RAMM TREATMENT SELECTION WORKSHOP (V3.7)

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1999

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1. THEORY

1.1 NEED FOR A DECISION AID

The ultimate aim of road maintenance management is to optimise the selection of available maintenance activities and to establish the priorities and timing of maintenance works so that the operating costs of the road network and the travellers upon it are minimised. In principle, selection of the best and most timely maintenance treatment requires a knowledge of the cost consequences, both now and in the future, of undertaking any of the alternative strategies available. The costs to be considered include costs to the travelling public as well as those to the maintenance authority. In addition, the decision-maker needs to know the cost and availability of finance to do the work, both now and in the future.

Considering the complexity of the choices and consequences of each maintenance decision and the sheer number of decisions that must be made on an entire network, it might be concluded that the case for a computerised optimisation procedure was obvious. However the development of a program able to take all the relevant factors into account is an enormous task. The prediction of future pavement performance under any particular maintenance regime is an inexact process. Even if the science of pavement performance prediction in New Zealand was more advanced, there would be great difficulty in estimating how much maintenance effort will be put into the pavements in future. In particular, general maintenance effort may strongly influence performance and yet the level of this type of maintenance may be very dependent on future circumstances.

In spite of these problems considerable progress has been made with predictive models and *Dtims* is perhaps the most advanced and relevant software for New Zealand conditions. Currently work is progressing on the development and implementation of *Dtims*. However, work on data collection and calibration of the model to New Zealand conditions is likely to take some time. When available, *Dtims* will require data on pavement and subgrade strength that is currently incomplete or entirely lacking for most New Zealand road networks.

One of the major responsibilities of the road maintenance engineer is to obtain budget approval for sufficient works to maintain the road network adequately. In order to do this, one must be able to convince decision makers, at both Local and Central Government level, that the standard set is close to the social and economic optimum standard, and is at least as productive as any competing demands on finance. One must also be able to show that the cost to maintain the standard is justifiable. The international literature on Road Maintenance Systems indicates that one of the major benefits of using a maintenance program optimisation system is in its ability to demonstrate to non-technical decision makers that the requested maintenance programmes are economically justified and soundly organised. There is good reason to suggest that New Zealand experience will be similar.

1.2 IMPLEMENTATION FOR RAMM

In developing a Maintenance Decision aid within the RAMM system, the initial approach has been to make use of relatively simple data such as the condition rating and roughometer measurements together with the descriptions of pavement surfacing etc from the Inventory. It has also been recognised that at a project (treatment length) level the experienced roading engineer, with more site specific information, will often be a better judge of a particular situation than a theoretically based pavement performance optimisation program. It will always be necessary for the engineer to check, and in many cases modify, the initial program selections produced by any computerised process. One of the major benefits of the program is that it interacts with the user to easily handle large amounts of data to make quick economic analyses and comparisons between the various maintenance options available, after taking into account the results of investigations and local knowledge specific to the site. The engineer is able to enter estimates of probable treatment costs and future maintenance consequences where it is considered that the program's estimations are inadequate. This allows the final maintenance program output to make use of both the human engineering skill of recognising exceptions to the generally programmed rules and the ability of the computer to process a large amount of data and to produce lists of work requirements in priority order.

1.3 SELECTION PROGRAM FOR NEW ZEALAND CONDITIONS

Although about half of New Zealand's total road network is unsealed, these roads serve a very small proportion of total road traffic and require only a small proportion of the total road maintenance expenditure. The great majority of the sealed roads in the road network are thin surfaced flexible pavements; the thin surfacing being usually provided by a chip seal but with a significant proportion of thin asphaltic concrete surfacing in urban areas. There is a small proportion of structural thickness (>70mm) asphaltic concrete surfacing and a very small proportion of older concrete pavements. The treatment selection algorithm development has concentrated on the thin surfaced flexible pavement, with consideration also being given to the structural asphaltic concrete pavement. Concrete and unsealed roads cannot currently be catered for in the treatment selection algorithm.

Although detailed information on long-term performance of road pavements in regard to maintenance costs, surface roughness and structural defects has not been collected systematically in New Zealand, a considerable body of experience does exist within the roading engineering community. There are, moreover, several features of New Zealand roads and their maintenance which make it possible to use a number of simplifying assumptions that very considerably reduce the data input requirements and the selection system complexity, and still produce a good approximation of the economically optimal maintenance programme.

The salient features are as follows:

- Most thin surfaced pavements in New Zealand are lightly constructed for the traffic they must carry.
- Even in the drier areas, pavement performance depends very strongly on the maintenance of a waterproof and well-drained surfacing.
- There is little empirical evidence to support the view that pavement strength, ride and surface condition all deteriorate at a gradually increasing rate.
  Instead, the general consensus is that pavement condition remains fairly static over much of the surfacing life, with a relatively sharp onset of deterioration at the initiation of the first surface cracking. Delay in resurfacing much beyond this stage will almost always result in a totally uneconomic amount of failure and/or heavy pavement maintenance.
  For this reason, the economically optimum time for a surface waterproofing treatment such as a reseal is usually relatively clear-cut and can be assessed on the basis of a technical evaluation of surface condition only.
- Good to average standard general maintenance patching and depression filling is capable of maintaining a road in a reasonable state in regard to pavement ride almost indefinitely, although often uneconomically.

This fact, and the relatively high level of total roading resources committed to general maintenance activities in New Zealand, makes the sophisticated methods of predicting the roughness development of pavements difficult to apply and probably not generally appropriate. Therefore, in assessing the expected value of the economic benefits of one type of maintenance treatment option in comparison with another, it is assumed that the divergence in the rates of change of future road roughness arising from each of the options is relatively slow and the difference in user benefits is insignificant.

Optimising the selection of maintenance works should, in principle, include the optimal selection of the amount and type of general maintenance activities. This is particularly true in N.Z because a fairly high proportion of total maintenance costs is expended under this category. This is not, however, addressed explicitly the RAMM treatment selection algorithm, except insofar as the reduction in need for general maintenance is counted as a justification of an area treatment option such as resurfacing or shape correction.

2. OVERVIEW OF THE SYSTEM

The new version of the RAMM Treatment Selection algorithm is available in the RAMM for Windows system. Treatment Selection is now a separate program loaded from the RAMM for Windows group file in Windows 95 or NT. Several enhancements have been made in order to increase to accuracy of the Treatment Selection process, and to provide a more useful format for the output of the program. The major changes a listed below.

2.1 Changes to the Unix RAMM 3.4 Program

2.1.1 Surface Material Life Cycles

The life cycles for surface materials are currently hard coded in the Treatment Selection program. The life cycles are now maintainable by the user in order to make them more flexible. A new table called surface_life has been created and life cycles are obtained from this. Default values from TNZ will be loaded initially.

Surfacing	**Use 1**	**Use 2**	**Use 3**	**Use 4**	**Use 5**	**Use 6**	**Use 7**
Portland Cement Concrete	60	60	50	50	40	40	40
Structural Asphaltic Concrete	20	20	19	19	18	17	16
Friction Course	12	11	10	9	8	7	6
Thin Asphaltic Concrete	12	11	10	9	8	7	6
Slurry Seal	8	7	6	5	4	3	2
Open Graded Emulsion Mix	12	11	10	9	8	7	6
Grade 6 Seal	6	5	4	3	2	1	1
Grade 5 Seal	8	7	6	5	4	3	2
Grade 4 Seal	12	10	8	7	6	5	4
Grade 3 Seal	14	12	10	9	8	7	6
Grade 2 Seal	16	14	12	11	10	9	8
First Coat Seal(grade 4)	3	2	1	1	1	1	1
First Coat Seal(grade 3)	4	3	2	1	1	1	1
Prime and Seal (grade 4)	7	6	5	4	3	2	1
Two Coat First surface (grades 2/3, 2/4, 2/5)	10	8	6	5	4	3	2
Two Coat First surface (grades 3/4, 3/5, 3/6)	8	6	5	4	3	2	1
Two Coat First surface (grades 4/5, 4/6)	6	4	3	2	2	1	1
Two Coat Second surface (grades 2/3, 2/4, 2/5)	18	16	14	13	12	10	9
Two Coat Second surface (grades ¾, 3/5, 3/6)	16	14	12	11	10	8	6
Two Coat Second surface (grades 4/5, 4/6)	14	12	10	9	8	6	4
Two Coat Reseal (grades 2/3, 2/4, 2/5	18	16	14	13	12	10	9
Two Coat Reseal (grades 3/4, 3/5, 3/6)	16	14	12	11	10	8	6
Two Coat Reseal (grades 4/5, 4/6)	14	12	10	9	8	6	4
Bicouche/Sandwich	14	12	10	9	8	6	4
Metal	3	2	1				
BOLIDT Polyurethane Mix	18	16	14	12	11	10	8

Default Surface Life table

2.1.2 New Treatment Tables

As the structure of the treatment selection program has changed, the table structure has changed also. The existing *treat* and *treat_msg* tables will not be converted so users wishing to retain their current data will need to make a copy Normally this data is overwritten each Treatment Selection run anyway.

Several New tables have been created

- treatment_length
- treatment_hdr (Treatment Headers)
- treatment_summary
- treatment
- treatment_reasons
- treatment_warnings
- tl_cost_set (Cost set linked with treatment lengths)
- tsa_costs

A default treatment header row is created using the decision factors currently stored in the parameter table

The tl_cost_set table is loaded from the existing tsf_unit_costs and sac_unit_costs tables. This table contains the cost set number and description so is created by combining details from both of the tables

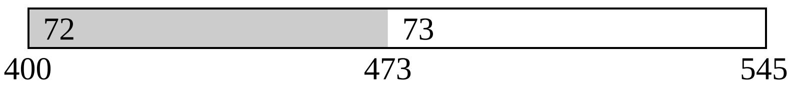
- The benefit_cost table has been renamed to rci_values
- The existing cci column to has been renamed rci

2.1.3 Rating Inspection Lengths

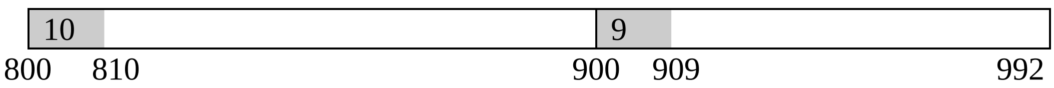
Currently rating sections must be between 300 and 800m in length, with an inspection length of either 50m or the whole section. With the introduction of treatment lengths the rating rows will be generated using the data available in this table. (Both sealed and unsealed rating rows.)

The Autorate procedure for sealed rating prompts the user to enter the rating interval (any length between 100 and 500 metres), the sample percentage to rate in each length, with a minimum of a 10% sampling and a minimum inspection length. A sampling percentage of 100 will rate the complete length. The default values are a rating interval of 500m with a 10% sampling. The current convention of stepping in 20 metres from the beginning of a carriageway section will remain true for treatment lengths except in those cases where the total length is less then 20m. When generating rating lengths for unsealed carriageways the existing policy of a 500 metre rating with a 50 metre inspection length is retained.

Example 1. In this example rating lengths are 100m with a 50% sampling. The remaining length is 145m and as this is less than 160m (100 times 1.6) the entire 145 will be made into one treatment length and the first 50% (72m) will be sampled.



Example 2. In this example rating lengths are 100m with a 10% sampling. The remaining length is 192m and as this is greater than 160m (100 times 1.6) the remaining length will be split in 2 with one length of 100m and the second of 92m.



The shaded sections are the inspection lengths.

The user is able to override the **Autorate** procedure and indicate that a treatment length should be 100% rated regardless of the sample percentage setting in the treatment header table. (Full_rating column in the treatment_length table)

```
PREVIOUS INSPECTION LENGTHS:   Use  Ignore  Exit
Use the previous Inspection Displacements where possible
----------------------- Rating Survey Header Information -----------------------

        Survey Number:   30
          Description: Annual Survey 1997
+-------------------------------------------------------+
|TREATMENT LENGTH RATINGS: ESC executes, DEL aborts    |
|                                                       |
|------------ Rating Inspection Parameters ------------|
|                                                       |
|             Minimum Treatment Length: 500 m          |
|                                                       |
|         Minimum Inspection Length:  10 m             |
|                                                       |
|                Percentage to rate:  10 %             |
|The rating interval any length between 100 and 500 met|
|res.                                                   |
+-------------------------------------------------------+



30 of 30 Rating Survey Headers found.
```

2.1.4 Event Codes

The event_code has been altered to include a new column *treatment_include* which is used to exclude certain event codes

Column Name	Type	Values	
treatment_include	char(1), upshift, not null default Include	I E	Include Exclude

Set the value to *Include* for all event codes except those in the table below:

Event code	Description
B	BRIDGE Abutment end (Both)
D	Detour route

G	GRID (e.g. Cattle Stop)
H	Speed humps
W	WORKS (Road works, marking, etc.)
X	Railway Crossing
Z	Raised zebra crossing

These codes are to be excluded from the Treatment Selection calculation. The user is able to maintain this column.

2.1.5 Equivalent Design Axles

EDAs have been redefined as Equivalent Single Axles (ESAs).

Column	Old Value	New Value
MCV	0.324	0.35
HCV I	0.496	0.83
HCV II	1.139	1.86

If the value in the ESA column is the old EDA value then it is updated with the equivalent ESA value and totals recalculated accordingly.

The loading classification Urban Industrial (UI) is no longer available in the Transfund Project Evaluation Manual and has been removed from the loading table. All existing rows with this classification are reclassified to Urban Other (UO).

2.2 RAMM FOR WINDOWS

RAMM for Windows exists as 2 separate programs as follows

• RAMM Administration	• Various setup and database management functions and Treatment Selection
• RAMM for Windows	• Front end for viewing RAMM data

2.2.1 Treatment Selection Algorithm Changes

The current Treatment Selection process has been modified in the following areas

- Treatment Descriptions and Reasons
- No cost for edge widenings is calculated
- The User Benefits calculation has been updated
- Altered TSF Seal Need Calculation Costs
- A user supplied value is used to identify outdated seals

Information from the following tables is now included

- HSD Roughness
- HSD Rutting & Shoving
- HSD Texture
- SCRIM

There is now a facility to save the results of each Treatment Selection run under separate *treatment Headers*. This will allow the user to run the program using a variety of decision factors and compare the results. Historical data from previous years can also be retained.

2.2.2 Treatment Descriptions and Reasons

The are currently seven different recommended treatments for TSF surfaces and eight for SAC. The recommended treatments remain (slightly reworded in some cases) and a new table treatment_reason expands on the recommended treatment giving the facts as to how the recommendation was arrived at. Treatment reasons are linked to treatments by treatment_id. There can be multiple reasons for a treatment. The full reason description will be stored in the treatment_reason table.

Code	Reason
1C	1st Coat requires 2nd
BE	Early Scabbing
BG	Scabbing
CH	Combined Cracking and Shoving
CR	Cracking
DL	Design Life Exceeded
EC	Significant B/C ratio
HV	Shoving
LM	Low Macrotexture
MC	High Maintenance Costs

PT	Potholes
RR	Resurfaced after Rating
SA	Skid Accidents
SC	Low Skid for site category
SF	Low Skid - continuous failed length
SL	Low Skid entire length
SM	Low Skid - maximum SCRIM deficiency

Before Treatment Selection can be run, treatment lengths must be defined. The algorithm recommends a treatment for each of these lengths.

2.3 TREATMENT LENGTHS

Treatment lengths are designed to give a better breakdown of the rating area. They will not replace carriageway sections, but will replace rating sections.

Treatment lengths for sealed pavements can be created either from the top_surface table using major seal lengths or from the carriageway table using the start and end displacements. Treatment lengths for unsealed pavements will be created directly from the carriageway table.

Condition rating will now occur on these treatment lengths that once created must be maintained. The Treatment Length Set-up procedure is located under the *RAMM Administration* program. It has been separated out because it is intended that this process will only run once

2.3.1 Treatment Length Set-up

Currently within RAMM there is a formula used in the SCRIM reporting module to create major seal lengths. This formula will be used as a base when creating Treatment Lengths.

The algorithm defines initial treatment lengths by finding the widest surfaces within each road but split these at changes in;

- ADT
- Number of lanes
- Pavement Type
- Pavement Use
- Urban/Rural flag

The treatment length algorithm applies the following parameters:

- Accept a minimum length, minimum width and maximum gap.
- Eliminate seal lengths shorter than the minimum length
- Eliminate seal lengths narrower than the minimum width
- The widest remaining seal is the major seal.
- Where adjacent major seals have the same surface number, join them into one provided the Urban/Rural, Pavement Type, Pavement Use and number of lanes are the same. These details come from the carr_way table. Joining is permitted to occur across carriageway boundaries but not across roadnames.
- If there are gaps between major seal lengths that are greater than the maximum gap, report these as an error.
- Otherwise, fill gaps by extending major seal lengths backward toward the origin except for the last seal length for a road, which is extended forward to the end of the road if necessary.

The resulting major seals are entered in the treatment length table with default values for all fields that are set from the surface major seal details.

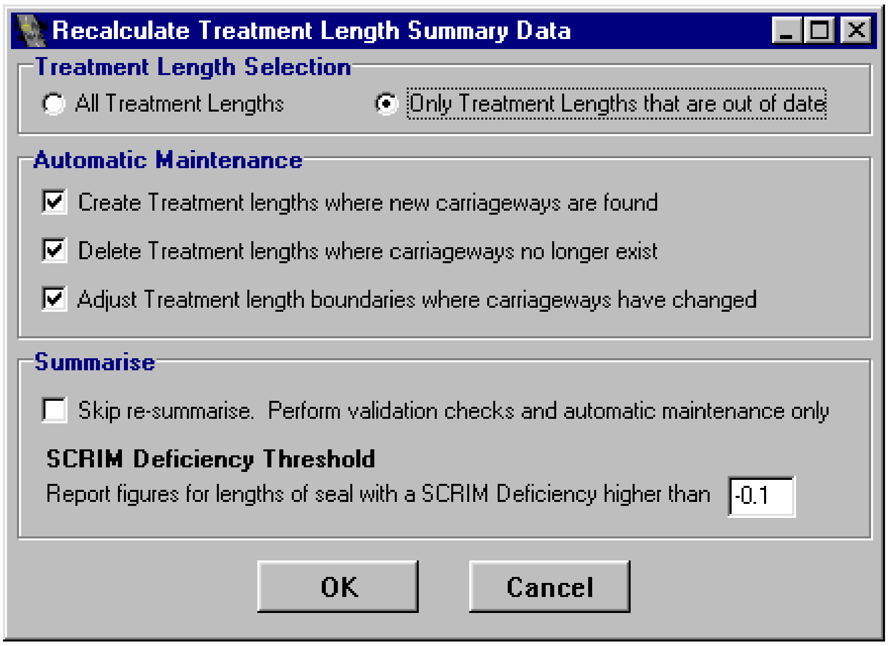
2.3.2 Re-summarise

The re-summarise process recalculates all summary columns for treatment lengths. It is run from the RAMM Admin program by selecting menu option Utilities/Re-summarise.

The re-summarise process performs two purposes it

- checks the start and end dimensions of the treatment lengths against the carriageway sections and, automatically maintains treatment lengths to match, if the user has selected Automatic Maintenance of treatment lengths.
- recalculates the RAMM summary data for treatment lengths.

2.3.3 Re-summarise Options Window



2.3.4 Automatic Maintenance and Validation

- For each road selected, various checks are performed testing whether treatment lengths need to be added, deleted or adjusted; then a validation report written of the results. For each validation error found, action is taken or suggested

- The length of the road (sum of the carriageway sections) is checked against the sum of the lengths for the treatment lengths. If they don't match then changes have been made to the carriageway table dimensions. These need to flow through to the treatment lengths.

- The start and end metres of the carriageway sections is checked against the treatment lengths which are adjusted to fit if required.

Where a new carriageway section has been added in the middle of a road where there was previously a gap, a new treatment length is created. It may be logical to join with ones on either side but that decision should be made by the user. To ensure the new treatment length is easily found by the user the treatment length name is set to "Auto generated". The cost set is defaulted to the same as the preceding or succeeding treatment length, or defaulted to "1"

2.3.5 Other Checks

For each treatment length:

- Verify that the treatment lengths do not overlap, if they do set *treat_length.valid* to Not OK on the overlapping lengths and write a line to the error report.
- Check the *pavement_type* and *cway_area* does not conflict with the pavement_type in any of the spanned carriageway sections, if so write a line to the error report.

2.3.6 Re-Summarise

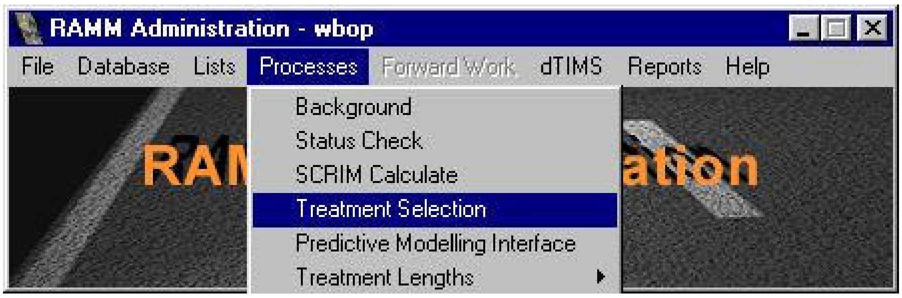
The Re-summarise Process groups data from the source carriageway rows within a treatment length to create a summary of data for the entire length as follows

- Update the top_surface details using the largest major seal in the treatment length
- Update *traffic count estimates* using the carr_way table values, adjusting them for the dimensions of the treatment length.
- Update *traffic loading* using the carr_way table values, use a weighted average based on length when many carriageways fall within the treatment length.
- Update the vehicle percentages, use the values from the loading table adjusting them for the dimensions of the treatment_length.
- If using HSD data then select roughness amounts from the HSD table otherwise use rough. Calculate the average, maximum, minimum, standard deviation. Enter the maximum roughness reading date into *naasra_ date*.
- Calculate m*aximum and average roughness* using the roughness data, checking the event code flag and excluding flagged event codes from the results.
- Summarise the rating results against the treatment_length using all rating where the treatment length lies completely or partly in the treatment length. The latest rows are summed for each inspection length. Pro rata the results where a rating length lies partly in the treatment length. The *insp_length*, *insp_area* and *insp_wheelpath* are recalculated from the rating rows.
- The *hsd_rutting* and *hsd_shoving* columns are summed (if available).

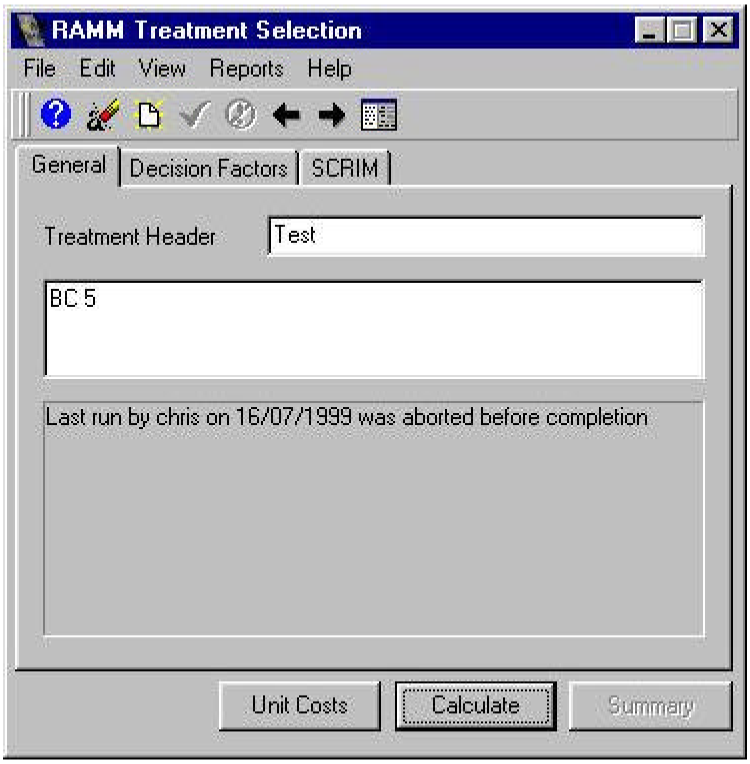
- layer, high speed, AIS accident and alligator cracking columns are updated as described in the treatment_length table data dictionary.
- The summary table of Skid Resistance information, is updated.

2.4 RAMM TREATMENT SELECTION

The user performs a treatment selection calculation using the Treatment Selection program. This is available from the RAMM Administration system by choosing PROCESSES-TREATMENT SELECTION.



The user is placed in the window below:



This windows allows the user to change the decision factors, change the unit costs, run the calculation, view, report or graph at a summary level and view or print treatments at a detailed level. This screen will display details from the latest Treatment Header.

The Calculate button performs the Treatment selection Calculation using the Treatment Lengths and the Decision Factors and Benefit Costs for the current Treatment Header

When the calculation has completed successfully, the summary table is populated using the results from the calculation summing the treatments for State Highways on Region and for Local Authorities on Area and Sub-area

The Summary button opens the Treatment Summary window and allows the user to view summary details for a selected header. The values initially displayed are for the header displayed in the main window. This window is also used for comparing results between different calculations by selection other headers.

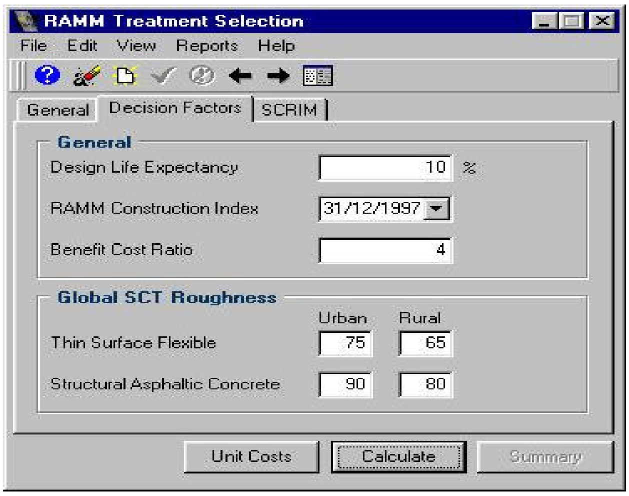
If the user creates a new Treatment Header, the details of the latest Treatment Header are used as defaults for the new Header.

2.4.1 Report Options

Warnings	This replaces the Treatment Selection Warning Messages reports sorted either by warning message or treatment length
Recommend Treatments	This replaces the Recommended Treatment reports sorted either by treatment type or treatment length.
Summary	This replaces the Summary of Treatment Selection report. Treatment Decision Factors

2.4.2 Decision Factors

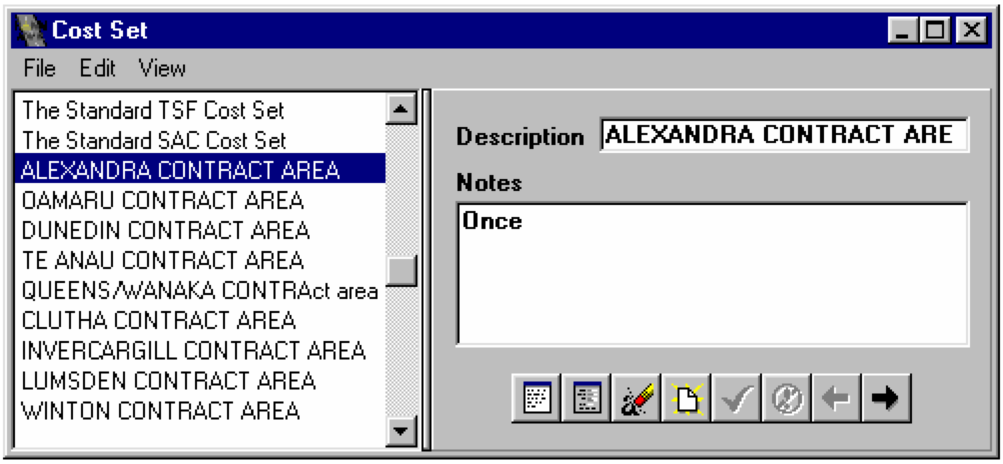
The Decision Factors screen displays the following screen where the user can change these values.



NOTES

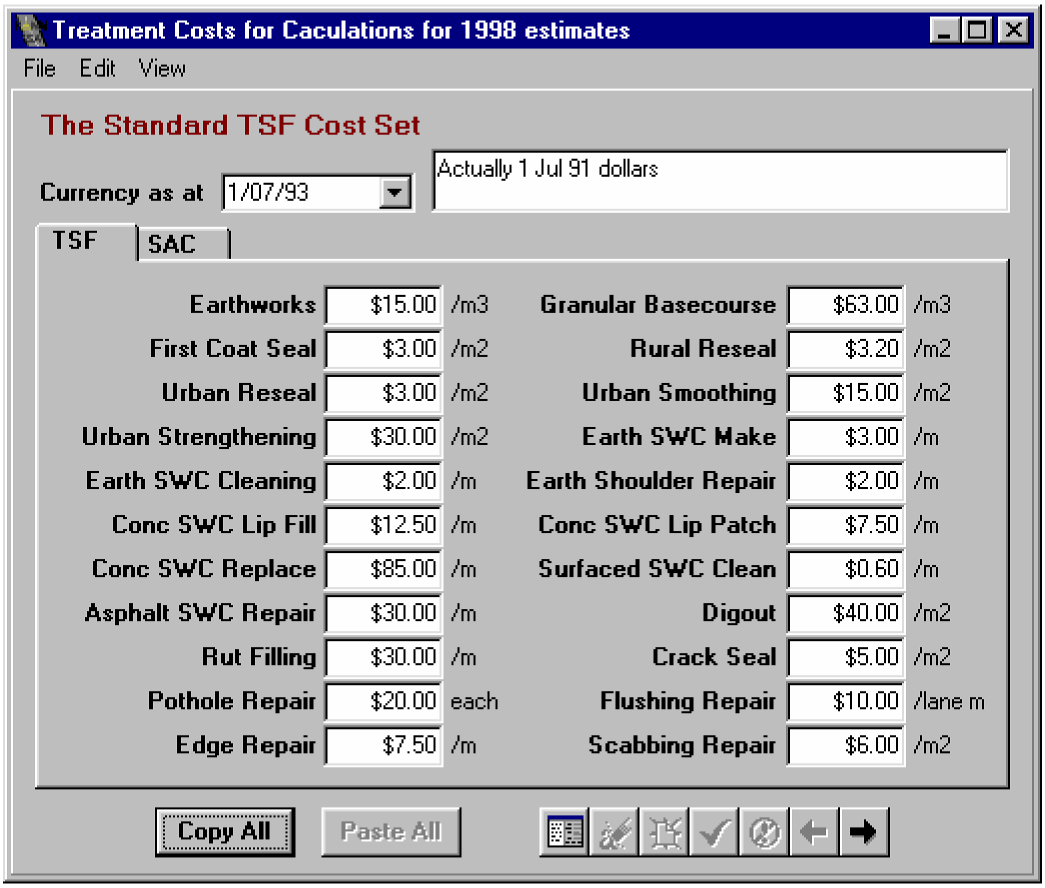
- The Benefit Cost Ratio should be between 0.1 and 100.0.
- The RCI date column has a Lookup to the list of current values.
- The Global SCT roughness values must be between 10 and 999.

2.4.3 Treatment Length Cost Sets



2.4.4 Treatment Costs

This window displays a list of the cost sets and their descriptions with a matching treatment_headers. Double-clicking on a cost set opens the right-hand side of the window to display details.



To alter the values the user can alter the existing amounts by typing in the new figures or using the Copy and Paste buttons which will copy the costs on display and paste them to a different cost set. All existing values will be overwritten with the copied values.

2.4.5 Treatment Summary

This window allows the user to access the summary results from a Treatment Selection Calculation and where required compare results against another Calculation run. There are two ways for the user to view the results either in the form of a report displayed on the screen or as a graph both can then be

Report: offer the options:

- No split
- Area
- Area/sub area
- State Highways Region

Graph: offer the options:

- Length
- Percentage of total network
- Costs

Either option selected will allow the user to select a treatment header to compare against.

Report

The heading block of the report displays the Decision Factors used from the treatment header. The portion of report below shows how the columns will look when results from two treatment selection runs are being compared. (The columns to the right are not shown in full0.

Recommended Treatment	Area		Length m	etc
General Maintenance	BURWOOD	01Mar1996	471,132	…
		01Apr1997	489,556	…
	FENDALTON	01Mar1996	309,105	…
		01Apr1997	376,899	…
	HAGLEY	01Mar1996	254,306	…
		01Apr1997	296,900	…
	Total	01Mar1996	1,034,543	…
		01Apr1997	1,163,355	…
Reseal (Flushed)	BURWOOD	01Mar1996	9,860	…
		01Apr1997	9,650	…
	FENDALTON	01Mar1996	7,014	…
		01Apr1997	7,522	…

Report Layout

Sample 1. No-split option

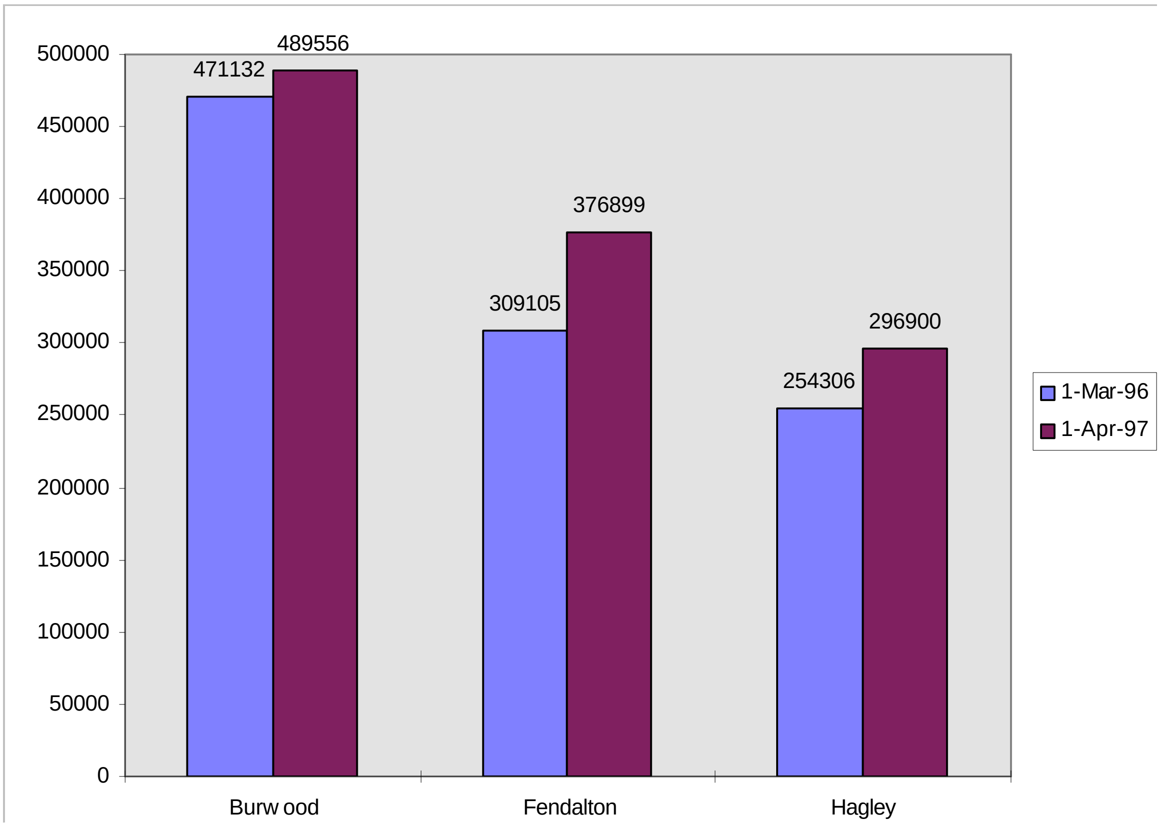
Recommended Treatment	Length m	% of Total	Treatment Cost $	Average $/m	Drainage Cost $	Average $/m	Maintenance Cost $	Average $/m
General Maintenance	1,163,355	75.71			503,153	.43	595,221	.51
Reseal (Flushed)	22,442	1.46			11,861	.53	8,118	.36
Reseal Next Time	107,630	7.00			57,277	.53	311,302	2.89
Reseal in Budget	97,961	6.37	2,107,624	21.51	172,005	1.76	94,622	.97
Resurfaced After Rating	1,810	.12						
Smoothing Overlay	143,460	9.34	11,069,399	77.16	247,019	1.72	16,285	.11
Total	1,536,658	15,311,939						

Sample 2. Area option

Recommended Treatment	Area	Length m	% of Total	Treatment Cost $	Average $/m	Drainage Cost $	Average $/m	Maintenance Cost $	Average $/m
General Maintenance	BURWOOD	489,556	31.85			205,772	.42	235,660	.49
	FENDALTON	376,899	24.53			178,995	.47	198,500	.58
	HAGLEY	296,900	19.33			118,386	.39	161,061	.53
	Total	1,163,355	75.71			503,153	.43	595,221	.54
Reseal (Flushed)	BURWOOD	9,650	.63			4,689	.48	3,998	.41
	FENDALTON	7,522	.49			3,980	.53	2,160	.29
	HAGLEY	5,270	.34			3,192	.61	1,953	.36
	Total	22.442	1.46			11,861	.53	8,118	.36

Graph

The user is able to display the summary information as a graph, depending on the option clicked the data will be displayed either as lengths (m), percentages of the total network, or as costs. The user will also be able to graphically represent comparison data, as shown in the graph below results from different treatment selection headers can be compared. The example below compares the lengths recommended for General Maintenance between two surveys 1Mar1996 and 1Apr1997 by Area.



3. OUTLINE OF PROCEDURES

3.1 OUTLINE OF TREATMENT SELECTION PROCEDURE FOR THIN SURFACED FLEXIBLE PAVEMENTS

NOTE: The procedures described here are carried out by the computer program and are documented in greater detail in section2.

Step 1 ***Compute Area Treatment Costs***

The cost of any necessary preliminary maintenance and the cost of drainage repairs required before each of the four possible treatment types is calculated.

The four treatments are

- continued general maintenance
- resurfacing
- smoothing shape correction treatment (SCT)
- strengthening SCT

The preliminary repair costs are approximately estimated from the deficiencies revealed in the pavement rating.

Step 2 ***Assess the Need for Resurfacing***

On the basis of surface condition ratings, assess the need for resurfacing the pavement, assuming at this stage that shape correction is not an option. Pavements are assessed as requiring a resurface in the budget year, the year following, or at a later date. If the seal does not appear to be in the first two categories, it is assumed that the seal will probably last the normal life for that type of seal at that particular traffic level.

Step 3 ***Estimate Resurfacing Cycle Times***

Estimate the likely length of the resurfacing cycle following each of the four area treatment choices listed in step 1 above.

If the existing pavement distress is very high, a check is made to see if some of the distress could have economically been averted by shortening the resurfacing cycle by one or two years. If so the future resurfacing cycle is adjusted accordingly.

Generally the life of future surfacing is estimated from the performance of the current surfacing. In the case of premature failure of the current surfacing (less than 70% of normal life span for the traffic level), the condition of the pavement drainage is checked. If the drainage is seriously deficient, the assumption is made that drainage improvements will partially restore the pavement performance in future.

The type of surface deficiencies are also checked and if these are not pavement structure related, e.g. scabbing failure, then the pavement is assumed to be capable of supporting the future surfacing for a normal life span.
If the drainage is not deficient and the distress types do not indicate a design or construction fault the pavement is assumed to be incapable of supporting future surfacing for normal life spans. Consequently, the pavement will have a short resurfacing cycle and high maintenance costs, which will significantly increase the present value of future maintenance and re surfacing.

Step 4 ***Compute the Present Value of Future Maintenance***

Compute the discounted present value (PV) of future reseals and general maintenance activities, for each of the four area treatment options.

The general maintenance costs are not estimated on any engineering theoretical basis but are arbitrarily assumed to occur mainly in the years immediately before each resurfacing, building up to a peak in each resurfacing year. Hence the general maintenance present value (PV) is a function of the length of the resurfacing cycle only.

In view of the usually low significance of this item and the great difficulty in predicting these costs, this procedure is thought to yield estimates of a similar order and accuracy to those made by experienced engineering staff. The discount rate used is 10%.

Step 5 ***Selection of SCT Option Strengthening and smoothing***

SCT's are assumed to provide a similar level of road roughness after treatment. Thus, the option with the lowest total treatment cost plus discounted maintenance costs is the preferred SCT option.

Step 6 ***Selection of Preferred Treatment Option***

Decide between the preferred SCT option and the non-SCT alternative already selected in Step (2).

It is assumed for the sake of simplicity that if the non-SCT alternative is chosen, the present level of road roughness will be maintained. It is assumed that a user supplied target roughness level for SCT's is to be attained by the preferred SCT option.

If the total treatment cost plus discounted maintenance cost of the SCT option is less than that of the non-SCT alternative, the SCT option is automatically given a high priority. In other cases the Benefit/Cost ratio of the SCT is computed.

Road user benefits from reduced roughness levels after SCT are computed on the same basis as Table A2. 16 of the National Roads Board Economic Appraisal Manual (4). This table is based on the World Bank Brazil Study

Equations Calibrated to NZ Conditions (5). If the Benefit/Cost ratio exceeds a user-supplied cut off value, the preferred SCT option is selected. The Benefit/Cost value is used as a priority-ranking indicator for the list of SCT treatments.

Step 7 ***Resurfacing Priority Indicator***

If the non-SCT option is selected and if this option is for a surfacing in the budget year, a resurfacing priority indicator is computed.

The additional cost of maintaining the road in good condition for an additional year is estimated, by assuming that most of the defects shown in the rating will require correction in the budget year and that a proportion of these will recur and require correction before resurfacing the following year.

This "delay cost" is divided by the cost of the resurfacing to give the First Year Rate of Return which is used as the priority ranking indicator for the resurfacing list.

Step 8 ***Seal Widening Need***

Consider the need for seal widening. (For road maintenance as opposed to road safety reasons). The annual rate of deterioration is calculated by dividing the amount of edge break plus past edge break repairs by the surfacing age. (This is clearly an approximation only as multiple repairs at the same location cannot be accounted for).

If the annual rate of deterioration is greater than 5% then the road is reported for a possible widening out to traffic volume dependent. The algorithm no longer calculates cost so project level economic analysis will still be required to determine the need and priority of seal widening treatments

Step 9 ***Drainage Maintenance Needs***

List drainage maintenance costs and requirements. For resurfacing or SCT all defects are assumed to require rectification.

This includes replacement or construction of drainage where the current surface water channels are unsatisfactory. For the maintenance-only option, only cleaning out of any blocked drainage or in the case of surfaced channels (e. g. Kerb and channel) the repair of any broken surface or filling of any low pavement at the channel lip, is costed as there are no structural indicators for the need for drainage. As this may only be because the surfacing of the pavement is relatively new, engineering judgement is necessary to interpret this aspect of the maintenance program. For this reason all drainage problems detected are also reported.

3.2 OUTLINE OF TREATMENT SELECTION PROCEDURE FOR STRUCTURAL ASPHALTIC SURFACINGS

NOTE	Unlike thin surfaced pavements, it is not really possible to make an adequately accurate prediction of future structural pavement performance based only on the information used by this system, namely, surfacing type, thickness, age and current condition. Furthermore, because such pavements are very rare in New Zealand, empirical experience is limited and design and quality is far more variable than for thin surfacing. Bearing this is mind, the output of this algorithm should be taken as a reasonable guide to the types of treatments to be considered, but choice of treatment will require manual checking. Because such pavements are rare this will not usually be a major task inmost roading authorities.

Step 1 Compute the treatment costs and the cost of any preliminary general maintenance before treatment for each of the seven possible options.
These are as follows:

- Reconstruction
- Milling and replacing unstable surface mix
- Thin overlay
- Thin overlay over a stress absorbing membrane interlayer (SAMI)
- Stress absorbing membrane reseal (SAM)
- Conventional reseal
- Continued general maintenance

The general maintenance repair costs are approximately estimated from the deficiencies reported in the pavement rating.

Step 2 On the basis of surface condition ratings, and assuming that an overlay is not an option, assess on technical grounds the best treatment from among the options of:

- mill and replace unstable mix
- SAM reseal
- conventional reseal
- continued general maintenance

In the case of reseals, assign a high or low priority, depending on distress level.

Step 3 Assuming that the surface roughness warrants a smoothing treatment, assess whether reconstruction, mill and replace unstable mix, a thin overlay or a thin overlay over a SAMI is the best option technically, based on the surface condition rating.

Step 4 For the options chosen in Steps 2 and 3 as the best depending on whether or not a smoothing treatment is warranted, estimate the likely difference in future maintenance costs between the two options.

It is assumed that there will be no significant cost differences arising from future general maintenance. Differences arising from differing requirements for major rehabilitation or reconstruction in the future are not possible to predict from the available information and are ignored. Providing that the pavement is sound, or will be, after the chosen treatments, this assumption will be reasonably acceptable. In other cases, afield engineering check using all available data will be necessary. All area treatment options are assumed to have very similar resurfacing costs and are assigned a zero relative future cost.

If the non-smoothing option is for normal general maintenance only, the future resurfacing cycles will be likely to fall due at an earlier date than for the smoothing option. The expected date is computed from the estimated Life Cycle for the surfacing, obtained from inventory. The relative present value cost of the earlier resurfacing dates is assumed to be the sole cause of differences in future costs.

Step 5 Decide between the best non-overlay option and the best overlay option, as selected in Steps 2 and 3. The simplifying assumption is made that existing roughness levels will be maintained if the non-overlay option is used, unless reconstruction is necessary. It is assumed that a user supplied target roughness level is attained by any option involving reconstruction, milling or overlay.

If the total treatment cost plus discounted maintenance cost of the best overlay option is less than that of the best non-overlay alternative, the overlay option is automatically given a high priority. In other cases, the Benefit/Cost ratio of the overlay is computed in the same manner as in Step 6 of the thin surfaced pavement procedure.

If the Benefit/Cost ratio exceeds the user supplied cut-off value, the overlay option is selected. The Benefit/Cost value is used to rank the priority of the overlays in the same list as the overlays selected for thin surfaced pavements.

NOTE Although poor drainage may have as significant an effect on pavement performance for thick structural pavements as for thin surfaced pavements, the effects are less reversible by subsequent improvements to the drainage. Hence defective drainage is identified as requiring rectification but no improvements to future surfacing life is assumed, rather it is considered that the drainage improvements will merely halt further deterioration.

3.3 DATA REQUIREMENTS OF THE TREATMENT SELECTION PROGRAM

The treatment selection program requires certain essential data before it can be operated. These data fall into the following three general categories.

A. Data from the RAMM database.

The tables accessed are as follows:

I. Road Names
II. Road Sections (Treatment Lengths)
III. Traffic volume
IV. Shoulders and Surface Water Channels
V. Carriageway Top Surfacing
VI. Carriageway Roughness
VII. Carriageway Rating
VIII. HSD Roughness
IX. HSD Rutting & Shoving
X. HSD Texture
XI. SCRIM

B. Decision Factors that must be entered by the user.

These are as follows:

I. Minimum Benefit/Cost ratio acceptable for SCT projects.
II. Target maximum roughness level achieved after SCT.
III. Seal life expectancy

C. Unit costs for maintenance and rehabilitation work with the construction cost index pertaining to these costs.

A full description for (A) above is found in section 2 and for(B) and (C) is contained in the Users Guide for Maintenance Treatment Selection.

3.4 SEQUENCE OF OPERATIONS

The treatment selection program uses a large number of standard assumptions in order to simplify the data input and computation. The system is interactive and designed to allow considerable flexibility in the way that the engineer can over-ride these standard assumptions for particular cases where they may not be relevant. It is envisaged that the normal mode of operations would be to set and then to run the program right through to produce a list of Treatment lengths and the treatment selected for each. Engineering investigation and judgement would then be applied to the priority areas. This may show up a need to modify some of the inputs or intermediate calculations in the program for particular locations. After these modifications have been made the program may then be re-run in whole or in part to produce a list of sections of road which require specific treatments along with an estimate of costs.

A detailed description of how the user operates the program to carry out the following operations is contained in the Users Guide for Maintenance Treatment Selection, which is part of the RAMM manual.

The sequence of operations is as follows, (see figure 1).

Step 1 Inventory and survey data must be loaded into tables for all rating sections where Treatment Selection will be run. All sections must have an AADT *Estimate* entered

Step 2 Standard unit cost sets must be completed and each rating section linked to a unit cost set.

Step 3 A valid RCI index must be available for inflation adjustment purposes

Step 4 The Update Table program should be run to ensure that all “Latest” flags have been set, and all data is current.

Step 5 All pre-treatment reports should be run and any erroneous or missing data corrected.

Step 6 Treatment lengths must be defined using the RAMM for Windows Administration program

Step 7 Summary data is recalculated for each treatment length.

Step 8 Decision factors, Target B/C, target roughness values and RCI date must be entered. (These are applied to the entire network)

Step 9 Run the Calculate Treatment option.

Step 10 Treatment reports should be run and examined paying particular attention to warning messages.

Step 11 The user may modify the input or intermediate data and this may be done as often as desired.

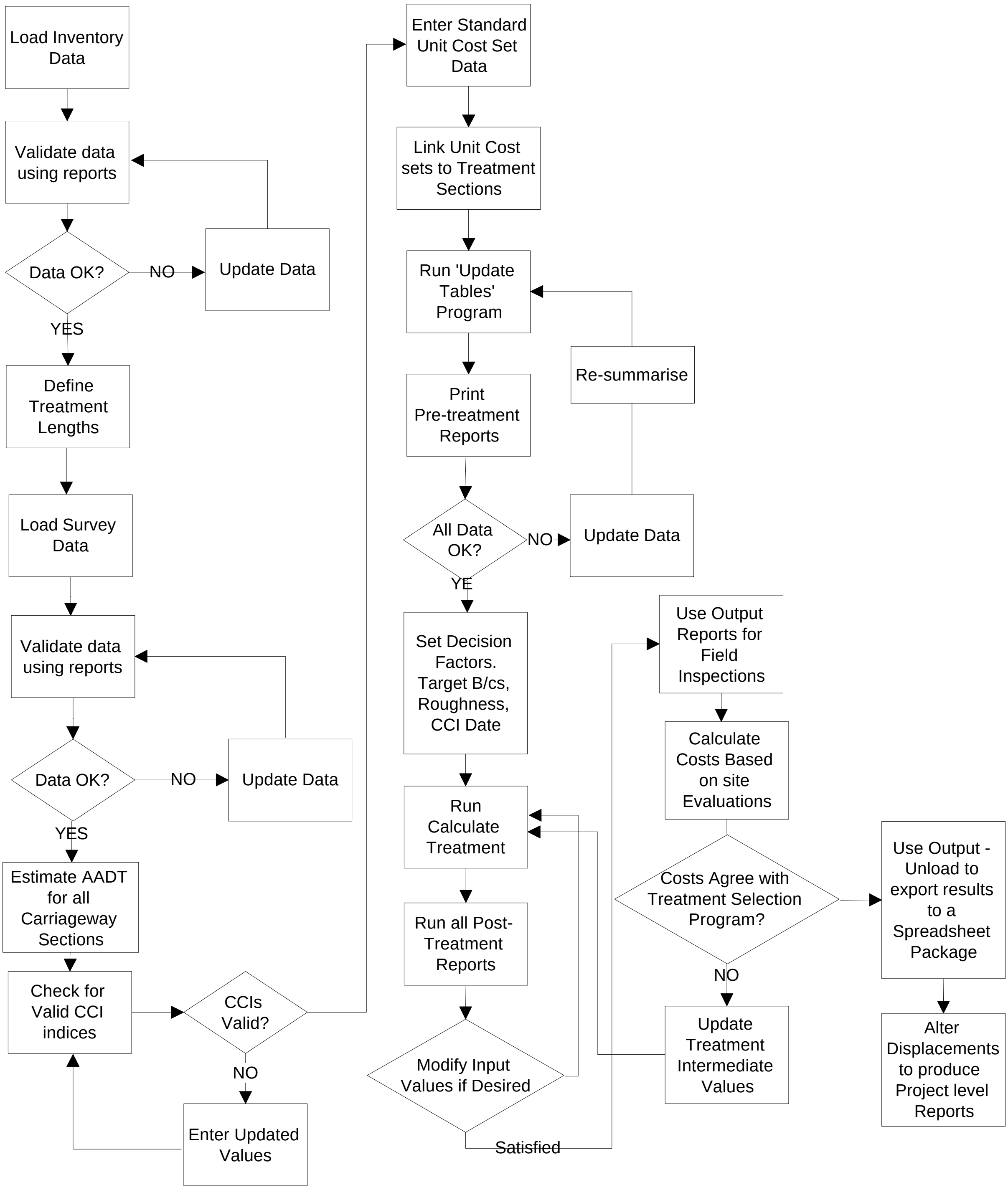
Step 12 The output reports for treatment by rating section should be used as a basis for field inspections to determine treatments based on engineering judgement and local knowledge. Results of these field exercises should be used to update the calculated treatment costs for each section effected

Step 13 The final output lists may be passed to a spreadsheet package for further processing..

The treatment sections are sorted into lists of particular types of treatment required, in priority order where relevant. The costs in each treatment category are totalled and the lists and totals are then reported.

The purpose of Step 13 is to allow the output from the selection program to be used as the starting point for the final maintenance budget preparation process. A number of factors may operate to further modify the lists produced by the selection system, even when individual local values have been edited in the input. Some of the road sections reported for maintenance work may already be programmed for the current season and these will need to be removed, thus leaving a nett amount of maintenance work required for the following season. Some of the current seasons programmed work may also be deferred until the following season to allow work detected from the most recent rating to be done if it requires urgent action. Finally, the construction and road safety programmes will independently throw up needs for works that will impinge on the maintenance programme.

3.5 SEQUENCE OF OPERATIONS (FLOW CHART)



4. TECHNICAL NOTES

This section provides the detailed technical background to the outline of the treatment selection procedures given in Section1.These notes describe the functions of the program and are not intended to be a user guide. The Treatment Selection Users Guide is available as part of the RAMM manual to give guidance on what tasks are required by the user to operate the program.

4.1 INPUT VARIABLES FROM THE INVENTORY

Road Names Table:

- Road Name and Number

Road Sections (Carriageway) Table:

- Start and Finish Displacements of the Road Sections.
- Maintenance Category
- Urban/Rural
- Average Carriageway Width

Traffic Table:

- Most recent AADT (where Status = E)

Shoulders and Surface Water Channels Tables:

To enable the program to perform cost computations from the drainage condition survey data, the program must determine the most significant type of surfaced surface water channel, (SWC) if any, that there is on each side of the carriageway.

Earth SWC's are rated as such and as they have similar maintenance cost characteristics there is no need to access the SHSWC table to determine what type of channels they are. In the case of surfaced SWC's the SHSWC table is checked and the type is selected from the row with the most recent date that exceeds 50% of the greatest length of surfaced SWC that has been recorded. From the type code it is determined if the channel is either a concrete channel or an asphalt channel.

The information extracted from the SHSWC table is therefore as follows:

- **Shoulder Width (L & R)** Average width of L.H. Shoulder plus average width of R.H shoulder in the rating section.
- **Concrete SWC Length LHS** Total length of concrete surfaced SWC on L.H.S. of the rating section, if a concrete channel is the most recent type recorded and is > 50% of the total length of surfaced SWC.

- **Concrete SWC Length RHS** Total length of concrete surfaced SWC on R.H.S. of rating section, if a concrete channel is the most recent type recorded and is > 50% of the total length of surfaced SWC.
- **Asphalt SWC Length LHS** Total length of asphalt surfaced SWC on L.H.S. of rating section, if an asphalt channel is the most recent type recorded and is > 50% of the total length of surfaced SWC
- **Asphalt SWC Length RHS** Total length of asphalt surfaced SWC on R.H.S. of rating section, if an asphalt channel is the most recent type recorded and is > 50% of the total length of surfaced SWC.

Top Surfacing Table:

The following data is extracted for the most significant area of surfacing in the inspection length.

- **Surfacing Type** Surfacing Type
- **Surfacing Aggregate** Aggregate grade or top size.
- **Surfacing Current Age** Computed from the date of construction of surfacing.
- **Surfacing Life Cycle** User defined, expected life cycle of surfacing.

Roughness Table:

- **Roughness values** The average and maximum NASSRA roughness values for the treatment length.

Rating Table:

- **Condition Survey Data**
    - The row with the most recent
    - date for each rating section is
    - extracted from the rating table to
    - obtain the pavement and drainage
    - condition survey data.
- **Carriageway Length** Carriageway length in the treatment length**.**
- **Number of Lanes** The number of traffic lanes in the inspection section**.**

- **Inspection Length** — The length of pavement inspected in detail within the rating section. (Either 50. 0m or the entire rating section)

4.2 TREATMENT SELECTION PROCEDURE FOR THIN SURFACED FLEXIBLE PAVEMENTS

4.2.1 Computation of Costs

4.2.1.1 Compute Construction Costs for Area Treatments

(a) Continued general maintenance

Treatment cost is zero.

(b) Reseals

The program assumes that resurfacing will be chip seals and all references refer to this type of surfacing.

Reseal costs = Carriageway Length * Carriageway Width * Unit Cost [Reseal]

(Urban or rural rate depending upon the value of the Urban/Rural Indicator)

(c) Smoothing SCT

Urban:

Urban smoothing treatments can include rip and reshape, thin asphaltic concrete overlay, friction course or open graded emulsion mix (OGEM) overlays. Granular overlays are not usually practical due to limitations imposed on levels by kerb and channel. All of these treatments have a similar order of cost. The value entered as the Unit Cost for Urban Smoothing should refer to the most economical treatment for the particular area of application.

Smoothing Cost =

Carriageway Length * Carriageway Width * Unit Cost Smoothing Overlay (Urban)

Rural:

Rural smoothing treatments can include an open graded asphaltic concrete overlay (e. g. Friction course or OGEM), 70mm granular over high spots or a rip and reshape. The treatment which would give an average cost is usually a 70mm granular overlay over high spots, which requires an average overlay depth of 100mm,plus first and second coat seals. The width of the overlay is the seal (carriageway width) plus the LHS & RHS shoulder widths plus an allowance of 1. 5m each side to place metal

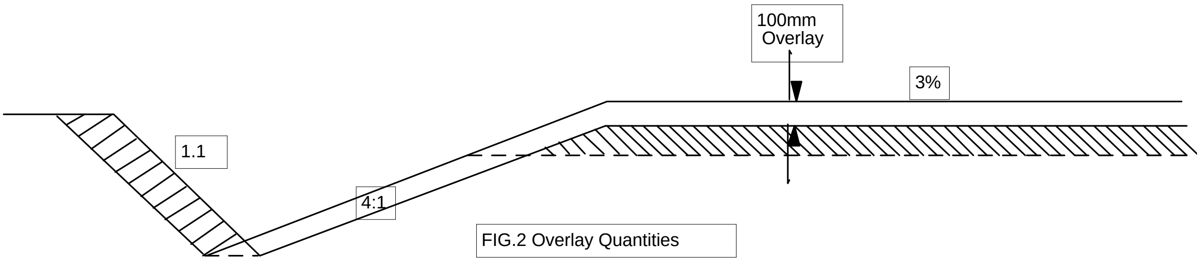


FIG.2 Overlay Quantities

down the feather edge.

Overlay Cost =

Unit Cost [Granular basecourse (in place)] * 0. 1 * (Carriageway Width + Shoulder Width (L & R) + 3. 0m) * Carriageway Length

The second coat seal cost is discounted 10% to allow for the fact that it is usually applied two years after construction and is treated as part of the future maintenance cost stream. All discounting in the program is at the rate of 10% and TABLE A1.1 from RRU Technical Recommendation No. 9 is included to show Present worth factors.

Cost to Seal Overlay =

Carriageway Length * Carriageway Width * Unit Cost [First Coat]

PV Future Maintenance will include an allowance for the second coat seal.

Cost for Second Coat Seal =

Carriageway Length * Carriageway Width * 0.826 * Unit cost [Rural Reseal])

There is also a cost in widening the surface water channels out to allow material to be placed down to the feather edges to support the overlay. The earthworks quantity to achieve this is assumed to average about 0. 35 cubic metres per lineal metre of the rating section length.

Cost of Drainage Relocation =

0. 35 * Carriageway Length * Unit Cost [Earthworks]

The total smoothing overlay cost is the sum of the above items.

0Strengthening Overlay Costs

Urban:

These treatments include stabilising the existing material in the basecourse, thick asphaltic concrete overlay, or replacement of the basecourse material. The unit rate for this type of work is expressed simply as a cost per square metre.

Strengthening Cost =

Carriageway Length * Carriageway Width * Unit Cost [Urban Strengthening Overlay]

EXTRACT FROM TRANSFUND PROJECT VALUATION MANUAL
TR 9 TABLE A1.1

Present Worth Factors			
Year	**Single Payment SPPWF(1)**	**Uniform Series USPWF(2)**	**Arithmetic Growth ACPWF(2)**
0	1		
1	0.9091	0.954	0.469
2	0.8264	1.821	1.763
3	0.7513	2.609	3.728
4	0.6830	3.326	6.230
5	0.6209	3.977	9.157
6	0.5645	4.570	12.409
7	0.5132	5.108	15.905
8	0.4665	5.597	19.572
9	0.4241	6.042	23.350
10	0.3855	6.447	27.190
11	0.3505	6.815	31.048
12	0.3186	7.149	34.890
13	0.2897	7.453	38.687
14	0.2633	7.729	42.415
15	0.2394	7.980	46.054
16	0.2176	8.209	49.592
17	0.1978	8.416	53.015
18	0.1799	8.605	56.316
19	0.1635	8.777	59.488
20	0.1486	8.932	62.529
21	0.1351	9.074	65.434
22	0.1228	9.203	68.204
23	0.1117	9.320	70.840
24	0.1015	9.427	73.342
25	0.0923	9.524	75.714
26	0.0839	9.612	77.958
27	0.0763	9.692	80.078
28	0.0693	9.765	82.078
29	0.0630	9.831	83.963
30	0.0573	9.891	85.736

(1) Assume cost or benefit occurs at end of each year

(2) Assume costs or benefits for year occur continuously throughout the year and are continuously compounded.

Rural:

These treatments include lime stabilising the existing material in the basecourse with or without new granular material being added, thick granular or asphaltic concrete overlay. The asphaltic concrete overlay is very seldom economically viable in the rural situation and therefore a 150mm granular overlay is taken as being typical in these situations. An allowance of 1.75m extra width of overlay each side is required to place metal down the feather edge.

Overlay Cost =

Unit Cost [Granular basecourse (in place)] * 0.15 * (Carriageway Width + Shoulder Width (L & R) + 3.5m) * Carriageway Length

Cost to seal overlay with first and second coat seals is the same as for a rural smoothing overlay.

The amount of earthworks required to relocate the surface water channels clear of the widened formation is assumed to average about 0. 55 cubic metres per lineal metre of the rating section length.

Cost of Drainage Relocation =
0.55 * Carriageway Length * Unit Cost [Earthworks]

Total strengthening cost is the sum of the above three factors.

4.2.1.2 Compute Pavement General Maintenance Costs

Regardless of the type of area maintenance treatment selected, the necessary preliminary on-pavement general maintenance is made up by combining the cost of repairing the following pavement defects:

(a) Rutting repair cost =

Metres of wheelpath rutting in inspection length * Carriageway Length/Inspection Length * Unit Cost [Rut Filling]

(b) Shoving repair cost =
Metres of wheelpath shoving in the inspection length * Carriageway Length/Inspection Length * Unit Cost [Digouts]

NOTE: The rating inspectors are instructed not to rate any other defect found in an area of shoving.

(c) Alligator Cracking Repair Cost =
Metres of wheelpath alligator cracking in the inspection length * Carriageway Length/Inspection Length * Unit Cost [Crack Sealing]

(d) Pothole repair cost =
Number of potholes in the inspection length * Carriageway Length/Inspection Length * Unit Cost [Each pothole repair]

(e) Scabbing repair cost =
Area of scabbing in the inspection length * Carriageway Length/Inspection Length * Unit Cost [Scabbing repair]

In the case where a reseal is to be programmed, it is assumed that the scabbing will not require correction unless the scabbing is so bad that more than 10% of the sealed carriageway is affected. Even then, only the worst 20% of that scabbing is likely to require repair before sealing.

(f) Flushing
If the surface is flushed it is assumed that the pavement will require burning, or an equivalent treatment prior to resurfacing. The minimum width that can practically be burnt is one lane width. Therefore the length of wheelpath flushing recorded in the rating is divided by 2 and then multiplied by the unit cost for flushing because it is assumed that the flushing will occur in the parallel wheelpaths of the same lane. This will not always be true but should be a reasonable approximation of the situation in most cases.

Flushing repair cost =
Metres of wheelpath flushing in inspection length * treatment length/(inspection length * 2) * [Repair flushed pavement]

(g) Edge Break repair cost =
Length of edge break on both sides of the inspection length * Carriageway Length/Inspection Length * Unit Cost [Edge break repair]

(h)Longitudinal, Transverse and Joint Crack repair cost =
(Length of Longitudinal and Transverse cracks + length of Joint cracks in the inspection length) * Carriageway Length/Inspection Length * Unit Cost [Crack sealing] * 0.67

Note: The unit cost for sealing L & T and Joint cracks in a thin surfaced pavement is considered to be approximately two thirds of the square metre cost for crack sealing area type cracking.

4.2.1.3 Compute General Maintenance Costs Prior To Each Area Treatment

The total preliminary general pavement maintenance costs for each of the four possible area treatment types is obtained by combining the above components:

(a) Continued General Maintenance:

Preliminary General Maintenance Cost =
Shoving Repair Cost
+ Alligator Cracking Repair Cost
+ Repair of all Scabbing Cost
+ Pothole Repair Cost
+ Edgebreak Repair Cost
+ Rutting Repair Cost
+ Joint and L & T Repair Cost

(b) Reseals:

Preliminary General Maintenance Cost =
Rutting Repair Cost
+ Shoving
+ Pothole Repair
+ Partial Scabbing Repair Cost
+ Edgebreak Repair Cost
+ Flushing Repair Cost

(c) Smoothing Overlay:

It is assumed that since the overlay is relatively thin, all unstable areas of pavement will be repaired.

Preliminary General Maintenance Cost = Shoving Repair Cost

(d) Strengthening Overlay:

The strengthening treatment will automatically correct all pavement defects. Hence the preliminary general maintenance cost is zero.

4.2.1.4 Compute Drainage Costs for Surfaced Surface Water Channels

Note: (1) Shoulders and surface water channels are rated for the full length of the rating section, not just the inspection length.

(2) The surfaced surface water channels are divided into the category of concrete or asphaltic because repair requirements and costs are quite different for each.

The following codes for surface water channels define which type fall into each category.

Asphaltic	
DS	Dished Channel (sealed)
DA	Dished Channel (asphalt)

Concrete	
KCS	Kerb & Channel (stone)
KCC	Kerb & Channel (concrete)
KDC	Kerb & Dished Channel (concrete)
MKCC	Mountable Kerb & Channel (concrete)
SLTC	Slot Channel (concrete)
KC	Kerb Only (concrete)
KS	Kerb Only (stone)
DC	Dished Channel (concrete)
DP	Dished Channel (half pipe)

(a) Broken Channel Repair

If channel is "concrete" THEN
Broken Channel Cost =
Length of broken channel * 1. 2 * unit cost [Concrete SWC replace]

Note: An allowance of 20% is made to tie the replacement channel into the existing channel levels.

If channel is "asphaltic" THEN
Broken Channel Cost =
Length of broken channel * unit cost [Asphaltic SWC repair/replace]

(b) Uphill Channel Repair

If channel is "concrete" THEN
Uphill Channel Cost =
Length uphill channel * 1. 2 * unit cost [Concrete SWC replace]

Note: An allowance of 20% is made to tie the replacement channel into the existing channel levels.

If channel is "asphaltic" THEN
Uphill Channel Cost =
Length uphill channel * unit cost [Asphaltic SWC repair/replace]

(c) Channel With High Lip

The cost of repairing this fault is not affected by the type of channel.
High Lip Channel cost =
Length of high lip * unit cost [Surfaced SWC, fill depressions at channel lip]

(d) Broken Pavement Surface at Channel Lip

The cost of repairing this fault is not affected by the type of channel
Broken Surface cost =
Length of broken surface * unit cost [Surfaced SWC, patch pavement at channel lip]

(e) Blocked Channel

The cost of repairing this fault is not affected by the type of channel.
Blocked channel cost =
Length of blocked channel * unit cost [Surfaced SWC, clean]

4.2.1.5 Compute Drainage Costs For Earth Surface Water Channels

(a) Inadequate Channel
Inadequate channel cost =
Length inadequate * unit cost [Earth SWC, make]

(b) Blocked Channel

Blocked channel cost =
Length blocked * unit cost [Earth SWC, clean]

(c) Length of Ineffective Shoulder

Ineffective shoulder cost =
Length ineffective * unit cost [Earth shoulder chipping]

4.2.1.6 Compute Drainage Costs for No Area Treatment

It is likely that the amount of drainage requiring upgrading or restoration will be more than can be accommodated in one budget year. For this reason it is considered that in many cases, a general tidy-up (partial fix) will suffice for areas receiving general maintenance only. Hence a drainage partial fix cost is computed for the no-area-treatment option.

For surfaced (concrete and asphalt) channels the partial fix cost is as follows:

Blocked channel cost
+ High channel lip cost
+ Broken pavement surface at channel lip cost
+ Broken channel cost for asphaltic channels
+ Uphill channel cost for asphaltic channels

For earth channels the partial fix cost is as follows:

Blocked channel cost
+ Length of inadequate channel * [Earth SWC, clean]
+ Ineffective shoulder cost

Note: This assumes inadequate channel is also very likely to be blocked.

4.2.1.7 Compute Drainage Costs for a Resurfacing Treatment

It is considered that complete restoration (fix all) is a necessity for any section being resealed. The cost of fixing all the drainage problems is as follows: For surfaced (concrete and asphalt) channels the fix all cost is as follows:

Blocked channel cost
+ High channel lip cost
+ Broken pavement surface at channel lip cost
+ Broken channel cost for asphaltic & concrete channels
+ Uphill channel cost for asphaltic & concrete channels

For earth channels the fix all cost is as follows:

Blocked channel cost
+ Inadequate channel cost + Ineffective shoulder cost

4.2.1.8 Compute Drainage Costs for a Shape Correction Treatment

For the case of surfaced (concrete and asphalt) SWCs some of the defects will be fixed by the overlay itself. Hence, the drainage cost for the strengthening or smoothing options where there are surfaced SWCs is as follows:

Blocked channel cost
+ Broken channel cost for asphaltic & concrete channels
+ Uphill channel cost for asphaltic & concrete channels

For the case of earth surface water channels the cost of remaking the channels is built into the construction cost because of the need to widen the formation to accommodate the extra width required for the overlay. Hence, the drainage cost for the strengthening or smoothing options where there are earth SWCs is nil.

4.3 Technical Analysis of Rating And Surfacing Data

4.3.1 Check for Resurfacing Need

Originally the Treatment Selection algorithm grouped tests together and if any one test failed then a specific treatment was recommended. Tests are now separate so that a reason can be defined for each treatment. When an individual test fails, a treatment is recommended. It is not necessary to check for another recommended treatment.

4.3.2 Check for 2nd Coat Seal Treatment.

If treatment length surface material = COAT1 AND pavement use category >2

OR

treatment length surface material = COAT1 and pavement use category <2 AND surface age >1

THEN Seal need = S

REASON = " 1^{st} coat seal (date) requires 2^{nd} coat seal by (expiry date)

The rating of pavement distress in the inspection length is checked. Depending on the extent and type of distress the seal may be considered to be in immediate need of reseal in the next budget year, be a likely candidate for reseal in the following year or be showing relatively little distress so its reseal timing is still indeterminate.

The selection logic is as follows:

4.3.3 Check for Reseal in Budget (Seal Need "1")

IF Length of Shoving wheeltrack in the Inspection Length. > 3% of Inspection Length * Number of Lanes * 2
THEN seal need = 1
REASON = "Percentage of wheelpath shoved exceeds 3%"

IF Length Alligator Cracked wheel-track in Inspection Length > 3% of Inspection Length * Number of Lanes * 2
THEN seal need = 1
REASON = "Percentage of wheelpath cracked exceeds 3%"

IF Area of Scabbing in the Inspection Length > 25% of inspection area AND top surface age > 50% of top surface life expectancy
THEN seal need = 1
REASON = "percentage of area scabbed exceeds 25%

IF No. Potholes + Potholes Patched in Inspection Length > 2.5% treatment length wheelpath
THEN seal need = 1
REASON = "No. Of potholes per lane km exceeds 50"

IF Shoving + Alligator cracked wheeltrack in Inspection Length > 3% of treatment length wheelpath
THEN seal need = 1
REASON = "combined percentage of wheelpath shoving and cracking exceeds 3%"

IF Flushing in Inspection Length wheelpath > 30% of treatment length wheelpath
THEN seal need = 1
REASON = "percentage of wheelpath with low macrotexture exceeds 30%"

IF SCRIM deficiency for entire treatment length >= SCRIM deficiency threshold
THEN seal need = 1
REASON = "SCRIM deficiency is high for percentage of surveyed treatment length"

IF SCRIM deficiency for site category >= SCRIM deficiency threshold
THEN seal need = 1
REASON = "SCRIM deficiency is high for percentage of surveyed site category"

IF SCRIM deficiency for continuous failed length >= SCRIM continuous length deficiency threshold
THEN seal need = 1
REASON = "Continuous length of deficient seal"

4.3.4 Check for Reseal in Next Budget Year (Seal Need "2")

IF Length of Shoving wheeltrack in the Inspection Length. > 1% of Inspection Length * Number of Lanes * 2
THEN seal need = 2
REASON = "Percentage of wheelpath shoved exceeds 1%"

IF Length Alligator Cracked wheel-track in Inspection Length > 1% of Inspection Length * Number of Lanes * 2
THEN seal need = 2
REASON = "Percentage of wheelpath cracked exceeds 1%"

IF Area of Scabbing in the Inspection Length > 10% of inspection area AND top surface age > 50% of top surface life expectancy
THEN seal need = 2
REASON = "percentage of area scabbed exceeds 10%

IF No. Potholes + Potholes Patched in Inspection Length > 2% treatment length wheelpath
THEN seal need = 2
REASON = "No. Of potholes per lane km exceeds 25"

IF Shoving + Alligator cracked wheeltrack in Inspection Length > 1% of treatment length wheelpath
THEN seal need = 2
REASON = "combined percentage of wheelpath shoving and cracking exceeds 1%"

IF Flushing in Inspection Length wheelpath > 15% of treatment length wheelpath
THEN seal need = 2
REASON "percentage of wheelpath with low macrotexture exceeds 15%"

4.3.5 Check for Locking Coat Seal

IF Area of Scabbing in the Inspection Length > 10% of inspection area AND top surface age < 50% of top surface life expectancy
THEN seal need = "L"
REASON = "percentage of area scabbed within x years of surfacing exceeds 10%"

4.3.6 Estimate Remaining Life of the Current Surfacing and The Likely Subsequent Resurfacing Cycle.

IF The surface requires resealing in the year being budgeted for. (Seal need = 1)
THEN The remaining life beyond the budget year is zero years.
The total life of the existing seal = surfacing current age + 1 year.

The condition of the existing seal is then examined to see if the reseal is possibly overdue. This is done by looking at the cost of work that must now be done to prepare for resealing that could probably have been avoided by sealing earlier. (This cost is assumed to be the sum of all shoving and pothole repairs.) If this factor is too high a proportion of the reseal cost, then the economically optimum total life of the current seal is one or two years shorter than it has actually been required to last. The logic is as follows:

IF	The cost of repairs	>	Cost of Reseal due to seal delay * Economic Factor
	THEN		The seal Total Life is reduced by one year.
IF	The cost of repairs	>	Cost of Reseal due to seal delay * Economic Factor * 2
	THEN		The seal Total life is reduced by a second year.

The Economic Factor is listed in table 1 below: Its derivation is given in below. Essentially, if the maintenance costs due to reseal delay become too high, then it is economical to reduce the resurfacing cycle length. If the cycle is already fairly short it is more expensive to reduce it by a year and so proportionately higher maintenance costs must be tolerated.

Seal Life Cycle	Economic Factor
2	1.0000
3	0.5238
4	0.3656
5	0.2868
6	0.2398
7	0.2087
8	0.1867
9	0.1704
10	0.1579
11	0.1480
12	0.1400
13	0.1334
14	0.1280
15	0.1234
16	0.1195
17	0.1162
18	0.1133

TABLE 1: Maximum Annual Maintenance Expenditure as a Proportion of Seal Cost

IF The surface requires resealing in the year after the budget year (Seal need = 2 or F)

THEN The remaining life beyond the budget year = 1 year and The Total Life of the existing seal = surfacing current age 2 years

IF The surface does not require resealing (Seal need = N)

THEN The Total Life of the current surfacing is the maximum of the Surfacing Current Age + 3 years Normal Life, where normal life is the cycle time adopted for a seal of that type in a specific traffic environment

Surfacing	**Use 1**	**Use 2**	**Use 3**	**Use 4**	**Use 5**	**Use 6**	**Use 7**
Portland Cement Concrete	60	60	50	50	40	40	40
Structural Asphaltic Concrete	20	20	19	19	18	17	16
Friction Course	12	11	10	9	8	7	6
Thin Asphaltic Concrete	12	11	10	9	8	7	6
Slurry Seal	8	7	6	5	4	3	2
Open Graded Emulsion Mix	12	11	10	9	8	7	6
Grade 6 Seal	6	5	4	3	2	1	1
Grade 5 Seal	8	7	6	5	4	3	2
Grade 4 Seal	12	10	8	7	6	5	4
Grade 3 Seal	14	12	10	9	8	7	6
Grade 2 Seal	16	14	12	11	10	9	8
First Coat Seal(grade 4)	3	2	1	1	1	1	1
First Coat Seal(grade 3)	4	3	2	1	1	1	1
Prime and Seal (grade 4)	7	6	5	4	3	2	1
Two Coat First surface (grades 2/3, 2/4, 2/5)	10	8	6	5	4	3	2
Two Coat First surface (grades 3/4, 3/5, 3/6)	8	6	5	4	3	2	1
Two Coat First surface (grades 4/5, 4/6)	6	4	3	2	2	1	1
Two Coat Second surface (grades 2/3, 2/4, 2/5)	18	16	14	13	12	10	9
Two Coat Second surface (grades ¾, 3/5, 3/6)	16	14	12	11	10	8	6
Two Coat Second surface (grades 4/5, 4/6)	14	12	10	9	8	6	4
Two Coat Reseal (grades 2/3, 2/4, 2/5	18	16	14	13	12	10	9
Two Coat Reseal (grades 3/4, 3/5, 3/6)	16	14	12	11	10	8	6
Two Coat Reseal (grades 4/5, 4/6)	14	12	10	9	8	6	4
Bicouche/Sandwich	14	12	10	9	8	6	4
Metal	3	2	1				
BOLIDT Polyurethane Mix	18	16	14	12	11	10	8

Normal Surfacing Lifetimes

It is assumed that future reseals will, on average, be grade 3 size seals. The life to be expected by these reseals is computed as follows:

Life of Future Seals = Economic Life of Current Seal

$$\frac{\text{Normal Life of Grade 3 seal}}{\text{Normally expected life of Current Seal}}$$

However the maximum life of the Future Seals is limited to 1.4 times the normally expected life. This is considered the maximum normal range.

Example: A grade 4 reseal is currently 8 years old and carries 300 vehicles/day. It requires a reseal in the budget year. The maintenance category is thus T2 and the normally expected life for a grade 4 is 10 years and 12 years for a grade 3. The total life the current seal will be required to serve is thus 8 + 1 = 9 years.

However maintenance costs are so high, it is apparent the seal could, with advantage, have been sealed 2 years ago at least. Hence the economic total life of the current seal is 9 - 2 = 7 years. Therefore life of Future Seals = 7/10 * 12 = 8.4 years.

If the cycle length computed for the future seals is less than a user defined minimum of the normally expected life for a grade 3 reseal the program checks to see if drainage deficiencies may have resulted in an abnormally short life span. If the drainage appears the cause, the assumption is made that drainage repairs will be made and that they will restore the sealing cycle to 80% of normal for the traffic usage.

The drainage deficiency checking logic is as follows:

The total length of ineffective drainage in the treatment length =

Total of any Asphalt or Concrete SWC rated ineffective due to it being blocked, broken, uphill or broken pavement surface at channel lip.

\+ Total length of Inadequate Earth SWC

\+ The greater of: Length Earth SWC Blocked and Length Unsealed Shoulder Ineffective.

NOTE: The assumption is made that ineffective shoulder generally coincides with a blocked earth channel. Also that a high channel lip does not necessarily mean that the water is leaking at this point in time and therefore would not have caused poor pavement performance. However, a high channel lip usually causes the pavement surface at the channel lip to deteriorate with time and is therefore still considered a problem that should be fixed before an area treatment.

IF	Total length of ineffective drainage in treatment length	>	0.50 * Treatment Length (i.e. 1/4 of seal edge Length)
THEN	The drainage is seriously deficient.		

If the drainage is seriously deficient, then the type of pavement distress is checked to see if it is the type of defect that would be expected to be caused by poor drainage.

IF	Length of Shoving wheeltrack in the Inspection Length	>	3% of Inspection Length * Number of Lanes * 2
OR	Length Alligator Cracked Wheeltrack in Inspection Length	>	3% of Inspection Length * Number of Lanes * 2
OR	No. Potholes & Pothole Patches in the inspection Length	>	5 * Inspection Length * Number of Lanes /100
OR	Length of Flushing Wheel- track in Inspection Length	>	25% of Inspection Length * Number of Lanes * 2
THEN	The shortened surfacing life is considered to have been due to the poor drainage and the expected future reseal cycle length is adjusted accordingly.		

If the current surfacing has had a shorter than normal life but there is no evidence that poor drainage is the cause, it indicates either a weak pavement. Alternatively, the failure may not be pavement strength related at all, but rather some defect in design supervision or construction of the surfacing. If this is the case, then there is no reason to expect a shorter than normal life from subsequent seals.

IF	Area of Scabbing in Inspection Length	>	10% of Carriageway Width * Inspection Length
OR	Length of Flushing Wheel-track in Inspection Length	>	10% of Inspection Length * Number of Lanes * 2
AND	Length of Shoving Wheel-track in the Inspection Length	<=	1% of Inspection Length * Number of Lanes * 2
AND	Length Alligator Cracked Wheel-track in Inspection Length	<=	1% of Inspection Length * Number of Lanes * 2
AND	No. Potholes & Potholes Patched in inspection Length	<=	2 * Inspection Length * Number of Lanes /100
THEN	The future reseal cycle length is assumed to be equal to the normal life for a grade 3 reseal.		

4.3.7 Derivation of Economic Factor

Consider a sequence of payments of size = 1.0, the first payment occurring at year N and the second and subsequent payments occurring at years 2xN, 3xN…etc. The present value of this series is

$$\frac{1}{(1+i)^N} + \frac{1}{(1+i)^{2N}} + \frac{1}{(1+i)^{3N}} + \text{.......... .....}$$

$$= \sum_{m=1} \left(\frac{1}{(1+i)^n} \right)^m$$

$$= \sum_{m=0} \left(\frac{1}{(1+i)^N} \right)^m - 1$$

The first term is a geometric series

Therefore PV =

$$\frac{1}{1-\left(\frac{1}{1+i}\right)^{\mathbf{n}}} - 1$$

$$= \frac{1}{(1+i)^{\mathbf{n}} - 1}$$

Hence, to obtain the PV of a sequence of future reseals, with reseal cycle = N and i = 10%:

PV = Cost [Reseal] * $\frac{1}{(1+i)^{\mathbf{n}} - 1}$

Now consider the economics of shortening a reseal cycle by one year in order to avoid the high maintenance costs that have occurred in the last year before resealing with the current reseal cycle length. The situation with and without shortening the cycle is shown graphically below

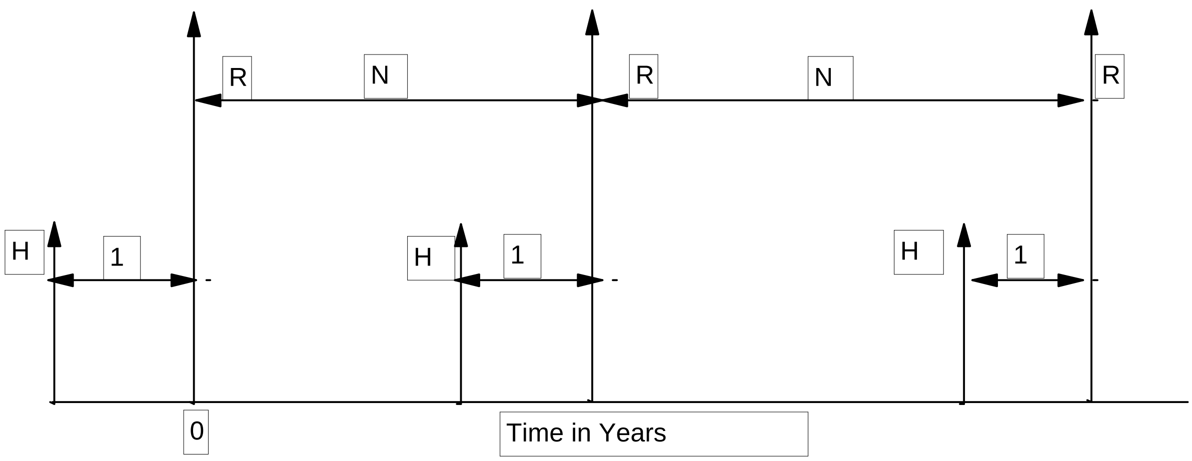


Figure 3 - Current cycle length

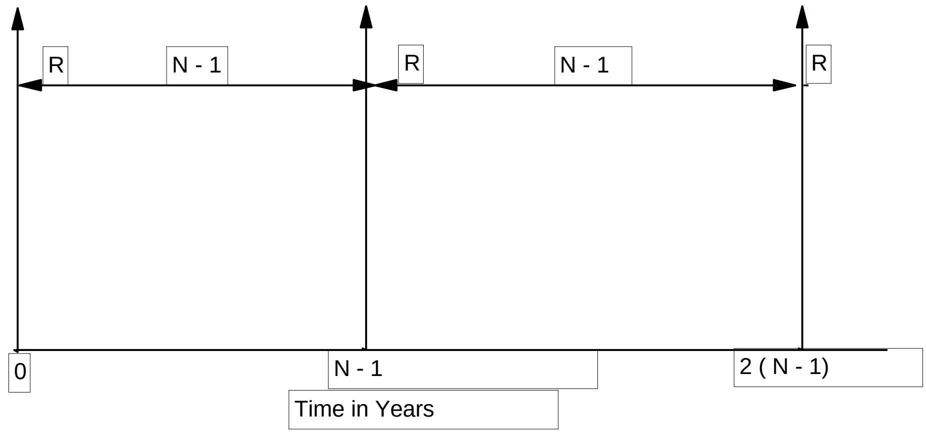


Figure 4 - Shortened cycle length

PV Cost with current cycle length = $\left(H + \frac{R}{1.1} * \left(\frac{1}{1.1^n - 1} + 1\right)\right)$

PV Cost with shortened cycle length = $R * \left(\frac{1}{1.1^{N-1} - 1} + 1\right)$

Hence shortening the cycle is worthwhile if:

$$\left(H + \frac{R}{1.1}\right)\frac{1.1^N}{1.1^N - 1} > R\frac{1.1^{N-1}}{1.1^{N-1} - 1}$$

$$H > R * \left(\frac{1}{1.1} * \frac{1.1^N - 1}{1.1^{N-1} - 1} - \frac{1}{1.1}\right)$$

$$H > R * 0.0909 \frac{1.1^{N-1}}{1.1^{N-1} - 1}$$

Where: R = Cost [Reseal]
H = Maintenance costs averted by an earlier reseal.

4.4 Economic Analysis of Each Area Treatment And Subsequent Treatment Selection

4.4.1 Compute Present Value of Future Maintenance

To compute the present value of future pavement maintenance is extremely difficult. The following procedure which is followed by the program, can only be expected to give a guide to the order of difference in future on-pavement costs that may be expected between the four possible options of strengthening, smoothing, resurfacing and general maintenance.

The following assumptions are made:

- For the non-overlay options, the assumed future reseal cycle length is that calculated in 2. 2. 2. 2. For the smoothing overlay option, the assumed future surfacing cycle is calculated as follows:

  IF 1. 5 * Life cycle from 2. 2. 2. 2 < normal cycle (Grade 3 seal from Table 2)

  THEN Let Future resurfacing cycle = 1. 5 * Life cycle from 2. 2. 2. 2

  ELSE Let Future resurfacing cycle = cycle from 2. 2. 2. 2

  Following a strengthening overlay, the assumed cycle is the normal Grade 3 life cycle value from Table 2. In reality, the cycle lengths will become shorter as the pavement ages. However, the practical impact of this is small due to the effects of discounting.

- It is assumed that after a reseal or overlay on-pavement maintenance will initially be very low, gradually increasing in magnitude, until at the end of the seal life it has reached a level that is uneconomic to sustain. In Section 2. 2. 3. 2, an approximation to the discounted present value of future resealing and general maintenance costs is derived. The Total Factor derived from this model is used in the following way to determine the PV of future maintenance costs:

  PV Total Future Costs = Reseal Cost * PV Total Factor

  Where : PV Total Factor depends on the resurfacing cycle (N) and the remaining life (N) of the present surfacing. This factor is listed in Table 3 of section 2. 2. 3. 2.

  - Where a short resurfacing cycle is calculated because the previous surfacing has failed prematurely and it is not a drainage or design/construction fault, it must be assumed that the pavement is inadequate. This type of pavement would be likely to have high maintenance costs and flushing problems due to frequent applications of relatively fresh binder. Hence, in designing the algorithm it has been assumed that where the calculated future life cycle is

< 5 years the surface will always need to be treated by burning or some similar treatment such as texturising just prior to resurfacing. This cost is added to the cost of the reseal which also has the desired effect of increasing the present value of future maintenance costs as shown in Figure 5 (d).

The calculation of PV Future Maintenance is carried out for the four different options as follows:

Reseal Case:

IF seal need = 1 and future life cycle < 5 years

THEN PV maint = (Reseal cost + Burn cost) * PV Total Factor
Where Burn cost = No. lanes * treatment length * unit cost flushing repairs and N = Future surfacing cycle = n

IF Seal need = 1 and future life cycle >= 5 years

THEN PV maint (reseal) = Reseal cost * PV Total Factor
Where N = Future surfacing cycle = n

Where the seal is only two years away general maintenance detected during the rating has been assumed to occur each year for the next 2 years and then the pavement is sealed. Before sealing, flushing problems will need to be taken care of. General maintenance after resealing is expected to be normal but the PV for this is adjusted to take account of it starting two years out.

IF Seal need = 2 or F and future life cycle < 5 years

THEN PV maint = (Reseal cost + Burn cost) * PV Total Factor * 0.826 + general maint * 1.821 + Flushing cost * 0.826
Where : N = Future surfacing cycle, n = 1 and Burn cost = No. lanes * treatment length * unit cost flushing repairs

IF Seal need = 2 or F and future life cycle >= 5 years

THEN PV maint = Reseal cost * PV Total Factor * 0.826 + General maint * 1. 821 + Flushing cost * 0.826
Where N = Future surfacing cycle, n = 1No Area Treatment Case:

For the computation of future maintenance costs when the reseal is some time in the future it is assumed that general maintenance as calculated by the model in figure 5 (b) will continue. A normal life cycle is assumed.

IF Seal need = N
THEN PV Maint = Reseal cost * PV Total Factor
Where N = Normal life cycle, n = Remaining life

Smoothing Overlay Case:
For the smoothing option the computation of the present value of future maintenance assumes that the stream of costs does not really start until the second coat is applied, generally two years after the overlay. After this normal general maintenance applies. Again a check is made for short cycle times for reseals.

IF Life cycle < 5 years
THEN PV maint = (Reseal cost + Burn cost) * PV Total factor * 0.826
Where N = Future surfacing cycle, n = 1 and Burn cost = No. lanes * rating length * unit cost flushing repairs

IF Life cycle >= 5 years
THEN PV maint = Reseal cost * PV Total factor * 0. 826
Where N = Future surfacing cycle, n = 1

Strengthening Overlay Case:

For the strengthening option the computation of the present value of future maintenance assumes that the stream of costs does not really start until the second coat is applied, generally two years after the overlay.

PV maint = Reseal cost * PV Total factor * 0. 826Where N = Future surfacing cycle, n = 1

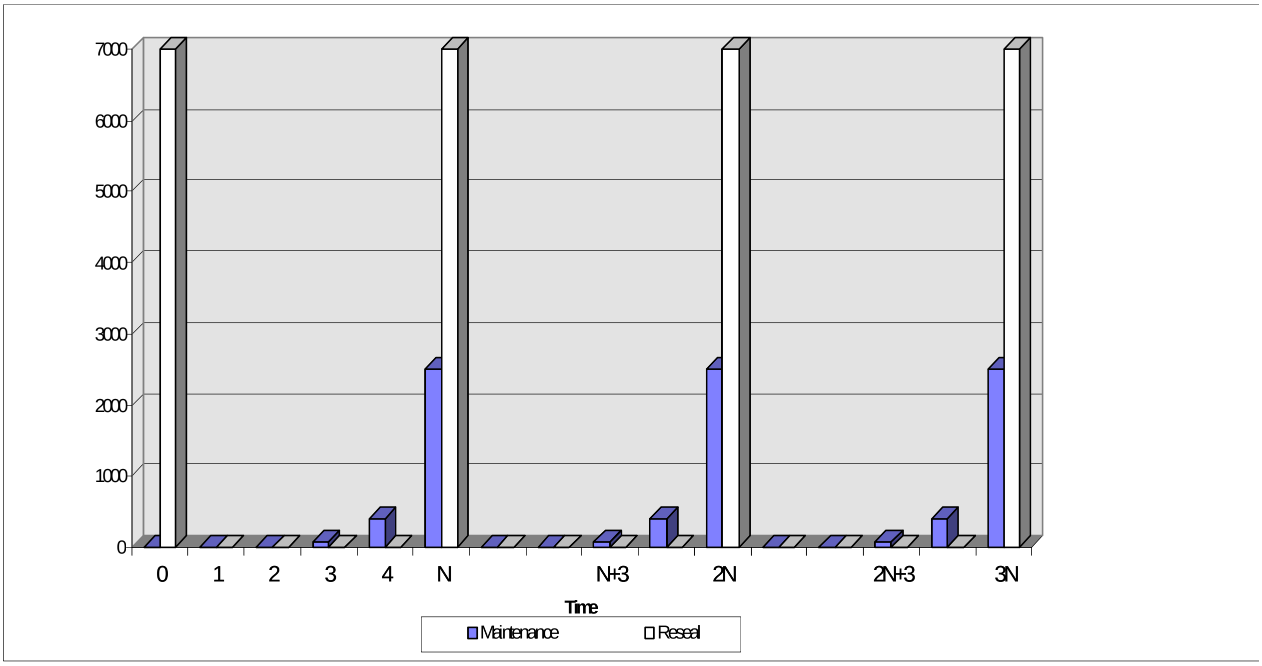


Figure 5(a) - Future Maintenance Cash Flow After Reseal Option

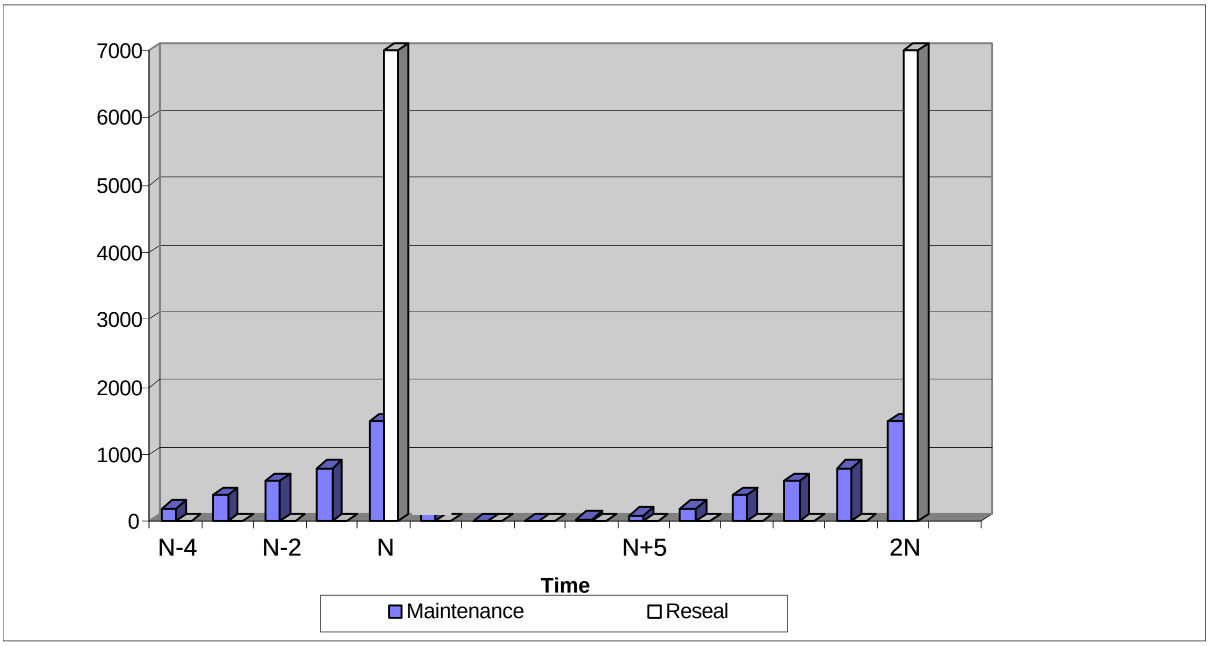


Figure 5(b) - Future Maintenance Cash Flow After No-Area

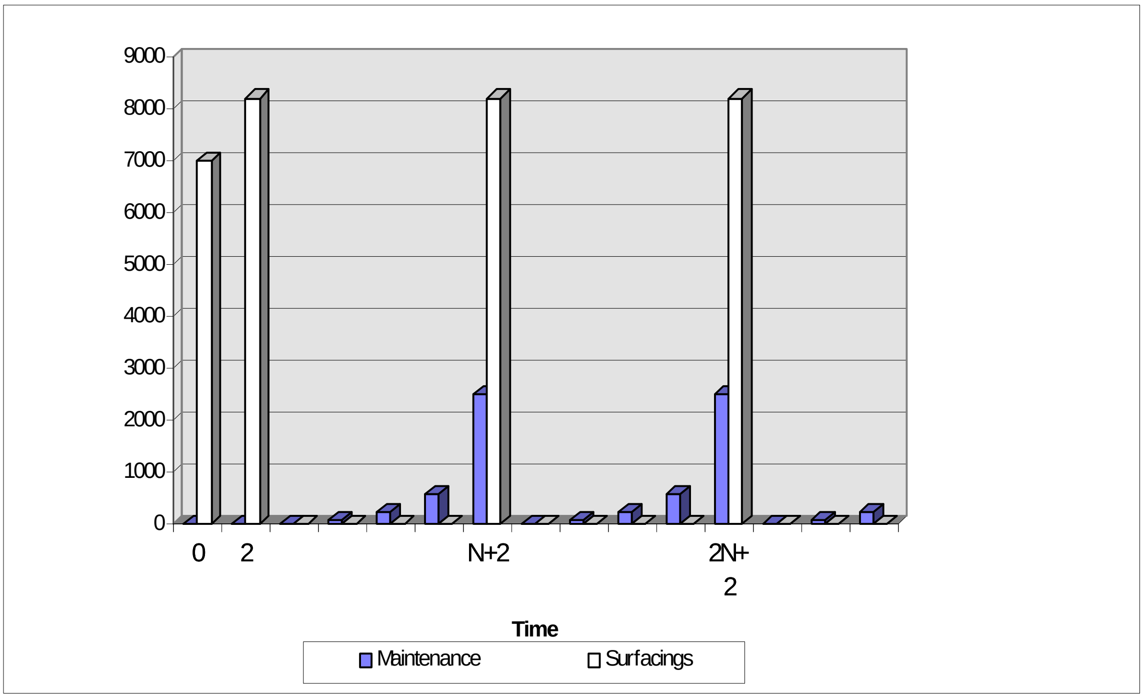

9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
2
N+2
2N+2
Time
Maintenance
Surfacings

Figure 5(c) - Future Maintenance Cash Flow After Overlay Option

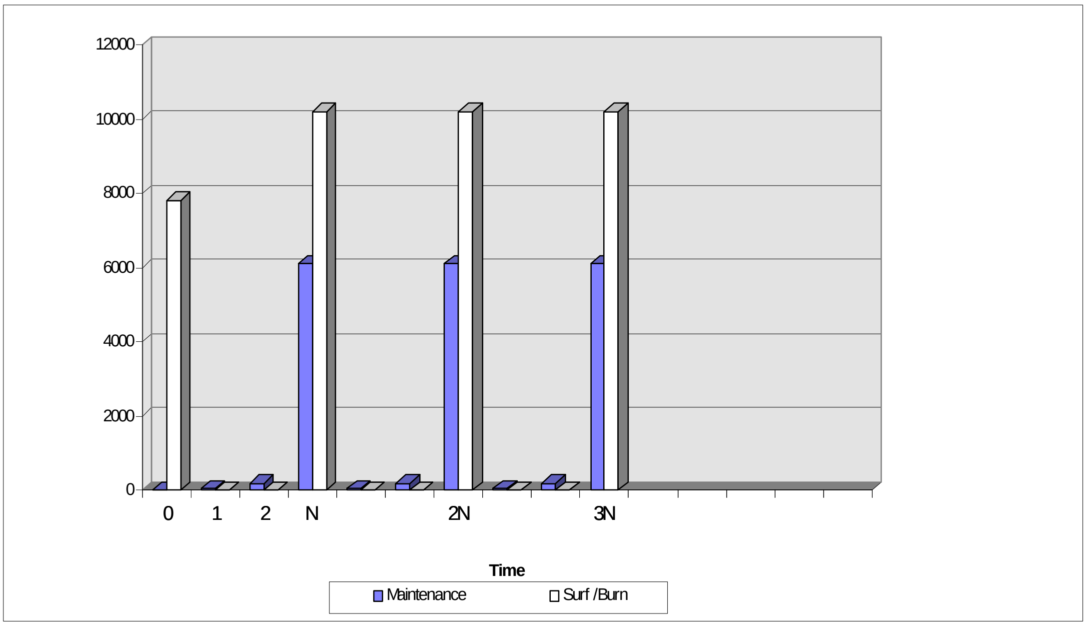


Figure 5(d) - Future Maintenance Cash Flow Where Life Cycle Less Than 5 yrs

4.4.2 Derivation Of Factor To Determine PV Future Maintenance

It is assumed that after a reseal or overlay on-pavement maintenance will initially be very low, gradually increasing in magnitude, until at the end of the surfacing life it has reached a level that is uneconomic to sustain. (Figure 6)

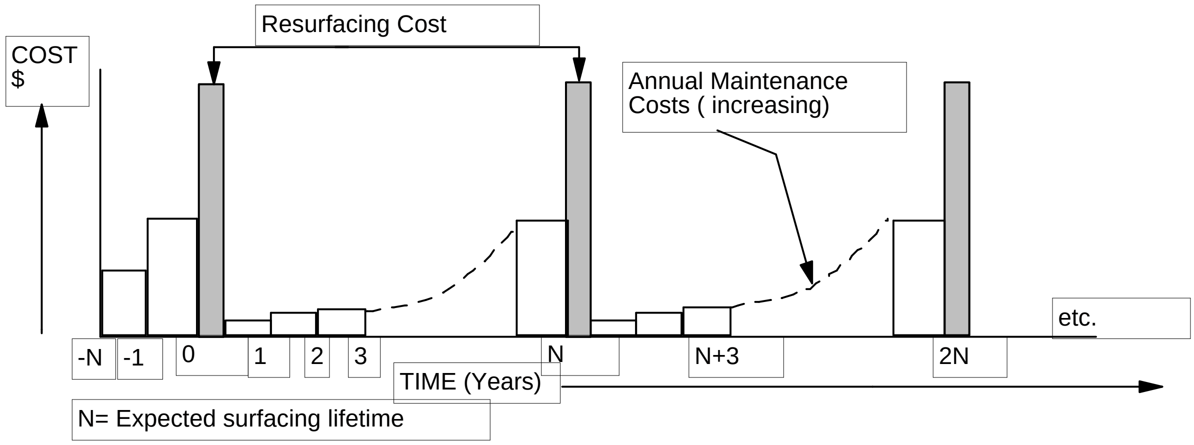


Figure 6 - Maintenance And Resurfacing Costs

(a) A Fundamental Formula

Let the discount rate be i as a decimal (let i = 0. 1).
Let g = 1 + I
Let n = remaining life of existing surfacing before next reseal.
Let N = surfacing cycle time.

Consider a unit payment to be made within the nth year in the future. e. g. If the present date is 1st April 1989 and n = 3, then the payment is to be made within the year commencing at 1st April 1991.

	n = 1	n = 2		n = 3	
1989	**1990**		**1991**		**1992**

Suppose further that after the nth year the payment continues to be made at intervals of N years. The total Present Value is the infinite geometric series.

$$PV = g^{-n} + g^{-n-N} + g^{-n-2N} + \ldots\ldots$$

$$= \frac{g-n}{1-g^{-N}}$$

$$PV = \frac{g^{N-n}}{g^{N}-1} \qquad \ldots\ldots\ldots \ (1)$$

(b) Partitioning of Resurfacing and Maintenance Costs

By reference to figure 6 above it can be seen that the total Present Value can be partitioned into three parts.

PV_1 = Reseal costs

PV_2 = Total general maintenance between reseals, repeating with an N year cycle. The first segment occurs immediately after the first reseal.

PV3 = The cost of the n years of general maintenance up to the next reseal. This cost is dependent upon the years of life remaining for the existing seal and does not recur. In figure 6 this corresponds to the initial section from -n to 0.

(c) Present Values

Regular resurfacing

If the reseal cost is R it follows immediately from equation (1) that:

$$PV_1 = R\frac{g^{N-n}}{g^{N}-1} \qquad \ldots\ldots\ldots \ (2)$$

(d) Modelling of Maintenance Costs

Yearly maintenance costs can be modelled as a geometric progression characterised by $y_{m+1} = ky_m$ where k is a constant greater than 1.

Let y_1 be the maintenance cost in the year immediately following the reseal
and y_N the cost in the year immediately preceding the next reseal.

Then the cost sequence is:

$$y_1, ky_1, k^2y_1, \ldots, k^{N-1} y_1$$

which is equivalent to:

$y_m = k^{m-1} y1 = k^{m-N} yN$. . . . .(3)

In this model there is a key parameter

$q = y_N/y_1 = k^{N-1}$ . . . . (4)

q is the ratio of the final year maintenance cost to the first year cost. The ratio of the final year cost to that of the mid-term is the square root of q. The assumed maintenance growth pattern is that after a reseal or overlay, on-pavement maintenance will initially be very low, gradually increasing in magnitude, until finally reaching a peak near the end of the economic seal life. To satisfy this assumption q has been taken as 400, for all cycle lengths N.

Therefore k is dependent on N by the law:

$k = 400^{1/(N-1)}$ . . . . (5)

4.4.3 Present Value of Maintenance Cycles

PV_2 can be found as follows.
The maintenance cost y_m for the mth year of the cycle, occurs in years n+m, n+m+2N, ...

Let the Present Value for repeated y_m be P_m.

Then by equation (1)

$$P_m = y_m \frac{g^{N-n-m}}{g^{N-1}}$$

From (3) and (4), $y_m = k^{m-1} y_N/q$ . . . . (6)

Hence Pm = $$(y_N / kq) \frac{g^{N-n}}{g^N - 1} (k / g)^m$$

Pm must be summed for m = 1,2, ... N.

Define the finite geometric series

$S(r) = k/g + (k/g)^2 + \ldots + (k/g)$

Then $PV_2 =$ $$y_N \frac{g^{N-n}}{g^{N-1}} . \frac{1}{kq} . s(N)$$ . . . . (7)

4.4.3.1 PV of Initial Years Maintenance

The required present value is

$$y_{N-n+1}\, g^{-1} + y_{N-n+2}\, g^{-2} + \ldots\ldots + y_N\, g^{-n}$$

$$= y_N\, k^{-n}\, [k/g + (k/g)^2 + \ldots\ldots + (k/g)^n]$$

$$\text{i.e. } PV_3 = y_N\, k^{-n}\, S(n) \qquad \ldots\ldots\ldots\ldots \quad (8)$$

4.4.3.2 Total Present Value

Adding expressions (2), (7) and (8) we have total

$$PV = PV^1 + PV^2 + PV^3$$

or

$$PV(n, N) = R\frac{g^{N-1}}{g^N - 1} + M\frac{g^{N-1}}{g^N - 1}.\frac{1}{kq}.S(N) + M^{-n}S(n) \quad \ldots \quad (9)$$

where $M = k_N$ the maintenance cost for the year terminated by the reseal.

4.4.4 Optimum Reseal Period

Consider the point in time at which the reseal would normally be scheduled a year later. If the reseal was carried out immediately and thereafter performed at intervals of N - 1years, the large final maintenance M would be saved, but at the expense of more frequent instances of reseal and maintenance cycles. The optimum value of N is assumed to be that for which the normal and alternative strategies would have equal present values.

It is desirable to know what M value, as a proportion of R, achieves this balance. The value is obtained by solving the following equation for M:

$$PV(1, N) = PV(0, N-1) \qquad \ldots\ldots\ldots\ldots \quad (10)$$

In this particular situation the value of k to be used in the term on the right hand side must also be the value appropriate for the left hand term.

Also the convention $S(0) = 0$ must be followed.

The Present Value factor obtained by this method is shown in Table 3 below.

Cycle Length (yrs)	Remaining Life of Present Surfacing (years)							
↓	1 9	2 10	3 11	4 12	5 13	6 14	7 15	8 18
2	11.028	10.028						
3	5.910	5.400	4.910					
4	4.224	3.892	3.545	3.224				
5	3.369	3.131	2.863	2.605	2.369			
6	2.848	2.667	2.448	2.233	2.032	1.848		
7	2.496	2.352	1.983	1.807	1.664	1.496		
8	2.242	2.124	1.968	1.805	1.647	1.500	1.365	1.242
9	2.050 1.050	1.952	1.8156	1.671	1.528	1.394	1.269	1.155
10	1.901 0.991	1.817 0.901	1.697	1.567	1.436	1.312	1.196	1.089
11	1.782 0.944	1.709 0.859	1.602 0.782	1.483	1.363	1.247	1.138	1.037
12	1.684 0.908	1.620 0.827	1.524 0.752	1.415 0.684	1.304	1.196	1.093	0.997
13	1.604 0.879	1.546 0.801	1.459 0.729	1.359 0.662	1.255 0.604	1.153	1.056	0.964
14	1.536 0.856	1.484 0.780	1.405 0.711	1.312 0.647	1.215 0.589	1.118 0.536	1.025	0.938
15	1.478 0.837	1.431 0.764	1.358 0.696	1.272 0.634	1.181 0.577	1.089 0.525	1.000 0.478	0.916
16	1.429 0.822	1.386 0.751	1.318 0.685	1.238 09.624	1.151 0.569	1.064 0.518	0.979 0.471	0.898 0.429

Present Value Total Factor (10% discount rate)

4.4.5 Selection of Optimum Treatment for Shape Correction

IF	Smoothing overlay cost + preliminary maintenance cost before smoothing overlay+ PV maintenance after smoothing overlay	>	Strengthening overlay cost + PV maintenance cost after strengthening overlay
THEN	Strengthening option is preferred overlay option and overlay option cost = strengthening cost + PV maintenance after strengthening.		
ELSE	Smoothing option is preferred overlay option and overlay option cost = smoothing cost + preliminary maintenance + PV maintenance after smoothing.		

4.4.6 Calculation of Benefit/Cost Ratio for Shape Correction

IF Reseal is required in the budget (Seal need = 1)

THEN Non-overlay cost = Reseal cost + Pre-reseal maintenance + PV maintenance after reseal

ELSE Non-overlay cost = General maintenance + PV maintenance after No-area Treatment

IF Non-overlay option cost > Overlay option cost

THEN Overlay option is selected at high priority (B/C = 100)

ELSE The benefit cost ratio of the overlay =

$$\frac{\text{User Benefits}}{\text{(Overlay Option Cost - Non-overlay option cost)}}$$

4.4.7 Compute User Benefits Arising from Reduction in Road Roughness

The basis for this calculation is Table A2. 16 of the National Roads Board's Economic Appraisal Manual, RRU Technical Recommendation TR 9. This Table and Figure A2. 26 of the manual are reproduced here and show the additional running costs due to roughness for an average vehicle for different road types. For the purpose of the program, the Rural Other cost curve was chosen as being sufficiently representative of all road categories.

As the computation of the table from first principles is very complex, a simple curve was fitted to the values listed in Table A2. 16.
The form of the curve is as follows:

Additional Cost($/Vehicle km travel) = $A(e^{(B*R)} - 1)$: $R<=300$
= $C + D(R - 300)$: $R> 300$

Where:

R = Average NAASRA Roughness Value of Road from Inventory
A, B, C, D are constants:

A = 0. 128486
B = 0. 00291887
C = 0. 180
D = 0. 00088167

Hence the Annual Value of Road User Savings =
Treatment length(m) / 1000 * 365 * AADT * (Additional Cost for Current Roughness Level
-Additional Cost at Target Roughness Level after shape correction)

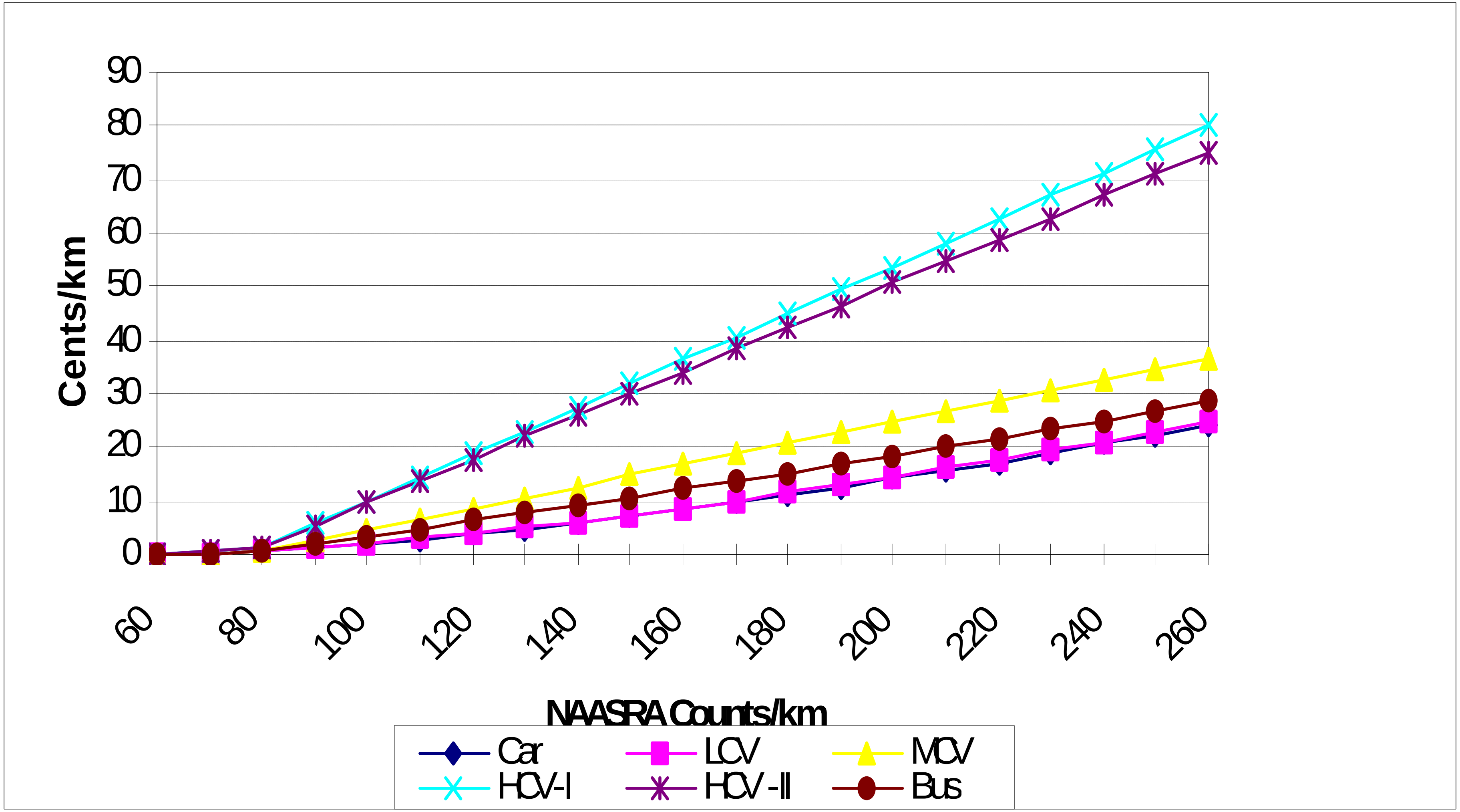
and

Present Value of Savings = Annual Savings
* Uniform Series Present Worth Factor
(25 years at 10%)
= 9.524 * Annual Savings.

Additional Running Costs Due To Roughness By Road Type (cents/km)*

naasra Counts per km	Car	LCV	MCV	HCV-I	HCV -II	Bus
60	0	0	0	0	0	0
70	0.17	0.19	0.17	0.34	0.42	0.18
80	0.59	0.63	0.69	1.21	1.40	0.61
90	1.27	1.34	2.69	5.59	5.50	1.98
100	2.04	2.13	4.69	9.96	9.60	3.37
110	2.90	3.02	6.68	14.34	13.70	4.78
120	3.84	3.99	8.68	18.72	17.80	6.21
130	4.86	5.04	10.68	23.09	21.90	7.66
140	5.96	6.17	12.68	27.47	26.01	9.13
150	7.14	7.38	14.68	31.85	30.11	10.63
160	8.39	8.66	16.67	36.23	34.21	12.15
170	9.71	10.01	18.67	40.60	38.31	13.69
180	11.10	11.43	20.67	44.98	42.41	15.25
190	12.55	12.91	22.67	49.36	46.51	16.84
200	14.07	14.45	24.67	53.73	50.61	18.45
210	15.64	16.05	26.66	58.11	54.71	20.08
220	17.27	17.71	28.66	62.49	58.81	21.73
230	18.94	19.42	30.66	66.86	62.91	23.40
240	20.67	21.17	32.66	71.24	67.02	25.09
250	22.45	22.98	34.66	75.62	71.12	26.81
260	24.26	24.82	36.65	80.00	75.22	28.55

* 1994 costs


90
80
70
60
50
40
30
20
10
0
Cents/km
60
80
100
120
140
160
180
200
220
240
260
NAASRA Counts/km
Car
LCV
MCV
HCV-I
HCV-II
Bus

4.4.8 Treatment Selection

IF The Benefit/Cost ratio > User Supplied Decision Factor

THEN Select Shape Correction Option with priority = B/C Ratio

ELSE IF Seal Need = 1,2 or F

THEN Select Resurfacing Option from seal need indicator.
1 = Reseal in Budget
1 = Reseal Next Time
S = Second coat seal
L = locking coat

ELSE Select General Maintenance Option

4.4.9 Compute Priority Ranking for Resurfacing

If the chosen option is a Reseal in Budget Year, the program computes a priority ranking value for the reseal for comparison with other reseals.

The additional maintenance costs that are incurred as a result of postponing the reseal one year are assumed to occur as shown in Table 4 below.

With the exception of rutting, at this stage the development of distress is fairly rapid and a similar level of distress will require fixing in the second year as in the first. Hence cancelling the costs out gives the following approximation of the additional costs.

Cost of delay = Shoving Cost + Alligator Cracking Cost
+ Pothole Cost + Scabbing Cost (no area treatment)
-Scabbing Cost (reseal) - 10% of Rutting Cost.

The First Year Rate of Return for resealing now rather than later is thus:

FYRR = Cost of Delay/Reseal Cost * 100%

This FYRR is used to rank the priority of reseals in the reseals listing for thin surfaced flexible pavements.

	Reseal This Year	Reseal Next Year	
Defect	**This Year's Maintenance**	**This Year's Maintenance**	**Next Year's Maintenance**
Shoving	Fix all	Fix all	Fix all
Rutting	Fix all	Fix none	Fix all
Alligator cracking	Fix all	Fix all	Fix all
Pot holes	Fix all	Fix all	Fix all
Pot hole patches	If repaired properly these should not require attention		
Scabbing	Fix 20%	Fix all	Fix none
Flushing	Fix all	Fix dangerous	Fix remainder
Edge break	Edgebreak is influenced more by seal width and carriageway use rather than by the event of a reseal. For this reason it should not be considered.		

Derivation of Additional Maintenance Costs as a Result Of Postponing the Reseal One Year

4.4.10 Assessment for Seal Widening Need

This assessment is only done if the rating section is more than 95% un-kerbed, or specifically:

IF Concrete SWC length (Left) + Concrete SWC length (Right)
< 0. 1 * Carriageway Length
OR Asphalt SWC length (Left) + Asphalt SWC length (Right)
< 0. 1 * Carriageway Length.

THEN
IF Length of Edge Break + Edge Break Patching/Seal age
< 0. 05 *inspection length * 2

THEN Report "Keep At Present Carriageway Width "

ELSE Report "Widen To Target Width"
Where
The target width is an average desirable width for the traffic conditions as shown in Table 5 below. Note that these are approximations for average conditions and should not be taken as standards for individual cases.

Use Code	ADT	Seal Width	Shoulder Width
1	<100	5.0	.75
2	100 - 500	6.5	0.00
3	500 - 2000	7.5	0.00
4	2000 - 10000	8.5	0.00
5	>10000	9.0	0.00

Target Seal and Unsealed Shoulder Widths

4.4.11 Selection of Drainage Treatment

The computation of the drainage costs is covered in Section 2. 2. 1. The total cost of the drainage work is reported for each carriageway treatment selected and a breakdown of the costs into the component parts is available through a window on the treatment selection screen. The drainage maintenance tasks are noted for each section requiring reseal or overlay. In addition, a separate listing of draining repair requirements is produced.

5 TREATMENT SELECTION PROCEDURE FOR STRUCTURAL ASPHALTIC PAVEMENTS

5.1 Computation of Costs

5.1.1 Compute Construction Costs for Area Treatments

(a) **Reconstruction**

In the case where the pavement is seriously damaged, repair will require full reconstruction of the AC layer or a thick structural overlay. Level limits usually preclude an overlay, so the standard unit cost must be computed assuming that, an average of 150mm of old pavement is removed and replaced by125mm of asphaltic concrete and 25mm of friction course. An allowance must be made for dealing with service boxes, etc.

Reconstruction Costs = Carriageway Length * Carriageway Width
* Unit Cost [Reconstruction]

(b) **Mill and Replace**

Where the existing surfacing is exhibiting signs of plastic instability, the assumed treatment is to mill off the top 75mmof mix and replace with stable asphaltic concrete.

Mill and Replace Cost = Carriageway Length * Carriageway Width
* Unit cost [Mill & Replace]

(c) **SAMI plus Levelling Overlay**

Where there is extensive joint, longitudinal or transverse cracking but the pavement is basically sound although rough, the optimum treatment assumed is to place a thick, elastic, polymer modified bitumen, stress absorbing membrane interlayer (SAMI), followed by a flexible, skid-resistant friction course (FC) or open graded emulsion mix (OGEM) in a thin, 30mm over high spots (40mm average depth), layer. An allowance must be made for dealing with services.

SAMI & Levelling Cost = Carriageway Length * Carriageway Width
*Unit Cost [SAMI & Smoothing]

(d) **Levelling Overlay**

For a sound but rough pavement, a 20mm over high spots (30mmaverage depth) FC or OGEM overlay is assumed. Allowances must be made for a heavy tack coat (to waterproof minor cracks), for filling and bandaging longitudinal, transverse and joint cracks and also for dealing with services.

Levelling Cost = Carriageway Length * Carriageway Width * Unit Cost [urban smoothing]

NOTE This unit cost is the same value used for smoothing of thin surfaced urban pavements.

(e) **SAM Seal**

Where the surface is heavily cracked but otherwise still sound and riding well, the assumed remedial treatment is a stress-absorbing membrane (SAM) reseal. This assumes a grade 3 reseal with a binder containing at least 6% polymer, followed by a grade 5 locking coat.

Cost SAM seal = Carriageway Length * Carriageway Width * Unit Cost [SAM]

(f) **Conventional Reseal**

Where the surface has significant surface defects such as ravelling, scabbing, rutting or flushing but insufficient cracking to warrant a SAM reseal, and is otherwise sound and riding adequately, a conventional reseal is indicated.

Cost Reseal = Carriageway Length * Carriageway Width * Unit Cost [Urban Reseal]

NOTE - This unit cost is the same value used for resealing thin surface urban pavements.

(g) **General Maintenance**

Construction cost is nil.

5.1.2 Compute Pavement General Maintenance Costs

The table below shows the remedial general maintenance actions required to repair the defects detected by the pavement rating before each of the seven area treatment options can be undertaken.

Option	Rut	Shove	Allig	Joint & L&T	Pot Holes	Edge Break	Scab/ Ravel	Flush
Recon	nil	nil	nil	nil	nil	N/A	nil	nil
Mill & replace	nil	nil	dig out	nil	nil	N/A	nil	nil
SAMI & level	fill	dig out	dig out	nil	fill	N/A	nil	nil
Level only	fill	dig out	dig out	fill & band	fill	N/A	nil	nil
SAM seal	fill	dig out	dig out	nil	fill	N/A	part if > 10%	repair (burn)
Convent Reseal	fill	dig out	dig out	fill	fill	N/A	part if > 10%	Repair (burn)
Normal maint	nil	dig out	crack seal	fill	fill	N/A	repair	nil

TABLE 6: General Maintenance Requirements for Thick Structural Asphaltic Pavements.

The repair costs for each repair type are as follows:

(a) **Digout shoving or alligator cracking**

It is assumed that the defective wheel tracks will require digging out to an average width of 1. 50 metres.

Cost = Metres defective wheelpath in inspection length
* Carriageway Length / Inspection Length
* Unit Cost [Digout of thick asphaltic layers]
* 1 50

•

b) Sealing Alligator Cracking

Where the pavement is basically sound but there is some very minor cracking it may be permissible to seal the cracks under general maintenance rather than to dig them out.

Cost = Metres alligator cracked wheelpath in inspection length
* Carriageway Length / Inspection Length
*Unit Cost [Crack Sealing]
* 1. 5

NOTE - The unit rate is the same as that used for crack sealing thin surface pavements.

(c) **Rutting**

Hand levelling of ruts and depressions with asphaltic mix. The repair costs are identical to the thin surfaced pavement case.

(d) **Crack Seal and Bandage Joint and Longitudinal and Transverse Cracks.**
The assumed treatment is for the cracks to be cleaned and filled with a polymer/bitumen filler and then for the cracks to be bandaged over with polymer binder and grade 6 grit.

Cost = Length of Joint, Longitudinal and Transverse Cracking in Inspection Length
* Carriageway Length/Inspection Length
* Unit Cost [Bandage & Crack Fill]

(e) Crack Fill
It is assumed that all joint, longitudinal and transverse cracks are cleaned and filled with a polymer/bitumen filler.
Cost = Length of Joint, Longitudinal and Transverse Cracking in Inspection Length
* Carriageway Length/Inspection Length
* Unit Cost [Crack Fill]

(f) **Pothole Repairs**
This includes filling each pothole with asphaltic mix.
The cost computation is as for thin surfaced pavements.

(g) **Scabbing Repairs**
The computation is as for thin surfaced pavements.

(h) **Flushing**
The computation is as for thin surfaced pavements.

5.1.3 Compute Drainage Repair Costs

This computation of drainage repair costs is identical to that for thin surfaced pavements.

5.2 Technical Analysis of Rating and Surfacing Data

5.2.1 Determine Most Appropriate Non-smoothing Treatment

Assuming that an overlay is not required, select the best non-overlay maintenance option on technical grounds based on the rating information. The decision logic is as follows:

IF	Length of Wheel track Shoving in Inspection length	>	0.50 * Inspection Length* Number of Lanes * 2 (i.e. 50% of wheelpath)
THEN			Mill the top 75mm and replace with stable asphaltic concrete
ELSE IF	Length of Alligator Cracked Wheel track in Inspection Length	>	0.10 * Inspection length* Number of Lanes* 2
OR	Length of Joint, plus L & T Cracking in Inspection length	>	0. 40 * Inspection Length* Carriageway Width
THEN			SAM seal and locking coat is first priority
ELSE IF	Length of Alligator Cracked Wheel track in Inspection length	>	0.05 * Inspection Length* Number of Lanes * 2
OR	Length of Joint, plus L & T Cracking in Inspection length	>	0.20 * Inspection Length* Carriageway Width
THEN			SAM seal and locking coat is second priority.
ELSE IF	Area of Scabbing in Inspection Length	>	0.40 * Inspection length* Carriageway Width
OR	Length of Rutted Wheel track in Inspection Length	>	0.20 * Inspection Length* Number of Lanes* 2
OR	Length of Flushing in Inspection Length	>	0.20 * Inspection Length* Number of Lanes* 2
THEN			A conventional reseal is first priority.
ELSE IF	Area of Scabbing in Inspection Length	>	0.20 * Inspection length* Carriageway Width
OR	Length of Rutted Wheel track in Inspection Length	>	0.10 * Inspection Length* Number of Lanes * 2
OR	Length of Flushing in Inspection Length	>	0.10 * Inspection Length* Number of Lanes * 2
THEN			A conventional reseal is second priority
ELSE			Continue with General Maintenance.

NOTE: Joint, Longitudinal and Transverse Cracks are considered to have an influence over a width of 1m and are therefore compared to the area of carriageway.

5.2.2 Determine Most Appropriate Smoothing Treatment

Assuming that a smoothing treatment will be required then select the optimum treatment:

ELSE IF	Length of Alligator Cracked Wheel track in inspection length	>	0.20 * Inspection Length * Number of Lanes * 2
THEN			Reconstruct or place structural asphaltic mix overlay where levels permit
ELSE IF	Length of Wheel track Shoving in Inspection length	>	0.20 * Inspection Length* Number of Lanes * 2
THEN			Mill the top 75mm of mix and replace with stable Asphaltic Mix
ELSE IF	Length of Joint, plus L & T Cracking in Inspection length	>	0.50 * Inspection Length * Carriageway Width
THEN			Place SAMI and overlay with thin layer of a flexible open graded mix
ELSE			Place thin layer of open-graded levelling mix on a heavy tack coat, after filling and bandaging cracks

5.2.3 Economic Analysis of Each Area Treatment and Subsequent Treatment Selection

5.2.3.1 Compute Present Value of Future Maintenance

Compute the relative long-term maintenance costs for the options. Because a thick structural asphaltic pavement has a relatively low expenditure on general maintenance items, compared with the cost of construction or resurfacing, general maintenance costs are ignored. It is also assumed that major rehabilitation or reconstruction will not be required for a considerable time after the current treatment is applied, and hence these costs are also ignored. This assumption will require checking manually.

The remaining costs are those for periodic resurfacing. All of the area treatments involve a resurfacing and the life times of the resurfacing treatments are similar; of the order of 8 years under the very heavy traffic loading which justify a thick structural asphaltic pavement. The relative costs of these options is taken to be zero.

For the general maintenance only case, the increased cost of resurfacing is computed by assuming that the future cost streams for resurfacing will be as shown in the Figure below.

The remaining life of the current surfacing is estimated from the Life Cycle estimate contained in the carriageway surfacings file and the current age of the surfacing.

Remaining Life = Life Cycle - (Current Age + 1)

Because it is clear that choosing the maintenance only option would not be reasonable if the Remaining Life was too short, a minimum value of 2 years is assumed.

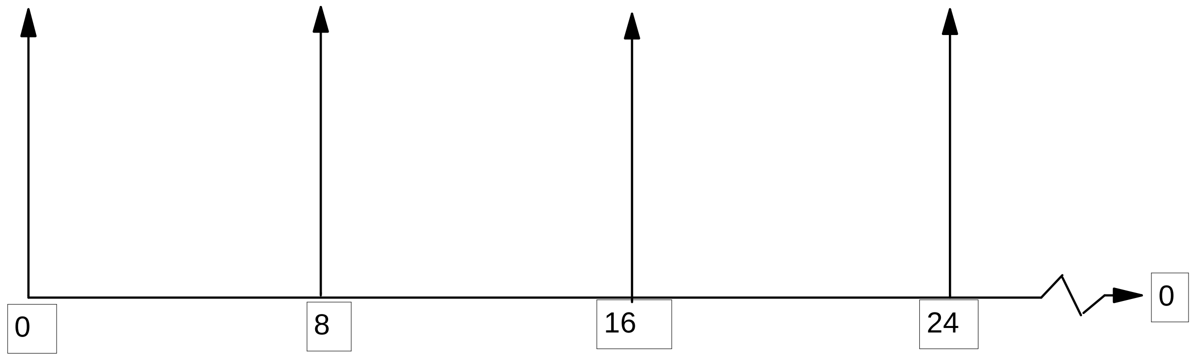


Figure 8 (a) - Future Resurfacing Costs If An Area Treatment Option

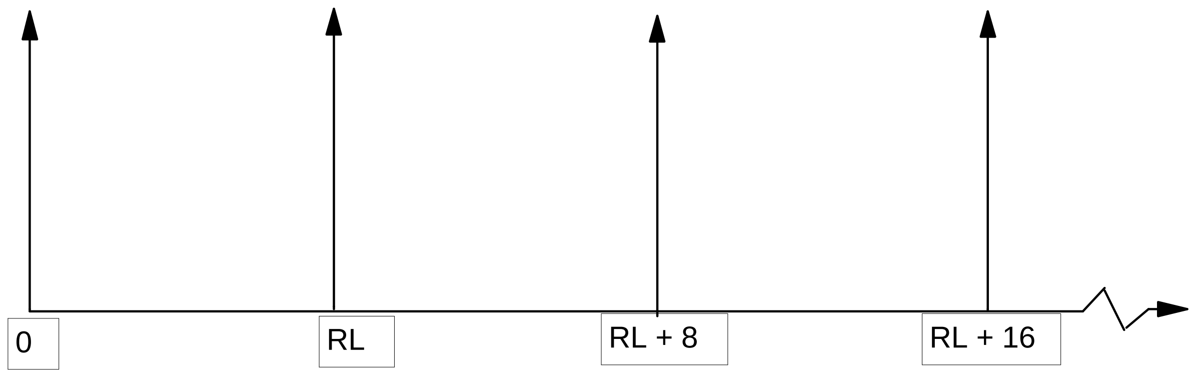


Figure 8 (b) - Future Resurfacing Costs If General Maintenance Only Chosen

IF Remaining Life < 8 years

THEN The additional cost of future resurfacing is due to the eight year cycle of resurfacings being advanced by (8-RL) years.

ELSE The additional resurfacing cost in the future compared with the other options is taken to be zero.

The additional cost, for a discount rate of 10% is therefore:

PV Additional Cost = $(1.1^{(8-RL)} - 1)$* PV Cost of Resurfacing cycle in Fig 8 (a)

From 2. 2. 2. 3

PV Resurfacing Cycle = Cost of Resurfacing * $\frac{1}{1.1^8 - 1}$

The cost of resurfacing is taken to be the cost of a thin levelling overlay. This is considered a reasonable mean value over several cycles.

Hence:

PV Additional Cost = Unit Cost [Urban Smoothing * $(1.1^{(8-RL)} - 1)$ * $\frac{1}{1.1^8 - 1}$

5.3 Treatment Selection

If the smoothing option present value cost is less than the cost for the non-smoothing alternative, then clearly the smoothing option is preferred as it provides a smoother ride at lower cost.

If milling is required for the non-smoothing option, then this will also provide smoothing. Where this treatment cost is less than the best smoothing option cost, then clearly the milling option is to be preferred.

For all other cases, the decision depends on the benefits gained for the road user from the smoother ride.

Benefit Cost Ratio =

$$\frac{\text{User Benefits from reduction of Roughness}}{\text{(Total PV Cost smoothing option - Total PV Cost of alternative)}}$$

Section 2. 2. 3. 5 discusses the computation of the user benefits.

6. APPENDIX :

RAMM TREATMENT

SELECTION EXAMPLE

THIN SURFACED FLEXIBLE PAVEMENT TREATMENT SELECTION ALGORITHM EXAMPLE – TEST ROAD

<u>Treatment Length Data :</u>

Displacements :	555m – 3775m
Length :	3120m
Width :	10m
Environment :	Rural (urban fringe)
Traffic Volume :	1000 vpd
Shoulders :	GRASS
Surface Water Channels :	100m of K&C on LHS remainder EARTH
Top Surface :	Grade 4 reseal, 01/02/87
Average Roughness :	90 NAASRA counts/km
Maximum Roughness :	198 NAASRA counts/km
Rating Sections :	6 sections of 10% treatment length
Vehicle Mix :	As per Transfund Project Evaluation Manual

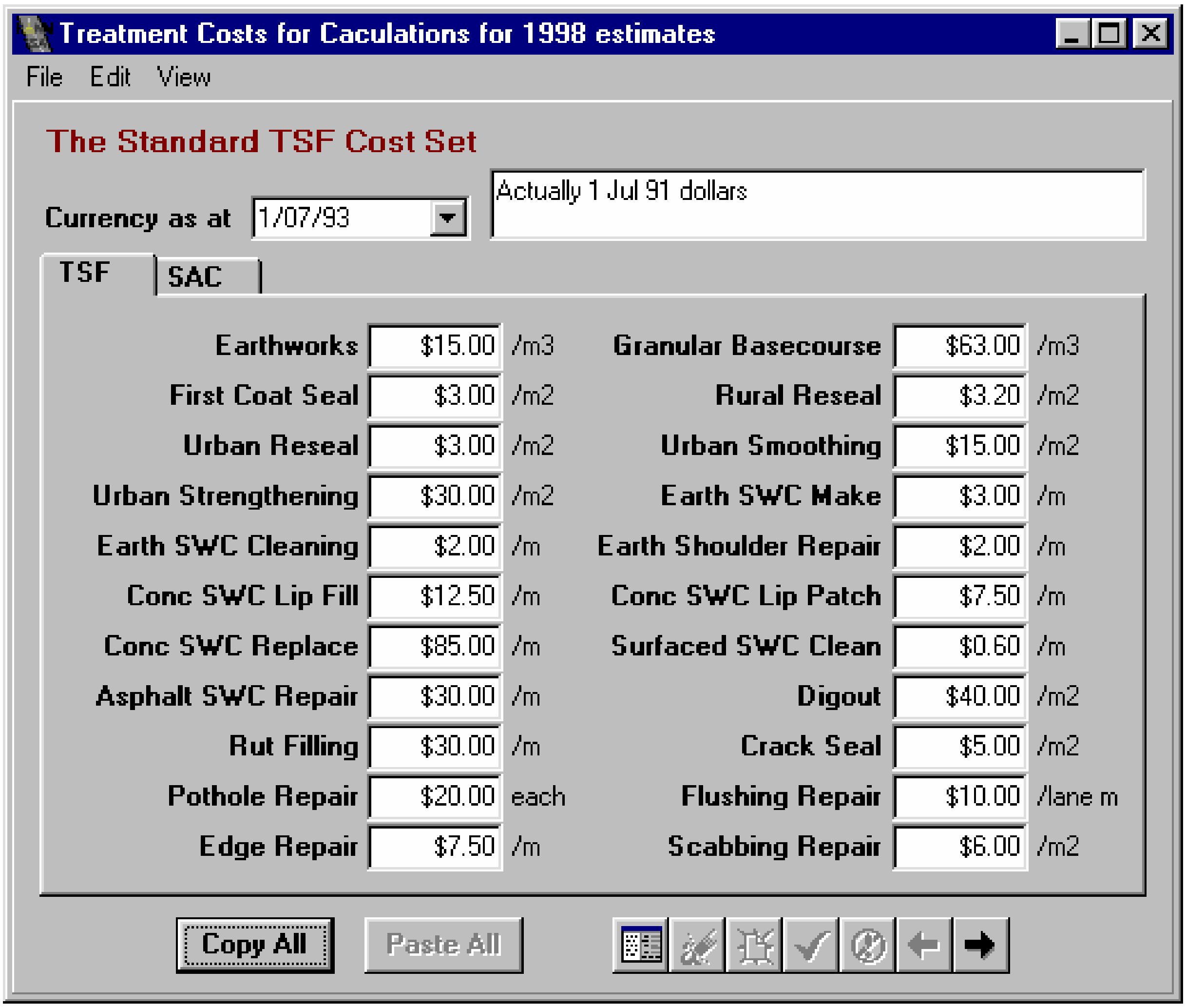
<u>Decision Factors :</u>

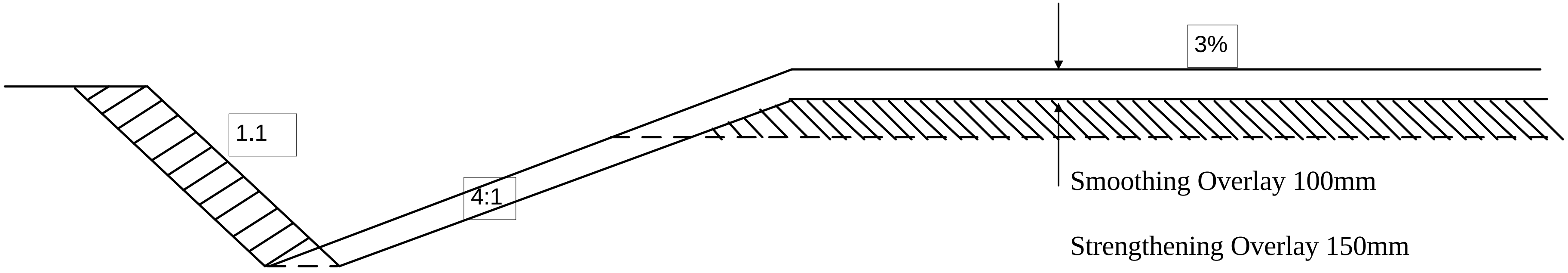
Target Roughness :	70 NAASRA counts/km
Benefit Cost Cut-off Ratio :	1.0
Date for RCI :	31/12/96
% of surface life exceeded :	10%

RATING RESULTS :

Rating	Rating		Inspection		Length	Rut	Shove	Scab	Flush	Allig	L&T	Joint	Holes	Patch	Edge	EdgeP
	Start	End	Start	End												
Section 1	555	1055	575	625	50	2	0	0	40	5	0	20	0	0	0	0
Section 2	1055	1555	1055	1105	50	0	20	0	25	2	0	0	2	5	2	3
Section 3	1555	2055	1555	1605	50	1	11	0	5	0	0	0	0	2	0	2
Section 4	2055	2555	2055	2105	50	5	2	5	0	10	0	0	0	4	0	0
Section 5	2555	3055	2555	2605	50	0	0	0	0	5	0	0	1	0	0	0
Section 6	3055	3675	3055	3117	62	3	0	0	0	12	0	0	0	2	0	0
Insp length total					312	11	33	5	70	34	0	20	3	13	2	5
Treat length total		3120				110	330	50	700	340	0	200	30	130	20	50

UNIT COSTS


Treatment Costs for Caculations for 1998 estimates
File Edit View
The Standard TSF Cost Set
Currency as at 1/07/93
Actually 1 Jul 91 dollars
TSF SAC
Earthworks $15.00 /m3
First Coat Seal $3.00 /m2
Urban Reseal $3.00 /m2
Urban Strengthening $30.00 /m2
Earth SWC Cleaning $2.00 /m
Conc SWC Lip Fill $12.50 /m
Conc SWC Replace $85.00 /m
Asphalt SWC Repair $30.00 /m
Rut Filling $30.00 /m
Pothole Repair $20.00 each
Edge Repair $7.50 /m
Granular Basecourse $63.00 /m3
Rural Reseal $3.20 /m2
Urban Smoothing $15.00 /m2
Earth SWC Make $3.00 /m
Earth Shoulder Repair $2.00 /m
Conc SWC Lip Patch $7.50 /m
Surfaced SWC Clean $0.60 /m
Digout $40.00 /m2
Crack Seal $5.00 /m2
Flushing Repair $10.00 /lane m
Scabbing Repair $6.00 /m2
Copy All
Paste All



Overlay Quantities

COMPUTE TREATMENT COSTS

1. Continued General Maintenance : = $0

2. Reseals : = Treatment Length * C/way width.
   * Unit cost (reseal).

   Example TEST ROAD :
   = 3120m x 10m x $3.20/m^2
   = $99,840.

3. Smoothing :
   Urban : = Treatment Length * C/way width
   * Unit cost (Urban Smoothing Overlay).

   Rural : = {Treatment Length * (C/way width
   \+ Shoulder width L & R + 3.0m) * 0.1
   * Unit cost [Granular Basecourse]}
   \+ {0.35 * Treatment Length * Unit cost [Earthworks]}
   \+ {Treatment Length * C/way width * Unit cost [First Coat]}.

   Example TEST ROAD :
   = {3120m * (10.0 + 0 + 0 + 3.0) * 0.1m*$63/m^3}
   + {0.35m^3/m * 3120 * $15.00/m^3}
   + {3120m * 10.0m * $3.00/m^2}
   = $365,508.

COMPUTE TREATMENT COSTS (Cont'd).

4. Strengthening :
   Urban :
   = Treatment Length * C/way width
   * Unit cost [Urban Strengthening Overlay].

   Rural :
   = {Treatment Length * (C/way width
   + Shoulder width L & R + 3.5m) * 0.15
   * Unit cost [Granular Basecourse]}
   + {0.55 * Treatment Length
   * Unit cost [earthworks]}
   + {Treatment Length * C/way width * Unit cost [First Coat]}

   Example ROAD TEST:
   = {3120m * (10.0 + 0 + 0 + 3.5) * 0.15m * $63/m^3
   + {0.55m^3/m * 3120 * $15.00/m^3}
   + {3120m * 10.0m * $3.00/m^2}
   = $517,374.

COMPUTE REPAIR COSTS

(a) Rutting Cost :

= Metres of wheelpath rutting in inspection length
* Treatment Length/Inspection Length * Unit Cost
Cost [Rut Filling].

Example TEST ROAD:
= 11m x 3120/312 x $30.00/m = $3,300.

(b) Shoving Cost :

= Metres of wheelpath shoving in the inspection length
* Treatment Length/Inspection Length * Unit Cost [Digouts].

Example TEST ROAD :
= 33m x 3120m/312m x $40.00/m^2*2= $26,400.

(c) Alligator Cracking Cost :

= Metres of wheelpath alligator cracking in the inspection length
* Treatment Length/Inspection Length
* Unit Cost [Crack Sealing}.

Example TEST ROAD :

= 34m x 3120m/312 * $5.00 = $1,700.

COMPUTE REPAIR COSTS (Cont'd).

(d) Edge Break Cost :

= Length of edgebreak on both sides of the inspection length
* Treatment Length/Inspection Length
* Unit Cost [Edgebreak Repair].

Example TEST ROAD :
= 2m x 3120m/312 x $7.50/m = $150.

(e) Scabbing Cost :

= Area of scabbing in the inspection length
* Treatment Length/Inspection Length
* Unit Cost [Scabbing repair].

Example TEST ROAD :
= 5m x 3120/312 x $6.00 = $300.

IF Reseal Option Chosen AND Area Scabbing > 10% C/way Area.

THEN
Scabbing Cost = Scabbing Cost * 0.2

ELSE
Scabbing Cost = $0.

Example TEST ROAD :
255m^2/(312 x 10.0) x 100 = 8.2% = $0.

COMPUTE REPAIR COSTS (Cont'd).

(f) Flushing Cost :

= Metres of wheelpath flushing in inspection length
* treatment length/(inspection length *2) *
[repair flushed pavement].

Example TEST ROAD :
= 70m x 3120/(312 x 2) x $10.00 = $3,500.

(g) L & T and Joint Crack Cost :

= (Length of Longitudinal and Transverse cracks
\+ length of Joint Cracks in the inspection length)
* Treatment Length/Inspection Length
* Unit Cost [Crack Sealing]
* 0.67.

Example TEST ROAD :
= 20m x 3120/312 x 0.67 x $5.00 = $670.

COMPUTE REPAIR COSTS (Cont'd).

(h) Potholes Cost :

= Number of potholes in the inspection length
* Treatment Length/Inspection Length
* Unit Cost [Each pothole repair].

Example TEST ROAD :
= 3ea x 3120/312 x $20.00 = $600.

COMPUTE TOTAL PRELIMINARY REPAIR COSTS FOR EACH TREATMENT OPTION

1. Continued General Maintenance :
Preliminary Repair Cost

= Shoving Repair Cost
+ Alligator Cracking Repair Cost
+ Repair of all Scabbing Cost
+ Pothole Repair Cost
+ Edgebreak Repair Cost
+ Rutting Repair Cost
+ Joint and L & T Repair Cost.

Example TEST ROAD :
= $26,400 + $1,700 + $300 + $600 + $150
+ $3,300 + $670
= $33,120.

2. Reseals :
Preliminary Repair Cost

= Rutting Repair Cost
+ Shoving Repair Cost
+ Pothole Repair
+ Partial Scabbing Repair Cost
+ Edgebreak Repair Cost
+ Flushing Repair Cost

Example TEST ROAD :
= $3,300 + $26,400 + $600 + $0 + $150 + $3,500
= $33,950.

COMPUTE TOTAL PRELIMINARY REPAIR COSTS FOR EACH TREATMENT OPTION (Cont'd).

3. Smoothing Overlay :
   Preliminary Repair Cost

   = Shoving Repair Cost.

Example TEST ROAD :
= $26,400.

4. Strengthening Overlay :
   Preliminary Repair Cost = $0.

Example TEST ROAD :
= $0.

5. Due to Delay :

   = Shoving Repair Cost
   + Alligator Cracking Repair Cost
   + Potholes Repair Cost
   + Scabbing Repair Cost (No Area)
   - Scabbing Repair Cost (Reseal)
   - 10% Rutting Repair Cost.

Example TEST ROAD :
= $26,400 + $1,700 + $600 + $300 - $0
- (0.1 x $3,300)
= $28,670.

COMPUTE DRAINAGE COSTS

1. Surfaced Surface Water Channels :

   Broken Concrete SWC Cost :
   = Length broken channel * 1.2 * unit cost
   [Concrete SWC replace].

   = 8 x 1.2 x $85.00
   = $816

   Broken Asphaltic SWC Cost :
   = Length of broken channel * unit cost
   [Asphaltic SWC repair/replace].

   Uphill Concrete SWC Cost :
   = Length uphill channel * 1.2 * unit cost
   [Concrete SWC replace].

   = 10 x 1.2 x $85.00
   = $1,020

   Uphill Asphaltic SWC Cost :
   = Length uphill channel * unit cost
   [Asphaltic SWC repair/replace].

   High Channel Lip Cost :
   = Length high lip channel * unit cost
   [Surfaced SWC, fill depressions at channel lip].

   = 15 x $12.50
   = $187.50

COMPUTE DRAINAGE COSTS (Cont'd).

Broken Surface at Channel Lip Cost :
= Length broken surface * unit cost [Surfaced SWC, patch pavement at channel lip].

= 55 x $7.50
= $412.50

Blocked SWC Cost :
= Length blocked channel * unit cost [Surfaced SWC, clean].

= 2 x $0.60
= $1.20

COMPUTE DRAINAGE COSTS (Cont'd).

2. Earth Surface Water Channels :

   Inadequate SWC Cost :
   = Length inadequate channel * unit cost
   [Earth SWC, construct].

   Example ROAD TEST :
   = 770m x $3.00/m = $2,310.

   Blocked SWC Cost :
   = Length blocked channel * unit cost
   [Earth SWC, clean].

   Example ROAD TEST :
   = 35m x $2.00/m = $70.

3. Shoulders :

   Ineffective Shoulder Cost :
   = Length ineffective shoulder + unit cost
   [Earth shoulder chip grass].

   Example TEST ROAD :
   = 65m x $2.00/m = $130.

SUMMARY OF DRAINAGE COSTS

1. Drainage Costs for Resurfacing Option.
(Fix All).

Surfaced SWCs :

= Blocked SWC cost.
\+ High channel lip cost.
\+ Broken surf. at channel lip cost.
\+ Broken channel cost.
\+ Uphill channel cost.

Earth SWCs :

= Blocked channel cost.
\+ Inadequate channel cost.
\+ Ineffective shoulder cost.

Example TEST ROAD :
= $1.20 + $187.50 + $412.50 + $816
+ $1,020 + $70 + $2,310 + $130
= $4,947.20

SUMMARY OF DRAINAGE COSTS (Cont'd).

2. Drainage Costs For General Maintenance Option. (Fix Part) (Drain Tidy).

Surfaced SWCs :

= Blocked SWC cost.
\+ High channel lip cost.
\+ Broken surf. at channel lip cost.
\+ Broken channel cost for asphaltic channels only.

Earth SWCs :

= (Blocked + Inadequate) * unit cost. [Earth SWC, clean].
\+ Ineffective shoulder cost.

Example TEST ROAD :

= $1.20 + $187.50 + $412.50
+ (805m x $2.00) + $130.00
= $2,341.20

SUMMARY OF DRAINAGE COSTS (Cont'd).

3. Drainage Costs for Overlay Option.

Surfaced SWCs :

= Blocked SWC cost.
+ Broken channel cost.
+ Uphill channel cost.

Earth SWCs :
The cost of remaking the channels is part of the construction cost.

Example TEST ROAD :
= $1.20 + $816 + $1,020
= $1,837.20

ASSESS NEED FOR RESURFACING

1. Second Coat Seal :

IF Surface type = COAT1 and Use Code >2

OR Surface type = COAT1 and Use Code <=2
And Surface Age >1,

THEN
LET Seal Need = S
LET Reason = 1st coat seal (surface date) requires
a second coat seal by (due date)

ASSESS NEED FOR RESURFACING (Cont'd)

2. Reseal in Budget Year :

IF	Shoving Length	>	3% wheelpath.
OR	Alligator cracking length.	>	3% wheelpath.
OR	Scabbing Area	>	25% cway area and seal age >0.5 x seal life cycle.
OR	Potholes + Pothole patches.	>	1 per 10m cway.
OR	Alligator cracking + Shoving Length.	>	3% wheelpath.
OR	Flushing	>	30% wheelpath.

THEN
LET Seal Need = 1
LET Reasons = any or all of the above faults have a quantity greater than the trigger levels shown.

ASSESS NEED FOR RESURFACING (Cont'd)

2. Reseal in Budget Year (Cont'd)

Example TEST ROAD

Shoving	= 2.6% WP
Alligator Cracking	= 2.7% WP
Scabbing	= 8.2% insp area
Potholes + Pot Hole Patches	= 1 per 20m of inspection length
Alligator Cracking + Shoving	= 5.3% WP
Flushing	= 5.6% WP

LET Seal Need = 1
LET Reason = Alligator Cracking + Shoving Exceeds 3% WP.

ASSESS NEED FOR RESURFACING (Cont'd)

2. Reseal in Budget Year (Cont'd)

* Reseal in Budget is also determined from SCRIM survey results where required by the user.

* The user must input the percentage above wheelpath which has a SCRIM deficiency value below which a surface treatment is indicated for the following situations :

  (1) The Entire Treatment Length (low average SCRIM value for the entire length)
  (2) A Site Category (low SCRIM value for a particular site, e.g. pedestrian crossing)
  (3) Continuous failed length (low SCRIM over a continuous length, e.g. 200m within the treatment length).
  (4) Maximum SCRIM deficiency too great for any reading.
  (5) Low SCRIM values and a history of wet or loss of control accidents at a particular site.

  Where the SCRIM deficiency values exceed the acceptable levels for greater than the % of wheelpath input site or treatment length.

  LET Seal Need = 1
  LET Reason = Low Skid Resistance

ASSESS NEED FOR RESURFACING (Cont'd)

3. Reseal In the Year Following The Budget Year :

ELSE

IF	Shoving Length	>	1% wheelpath.
OR	Alligator cracking length.	>	1% wheelpath.
OR	Scabbing Area	>	10% cway area.
OR	Potholes + Pothole patches.	>	1 per 25m cway.
OR	Alligator cracking + Shoving Length.	>	1% wheelpath.
OR	Flushing	>	15% wheelpath.

THEN

LET Seal Need = 2.

LET Reasons = any or all of the above faults have a quantity greater than the trigger levels shown.

ASSESS NEED FOR RESURFACING (Cont'd)

4. Locking Coat Seal

IF	Scabbing	>	10% insp area
AND	Seal Age	<	0.5 * Normal Life Cycle

THEN
LET Seal Need = L
LET Reason = % area scabbed (x%) within (y) years of surfacing (surfacing date).

6. Expired Seal

IF ALL tests (Including Resurfacing, Smoothing and Strengthening) fail to trigger a treatment

THEN
IF 100* (Seal Age – Normal Life Cycle)/Normal Life Cycle
> User Defined Tolerance specified by user in treatment selection decision factors.

THEN
LET Treatment Description = RN
LET Reason = Design life exceeded

ELSE
LET Treatment Description = GM

ESTIMATE RESURFACING CYCLE FOR EXISTING PAVEMENT

1. Estimate total life of present seal.

Total Life For :

Seal need 1 = seal age + 1 year.
Seal need 2 or L or RN = seal age + 2 years.
Seal need GM = greater of :
seal age + 3 years
or normal cycle.

Example TEST ROAD
Seal Need = 1.
Seal Age = 1987 - 1997 = 10 years.
Total Life = 10 + 1 = 11 years.

ESTIMATE RESURFACING CYCLE (Cont'd).

2. Check resurfacing cycle against present seal condition.

IF	Cost of repairs from seal delay	>	Cost of reseal * Economic factor.

THEN reduce Total Life by 1 year.

IF	Cost of repairs from seal delay	>	Cost of reseal * 2 Economic factor.

THEN reduce Total Life by 2 years.

Example TEST ROAD :

Seal age	**=**	**10 years.**
Total Life	**=**	**11 years.**
Economic factor	**=**	**0.1480**
Maintenance due to delay	**=**	**$15,470.**

Reseal Cost * Economic Factor =
$99,840 x 0.1480 = $14,776

Total Life Reduced to 10 years.

ESTIMATE RESURFACING CYCLE (Cont'd).

3. Estimate Resurfacing Cycle for Average Grade 3 Reseal.

Resurfacing cycle =

$$\frac{\text{Normal life Grade 3}}{\text{Normal life existing}} * \frac{\text{Total Life}}{1}$$

Example TEST ROAD :

Total Life = 10 years.
Use Code = 3.
Normal Life for grade 3 = 10 years.
Normal Life for grade 4 = 8 years.

Resurfacing cycle =

$$\frac{\text{10 years}}{\text{8 years}} * \frac{\text{10 years}}{1} = \text{12 years}$$

ESTIMATE RESURFACING CYCLE (Cont'd).

4. Check resurfacing cycle against normal cycle time.

IF Cycle time < 70% normal cycle.

THEN Check drainage deficiencies.

Surfaced Surface Water channels :
= Length blocked + length broken
+ Length uphill + length broken surface.

Earth Surface Water channels :
= Length inadequate.
+ Greater of : Length blocked, or
Length ineffective shoulder.

IF Drainage length deficient > 0.5 * Rating Length.

THEN Check for drainage related distress types.

Example TEST ROAD :

70% of normal cycle = 0.7 * 10 = 7.0 years.
Cycle time for TEST RD = 12 years, therefore reseal cycle is normal.

ESTIMATE RESURFACING CYCLE (Cont'd).

5. If the reseal cycle was <70% normal, check for drainage related distress types.

IF	Shoving Length	>	3% wheelpath.
OR	Alligator cracking length	>	3% wheelpath.
OR	Potholes + Pothole patches	>	1 per 10m cway
OR	Flushing Length	>	25% wheelpath

THEN Assume shortened life cycle is due to poor drainage and resurfacing cycle = 1.2 * existing cycle if drainage repaired.

ESTIMATE RESURFACING CYCLE (Cont'd).

6. If the drainage is not deficient, check for poor construction, supervision or design.

IF	Area of Scabbing	>	10% of cway area
OR	Flushing Length	>	10% wheelpath
AND	Shoving Length	< =	1% wheelpath
AND	Alligator cracking length	< =	1% wheelpath
AND	Potholes + Pothole patches	< =	1 per 25m cway

THEN The resurfacing cycle = normal life for a grade 3 reseal.

ELSE

Resurfacing cycle = Total life of existing seal.

ESTIMATE RESURFACING CYCLE FOR SMOOTHING OVERLAY

IF	Resurfacing cycle for existing pavement	>	Normal cycle
LET	Smoothing cycle=		Existing resurfacing cycle
ELSE			
IF	Resurfacing cycle for existing resurfacing * 1.5	>	Normal cycle
LET	Smoothing cycle=		Normal cycle
ELSE			
LET	Smoothing cycle=		Existing pavement cycle * 1.5

Note : All cycle times in terms of grade 3 seal.

Example TEST ROAD :

Existing resurfacing cycle	**=**	**12 years**
Normal cycle	**=**	**10 years**
Existing cycle	**>**	**normal cycle**
Therefore smoothing resurfacing cycle	**=**	**12 years.**

ESTIMATE RESURFACING CYCLE FOR STRENGTHENING OVERLAY

IF	Resurfacing cycle for existing pavement	>	Normal cycle
LET	Strengthening cycle	=	Existing resurfacing cycle.

ELSE

LET	Strengthening cycle	=	Normal cycle.

Note : All cycle times in terms of grade 3 seal.

Example TEST ROAD :

Existing resurfacing cycle	**=**	**12 years.**
Normal cycle	**=**	**10 years.**

Existing cycle > normal cycle.

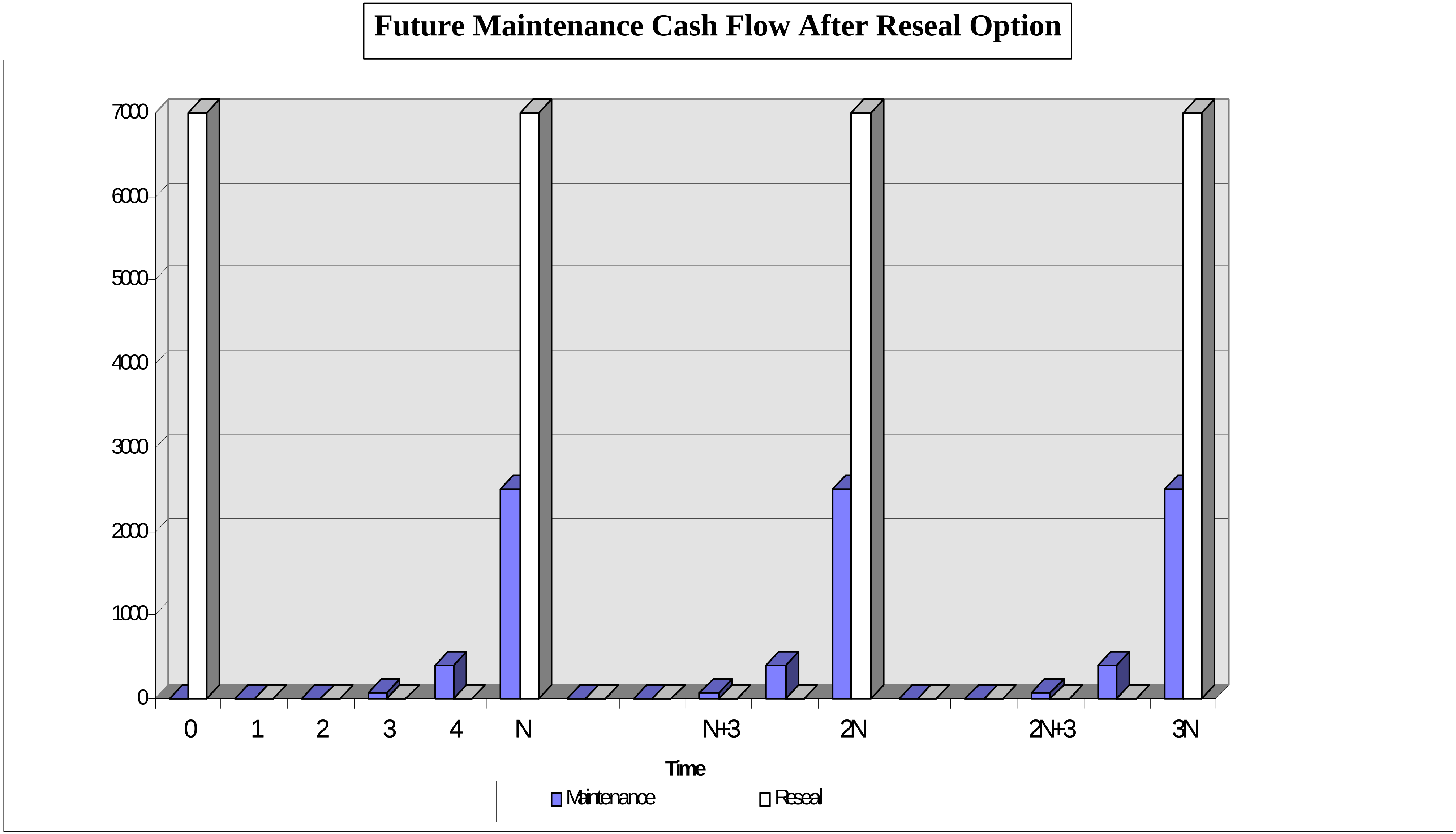
Therefore strengthening resurfacing cycle = normal cycle = 12 years.

ESTIMATE PRESENT VALUE OF FUTURE RESEALS AND GENERAL MAINTENANCE

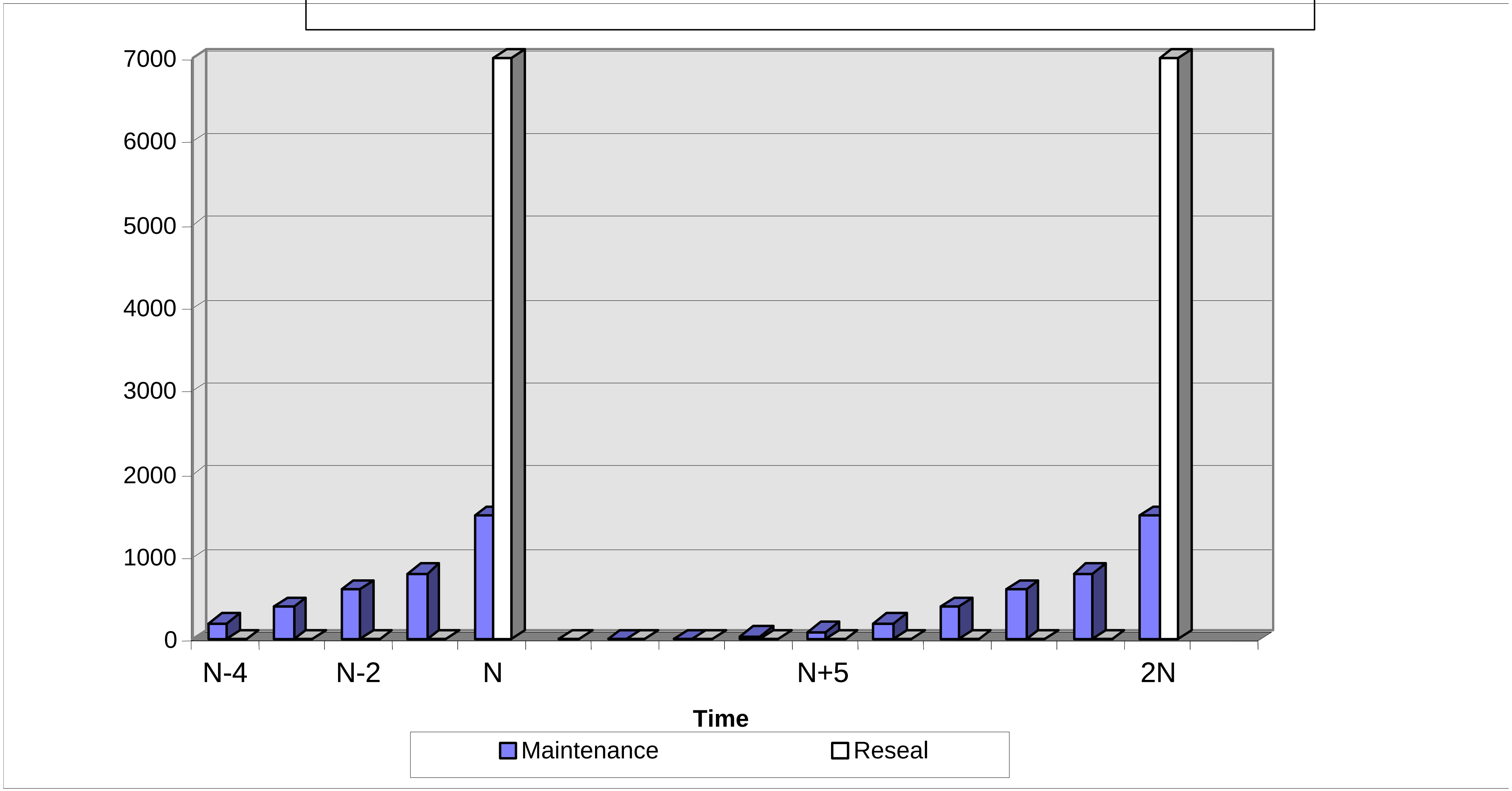
1. Assumptions.

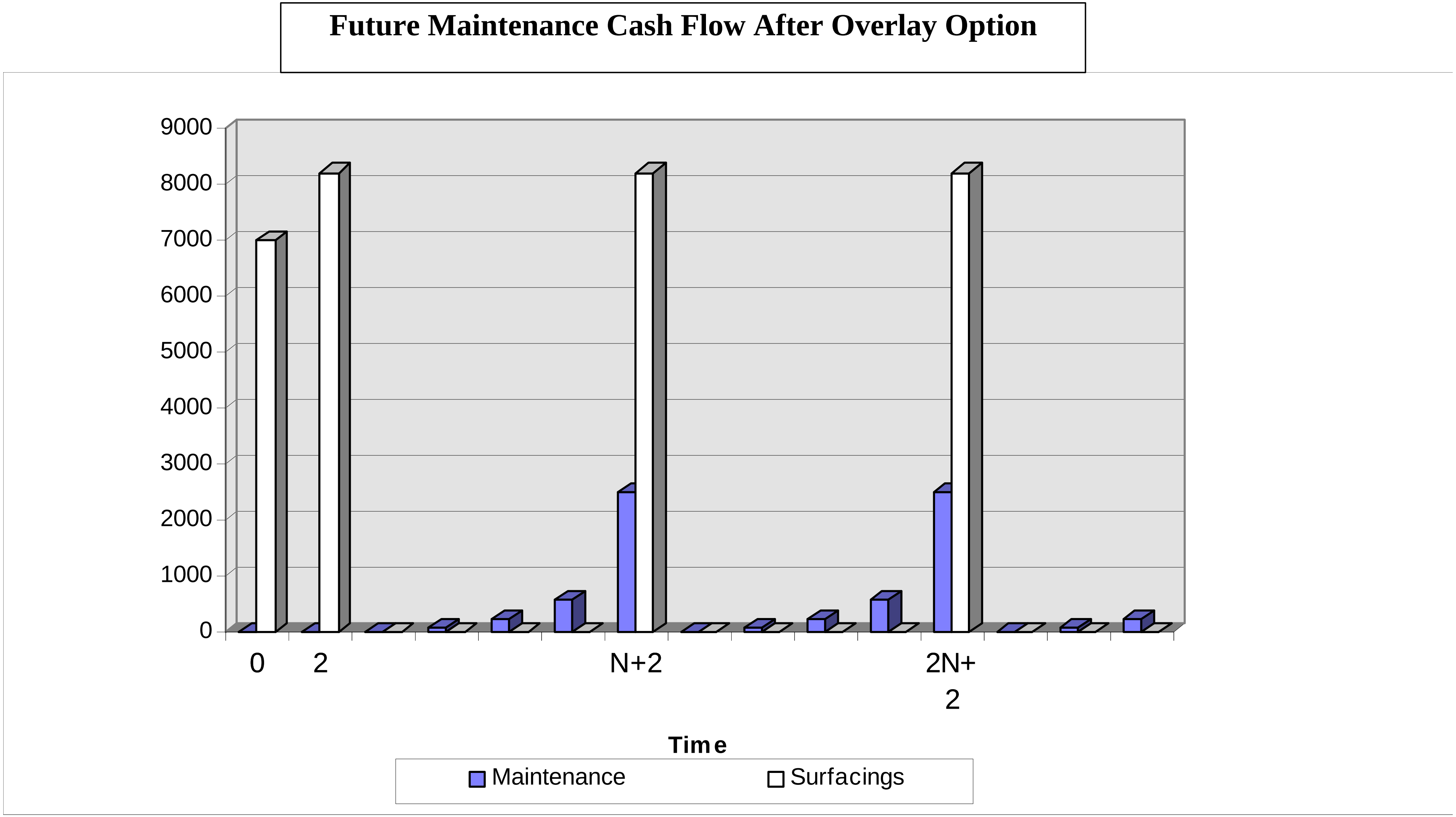
   (a) After an area treatment pavement maintenance will be low, gradually increasing in magnitude, until it is economic to resurface.

   (b) A resurfacing cycle < 5 years indicates an inadequate pavement structure with subsequent high maintenance costs and high pre-reseal treatment costs.

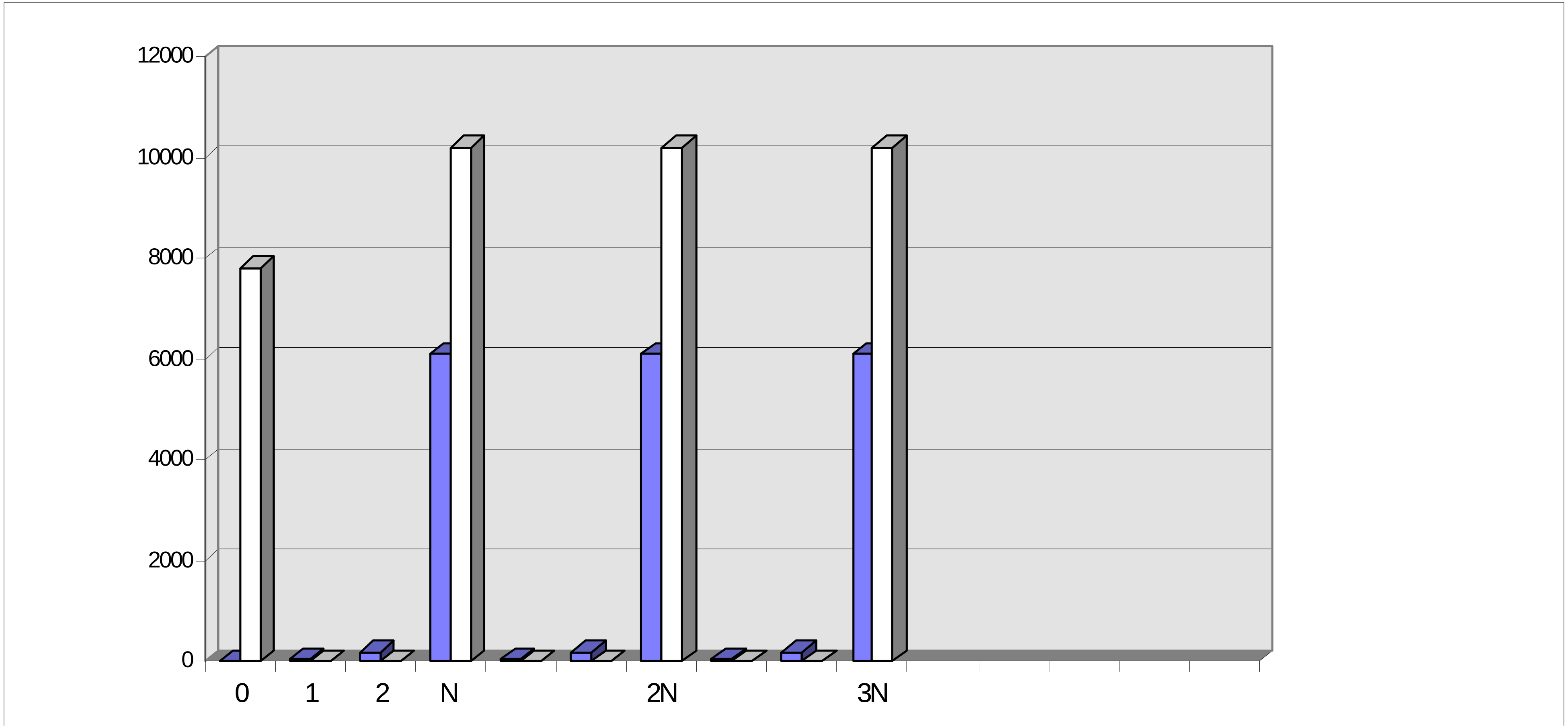

Future Maintenance Cash Flow After Reseal Option
7000
6000
5000
4000
3000
2000
1000
0
0
1
2
3
4
N
N+3
2N
2N+3
3N
Time
Maintenance
Reseal

Future Maintenance Cash Flow After No Area Treatment




Future Maintenance Cash Flow After Overlay Option
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
2
N+2
2N+
2
Time
Maintenance
Surfacings

Future Maintenance Cash Flow Where Life Cycle < 5 Years



ESTIMATE PRESENT VALUE OF FUTURE RESEALS AND GENERAL MAINTENANCE

Mathematical Model

Relationship is :
PV of future Reseals and General Maintenance
= Reseal cost * PV Total Factor.

Where PV Total Factor depends on :
Resurfacing cycle and
Remaining life to next resurfacing.

Example TEST ROAD :

Continued General Maintenance :
Not an option.

Resurfacing Option :
Resurfacing cycle N = 12 years.
Life to next resurfacing = 12 years.
PV Factor = 0.684.
PV Maint = 0.684 x $99,840 = $68,291.

Smoothing Option :
Resurfacing cycle after second coat
N = 12 years.
Life to next resurfacing = 12 years (after 2nd coat)
PV Factor = 0.684.
Second Coat in 2 years' time PWF = 0.826.
PV Maintenance = (1 + 0.684) * $99,840 * 0.826
= $138,876.
Strengthening Option :
Same as smoothing.

SUMMARY OF COSTS

Treatment	Maintenance	Reseal	Smoothing	Strengthening
Construction	N/A	$99,840	$365,508	$517,374
Maintenance	$33,120	$33,950	$26,400	$0
PV Maintenance	N/A	$68,291	$138,876	$138,876
Drainage	$2,341	$4,947	$1,837	$1,837
TOTAL	N/A	$207,038	$532,621	$658,087

CHOOSE BEST SHAPE CORRECTION OPTION AND CALCULATE USER BENEFITS

1. Choose between Smoothing and Strengthening :

   Example TEST ROAD :
   Choose Smoothing.

2. User Benefits :

   Annual Savings =
   Additional vehicle costs/Km (present roughness) - Additional vehicle costs/Km (roughness after smoothing) * AADT * 365 * treatment length (m)/1000
   P V Savings = Annual Savings * 9.524.

CHOOSE BEST SHAPE CORRECTION OPTION AND CALCULATE USER BENEFITS (Cont'd)

Example TEST ROAD :

Heavy Commercial Vehicles (Type 1)

HCVI = Vehicles per day = 10
Average roughness now = 88 counts/Km.
Average roughness smoothed = 70 counts/Km.
Additional $/vehicle Km (90) = 0.0559.
Additional $/vehicle Km (70) = 0.0034.
Savings = $0.0525/HCV 1 Km.

Annual savings = AADT * $0.0525 * 365 * Treatment Length/1000
= 10 * $0.0525 * 365 * 3120/1000 = $598

Present Value (including 1% growth rate) from PEM

Growth rate (r) = 0.01

$598 * (9.524 + 0.01*75.714) = $6,147

CHOOSE BEST SHAPE CORRECTION OPTION AND CALCULATE USER BENEFITS (Cont'd)

Example : TEST ROAD :
All vehicle types

		AADT	Target Roughness VOC	Present Roughness VOC	Diff	PV VOC 1% Growth 25 yrs 10% Discount
	%	Number	Cents/km	Cents/km	Cents/km	$
Cars	82%	820	0.17	1.13	0.96	92,361
LCV	9%	90	0.19	1.19	1.00	10,530
MCV	3%	30	0.17	2.29	2.12	7,441
HCV 1	3%	30	0.34	4.71	4.38	15,370
HCV11	3%	30	0.42	4.68	4.26	14,071
Bus	0%	0	0.18	1.70	1.53	
Total	100%	1000				
PV						$140,673

RC1 Adjustment 1048/1002 x $140,673.00 = $147,131.00

CALCULATE BENEFIT/COST RATIO AND CHOOSE TREATMENT

1. Calculate Benefit/Cost Ratio :

$$= \frac{\text{User Benefits}}{\text{Overlay Cost - Non-overlay cost}}$$

Example TEST ROAD :

PV User Benefits	**=**	**$147,131.**
PV Smoothing Cost	**=**	**$519,421.**
PV Reseal Cost	**=**	**$193,828.**

$$\text{B/C Ratio} = \frac{\$147{,}131}{\$519{,}421 - \$193{,}828} = 0.45$$

2. Choose Treatment :

IF Benefit/Cost > User Supplied Value Ratio

THEN Choose Overlay Option.

ELSE Choose Non-overlay Option.

Example TEST ROAD :

Benefit/Cost Ratio	**=**	**0.45**
User Supplied Value	**=**	**1.0**
Non-overlay option	**=**	**Seal Need = 1.**
Treatment Selected	**=**	**Reseal in Budget.**

COMPUTE RESEAL PRIORITY IF OPTION IS RESEAL IN THE BUDGET YEAR

1. Estimate additional maintenance costs as a result of delaying reseal by 1 year.

2. Calculate first year rate of return.

$$= \frac{\text{Cost of Delay}}{\text{Reseal Cost}} * \frac{100}{1} \%$$

3. FYRR = Priority Indicator.

Example TEST ROAD :
Maintenance due to delay = $15,470.
Reseal Cost = $99,840.

FYRR = $15,470/$99,840* 100 %
= 15.5%.

ASSESS NEED FOR SEAL WIDENING

This assessment is only done if the treatment section has more than 95% earth surface water channels.

IF Annual rate of Edge Break < 5% of the length of c/way edge.

THEN
Report ‘Keep at Present C/way Width’

ELSE
Report “Widen “

Example TEST ROAD :
Treatment section has 97% Earth SWCs.
Edge Break + Edge Break Patches = 7m.
Seal age = 10 years.
Length of seal edge in inspection length = 574m.
Annual rate of edge break = 7m/10 years. 0.7m/year
= 0.7m/574 x 100 = 0.12%.
Report ‘Keep at Existing Width.’

SELECTION OF DRAINAGE TREATMENT

IF Shape Correction option chosen

THEN
- Earth SWCs are excavated as part of construction.
- Surfaced SWCs are reported for :
  Drainage for Overlay.

ELSE IF
Reseal in Budget option is chosen
Drainage - Fix All

THEN
- All SWCs are reported for :
  Drainage - Fix Part.

Example TEST ROAD :

Treatment chosen	**=**	**Reseal in Budget.**
Therefore drainage	**=**	**Fix All.**
Drainage cost	**=**	**$4,947.**

7. CASE STUDY

Rodney District Council

Hibiscus Ward

Report for Rodney District Council

STATISTICS FOR HIBISCUS WARD

Length of road	=	239 km
Length of sealed road	=	170 km
AADT < 500 vpd	=	36%
AADT 500 - 1000	=	30%
AADT 1000 - 2000	=	12%
AADT > 2000	=	22 %

PARAMETERS USED FOR

TREATMENT SELECTION PROGRAMME

Unit Costs :

- 30 September 1989.

Target Roughness Values :

- Urban = 69 counts/Km.
- Rural = 80 counts/Km.

Benefit Cost Ratios for SCT Reports :

- 1.5 (Good return).
- 3.0 (Approx. same as Shs).
- 5.5 (Present level of funding).

ANALYSIS OF TREATMENT SELECTION RESULTS

Resurface Next Time : (Approx. 2 years on)

- 16.5 Km (Implies annual requirement).

Resurface in Budget : (Approx. 1 year on)

- 37.1 Km.

Backlog :

- Approx. 20 Km.

Estimated Maintenance Costs :

- $10,336/Km	when 'Reseal in Budget.'
- $902/Km	when 'Gen. Maintenance.'

Estimated Savings in Maintenance Costs :

- $9,424/Km * 20 Km = $188,676.

From FYRR Method, Estimated Savings :

- $7,738/Km.
- $7,738/Km * 20 Km = $154,760.

ANALYSIS OF TREATMENT SELECTION RESULTS (Cont'd).

Shape Correction (Smoothing) :

-	B/C 1.5	=	26.1 Km.
-	B/C 3.0	=	9.7 Km.
-	B/C 5.5	=	2.4 Km.

Shape Correction (Strengthening) :

-	B/C 1.5	=	3.7 Km.
-	B/C 3.0	=	2.3 Km.
-	B/C 5.5	=	1.2 Km.

'<u>One Off</u>' Costs vs <u>Annual</u> User Savings :

B/C = 5.5 to B/C = 3.0.

-	Cost	=	$1,088,704.	
-	User Savings	=	$638,000.	p.a.

B/C = 5.5 to B/C = 1.5.

-	Cost	=	$4,479,616.	
-	User Savings	=	$1,218,689	p.a.

7.1 Results of Treatment Selection Programme for Hibiscus Ward

7.1.1 General

The data collection for the Hibiscus ward was completed by the end of 1989 and the Treatment Selection programme was run in early 1990. The programme generally ran without difficulty with only minor problems. Generally, the data appeared to have been conscientiously collected and input.

The initial results were improved and updated with the input of the surfacings from the 1989/90 resurfacing season and then these roads were re-rated. The road sections on the shape correction list for 1989/90 were manually removed from the reported results. The pleasing aspect of this exercise was that all the sections on the SCT list for 1989/90 were shown by the RAMM system to need shape correction and had benefit/cost (B/C) ratios of between 4 and 10.

7.1.2 Target Roughness Values

The average roughness values achieved for the 1988/89 SCT work were used as target roughness values which the programme uses for the calculation of B/C ratios. The values input were 69 counts/Km for urban work and 80 counts/Km for rural work.

7.1.3 Unit Costs

Unit costs (30 September 1989) for maintenance work were supplied and input into the programme. All consequent calculations were carried out with costs pertaining to 30 September 1989.

7.1.4 Future Maintenance Options

The programme was run with three different benefit cost ratios as a cut-off value above which shape correction is reported. The three values used were B/C = 1.5, B/C = 3.0 and B/C = 5.5. The value of 1.5 was chosen because it represented a significant return for money expended on SCT work. The value of 3.0 was chosen because it represents the approximate trigger level at which SCT work is carried out on the state highways. The value of 5.5 was chosen because it was estimated from the initial results as representing approximately the trigger level at which SCT work is currently being carried out in the Hibiscus Ward. The benefits resulting from undertaking all the work reported at each of these cutoff values was also calculated. The following results have also been graphed.

Option 1 (Minimum B/C Ratio of 1.5 for SCT)

Lengths Reported			**Costs Reported**	
General maintenance	100,591m		General maintenance	$274,906
Flushing	1,075m		Drainage (gen maintenance)	$309,506
Reseal (2nd priority)	10,109m		Reseal (1st priority)	$494,209
Reseal (1st priority)	27,070m		SCT (smoothing)	$3,559,965
SCT (smoothing)	26,087m		SCT (strengthening)	$614,018
SCT (strengthening)	3,720m		Widening	$33,324
	168,652m			$5,285,928

Option 2 (Minimum B/C Ratio of 3.0 for SCT)

Lengths Reported			**Costs Reported**	
General maintenance	109,656m		General maintenance	$354,0005
Flushing	1,075m		Drainage (gen maintenance)	$314,101
Reseal (2nd priority)	13,132m		Reseal (1st priority)	$598,072
Reseal (1st priority)	32,767m		SCT (smoothing)	$1,275,887
SCT (smoothing)	9,682m		SCT (strengthening)	$419,627
SCT (strengthening)	2,340m		Widening	$33,324
	168,652m			$2,995,016

User benefits resulting from a move from B/C 1.5 to B/C 3.0 = $580,604 per year.
Car = 2 cents/Km. Truck = 10 cents/Km.

Option 3 (Minimum B/C Ratio of 5.5 for SCT)

Lengths Reported			**Costs Reported**	
General maintenance	111,462m		General maintenance	$408,903
Flushing	1,503m		Drainage (gen maintenance)	$319,037
Reseal (2nd priority)	14,882m		Reseal (1st priority)	$669,933
Reseal (1st priority)	37,137m		SCT (smoothing)	$300,568
SCT (smoothing)	2,409m		SCT (strengthening)	$174,547
SCT (strengthening)	1,259m		Widening	$33,324
	168,652m			$1,906,312

User benefits resulting from a move from B/C 3.0 to B/C 5.5 = $638,085 per year.
Car = 3 cents/Km. Truck = 15 cents/Km.

Discussion of Results

The results indicate that there is a significant backlog of resurfacing work. This backlog calculates to approximately 20 Km of resurfacing work, given that last season approximately 17 Km of reseal work was carried out. (Note that 2nd coat seals are dealt with outside the RAMM system.) The level at which reseal work is carried out at present is confirmed by the report as being approximately the correct level to cope with the annual deterioration rate. This confirmation comes from the quantity of work reported in the ‘Reseal Next Time’ and ‘Reseal Flushed’ categories which are calculated by the Treatment Selection programme as being likely to require a reseal approximately two years hence.

The need for shape correction is quite high, although it could be argued that the current trigger level is not too unreasonable, given that the state highways were in a similar position some 4 years ago. As can be expected, the higher B/C ratio trigger levels for SCT work (i.e. *lower performance levels*), indicate reductions in maintenance budgets. However, they also indicate significantly higher user costs that are *annual* costs and therefore represent an on going cost to road users in vehicle maintenance.

The demand for general maintenance would decrease if the resurfacing backlog was eliminated and routine maintenance costs reduced. The size of this reduction can be estimated from the costs reported by the treatment selection programme. The maintenance costs reported by the programme indicate that roads which are in a condition, such that they require a reseal in the budget year, have average routine carriageway maintenance needs estimated to be $10,336/Km and that roads which are in a condition, such that they only require general maintenance, have average routine carriageway maintenance needs estimated to be $902/Km. This difference of $9,434/Km indicates that if the backlog of 20Km of reseal was eliminated an estimated maintenance cost saving of $188,680 per year or 16% of the present routine maintenance allocation costs was effected by the elimination of a large backlog of resurfacing from 1980 to 1986.

The treatment selection programme calculates a first year rate of return (FYRR) for all sections of carriageway reported for a reseal in the budget year. This FYRR is based on the likely savings to be made in carriageway routine maintenance by carrying out a reseal when it is technically required. Therefore, another way of calculating the savings in maintenance by carrying out resurfacing when it is required is to multiply the first year rate of return (FYRR) by the reseal cost year. This calculation was carried out through the database programme facilities and an average value of $7,738/Km was returned. This is a similar amount to that calculated above and gives a total saving of $154,760 per year if the resurfacing backlog was eliminated.

A further saving to accrue by eliminating the resurfacing backlog will come from the decrease in the rate at which roads will require shape correction. This is not easy to quantify until several ratings and roughness measurements have been carried out, but again the Dunedin City experience was that the demand for SCT work declined significantly after the resurfacing backlog was eliminated.

Recommendation

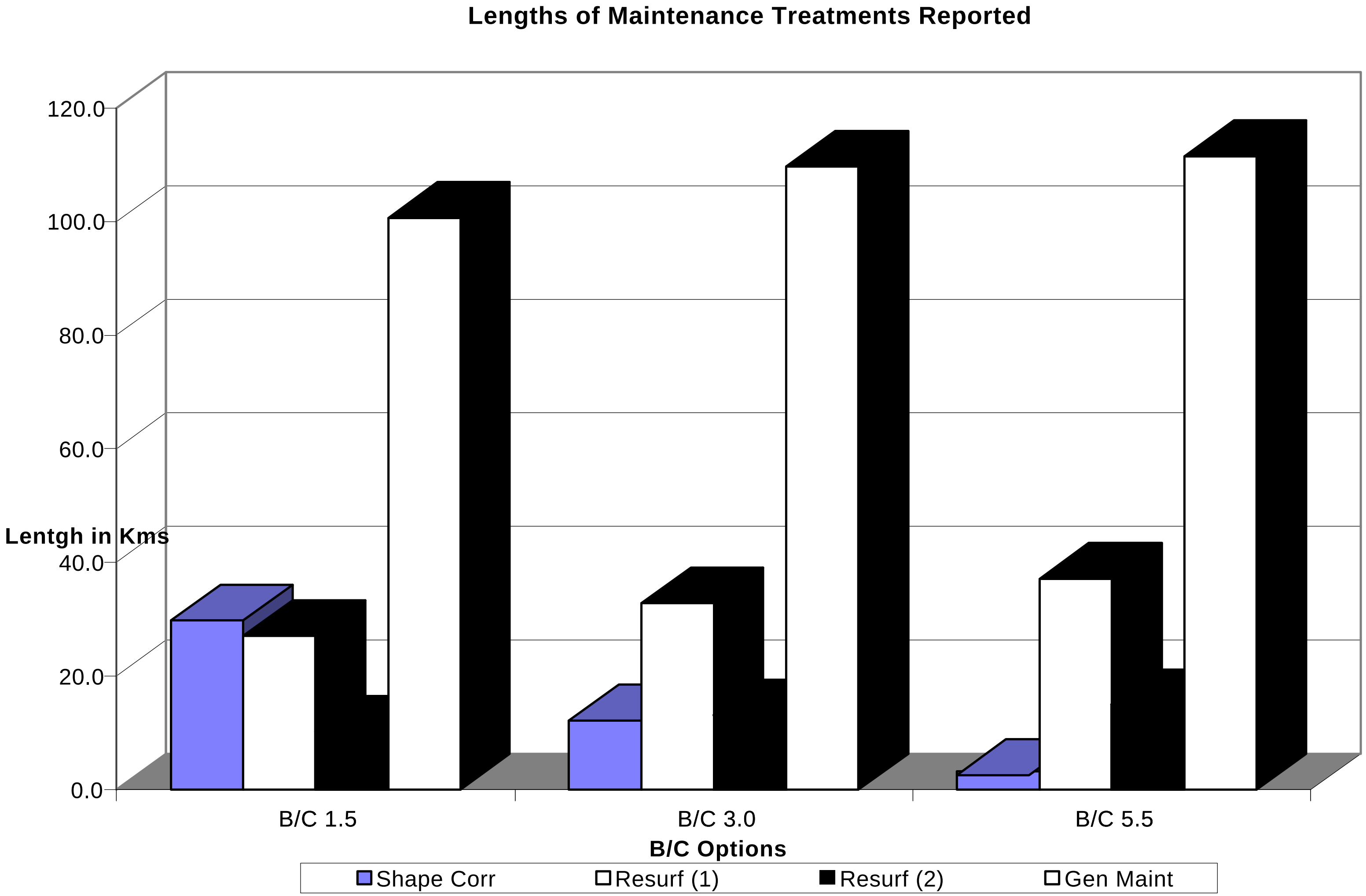
The following recommendations should give medium to long term benefits for the roading system in the Hibiscus Ward. It should be noted that the extra expenditure required by the maintenance strategy suggested is only required until the maintenance backlogs are eliminated and after that time expenditure should be able to be brought back to a level consistent with the annual amount of deterioration in the road network. The level of expenditure at which the maintenance work settles may well be less than the current annual expenditure in real terms. There should also be significant savings in user costs that should benefit the users of vehicles on the road network.

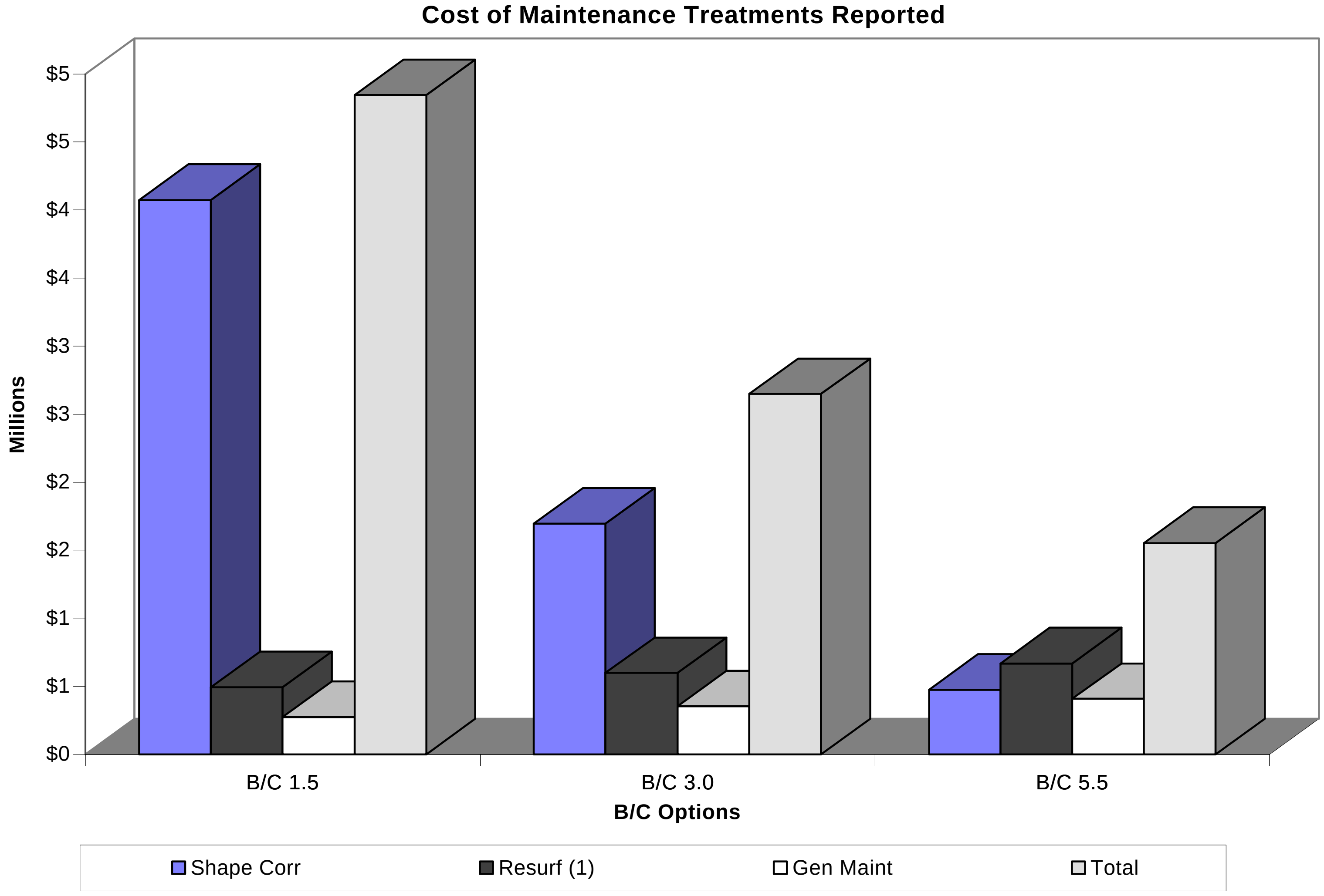
1. Increase the level of reseal work by approximately 7 Km/yr and therefore eliminate the reseal backlog over a period of three years. This will require approximately $120,000 more expenditure in reseals for the Hibiscus Ward. If overall roading funds cannot be increased this money would have to be transferred from construction work.

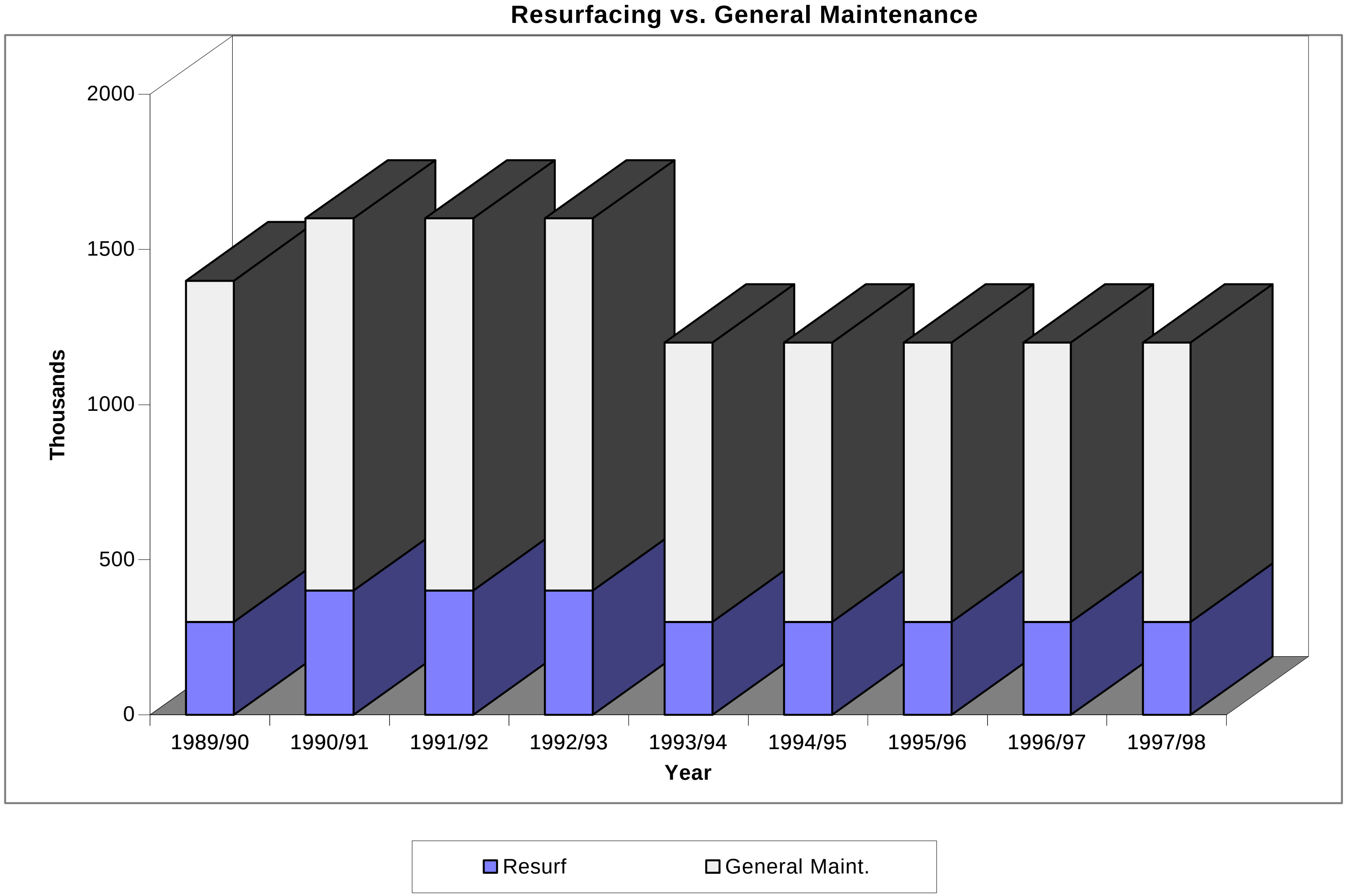
2. After three years reduce the resurfacing to cope with annual average deterioration (treatment selection reports indicate 10% or 17 Km of road network). Use the savings effected in general maintenance and the $120,000 from resurfacings to reduce the SCT work to a trigger level of 3.0 over a further period of approximately 3 years.

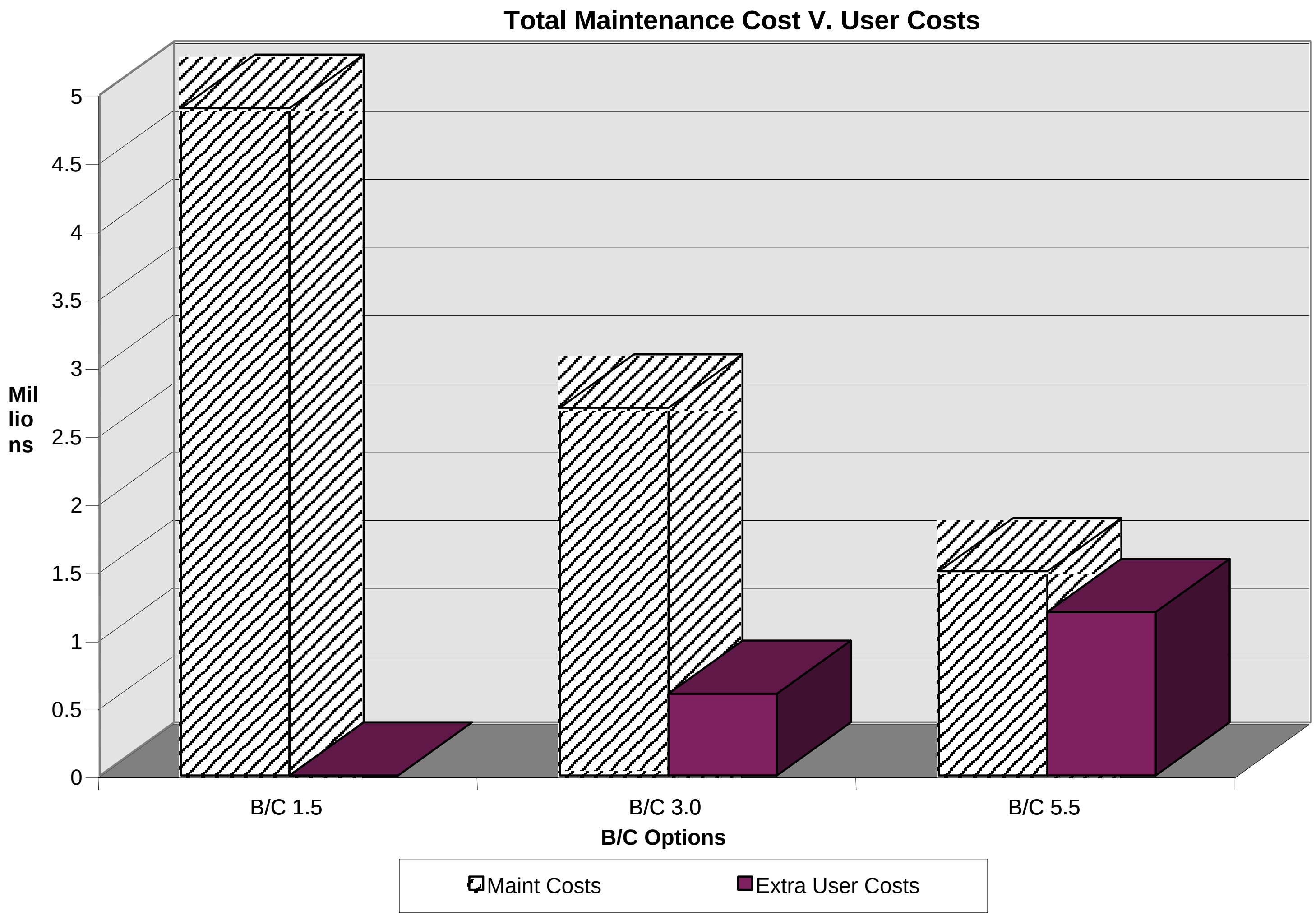
3. After 6 years reduce expenditure to cope with annual deterioration in surfacings and to maintain a trigger level of 3.0 for SCT work.

NOTE: The above plan does not allow for any significant increase in pavement loadings or unexpected climatic disasters.


Lengths of Maintenance Treatments Reported
120.0
100.0
80.0
60.0
Lentgh in Kms
40.0
20.0
0.0
B/C 1.5
B/C 3.0
B/C 5.5
B/C Options
Shape Corr
Resurf (1)
Resurf (2)
Gen Maint


Cost of Maintenance Treatments Reported
Millions
$5
$5
$4
$4
$3
$3
$2
$2
$1
$1
$0
B/C 1.5
B/C 3.0
B/C 5.5
B/C Options
Shape Corr
Resurf (1)
Gen Maint
Total


Resurfacing vs. General Maintenance
Thousands
2000
1500
1000
500
0
1989/90
1990/91
1991/92
1992/93
1993/94
1994/95
1995/96
1996/97
1997/98
Year
Resurf
General Maint.


Total Maintenance Cost V. User Costs
Millions
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
B/C 1.5
B/C 3.0
B/C 5.5
B/C Options
Maint Costs
Extra User Costs