future pavement maintenance costs and would need to be calibrated to suit New Zealand conditions. It is likely that such a model would be based on the following parameters:

- The quantity and type of maintenance activity required in past years.
- Present age and condition of the pavement.
- Traffic loading of the pavement.
- The structural capacity of the pavement, which would require deflection testing or similar.

10. RECOMMENDATIONS

- ***Allowable limits of variation for road condition rating should be improved***

The results from the quality assurance checks on road condition rating surveys carried out in 1995 and 1996 for state highways and a selection of local authority roads, should be analysed to ascertain if the limits of variation allowed for shoving, rutting, cracking, potholes and edge break can be narrowed.

- ***Data from the multi-laser profilometer and SCRIM vehicle surveys should be used in the TSP***

- ***The calculation of user benefits should allow for the TSP to access the RAMM traffic loading table***

The calculation of user benefits should allow for the TSP to access the RAMM traffic loading table to select data relevant to traffic mix. If these data are not available the user benefits should be derived as at present with the use of default vehicle mixes provided in the Transit New Zealand *Project Evaluation Manual* for road categories "Rural Other", "Urban Other", "Rural Strategic" and "Urban Arterial". These road categories could be selected by examination of the urban/rural indicator and the pavement use indicator in the RAMM carriageway table.

- ***Routine pavement maintenance costs should be recorded in RAMM***

The capability contained in RAMM Version 3.2 (May 1996) to record routine maintenance effort and costs, should be utilised for state highways and local authority roads to record such data.

- ***The relationship between routine pavement maintenance costs and RAMM reported routine pavement maintenance costs should be investigated***

Research using the routine maintenance data should be carried out to determine the relationship between the annual pavement maintenance expenditure and the pavement maintenance costs reported by the TSP from the road condition rating.

- ***The TSP model to predict future maintenance costs should be improved with the development of a family of pavement maintenance cost-prediction curves***

Historical maintenance cost data for both state highways and local authority roads should be researched, and a family of road maintenance cost-prediction curves developed. The model used in the TSP to predict future maintenance costs could then be improved to select a road maintenance cost-prediction curve which best suits the rating section being analysed by the TSP. Selection should be based on certain pavement performance criteria which could include the presence of shoving, cracking, rutting, the historical surface life achieved, and the historical maintenance activities carried out in the recent past few years if these data are available.

- ***The TSP model to predict future surface treatment life cycles should be improved***

Improvement should be made to the prediction of future maintenance costs by altering the assumed improvement in the surface treatment life cycle after the repair of defective drainage.

- ***World Bank pavement deterioration models should be trialed in New Zealand***

For the medium term, the World Bank pavement deterioration models should be trialed in New Zealand. If successful, the models should be calibrated for the longer term using the historical pavement condition and maintenance cost data that are now becoming available. The recommended pavement deterioration modelling will require data for climate, altitude, road curvature, road gradient and pavement strength, which are not presently available in RAMM.

- ***Roads should be sectioned on the basis of homogenous lengths into treatment sections***

Roads should be sectioned on the basis of homogenous lengths that have similar pavement type, traffic loading and condition (i.e. dynamic segmentation). The resulting sections should be termed "treatment sections" and the analysis of pavement maintenance needs using the TSP should be carried out on these treatment sections, rather than on the road rating sections.

- ***Sampling of the road for condition should be carried out more frequently than 500 m***

Sampling of the road for condition should be carried out more frequently than it is at present to facilitate the dynamic segmentation of roads into treatment sections. Each section should be allocated to a predetermined category which describes a "condition state". This procedure would help to detect and quantify potential short sections of SCT currently flagged by the TSP with the warning message "Partial Smoothing" or "Partial Strengthening".

- ***Reports for surface treatments should include more categories***

Reports for surface treatments should include categories for "Locking Coat Seals", "Second Coat Seals" and the need for a "Reseal after a Texturising Seal".

- ***The calculation of a width, and cost, for sections of potential seal widening should be excluded from the TSP***

The calculation of a desirable width, and therefore the cost, for potential sections of widening of seal should be excluded from the TSP because the program cannot model site conditions. The flag for the possible need for seal widening should remain to assist the roading manager with the identification of potential seal widening projects.

- ***The road condition rating procedure should be altered to allow the Roading Manager to set the criteria for the rating of inadequate surface water channels***

The road condition rating procedure should be altered to allow the roading manager to set the criteria for the rating of inadequate surface-water channels. Furthermore the procedure adopted should also allow for the criteria to alter within a road network.

11. REFERENCES

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APPENDICES

APPENDIX 1
RESULTS OF FIELD ASSESSMENT FOR STATE HIGHWAYS

Field Assessment of State Highways in the TNZ Wanganui Region

RAMM - TSP Treatment Selection | **TNZ - Treatment Selection**

Ref. Statn.	Start (km)	End (km)	Length (km)	Treatment	Prior.	Urban/ Rural	Treatment	Details	Start (km)	End (km)	Length (km)	Comments
State Highway 1North												
728-O	0.00	0.11	0.11	Reseal Next Time	0	U	Maintenance	Repair Scabbing	0.00	0.11	0.11	
728	0.32	0.82	0.50	Reseal in Budget	38.4	R	Maintenance	Partial Texturise	0.32	0.82	0.50	
728	0.82	1.32	0.50	Reseal Next Time	0	R	Maintenance	Partial Texturise	0.82	1.32	0.50	
728	2.59	3.09	0.50	Reseal (Flushed)	0	R	Resurface (1)	Reseal 93/94	2.69	3.09	0.40	
728	3.59	4.09	0.50	Reseal in Budget	58.3	R	Resurface (1)	Reseal 93/94	3.09	4.09	1.00	
728	4.09	5.09	1.00	Reseal (Flushed)	0	R	Resurface (1)	Reseal 93/94	4.09	5.40	1.31	
728	7.67	8.17	0.50	Reseal in Budget	15.6	R	Resurfaced	2nd Coat 92/93	7.67	7.90	0.23	
728	10.66	11.16	0.50	Reseal in Budget	4.5	R	Resurfaced	Reseal 92/93	10.60	11.70	1.10	
741	0.00	0.50	0.50	Reseal in Budget	58.8	R	Maintenance	Repair Scabbing	0.00	0.50	0.50	Inspection length not typical
741	2.42	3.92	1.50	Reseal Next Time	0	R	Resurface (1)	Reseal 93/94	3.30	4.90	1.60	
741	4.93	5.43	0.50	Strengthening	100	R	Resurfaced	Reseal 92/93	5.00	5.70	0.70	Heavy maint. - reseal to even texture
741	5.93	6.43	0.50	Smoothing	4.4	R	SCT (1992/93)	2nd Coat 93/94	5.98	6.43	0.32	SCT(Strengthening) 1992/93
741	6.43	6.93	0.50	Reseal in Budget	6.0	R	SCT (1992/93)	2nd Coat 93/94	6.43	7.43	1.00	SCT(Strengthening) 1992/93
741	7.43	7.78	0.35	Smoothing	5.2	R	SCT (1992/93)	2nd Coat 93/94	7.43	7.86	0.43	SCT(Strengthening) 1992/93
741	7.78	8.28	0.50	Reseal (Flushed)	0	R	Resurface (2)	Reseal 94/95	7.86	9.70	1.84	
741	9.73	10.73	1.00	Reseal (Flushed)	0	R	Resurface (2)	Reseal 94/95	9.70	10.50	0.80	
741	10.73	11.23	0.50	Smoothing	4.7	R	SCT (1)	Smooth 93/94	10.50	11.00	0.50	Plus widening
741	11.73	12.23	0.50	Reseal (Flushed)	0	R	Resurface (2)	Reseal 94/95	11.00	12.00	1.00	
							Resurface (1)	Reseal 93/94	12.00	12.60	0.60	
741	14.23	14.75	0.52	Reseal Next Time	0	R	Resurfaced	Reseal 92/93	14.20	14.75	0.55	Due to age and condition
756	0.00	0.09	0.09	Smoothing	100	U	Resurfaced	Reseal 92/93	0.00	0.18	0.18	Pavement sound and not rough. Holes in 1991/92 Seal.
756	0.18	0.93	0.75	Reseal (Flushed)	0	U	Resurfaced	Reseal 92/93	0.18	0.60	0.42	Due to age and condition
756	0.93	1.05	0.12	Reseal in Budget	5.6	U	Resurface (3)	Reseal 95/96	0.60	1.16	0.56	(Observe) Premature cracking use PMB

RAMM - TSP Treatment Selection / **TNZ - Treatment Selection**

Ref. Statn.	Start (km)	End (km)	Length	Treatment	Prior.	Urban/ Rural	Treatment	Details	Start (km)	End (km)	Length (km)	Comments
756	1.23	1.49	0.26	Reseal in Budget	6.5	U	Resurface (3)	Reseal 95/96	1.16	1.55	0.39	(Observe) Premature cracking use PMB
756	3.99	4.99	1.00	Reseal in Budget	4	R	Resurface (3)	Reseal 95/96	3.60	5.52	1.92	1987 Seal held with crack sealing.
756	7.58	8.08	0.50	Reseal Next Time	0	R	Maintenance	Repair Scabbing	7.58	8.08	0.50	Localised scabbing in inspection length
756	8.08	8.58	0.50	Smoothing	100	R	Maintenance	Heavy maint.	8.10	8.20	0.10	(Observe) 100m cracking and rutting - possible short SCT.
756	9.39	9.89	0.50	Reseal (Flushed)	0	R	Maintenance	Do Nothing	9.39	9.89	0.50	Inspection not typical
756	11.00	11.52	0.52	Reseal Next Time	0	R	Maintenance	Heavy maint	11.00	11.79	0.79	Localised shoving in inspection
756	12.02	12.50	0.48	Reseal Next Time	0	R	Resurface (3)	Reseal 95/96 ?	11.50	12.50	1.00	(Observe) Some cracking starting
768	3.38	3.88	0.50	Reseal Next Time	0	R	Maintenance	Do Nothing	3.38	3.88	0.50	Inspection not typical
780	1.16	2.18	1.02	Reseal (Flushed)	0	R	Maintenance	Do Nothing	1.16	2.18	1.02	Flushing on seal joins
780	2.18	2.68	0.50	Reseal Next Time	0	R	Resurface (3)	Reseal 95/96 ?	0.88	2.31	1.43	1986 2nd coat showing its age
780	5.04	5.54	0.50	Reseal Next Time	0	R	Maintenance	Repair Scabbing	5.04	5.54	0.50	Scabbing at centreline repaired
780	6.04	6.54	0.50	Reseal Next Time	0	R	Maintenance	Repair Scabbing	6.04	6.54	0.50	Scabbing at centreline repaired
780							Resurface (1)	Reseal 93/94	7.44	7.84	0.40	1989 Grade 5 Void Fill seal
780							Resurfaced	Reseal 92/93	8.80	9.80	1.00	1987 Grade 5 Void Fill seal
780	11.49	11.99	0.50	Reseal (Flushed)	0	R	Resurface (1)	Reseal 93/94	11.23	11.75	0.52	1983 reseal showing its age
780							Resurfaced	Reseal 92/93	14.60	15.50	0.90	1983 resealed due to age
780	18.51	19.01	0.50	Reseal Next Time	0	R	Maintenance	Partial Texturise	18.51	19.01	0.50	Premature scabbing on shoulder and centre
801	2.95	3.95	1.00	Reseal Next Time	0	R	SCT	Strengthen	2.80	3.80	1.00	Excessive heavy maint. past 3 yrs
801	4.45	4.95	0.50	Reseal Next Time	0	R	Maintenance	Repair Scabbing	4.45	4.95	0.50	Premature scabbing on shoulder and centre
801	6.61	7.09	0.48	Reseal Next Time	0	U	Resurface (2)	Reseal 94/95?	6.63	7.09	0.46	Premature cracking - patch and observe
801	8.79	9.29	0.50	Reseal Next Time	0	R	Maintenance	Repair Scabbing	8.79	9.29	0.50	Scabbing on past shoulder widening
801	9.79	10.76	0.97	Reseal Next Time	0	R	Maintenance	Repair Scabbing	9.79	10.76	0.97	Scabbing on past shoulder widening
801	12.36	12.86	0.50	Reseal in Budget	53.3	R	Resurface (1)	Locking 93/94	11.90	12.87	0.97	Locking coat - if winter chip loss
801	14.36	14.86	0.50	Reseal Next Time	0	R	SCT	1993/94	14.50	14.90	0.40	

RAMM - TSP Treatment Selection | **TNZ - Treatment Selection**

Ref. Statn.	Start (km)	End (km)	Length	Treatment	Prior.	Urban/ Rural	Treatment	Details	Start (km)	End (km)	Length (km)	Comments
State Highway 4												
140							Resurface (1)	Reseal 93/94	0.00	0.32	0.32	No problems but 1988 texturising seal
140	5.00	5.50	0.50	Reseal in Budget	6.9	R	Resurface (2)	Reseal 94/95	4.60	5.80	1.20	
140	7.00	7.50	0.50	Reseal Next Time	0	R	Resurface (2)	Reseal 94/95	5.80	7.80	2.00	
148	0.00	0.13	0.13	Reseal in Budget	3.4	U	Maintenance	Crack Seal	0.00	0.13	0.13	(Observe) 1988 reseal starting to crack
148	0.56	0.69	0.13	Reseal Next Time	0	U	Maintenance	Crack Seal	0.56	0.69	0.13	(Observe) 1988 reseal starting to crack
148	3.13	4.63	1.50	Reseal Next Time	0	R	Resurface (1)	Lock Coat 93/94	2.13	4.63	2.50	Premature scabbing in 1991/92 reseal.
148	5.13	5.63	0.50	Reseal Next Time	0	R	Resurface (1)	Lock Coat 93/94	4.63	5.56	0.93	If a lock coat is not placed, then
148	7.30	7.80	0.50	Reseal in Budget	6.2	R	Resurface (1)	Lock Coat 93/94	7.30	7.45	0.15	extensive scabbing repair required.
148	8.80	9.30	0.50	Strengthening	100	R	Maintenance	Repair Scabbing	8.80	9.30	0.50	(Observe) Premature scabbing and cracking in 1991/92 seal
148	9.30	9.80	0.50	Reseal Next Time	0	R	Maintenance	Repair Scabbing	9.30	9.80	0.50	(Observe) Premature scabbing, possible locking coat seal
158	2.00	2.77	0.77	Reseal (Flushed)	0	R	Resurface (2)	Reseal 94/95	2.00	2.77	0.77	
158	6.65	7.15	0.50	Reseal (Flushed)	0	R	Resurface (2)	Reseal 94/95	6.04	7.02	0.98	1982/83 second coat
158	7.15	7.65	0.50	Reseal Next Time	0	R	Resurface (3)	Reseal 95/96	7.44	8.04	0.60	1985/86 second coat
158	9.65	10.15	0.50	Reseal Next Time	0	R	Maintenance	Repair Scabbing	9.65	10.15	0.50	Keep sections of seal under observation,
158	11.15	11.65	0.50	Reseal in Budget	29.5	R	Maintenance	Repair Scabbing	11.15	11.65	0.50	due to premature chip loss in 1990/91
158	11.65	12.15	0.50	Reseal Next Time	0	R	Maintenance	Repair Scabbing	11.65	12.15	0.50	and 1991/92 grade 2 and grade 3 reseals.
158	15.12	15.62	0.50	Reseal Next Time	0	R	Maintenance	Repair Scabbing	15.12	15.62	0.50	If chip loss continues over the winter a
158	15.62	16.12	0.50	Reseal in Budget	34.5	R	Maintenance	Repair Scabbing	15.62	16.12	0.50	locking coat may be required.
158	16.62	17.12	0.50	Reseal (Flushed)	0	R	Resurfaced	Reseal 92/93	16.10	17.10	1.00	

RAMM - Treatment Selection | **TNZ - Treatment Selection**

RS	Start (km)	End (km)	Length	Treatment	Prior.	Urban/ Rural	Treatment	Details	RP1	RP2	Length	Comments
State Highway 49												
0	3.00	3.50	0.50	Reseal in Budget	10.2	R	Maintenance	Crack Seal	3.00	3.50	0.50	(Observe) Reseal 3-4 years if more cracking
0	8.00	8.64	0.64	Reseal in Budget	139.9	R	Resurface (2)	Reseal 94/95	6.58	8.56	1.98	Premature cracking in a 1991/92 Reseal.
0	8.78	8.87	0.09	Reseal in Budget	5.4	U	Resurface (3)	Reseal 95/96	8.78	8.94	0.16	Observe and crack seal during next 3 years.
0	8.94	9.12	0.18	Reseal Next Time	0	U	Resurface (3)	Reseal 95/96	8.94	9.12	0.18	If pavement ride deteriorates pavement
0	9.12	9.24	0.12	Reseal in Budget	8.7	U	Resurface (3)	Reseal 95/96	9.12	9.24	0.12	SCT with strengthening may be required.
11	0.00	0.13	0.13	Reseal in Budget	9.3	U	Resurface (2)	Reseal 94/95	0.00	0.13	0.13	Same as above
11	4.39	5.40	1.01	Reseal in Budget	10.95	R	Resurface (3)	Reseal 95/96	4.39	6.90	2.51	(Observe) - Some heavy maintenance
11	6.40	6.90	0.50	Smoothing	100	R	Resurface (3)	Reseal 95/96	4.39	6.90	2.51	is required. Some short sections of
11	6.90	7.90	1.00	Reseal in Budget	9.3	R	Resurface (3)	Reseal 95/96	6.90	7.90	1.00	maintenance SCT to strengthen weak
11	7.90	8.40	0.50	Reseal Next Time	0	R	Resurface (3)	Reseal 95/96	7.90	8.90	1.00	sections of pavement may be required.
11	8.90	9.40	0.50	Reseal in Budget	16.6	R	Resurface (3)	Reseal 95/96	8.90	9.40	0.50	
11	9.40	9.90	0.50	Reseal Next Time	0	R	Resurface (3)	Reseal 95/96	9.40	10.80	1.40	
11	10.40	11.40	1.00	Reseal in Budget	38	R	Resurface (1)	Reseal 93/94	10.80	11.64	0.84	1980/81 Reseal showing its age
11	13.47	13.97	0.50	Reseal in Budget	11.8	R	Resurface (3)	Reseal 95/96	12.44	13.97	1.53	(Observe) - Reseal in 2-3 years after heavy
11	14.47	14.97	0.50	Reseal Next Time	0	R	Resurface (3)	Reseal 95/96	13.97	14.97	1.00	maintenance. May require a section of SCT
11	15.47	15.97	0.50	Reseal in Budget	11.1	R	Resurface (3)	Reseal 95/96	14.97	16.39	1.42	if shallow shear increases.
29							Resurfaced	Reseal 92/93	0.00	1.20	1.2	1988 grade 5 chip texturising seal
29	1.64	2.14	0.50	Reseal Next Time	0	R	Maintenance	Partial Texturise	1.20	2.14	0.9	Premature scabbing, 2m wide locking coat
29	2.64	3.10	0.46	Reseal Next Time	0	R	Maintenance	Partial Texturise	2.14	3.00	0.9	required along the centre line.
29	3.10	3.60	0.50	Smoothing	4.6	R	SCT	With Imp. 93/94	3.00	3.60	0.60	
29	3.60	4.10	0.50	Strengthening	100	R	SCT	With Imp. 93/94	3.60	3.90	0.30	
29	5.10	5.60	0.50	Reseal Next Time	0	R	Maintenance	Repair Scabbing	5.10	5.60	0.50	
29	6.26	6.76	0.50	Reseal in Budget	116.9	R	SCT	94/95	6.30	6.40	0.10	Short section of SCT required 2-3 years

Resurface (1) - High priority surface treatment required
Resurface (2) - Medium priority surface treatment required
Resurface (3) - Low priority surface treatment required

APPENDIX 2
RESULTS OF FIELD ASSESSMENT FOR LOCAL AUTHORITY ROADS

Field Assessment for roads Controlled by Rotorua District Council

Road Name	Start (m)	End (m)	Length (m)	RAMM TSP Treatment Selection	Rotorua District Treatment Selection	Comments
ALLAN ST	0	79	79	General Maint.	General Maint.	
ANN ST	0	426	426	General Maint.	General Maint.	
ARTHUR ST	0	226	226	General Maint.	General Maint.	
ASHLEY ST	0	220	220	General Maint.	General Maint.	
BATTEN ST	0	102	102	General Maint.	General Maint.	
CARLTON ST	0	400	400	General Maint.	Reseal 1992/93	Too little binder in plant mix overlay
CARNOT ST	0	182	182	General Maint.	General Maint.	
	182	433	251	General Maint.	Reseal 1993/94	Advanced due to service openings for new housing
CLINKARD AVE	0	779	779	Reseal Next Time	General Maint.	Alligator cracking from rating not apparent
CLINKARD PLACE	0	54	54	General Maint.	General Maint.	
CORBETT RD	2500	4000	1500	General Maint.	General Maint.	
	4000	4500	500	Reseal Next Time	General Maint.	Inspection not typical
	4500	9270	4770	General Maint.	General Maint.	
DAVIDSON ST	0	125	125	General Maint.	General Maint.	
DEVON ST	0	560	560	Smoothing Overlay	Reseal 1992/93	Heavy maint. and local levelling (SCT if finance available)
	560	1149	589	Smoothing Overlay	SCT 1992/93	
DUNCAN ST	0	327	327	General Maint.	Reseal 1992/93	Too little binder in plant mix overlay
EASON ST	0	249	249	Reseal Next Time	Reseal 1995/96	Old grade 5 chip seal with minor cracking & scabbing
ELIZABETH ST	0	785	785	General Maint.	General Maint.	
GREY ST	0	593	593	General Maint.	Reseal 1993/94	Advanced due to service openings
HAZLETT ST	0	96	96	General Maint.	General Maint.	
HEREWINI ST	0	251	251	General Maint.	Reseal 1993/94	Minor cracking, kerb and service trench repairs
HIGH ST	0	572	572	General Maint.	General Maint.	
HOLLAND ST	0	341	341	General Maint.	Reseal 1993/94	To maintain a rational seal length with adjacent section
	341	571	230	Reseal Next Time	Reseal 1993/94	

Road Name	Start (m)	End (m)	Length (m)	RAMM TSP Treatment Selection	Rotorua District Treatment Selection	Comments
HOSSACK RD	0	4170	4170	General Maint.	General Maint.	
	4170	4670	500	Reseal in Budget	General Maint.	Crack Seal - Inspection not typical
	4670	5130	460	General Maint.	General Maint.	
JAMES ST	0	280	280	General Maint.	General Maint.	
	280	705	425	General Maint.	Reseal 200 m 1995/96	
KAHIKATEA ST	0	134	134	Reseal Next Time	Reseal 1994/95	
KEVIN ST	0	79	79	General Maint.	General Maint.	
KING ST	0	423	423	General Maint.	General Maint.	
KOTARE ST	0	108	108	General Maint.	General Maint.	
KOWHAI ST	0	279	279	General Maint.	Reseal 1994/95	10year old grade 5 chip seal with some L&T cracking
LARCH ST	0	361	361	General Maint.	General Maint.	
LIGHTHEART ST	0	60	60	General Maint.	General Maint.	
LYTTON ST	479	983	504	Reseal Next Time	Reseal 1993/94	
	983	1317	334	Reseal Next Time	Reseal 1992/93	
MAHOE ST	0	147	147	Reseal Next Time	Reseal 1994/95	
MALFROY RD	0	1395	1395	General Maint.	General Maint.	
MCLEAN ST	0	287	287	General Maint.	Reseal 1992/93	Due to age
MILLER ST	0	780	780	General Maint.	General Maint.	
PERERIKA ST	0	916	916	Reseal in Budget	Reseal 1993/94	
PHILLIP ST	0	338	338	Reseal in Budget	Reseal 1994/95	Missed from 1993/94 programme
PRETORIA	0	195	195	General Maint.	General Maint.	
RANOLF ST	1291	1716	425	General Maint.	Reseal 1993/94	
	1716	2703	987	Reseal Next Time	Reseal 1994/95	
	2703	3026	323	General Maint.	General Maint.	
RIMU ST	0	442	442	General Maint.	General Maint.	

Road Name	Start (m)	End (m)	Length (m)	RAMM TSP Treatment Selection	Rotorua District Treatment Selection	Comments
ROBERTSON ST	0	342	342	Reseal Next Time	Reseal 1993/94	
	342	594	252	General Maint.	Reseal 1993/94	To maintain a rational seal length with adjacent section
RUIHI ST	0	250	250	General Maint.	General Maint.	
SEDDON ST	0	592	592	Reseal Next Time	Reseal 1996/97	
SOPHIA ST	0	1081	1081	General Maint.	General Maint.	
SUMNER ST	0	345	345	General Maint.	Reseal 1993/94	To maintain a rational seal length with adjacent section
	345	596	251	Reseal Next Time	Reseal 1993/94	
TILSLEY ST	0	341	341	Reseal Next Time	Reseal 1993/94	
	341	572	231	General Maint.	Reseal 1993/94	To maintain a rational seal length with adjacent section
TOKO ST	0	249	249	General Maint.	Reseal 1993/94	Old grade 5 chip seal and some cracking
TOTARA ST	0	265	265	General Maint.	General Maint.	
UNION ST	0	250	250	General Maint.	General Maint.	
VICTORIA ST	0	591	591	Reseal in Budget	Reseal 1992/93	
WAIKAUKAU RD	0	500	500	Reseal Next Time	Reseal 1992/93	
	500	2000	1500	General Maint.	Reseal 1992/93	
	2000	3000	1000	Reseal in Budget	Reseal 1992/93	
	3000	3500	500	Reseal Next Time	Reseal 1992/93	
	3500	4200	700	Reseal in Budget	Reseal 1992/93	
WAIKITE VALLEY RD	0	3000	3000	General Maint.	General Maint.	
	3000	3870	870	Reseal Next Time	Heavy Maintenance	Digouts + drainage + sections of maintenance seal
	3870	4500	630	General Maint.	General Maint.	
	4500	5870	1370	General Maint.	SCT	Shoving, cracking rutting
	5870	6370	500	Reseal in Budget	SCT	missed by inspection lengths
	6370	6750	380	General Maint.	SCT	Historic high maintenance costs
	6750	18700	11950	General Maint.	General Maint.	
WALLACE CR	0	417	417	Reseal Next Time	Reseal 1995/96	Some minor cracks North end. Inspection not typical

Road Name	Start (m)	End (m)	Length (m)	RAMM TSP Treatment Selection	Rotorua District Treatment Selection	Comments
WHIRINAKI VALLEY RD	0	500	500	General Maint.	General Maint.	
	500	1000	500	Reseal Next Time	Reseal 1993/94	
	1000	1500	500	General Maint.	Reseal 1993/94	
	1500	2000	500	Reseal in Budget	Reseal 1993/94	
	2000	2500	500	Reseal Next Time	Reseal 1993/94	
	2500	3940	1440	General Maint.	Reseal 1993/94	
	3940	4440	500	Reseal in Budget	Reseal 1994/95	Heavy maint. before reseal
	4440	5940	1500	General Maint.	General Maint.	
	5940	6100	160	Reseal in Budget	General Maint.	
	6100	7560	1460	Reseal in Budget	Reseal 1992/93	
	7560	8560	1000	Reseal Next Time	Reseal 1992/93	
	8560	14490	5930	General Maint.	General Maint.	
WYLIE ST	0	402	402	General Maint.	Reseal 1992/93	Too little binder in plant mix overlay
	402	744	342	General Maint.	General Maint.	
	744	995	251	Reseal in Budget	Reseal 1992/93	
YORK ST	0	535	535	General Maint.	General Maint.	

APPENDIX 3
PROJECT EVALUATION OF ONE SECTION OF WAIKITE ROAD, ROTORUA

PROJECT REPORT
SHAPE CORRECTION (REHABILITATION)
SUMMARY OF ANALYSIS OF CHOSEN OPTION

WS 1

Project Name: Waikite Valley Road
Location: RP 4500 - RP 6750
Date: 01/12/96
Office or Organisation: BCHF

Base Date: 1 July 1995
Time Zero 01 July 1996
Submitted By: John Hallett
Checked By: John Hannah

1 **Description of the Problem** Rough Pavement Requiring high Maintenance Input. Digout patching, rut filling and various sections of maintenance seals placed since 1987 now becoming more frequent in recent years. Uphill lane develops corrugations and flushed surface due to traction forces from trucking. Also on active fault which distorts road.

2 **Do-Minimum Description** (Cost from WS 3) **Cost** 318820 **A**
Maintain Existing

3 **Option Descriptions** **Cost** (without improvements) 328825.75 **B1**
Shape Correction With No Improvements - 100mm M/4 AP 40 overlay

Improvements (if any) - Description **Cost** 0 **B2**
Nill

4 **Programming Information**

Earliest Start Date 1/10/96
Land Designation Required N
Construction Period - Months 3
Other Statutory/Regulatory Requirements None

5 **Road and Traffic Data**

Traffic Vol AADT 400 in **1994**
Existing Traffic Speed 80 km/h
Traffic Growth Rate 2.00%
Predicted Traffic Speed 80 km/h
Existing Roughness Count **95** NAASRA
Predicted Roughness Count **70** NAASRA
Length of Job **2.25** km

6 **Economic Appraisal Data**

6.1 Vehicle Operating Costs savings **Benefit** $70,530.00 **C** x Update Factor $1.00 = $70,530.00 **W**

6.2 Travel Time Cost savings: **Benefit** 0 **D** x Update Factor 1 = 0 **Y**

6.3 Accident Costs savings : **Benefit** 0 **E** x Update Factor 1 = 0 **Z**

B / C Ratio = (W + Y + Z) / ((B1+B2) - A) = BENEFITS / COSTS = $70,530.00 / $10,005.75 = **7.05**

FYRR = 1st Year BENEFITS / COSTS = [(W+Y)/DF +Z/DF] / (B1+B2)/A = $7,003.97 / $10,005.75 = **0.70**

7 **Carbon Dioxide** change in CO2 0 tonnes (Decrease) **F**

8 **Intangible Factors**

9 Does the proposed work impact on Maori economic or cultural activities? /N

ACTION: PROCEED WITH

SHAPE CORRECTION WORKS - DO MINIMUM

1 **Annual Maintenance Costs**

Total = $7,875.00 x 9.52 = $74,970.00 (a)

2 **Periodic Maintenance Costs**

Periodic Maintenance will be required in the following years

Year	Type of Maintenance	Amount	SPPWF	PV
1	Heavy maint. & Reseal	$131,100.00	0.91	$119,301.00
7	Heavy maint. & Reseal	$131,100.00	0.51	$66,861.00
13	Heavy maint. & Reseal	$131,100.00	0.29	$38,019.00
20	Heavy maint. & Reseal	$131,100.00	0.15	$19,665.00
			Total	$243,846.00 (b)

3 (a) + (b) = **TOTAL A** 318820

Total A is the PV of the Do Minimum
Transfer it to the COST$ ______________ A position on WS 1

Notes:

SHAPE CORRECTION WORK - COST OF THE OPTION

1 Shape correction without/with improvements (describe improvements)

____

____

2 Cost of works without improvements

2.1 Estimated costs of works (excluding improvements if any) as per attached estimate sheets

$243,000.00 (a) x 0.91 = **$221,130.00** (a)

2.2 Estimated cost of annual maintenance in year 1 = **$7,150.00** (b)

2.3 Estimated PV of maintenance costs in years 2 to 25 following completion of the works

= **$1,125.00** x 8.57 = **$9,641.25** (c)

2.4 PV of periodic maintenance including second coat seal following works

Year	Type of Maintenance	Amount	SPPWF	PV
2	Reseal	$68,850.00	0.83	$57,145.50
12	Heavy maint. & Reseal	$76,725.00	0.32	$24,552.00
22	Heavy maint. & Reseal	$76,725.00	0.12	$9,207.00
				$0.00
				$0.00
				$0.00
				$0.00
			Total	$90,904.50 (d)

(a) + (b) + (c) + (d) = **TOTAL B1** **$328,825.75**

Total B is the cost of the Option
Transfer Total B1 to position Cost$ ________ B1 on Worksheet 1

3 Cost of Improvements (if any)

3.1 Estimated costs of improvements as per attached estimate sheets

$0.00 x 0.91 = **0** **TOTAL B2**

Transfer Total B1 to position Cost$ ________ B1 on Worksheet 1

Notes:

This worksheet is for calculating the benefits from Vehicle Operating Cost savings due to reductions in surface roughness.

1 List values for : **time zero AADT** 416 ; **Length** 2.25 km,
Traffic Growth Rate 0.02 ; and,

	Do Minimum		Proposed Option	
NAASRA counts		95		70
Roughness Costs (CR) in c/km	CRm =	2.25	CRp =	0.2

Use these values in the formulae to calculate (a) and (b)

2 Annual VOC for the Do Minimum

$$= \frac{L \times CRm \times AADT \times 365}{\$100.00}$$

= $7,686.90 (a)

3 Annual VOC for the Proposed Option

$$= \frac{L \times CRp \times AADT \times 365}{\$100.00}$$

= $683.28 (b)

4 The VOC Savings are calculated as:

(a - b) x DF = $7,003.62 x 10.07 = $70,530.00 **TOTAL D**

Transfer total D to position ______ D on Worksheet 1.

Notes:

APPENDIX 4
TERMINOLOGY

A4. TERMINOLOGY

The terminology used in this review is described for those terms which apply to the Treatment Selection Process. The descriptions are as follows:

Road Assessment and Maintenance Management System (RAMM)	A system designed to assist a Roading Manager to efficiently maintain the road network under his/hers control. The system consists of a database, data collection procedures, data analysis procedures and standard management reports.
Treatment Selection Process (TSP)	A process devised to aid in the selection of pavement maintenance and rehabilitation strategies. The TSP in RAMM analyses the data stored in the database and produces reports which help the Roading Manager, to optimise the selection and to establish the priorities and timing of road maintenance, so that the operating costs of the road network and the vehicles upon it are minimised.
General Maintenance	All other road maintenance which is not Major Maintenance such as patching the pavement, cleaning the water channels, painting road markings, repairing signs, maintaining road shoulders, etc. General maintenance can be subdivided as follows: • *Heavy Maintenance* General maintenance which is not routine in nature, requires considerable resources and which is usually scheduled rather than cyclic. It includes digout patching of the pavement, short sections of overlay and large areas of depression filling. It is most often carried out immediately before a surface treatment. • *Routine Maintenance* Road maintenance which is routine in nature such as pothole repairs, crack sealing, edge break repairs, culvert cleaning, etc.
Major Maintenance	Road maintenance which is of a major nature such as surface treatments, SCT, surface-water channel upgrading, etc.
Reseal In Budget	Rating sections which have been selected and reported for a surface treatment which is likely to be required in the next budget year.
Reseal Next Time	Rating sections which have been selected and reported for a surface treatment which is likely to be required in the year following the next budget year.

Riding Quality	The quality of the ride experienced by a vehicle when driven upon a road surface. The measurement of the quality of ride is made by a NAASRA meter which measures the response of a vehicle suspension when driven over a road surface at a certain speed.
Road Condition Rating	A standard procedure for assessing and recording the condition of a road network. Rating is performed as a visual inspection on sample sections of each road in the network to identify and record well defined faults on the pavement and surface-water channels. In rural areas the rating procedure is usually carried out on a 10% sample of each 500 m section of road (rating section). In urban areas the rating sample length may range from 10% to 100% of each road.
Rating Section	Road sections are automatically divided into rating sections by the RAMM software. Rating sections must lie within a road section and cannot overlap a road section. There may be several rating sections within one road section. Rating sections are 500 m in length with the following exceptions: • The last rating section of a road section which may be an odd length between 300 m and 799 m. • A road section which is between 0 - 799 m in length (e.g. a street block), will be one rating section.
Road Section	The base unit of the RAMM inventory. Each road is divided into sections which are relatively uniform in nature and only seldom extend greater than 5000 m in length in rural areas or 300 m in length in urban areas.
Shape Correction Treatment (SCT)	Refers to a treatment which improves the riding quality of a pavement and may also improve pavement strength. An SCT with improvements may include widening of the sealed road width or minor improvements to the vertical or horizontal alignment.
Smoothing SCT	An SCT which improves the riding quality of the pavement but adds little to the pavement strength (e.g. thin granular overlay, thin AC overlay, rip and remake, etc.).
Strengthening SCT	An SCT which improves the riding quality of the pavement and adds pavement strength (e.g. thick granular overlay, thick AC overlay, pavement stabilisation, etc.).
Surface Treatment	Surface treatment placed on the road carriageway (e.g. chipseal, thin asphaltic concrete (AC), friction course (FC), etc.). It includes all surface treatment types.

Benefit/Cost (B/C); Benefit/Cost Ratio	The analysis required to determine the B/C ratio involves determining the various costs and benefits associated with a project option over a certain evaluation period. The ratio of the PV of the benefits to the PV of the costs of the project is termed the Benefit/Cost (B/C) ratio.
Discount Rate	The time value of money is handled in economic analyses by discounting. The discount rate represents the rate at which present benefits and costs can be exchanged for future benefits and costs. A present amount may be invested or used immediately and is therefore worth more than the same amount at some future time by its return on investment in the interim.
Present Value (PV)	The present value of a future cost or benefit is its discounted value at the present day. For a series of annual costs or benefits, the discounted values for each future year can be summed to give their present value.
Alligator Cracking	Cracking in the surface of the pavement which has an irregular pattern (similar to the pattern of an alligator skin). Usually found in the wheelpaths on the pavement and is associated with the fatigue of the pavement surface material.
Edge Break	The length of pavement edge which has broken back from the original line to which it was constructed by more than 100 mm.
Flushing	The length of wheelpath on the surface of a pavement where the sealing binder is level with or above the sealing chip.
Pothole	An area in the pavement where the pavement surface has broken up and displaced to form a cavity.
Rutting	Depressed wheel tracks in the pavement with no associated heave alongside the depressed area.
Scabbing	The area of a chipsealed pavement surface which has lost more than 10% of the sealing chip.
Shoving	A depression in the wheelpath of a pavement where material is displaced to form a heave alongside the depressed area.