

REG | THE ROAD EFFICIENCY GROUP

# BEST PRACTICE AMP WORKING GROUP

## Case Study

# Enhanced NPV Analysis

Initiative Number 2013\_05



Version No	Date	Item Affected	Description of Change
1	24 Feb 14		Draft Document Created
2	25 Feb 14		Clarity edits after internal review by HNO Outcome Delivery
3	24 Oct 14		Edit for release

# Executive Summary

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The Highway and Network Operations Group has found it beneficial to supplement traditional Net Present Value analysis by requiring that at least three options are analysed (the do-maintenance, do-something (or do-intermediate treatment), and do-rehabilitation) and that an Economic Indicator which reflects cash flow differences between optional programmes is derived.

The benefits arise from:

- A more effective and efficient renewals programme created through the adoption of better value for money renewal treatments
- A better understanding of the need to consider many potential treatment strategies before selecting an option in order to demonstrate value for money robustly
- Better uptake of the approach to asset management required to deliver the goals of the Road Efficiency Group
- Anticipated improved programme selection in the future

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# 1 Introduction

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## 1.1 Project Outline

<b>Project Name:</b>	
Project Location:	HNO Annual Plan development
Project Objectives:	To improve option selection by comparing a broader array of renewal options comparably by using HNOs enhanced NPV analysis
Length:	
Traffic Volume:	
Supplier(s):	Internal
Project Stage:	
Value: (cost savings)	
Scope of Work:	
Environment:	
Constraints:	
Project commenced:	
Key Issues:	

## 1.2 Project Team

<b>Name</b>	<b>Organisation / Role</b>	<b>Contact Details (Email and Telephone)</b>
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## 2 Case study

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### 2.1 Introduction

This case study outlines the process the Highways and Network Operations (HNO) Group is undertaking to improve renewal options selection and NPV assessment and the benefits that are being obtained. These findings have been derived from the experience gained by staff on the 2014/15 Review and Prioritisation Team (RAPT) tour. Because the tour was not complete at the time of preparing this case study the findings are based on the learnings from the 50% of networks visited.

### 2.2 Background And Rationale For Change

There is an increasing need to ensure that the right maintenance and renewal interventions are implemented in the right place at the right time if we are to deliver customer levels of service as effectively and efficiently as we can.

For the NZ Transport Agency's Highways and Network Operations Group this not only means that this must be done well on each of the 23 ongoing networks, but that planning, prioritising, programming and then delivering maintenance and renewal programmes is consistently effective and efficient across all categories of State Highway irrespective of network.

Recent findings from RAPT reviews (annual field based moderation of network programmes) revealed opportunities for improving the timing of renewal interventions. The HNO Group's Maintenance & Operations review documented inconsistent approaches to intervention and treatment selection, collectively signalling opportunities for improved programme development.

A NZ Transport Agency research report (Research Report No. 491- Factors Influencing The Decision To Rehabilitate A Pavement by JE Patrick, and H Aramoorthy of OPUS) reviewed many recent examples of renewal proposals and assessment. The report recommended changes to programme option development and assessment to improve the efficiency of renewal programmes.

Collectively these supported the need for a change in approach to proposing, characterising and assessing renewal proposals to improve the efficiency of each treatment and collectively the effectiveness of the State Highway renewals programme

### 2.3 The Issues Being Addressed

The default Net Present Value analysis techniques published by the NZ Transport Agency for renewal have been in use for some time. Use of these has not been as rigorous as it should be. The tendency has been to propose two options only:

1. A Do Minimum option involving significant and rapidly growing maintenance
2. A Do Rehabilitation treatment involving pavement rehabilitation.

This option proposal and assessment analysis has not always been sufficient to identify the best treatment because:

- Other proposals such as heavy maintenance and resurfacing have not been considered.
- There is confusion between the do-maintenance and do-something options.
- Maintenance costs and maintenance-need growth rates have not always been established by reference to documented experience, nor have they always been well related to the current condition of the pavement. Recent trends in condition and maintenance need often appear to be over stated.
- The reduction in maintenance need following heavy maintenance and resurfacing has often been understated, and not always understood.
- There is patchy acceptance and understanding of the changes in levels of service and the levels of acceptable risk on each of the new State Highway classifications across the supply chain.
- Potential learning from the performance of similar sites and treatments, and the learning from Long Term Pavement Performance Programme has not been referenced.

Programme options with similar Net Present Values often have different cash flows. It is advantageous to select the option with a lower short term cash flow, having confirmed the validity of each option and its cash flow. This factor is not recognized in the default Net Present Value analysis.

The objective was to improve the effectiveness and efficiency of renewal programmes by improving the scope of renewal options, the timing, and treatment selection, at an increased but acceptable risk of surface or pavement failure.

## **2.4 The Revised Net Present Value Guidelines**

The HNO Group developed a supplement to the default Net Present Value guidelines and obtained agreement from the Transport Agency's P&I group to use these. Suppliers were required to use the supplement when developing the 2014/15 annual programme renewal proposals. The revised Net Present Value guidelines are in Appendix 1 of this case study.

The process was developed by the Transport Agency and OPUS and includes alterations as a result of experience in 2013/14. This process builds on the UK Highways Agency's framework within a New Zealand context. The guidelines were tested and calibrated against many test sites before publication.

The guidelines require at least three options to be investigated and assessed:

1. The Do Maintenance option: a reactive maintenance only option for at least 7 years (still with an analysis period of 30 years)
2. The Do Something option: this involves more extensive treatment than reactive maintenance.

Examples of alternative treatments include:

- targeted heavy maintenance and resurfacing, with an expected subsequent reduction in reactive maintenance and deferral of rehabilitation,
  - where the deterioration is caused by water, improvement to drainage to slow the rate of deterioration and monitoring of the pavement to potentially defer the rehabilitation for a significant time.
3. The Do Rehabilitation option: rehabilitation plus subsequent maintenance and resurfacing cycles

The Net Present Value of each option is developed for year 7 and year 30.

An economic efficiency indicator is calculated for each option. This indicator shows the relative cashflow impacts of options.

The *Economic Indicator* (EI) is the ratio of the 30 year whole of life cost savings offered by an option over the cost difference for years 0 - 7 of choosing to do the option. This can be shown as:

$$EI = \frac{PV_{\text{Year 0 - 30}} \text{ Option B} - PV_{\text{Year 0 - 30}} \text{ Option A}}{PV_{\text{Year 0 - 7}} \text{ Option A} - PV_{\text{Year 0 - 7}} \text{ Option B}}$$

Where:

$PV_{\text{Year 0 - 7}} \text{ Option Y}$  = Present value of the costs incurred between years 0 and 7 for Option Y.

In order for any treatment option to be considered for funding the economic evaluation for the treatment must achieve a positive net present value and meet the required Economic Indicator criteria:

- When the Net Present Value is positive and the EI is positive, a minimum Economic Indicator of between 0.8 and 2.0 must be achieved in order for a treatment to be considered economically justified.
- When the Net Present Value is positive and the Economic Indicator is negative the Do Treatment Option being considered becomes the lowest cost option within the seven years analysis and thus becomes the new Do Minimum Option that all other options are tested against.



Where more than one treatment option exists that returns a positive net present value the preferred option shall be determined as follows:

1. Calculate net present value for each option considered in the analysis.
2. Options that do not achieve a positive net present value are rejected and not considered further in the analysis.
3. The Economic Indicator is determined for the first option (i.e. the Do Something option with the lowest Year 1 cost) compared with the Do-Maintenance option. When a negative EI is returned this means that the option will only yield cost savings over the seven year analysis period. This means that either the first option is highly efficient and will be considered the preferred option or the Do Maintenance option costs have been overstated. A closer review of the Do-Maintenance is required to confirm the assumptions are valid. Assuming the Do Maintenance costs are reliable then the analysis should be progressed.
4. The EI is calculated for the each subsequent option in the analysis compared with the Do-Minimum.
5. The preferred option is the option that returns either the highest positive EI or negative EI when the Net Present Value is positive. Where no option meets the EI criteria, the Do Minimum will be the preferred option.
6. When the Economic Indicator is  $>2$  or negative this suggests that the Do-Minimum option could be overestimated and it should be reviewed.

Based on field trials undertaken in New Zealand, a value between 0.8 and 2.0 is considered optimal. This is a lower value than used by the Highways Agency in England as New Zealand's mostly unbound pavements are cheaper than pavements in England.

## **2.5 Using The Net Present Value Guidelines To Develop And Moderate The 2014/15 SH Renewal Programme**

All State Highway rehabilitation programme proposals for 2014/15 were required to be supported by Net Present Value analysis using the new method. The preliminary outcomes from this have become available as the RAPT tours are being completed over January and February 2014.

To date we have found:

1. The requirement to consider three optional intervention treatments has enabled adoption of Do Something options where once a treatment length rehabilitation would have been implemented.
2. Discussions around the greater number of intervention options and their scope has improved and reinforced the need for and the means of attaining improved renewal programme effectiveness and efficiency.

3. Sector fluency with the principles behind option development and Net Present Value analysis is highly varied, yet this is a basic tool of our business.
4. Awareness and evidence of surface and pavement deterioration rates and maintenance need is patchy so renewal works are sometimes programmed early.

### **2.5.1 Increase In Treatment Options Considered**

Traditionally the State Highway supply chain has considered and proposed only two treatment options. These have generally been a maintenance only option and a rehabilitation option. In essentially all cases the rehabilitation option has been presented as having a beneficial Net Present Value and so the rehabilitation option is recommended.

The weaknesses with this approach is that while the rehabilitation proposal may be better than the do-maintenance option it does not consider if there are any intermediate strategies which would have provided the require outcomes, or what the most affordable option is.

The framework provides a structured approach to programme optimisation, adds rigour to decision making, and provides a better rationale and framework for supporting the recommended intervention. Whereas the two option approach could be characterised as “not the worst” option, this is closer to the “best available” option in terms of value for money.

The supply chain has found this challenging and has struggled to separate the do-maintenance and do-something options, especially where they believe the do-maintenance option will never be implemented. Consideration of intermediate options has not been a habitual part of their programme options.

### **2.5.2 Improved Approach To Programme Delivery**

Rehabilitation programmes have in the past been developed to remove the risk of pavement failure and its impact on service delivery when the pavement is showing signs of significant distress.

The adoption of the new approach has taken the focus away from “risk elimination” and moved towards the “best means of risk management”.

The value for money of option identification and assessment is more apparent. This is an area where asset managers can add value and deliver tangible differences on site which meet the goals of the Road Efficiency Group.

The RAPT Team reports that discussions with network managers around the required three option assessments have been useful in demonstrating the greater emphasis

NZTA is placing on programme optimization and setting appropriate levels of risk. The discussions about the acceptability of heavy maintenance and resurfacing, or smaller area treatments than before have reinforced this new approach and made it tangible. The RAPT Team advise that an on-going emphasis is still required on appropriate segmentation of treatment lengths to ensure that work undertaken is well targeted.

### **2.5.3 Sector Fluency With Net Present Value Analysis – Awareness Of Maintenance Growth Rates**

The RAPT Teams have found that the quality of options selection and Net Present Value analysis have not been up to the expected standard. The awareness of the principles of Net Present Value analysis and the mechanics of it both need improvement. We are developing a training programme to meet these needs.

We found that:

- There is too little awareness of the rate of deterioration of pavements and surfaces, and the associated change in maintenance need.
- There is too little awareness of the impact that treatments such as resurfacing has on short to mid-term maintenance need with many Net Present Value analyses having no reset in maintenance quantity post resurfacing.
- Elevating the expectation for quality option development and assessment has created a need for capability development.

### **2.5.4 The Best Asset Management Decisions Are To Do No Work Early**

Every decision to do work incurs cost. Every decision to not renew a deteriorating asset incurs the risk of escalating maintenance requirement and risk of service disruption, yet is the cheapest option when successful.

We have found that asset managers are not sufficiently aware of:

- The relationship between condition and future maintenance need
- The risk of service disruption arising from a deteriorating surface or pavement

and tend to sometimes programme an intervention earlier than warranted.

Performance management has traditionally focussed on the need for and effectiveness of work undertaken, and not on the success of decisions to do no work yet.

Because we have not generally run infrastructure to failure, asset managers have limited knowledge of on the optimum timing of interventions. The current State Highway Long Term Pavement Performance Programme is now almost doing this.

## 2.6 Examples of findings

Because the programme development for 2014/15 was not yet complete at the time of preparing this case study we have been unable to provide data quantifying the impact of the new Net Present Value approach. Given the other initiatives that have been introduced at the same time, such as the base preservation quantities, attribution of benefit would be difficult.

An example option and Net Present Value assessments derived from the current programme proposals is provided in Appendix 2. It demonstrates the decision to select between the do-maintenance only, do something: resurfacing, and do rehabilitation. The charts show the different maintenance quantities assumed for each option.

## 3 Recommendations

Specific Recommendations	Suggested Action to be Taken
RCA's should require 3 or more options be investigated for Net Present Value analysis because this supports a "best treatment considered" proposal rather than "not worst", when rehabs are being considered.	REG recommends this as good practice, P&I to consider its place in PIKB, dissemination by REG
The economic indicator should be refined and included in Net Present Value analysis to guide option selection with the lowest cash flow	Improve interpretation guidance
Focussed discussions around intermediate treatment options should be held for every significant investment proposal such as a rehab to increase the confidence we can have in rehabilitation programmes	P&I raise this as part of expectations
Asset managers should monitor the success of decisions to do no work in a structured way as much as the decisions to do work.	AMPs should reflect the success of the risk taken with prior programmes
The findings from the Long Term Pavement Performance Programme should be more widely known and used.	Findings from this work be published
NZ should adopt and implement a standardised way of capturing maintenance data per treatment length, and should have a standardised way of reviewing and sharing trends in maintenance	REG to consider this recommendation

Specific Recommendations	Suggested Action to be Taken

# Appendix One

## Supplementary Net Present Value Instructions

This guideline describes an enhanced NPV analysis method to deliver more robust economic analysis in support of pavement rehabilitation decisions than is provided by the minimum requirements of the EEM.

The new method keeps the same basic format as used in the past, (NPV of a treatment is developed over a 30 year time frame) but it enhances this process by:

1. Requiring that as a minimum three options be investigated because this requires investigation of at least two proposals for changing the prior maintenance regime, and not just a “do-maximum” option
2. Using a discount rate of 6% rather than 8%
3. Using an Economic Indicator to reflect the cashflow efficiency of options.

### 1 Use a minimum of three options for analysis

Instead of a “do minimum” and a rehabilitation comparison at least three options should be developed. These are:

- Scenario 1 - Do Minimum
- Scenario 2 - Do Something – Holding Treatment
- Scenario 3 - Full Pavement Renewal

## 1.1 Do- minimum

The EEM defines the do-minimum scenario as the minimum level of expenditure required to maintain a minimum level of service. This means the minimum level of routine and reactive maintenance necessary to maintain compliance with targeted levels of service or contractual targets that meet targeted customer levels of service, for example the Operational Performance Measures in HNO's Network Outcomes Contract.

Maintenance costs for the do-minimum shall be derived from the applicable maintenance cost model. A maintenance cost model is an evidence based model relating the age of a surface to the change in expected maintenance works required to address defects for categories of road surface in different circumstances. These models are often developed by a Contractor or Network Manager, for example HNO's Network Outcomes Contract requires the contractor to develop such a model for use in that contract.

## 1.2 Do Something – Holding Treatment

Viable treatment options include more extensive pavement repairs and subsequent reseal treatments than the do-minimum option. When implemented well these provide reasonable treatment alternatives to full rehabilitation. This is generally the case when:

1. the pavement in a treatment length is generally sound, but has significant areas of poor condition that could be rectified by a Rehabilitation Treatments, and
2. there is a low likelihood and consequence of any failure elsewhere in the treatment length.

There can be significant benefit in delaying a full treatment of a pavement. A so called "holding treatment" can often delay the full treatment by 10 or more years giving financial benefit by delaying the significant cost of a full rehabilitation treatment without any significant cost in the rehabilitation treatment.

Therefore it is always necessary to test whether a holding treatment has economic advantages over a full rehabilitation treatment. It is always necessary to test whether a "holding treatment", or a do-something option is the lowest whole of life cost option.

The do-something options that should be investigated can be considered to be some form of holding treatment that requires a higher level of investment in year 1 compared to the do minimum, but lower than the full renewal. The implementation of the do something option will require a full renewal at some point in the analysis period beyond the life of the reseal (or similar treatment generally expected to be 7 plus years). The do-something options will typically include a period of low maintenance after the reseal compared to the do-minimum option.

### 1.3 Full Renewal

The full renewal is a pavement rehabilitation treatment in year one, properly designed for the circumstances, followed by a period of negligible maintenance and a series of resurfacing treatments.

This could involve, but is not limited to:

- Recycling of the surface, or pavement, with or without additional binder, or new material
- An overlay
- Reconstruction of the pavement

## 2 Pavement Design Life

Unless there is good reason the pavement design life should be 50 years, noting that this is the mean life for pavements where 95% are expected to endure beyond 25 years as the Austroads design method provides.

## 3 The Current Methodology

For road renewals, the EEM states that to be eligible for funding the work must be shown to be the long-term, least cost option for the road controlling authority. Ordinarily the maintenance cost differential in the early years of the analysis period has a significant influence on the economic viability of a pavement renewal project.

## 4 Economic Indicator – Efficiency

Two further modifications are to be made to the procedures outlined in the EEM.

The first modification is that the reactive maintenance costs considered for each option will be based on the actual expected costs.

Where a maintenance contract has a lump-sum provision for reactive pavement maintenance these costs need to be derived considering the risk transfer and based on the maintenance cost curve derived by the network manager or agreed with the contractor. These should be related to the growth rate in faults occurring on the network at a standard repair cost.

Whenever the present value of a do-something option is small compared to the cost of the do minimum treatment options, there is a chance that erroneous overstatement of the do-minimum maintenance costs is causing the do-something option to appear better when it is not or that the initial years maintenance costs of the do-something option are understated, this is a ‘false-positive’ result. Therefore the maintenance costs should be reconsidered in every such case, referenced to valid robust evidence before any do-something or do-option is adopted. This is a requirement of the EEM.

To minimise the risk of the Network manager funding a renewal following a 'false positive' the second modification to the evaluation process is the introduction of the Economic Indicator (EI) to ensure a minimum degree of confidence is achieved. In order for a treatment to be economically justified it will need to achieve a specified minimum EI as well as demonstrating lowest whole-of-life cost. Satisfying the criteria of EI will also confirm that the treatment is the best use of the limited funds available for pavement rehabilitation.

The *Economic Indicator* (EI) is the ratio of the 30 year whole of life cost savings offered by an option over the cost difference for years 0 - 7 of choosing to do the option. This can be shown as:

$$EI = \frac{PV_{\text{Year 0 - 30}} \text{ Option B} - PV_{\text{Year 0 - 30}} \text{ Option A}}{PV_{\text{Year 0 - z}} \text{ Option A} - PV_{\text{Year 0 - z}} \text{ Option B}}$$

**Where:**

$PV_{\text{Year 0 - x}}$  Option Y = Present value of the costs incurred between years 0 and x for Option Y.

Z = 7 years which is based on a reasonable life for a reseal holding treatment..

If Option A is the do-minimum and Option B is the first treatment option considered it can be seen that that numerator is the net present value or whole-of-life cost savings offered by the treatment option. The denominator is the cost savings offered over the contract period of choosing *not* to implement the treatment. I.e. if the treatment was deferred for seven years the do-minimum costs will be incurred over seven years but this is still expected to be less than the cost of advancing the treatment in year 1 of the analysis period.

In addition to offering a positive net present value, in order for any treatment option to be considered for funding the economic evaluation for the treatment must demonstrate the treatment achieves the Economic Indicator's criteria:

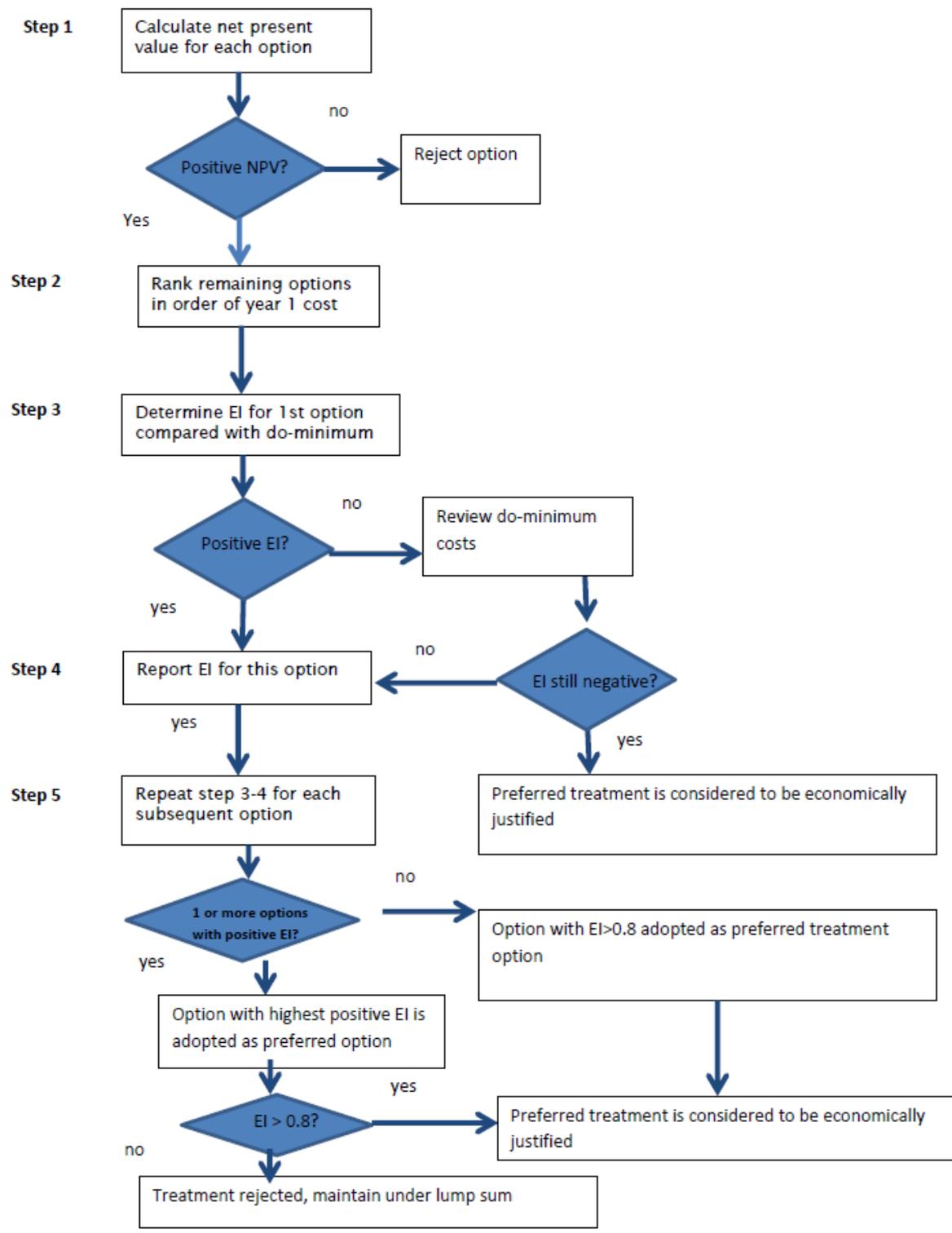
- **When the NPV is positive and the EI is positive, the minimum Economic Indicator that must be achieved in order for a treatment to be considered economically justified is between 0.8. and 2.0.**
- **When the NPV is positive and the Economic Indicator is negative the Do Treatment Option becomes the lowest cost option within the seven years analysis then this becomes the new Do Minimum Option resulting in the preferred option.**

Where more than one treatment option exists that represents a positive net present value compared with the do-minimum the preferred option shall be determined as follows:

- 1.) Calculate net present value for each option considered in the analysis.

- 2.) Options that do not achieve a positive net present value are rejected and not considered further in the analysis.
- 3.) The Economic Indicator is determined for the first option (i.e. the do something option with the lowest year 1 cost) compared with the do-minimum. When a negative EI is returned then this means that the option will yield a cost savings over only the duration equal to the seven years analysis. This means that either the first option is highly efficient and will be considered the preferred option or the do minimum maintenance costs have been overstated. A closer review of the do-minimum is required to confirm the assumptions are valid. Assuming the do-minimum costs are reliable then the analysis is to be progressed.
- 4.) The EI is calculated for the each subsequent option in the analysis compared with the do-minimum.
- 5.) The preferred option is the option that returns either the highest positive EI or negative EI when the NPV is positive. **Where** no option meets the EI criteria, the Do Minimum will be the preferred option.
- 6.) When the Economic Indicator  $>2$  or negative suggesting in that the do-minimum option could be overestimated it will be subjected to peer review.

This process is outlined in the following flow chart:



## 5 Peer Review

Any economic evaluation may be subjected to an external peer review at the discretion of the network manager. This could typically occur when the EI is greater than 2, or negative.

## 6 Further explanation

### 6.1 Do Minimum

The do minimum option that has traditionally been used has included treatments that continue for the 30 year analysis period. In this new system the do minimum may often include rehabilitation at some time in the 30 year analysis period. The Do minimum is not a holding treatment as such but is the minimum reactive maintenance work that is required to keep the **road open and safe and to meet the network performance requirements.**

Do minimum treatments include:

- Chip sealing to address polishing, texture and/or waterproofing.
- Water cutting
- Scabbing or other methods to restore microtexture
- Rut-filling
- Crack bandaging
- Patch repairs

The chip seal option is viable where it is cheaper than performing more isolated treatments. The timing of crack treatment can be crucial and if areas of cracking were not sealed in year 1 and pot holes developed in year 3 then this may be the lowest cost option. The current surface selection algorithm in the RAMM system suggest if cracking is greater than 3% then the option is to seal next year. Therefore crack sealing of minor areas of cracking cannot be considered a do minimum treatment but should be a do something. The treatments only have to last seven years and could for example include two water cutting treatments in the schedule.

For the 30 year analysis the timing and extent of future interventions needs to be estimated as well as the timing of a full rehabilitation; although no rehabilitation will be included in the first seven years.

### 6.2 Do Something – Holding Treatment

This treatment is designed as a more extensive treatment than the do minimum which will not have the full life expectancy of a rehabilitation treatment. It can involve more extensive digouts and repairs followed by a surfacing. Again it is designed to last at least seven years but would normally it would be expected to last at least 10 years before a full rehabilitation is performed. However a treatment that involved two seal coats inside the contract period could still be the most economic treatment where the second seal coat was expected to have a reasonable life expectancy.

The Do Something option must also include a full rehabilitation treatment in the 30 year analysis.

The do something option is similar to the “do minimum” that has traditionally used but includes the programming of an earlier renewal.

### **6.3 Full Renewal**

This treatment would be expected to have an effective life of 40-50 years. This is the normal life achieved when a thin surfaced granular pavement is designed for a 25 year life with 95% of pavement lives exceeding this. Data on the expected life of a structural asphalt pavement is not available but experience from the Wellington and Auckland Motorways suggest that at least a similar life (45 years) should be attained.

Unless unusual circumstances exist we expect that any rehabilitation would be followed by a period of low maintenance and a series of resurfacing treatments, each of which is followed by periods of low maintenance. The average life of 45 years can also be used to estimate when a renewal treatment could be programmed. If a pavement is 30 years old then in the Do minimum or Do something scenarios a renewal could be considered for year 15 in the analysis. No renewal in the 30 year analysis would suggest that the expected life in this case is over 60 years.

### **6.4 Maintenance Cost**

The NPV estimation of future maintenance costs has become the most significant factor in the current justification of rehabilitation treatments.

Reliable relationships of maintenance costs changes with time for NZ pavements have not been developed and are acknowledged as very difficult to determine. The estimation is therefore very subjective and is one of the areas where more robust analysis should be performed.

In the economic analysis over the 30 year period the NPV of maintenance costs is used.

RAMM has the routine maintenance costs divided into pavement, surfacing and shoulder and the PV of each of these categories needs to be estimated.

At present some engineers extrapolate cost from the present time using a quadratic function. When the pavement is resurfaced there is no allowance for the effect of the surfacing on maintenance costs and the extrapolated costs are included.

Pavement maintenance costs are not necessarily directly related to age. Costs are more likely to be associated with “high” traffic loading on a “weak” pavement. With many of the pavements on the State Highway having evolved rather than being designed then a change in use where significantly higher traffic volumes are imposed on an “old” road can lead to shear failures, rutting leading to higher maintenance costs. Without a change in use then the assumptions that “old” pavements automatically lead to higher costs can be challenged.

In estimating future maintenance costs the following need to be considered:

- Rate of change in roughness and current level
- Rate of change of rutting and current levels
- Effect of pre-seal repairs
- Seal lives
- Shear failure
- Historic area of repairs
- Historic type of repairs
- Change in traffic
- Number of seal layers.
- Previous seal lives

As the estimation of maintenance costs on a project level will use limited data with some years with zero maintenance cost and others with significant levels then the use of regression analysis to extrapolate costs can lead to unrealistic estimates. It is suggested that where significantly greater than average expenditure occur reasons need to be explored. If a significant area has been treated then the possibility that the repairs will arrest deterioration needs to be considered and the expectation that deterioration will accelerate challenged.

The costs of maintenance repairs of repairs are not justified. If the estimation of area of future maintenance is made then a realistic area needs to be assumed. It is not reasonable to repair 20% of the area per year for 8 years, for example.

The maintenance costs for SH 36 0.5 to 1.57 are shown in the table below.

Year	Actual Costs	Actual (Cumm)	Actual quantity m2	% total Area	\$/m2
2005	18,146	18,146	472	5.5%	38.42
2006	10,042	28,188	688	8.0%	14.60
2007	779	28,968	18	0.2%	43.30
2008	0	28,968	0	0.0%	
2009	8,529	37,497	265	3.1%	32.15
2010	920	38,417	23	0.3%	40.00
2011	187,447	225,863	1,039	12.1%	180.38
2012	35,115	260,979	1,218	14.2%	28.82

The average is approximately \$33,000 per year and the average rate is \$47/m<sup>2</sup>. In the example given below where this average level is assumed to continue in the Do minimum option for 9 years it would equate to 700m<sup>2</sup>/yr, or 73% of the pavement area over the 9 years. This level of maintenance is obviously unrealistic but the example illustrates the difficulties in developing a realistic maintenance model.

Network managers should develop a maintenance cost model for their network. This model describes the amount of surface and pavement maintenance that can be expected each year after a renewal treatment. The assumptions and data used to develop any maintenance cost model for any network will need to be closely examined to confirm its reliability and the accuracy or range of forecasts before it is used to estimate site specific maintenance.

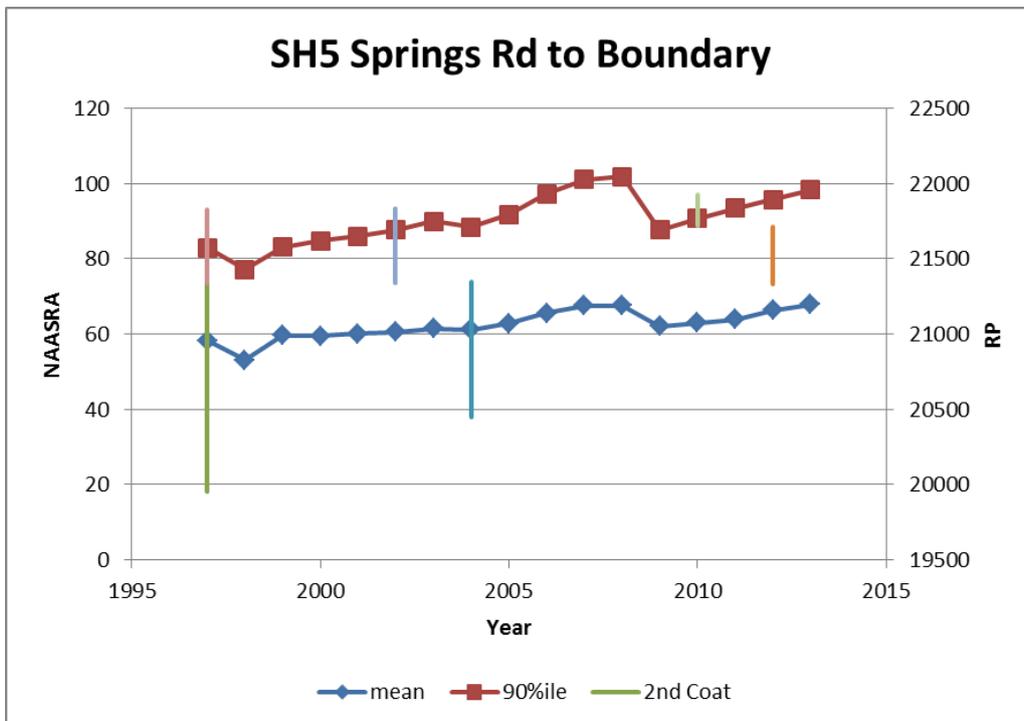
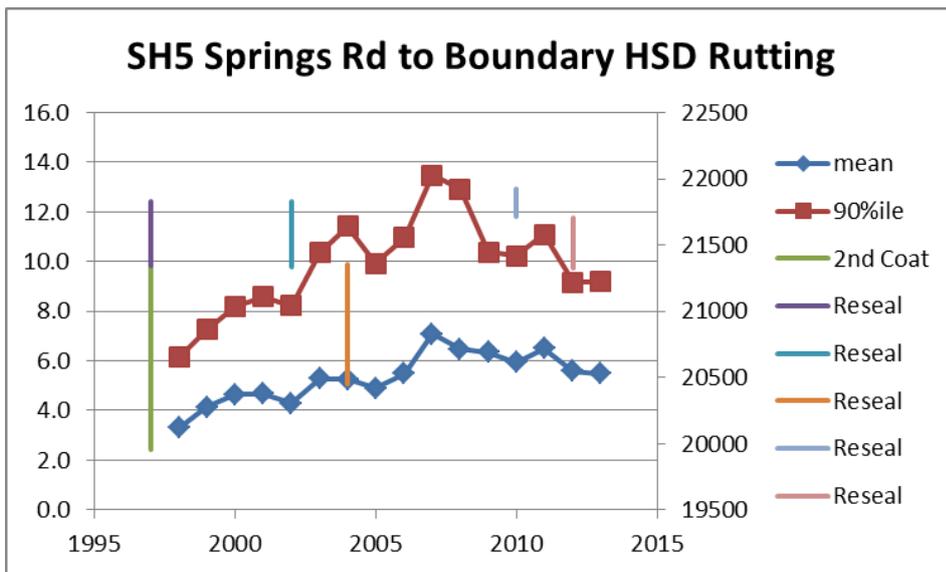
In the estimation of future maintenance costs both approaches shall be used to help develop the most robust estimations.

Surfacing maintenance costs cannot be regarded as constant. When a seal is constructed then the maintenance costs should be close to zero. If the surface is expected to fail by flushing then in the last few years of life water cutting could be considered an appropriate treatment and thus the maintenance costs rise.

## 7 Example 1

This is a 1.7km stretch of State Highway on the road from Rotorua to Taupo

The Rutting and roughness data is given below



Average maintenance costs over the last 11 years are approx. \$5,000 /annum. Over the last three years the cost had averaged \$24,000 per year and thus there was concern that renewal would possibly be required within the next 5 years. The cost of renewal with a granular overlay is \$445,000.

There was no attempt made to divide the section into 100 metre lengths and the site although starting to look tired would not be considered for renewal immediately. Roughness and rutting was not excessive.

With a combination of maintenance and crack sealing as the do minimum and a reseal as the do something and a renewal in year one the following treatments summary was proposed. The pavement maintenance cost of \$5,000/year was used. It is assumed that the average maintenance cost after renewal is \$2,000/year

	Do Minimum		Do Something		Renewal	
Year	Major Treatment		Major Treatment		Major Treatment	
0						
1	Crack seal light	1,283	Reseal	171,000	Rehab	444,600
2	Pre Reseal Repairs - Light	16,673			Reseal	171,000
3	Reseal	171,000				
4						
5						
6						
7						
8						
9						
10	Pre Reseal Repairs - Medium	55,575	Rehab	444,600	Reseal Repairs -	16,673
11	Reseal	171,000	Reseal	171,000	Reseal	171,000
12						
13						
14						
15					Rehab	444,600
16	Rehab	444,600			Reseal	171,000
17	Reseal	171,000				
18						
19			Reseal Repairs - L	16,673		
20			Reseal	171,000		
21						
22						
23						
24						
25					Reseal Repairs -	16,673
26	Pre Reseal Repairs - Light	16,673	Reseal Repairs - L	16,673	Reseal	171,000
27	Reseal	171,000	Reseal	171,000		
28						
29						
30						

The economic summary is given below which shows that no option has a positive NPV and thus the do minimum is the preferred option

Comparison Do Minimum - Do something				Comparison Do minimum - Renewal			
NPV	= \$678242	- \$751495 =	-73253	NPV	= \$678242	- \$1180200 =	-501,958
EI	220,412	202,042	-3.99	EI	715,992	202,042	-0.98
	something	minimum			Renewal	Do Min	

If the pavement maintenance cost over the last three years of \$24k /annum is assumed then the analysis results is given below. The Do something is the preferred option. This option was to reseal and then perform a renewal in year 10. The Do minimum had the renewal at year 16 when the pavement would be 46 years old. The

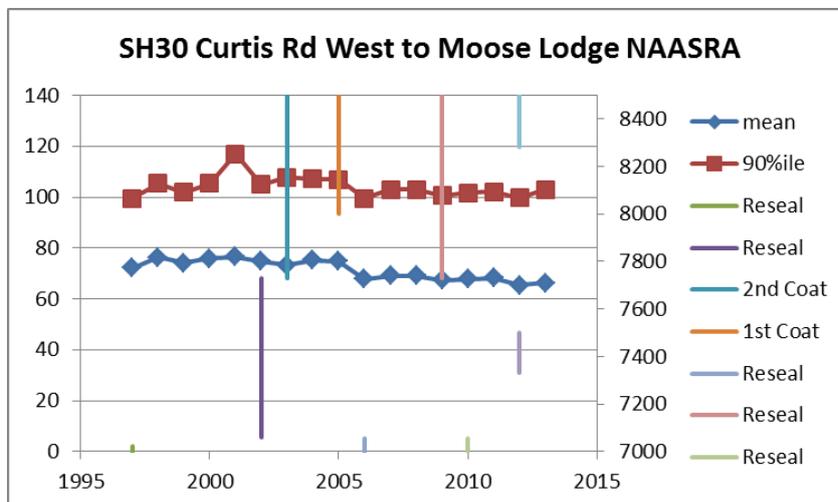
difference in assumed pavement maintenance cost of \$24k without a renewal and \$2k after a renewal makes the difference.

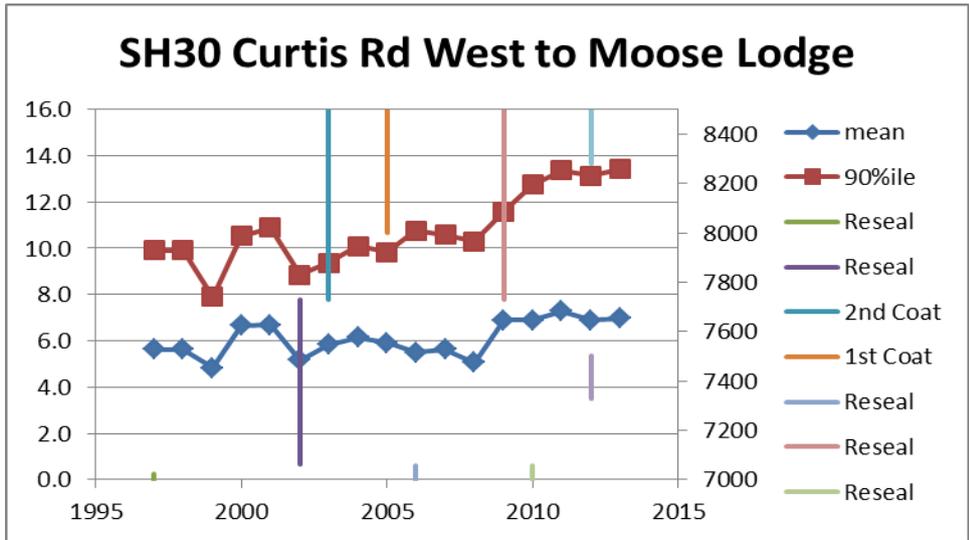
Comparison Do Minimum - Do something				Comparison Do minimum - Renewal			
NPV	= \$858131 - \$826113 =		32018	NPV	= \$858131 - \$1055585 =		-197,454
EI	261,809	260,111	18.86	EI	592,212	260,111	-0.59
	something	minimum			Renewal	Do Min	

## 8 Example 2

The consultant considers that the cracking is a function of the dacite aggregate used as the base course in the pavement.

Since 1996/97 the surfacing repairs have averaged \$6,500 /yr. but over the last 4 years the average is \$22,400. This is predominantly patch sealing over cracked areas. The roughness and rutting are not at high levels although it appears that rutting is starting to increase





Pavement maintenance costs over the last 16 years have averaged \$5,500 /year but \$18,000 over the last 4 years.

The following strategy was developed. This uses pavement and surfacing average costs

Year	Do Minimum			Do Something		Renewal	
	Major Treatment	PA MAINT	SU MAINT	Major Treatment			Ma
0							
1	Crack seal med	6,115	5000	Reseal Repairs - M	39,748	Rehab	317,980
2	Crack seal med	6,115	5000	Reseal	122,300	Reseal	122,300
3	Crack seal med	6,115	5000				
4	Crack seal med	6,115	5000				
5	Crack seal heavy	12,230	5000				
6	Crack seal heavy	12,230	5000				
7	Crack seal heavy	12,230	5000				
8	Crack seal heavy	12,230	5000				
9	Crack seal heavy	12,230	5000				
10	Rehab	317,980	0				
11	Reseal	122,300	1000	Reseal Repairs - M	39,748	Reseal Repairs	11,924
12			1000	Reseal	122,300	Reseal	122,300
13			1000				
14			1000				
15			1000				
16			1000				
17			1000				
18			1000	Rehab	317,980		
19			1000	Reseal	122,300		
20	Pre Reseal Repairs - Light	11,924	1000				
21	Reseal	122,300	1000				
22			\$ 1,000.00				
23			1000			Reseal Repairs	11,924
24			1000			Reseal	122,300
25			1000				
26			1000				
27			1000				
28			1000	Reseal Repairs -	11,924		
29			1000	Reseal	122,300		
30			1000				

The summary is given below which shows

Comparison Do Minimum - Do something				Comparison Do minimum - Renewal			
NPV	= \$429990 - \$496525 =		-66535	NPV	= \$429990 - \$577771 =		-147,781
EI	190,834	104,435	-0.77	EI	439,220	104,435	-0.44
	something	minimum			Renewal	Do Min	

This shows that heavy crack sealing to maintain the surface over 9 years and then renewal is better than resealing twice and performing the renewal in year 18.

For a more detailed process please request a copy of the Renewal Economic Justification Report dated 29 July, 2013 from National Office.

# Appendix Two – Example NVP analysis

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Charlotte St Nth  
SH 2 RP 729 / 10.11 - 11.21

7. Net Present Value (NPV) Analysis and Economic Efficiency Indicator

DO MINIMUM								
Year	Rehab	Resurfacing	Annual Maint (Pavement)	Annual Maint (Surface)	Annual Maint (Shoulder)	Total Costs (Periodic + Maint)	SPPWF	Discounted Total Costs
2013/14	0		\$27,132	\$1,860	\$4,911	\$33,903	1.0000	\$33,903
2014/15	1		\$49,000	\$4,340	\$490	\$53,830	0.9434	\$50,783
2015/16	2		\$7,500	\$434	\$49	\$7,983	0.8900	\$7,105
2016/17	3		\$11,250	\$868	\$59	\$12,177	0.8396	\$10,224
2017/18	4		\$16,875	\$1,736	\$71	\$18,682	0.7921	\$14,798
2018/19	5		\$25,313	\$3,472	\$85	\$28,869	0.7473	\$21,573
2019/20	6		\$37,969	\$6,944	\$102	\$45,014	0.7050	\$31,733
2020/21	7		\$56,953	\$13,888	\$122	\$70,963	0.6651	\$47,194
2021/22	8	\$421,545	\$0	\$0	\$0	\$421,545	0.6274	\$264,483
2022/23	9		\$0	\$0	\$0	\$0	0.5919	\$0
2023/24	10	\$73,013	\$370	\$303	\$134	\$73,819	0.5584	\$41,220
2024/25	11		\$463	\$387	\$163	\$1,014	0.5268	\$534
2025/26	12		\$556	\$472	\$193	\$1,221	0.4970	\$607
2026/27	13		\$649	\$557	\$222	\$1,428	0.4688	\$670
2027/28	14		\$742	\$642	\$251	\$1,635	0.4423	\$723
2028/29	15		\$835	\$727	\$281	\$1,843	0.4173	\$769
2029/30	16		\$928	\$811	\$310	\$2,050	0.3936	\$807
2030/31	17		\$1,021	\$896	\$340	\$2,257	0.3714	\$838
2031/32	18		\$1,114	\$981	\$369	\$2,464	0.3503	\$863
2032/33	19		\$1,207	\$1,066	\$399	\$2,672	0.3305	\$883
2033/34	20		\$1,300	\$1,150	\$428	\$2,879	0.3118	\$898
2034/35	21		\$1,393	\$1,235	\$457	\$3,086	0.2942	\$908
2035/36	22	\$73,013	\$556	\$472	\$193	\$74,233	0.2775	\$20,600
2036/37	23		\$649	\$557	\$222	\$1,428	0.2618	\$374
2037/38	24		\$742	\$642	\$251	\$1,635	0.2470	\$404
2038/39	25		\$835	\$727	\$281	\$1,843	0.2330	\$429
2039/40	26		\$928	\$811	\$310	\$2,050	0.2198	\$451
2040/41	27		\$1,021	\$896	\$340	\$2,257	0.2074	\$468
2041/42	28		\$1,114	\$981	\$369	\$2,464	0.1956	\$482
2042/43	29		\$1,207	\$1,066	\$399	\$2,672	0.1846	\$493
2043/44	30		\$1,300	\$1,150	\$428	\$2,879	0.1741	\$501
Discounted Total Cost for Length								\$521,815

DO SOMETHING								
Year	Rehab	Resurfacing	Annual Maint (Pavement)	Annual Maint (Surface)	Annual Maint (Shoulder)	Total Costs (Periodic + Maint)	SPPWF	Discounted Total Costs
2013/14	0		\$13,132	\$620	\$4,771	\$18,523	1.0000	\$18,523
2014/15	1	\$169,219	\$0	\$0	\$0	\$169,219	0.9434	\$159,640
2015/16	2		\$0	\$0	\$0	\$0	0.8900	\$0
2016/17	3		\$370	\$303	\$134	\$73,819	0.8396	\$61,980
2017/18	4		\$556	\$472	\$193	\$1,221	0.7921	\$967
2018/19	5		\$742	\$642	\$251	\$1,635	0.7473	\$1,222
2019/20	6		\$928	\$811	\$310	\$2,050	0.7050	\$1,445
2020/21	7		\$1,114	\$981	\$369	\$2,464	0.6651	\$1,639
2021/22	8		\$1,300	\$1,150	\$428	\$2,879	0.6274	\$1,806
2022/23	9		\$1,487	\$1,320	\$487	\$3,293	0.5919	\$1,949
2023/24	10		\$1,673	\$1,489	\$546	\$3,708	0.5584	\$2,070
2024/25	11	\$421,545	\$0	\$0	\$0	\$421,545	0.5268	\$222,065
2025/26	12		\$0	\$0	\$0	\$0	0.4970	\$0
2026/27	13		\$370	\$303	\$134	\$73,819	0.4688	\$34,609
2027/28	14		\$463	\$387	\$163	\$1,014	0.4423	\$448
2028/29	15		\$556	\$472	\$193	\$1,221	0.4173	\$509
2029/30	16		\$649	\$557	\$222	\$1,428	0.3936	\$562
2030/31	17		\$742	\$642	\$251	\$1,635	0.3714	\$607
2031/32	18		\$835	\$727	\$281	\$1,843	0.3503	\$646
2032/33	19		\$928	\$811	\$310	\$2,050	0.3305	\$678
2033/34	20		\$1,021	\$896	\$340	\$2,257	0.3118	\$704
2034/35	21		\$1,114	\$981	\$369	\$2,464	0.2942	\$725
2035/36	22		\$1,207	\$1,066	\$399	\$2,672	0.2775	\$741
2036/37	23		\$1,300	\$1,150	\$428	\$2,879	0.2618	\$754
2037/38	24		\$1,393	\$1,235	\$457	\$3,086	0.2470	\$762
2038/39	25		\$1,487	\$1,320	\$487	\$3,293	0.2330	\$767
2039/40	26		\$1,580	\$1,405	\$516	\$3,501	0.2198	\$769
2040/41	27	\$73,013	\$742	\$642	\$251	\$74,648	0.2074	\$15,480
2041/42	28		\$835	\$727	\$281	\$1,843	0.1956	\$360
2042/43	29		\$928	\$811	\$310	\$2,050	0.1846	\$378
2043/44	30		\$1,021	\$896	\$340	\$2,257	0.1741	\$393
Discounted Total Cost for Length								\$515,611

FULL RENEWAL								
Year	Rehab	Resurfacing	Annual Maint (Pavement)	Annual Maint (Surface)	Annual Maint (Shoulder)	Total Costs (Periodic + Maint)	SPPWF	Discounted Total Costs
2013/14	0		\$13,132	\$620	\$4,771	\$18,523	1.0000	\$18,523
2014/15	1	\$421,545	\$0	\$0	\$0	\$421,545	0.9434	\$397,684
2015/16	2		\$0	\$0	\$0	\$0	0.8900	\$0
2016/17	3		\$370	\$303	\$134	\$73,819	0.8396	\$61,980
2017/18	4		\$463	\$387	\$163	\$1,014	0.7921	\$803
2018/19	5		\$556	\$472	\$193	\$1,221	0.7473	\$912
2019/20	6		\$649	\$557	\$222	\$1,428	0.7050	\$1,007
2020/21	7		\$742	\$642	\$251	\$1,635	0.6651	\$1,088
2021/22	8		\$835	\$727	\$281	\$1,843	0.6274	\$1,156
2022/23	9		\$928	\$811	\$310	\$2,050	0.5919	\$1,213
2023/24	10		\$1,021	\$896	\$340	\$2,257	0.5584	\$1,260
2024/25	11		\$1,114	\$981	\$369	\$2,464	0.5268	\$1,298
2025/26	12		\$1,207	\$1,066	\$399	\$2,672	0.4970	\$1,328
2026/27	13		\$1,300	\$1,150	\$428	\$2,879	0.4688	\$1,350
2027/28	14		\$1,393	\$1,235	\$457	\$3,086	0.4423	\$1,365
2028/29	15		\$1,487	\$1,320	\$487	\$3,293	0.4173	\$1,375
2029/30	16		\$1,580	\$1,405	\$516	\$3,501	0.3936	\$1,380
2030/31	17		\$1,673	\$1,489	\$546	\$3,708	0.3714	\$1,381
2031/32	18		\$1,766	\$1,573	\$575	\$3,915	0.3503	\$1,378
2032/33	19		\$1,859	\$1,657	\$604	\$4,122	0.3305	\$1,371
2033/34	20		\$1,952	\$1,741	\$633	\$4,329	0.3118	\$1,360
2034/35	21		\$2,045	\$1,825	\$662	\$4,536	0.2942	\$1,345
2035/36	22		\$2,138	\$1,909	\$691	\$4,743	0.2775	\$1,327
2036/37	23		\$2,231	\$1,993	\$720	\$4,950	0.2618	\$1,305
2037/38	24		\$2,324	\$2,077	\$749	\$5,157	0.2470	\$1,279
2038/39	25		\$2,417	\$2,161	\$778	\$5,364	0.2330	\$1,250
2039/40	26		\$2,510	\$2,245	\$807	\$5,571	0.2198	\$1,218
2040/41	27		\$2,603	\$2,329	\$836	\$5,778	0.2074	\$1,183
2041/42	28		\$2,696	\$2,413	\$865	\$5,985	0.1956	\$1,145
2042/43	29		\$2,789	\$2,497	\$894	\$6,192	0.1846	\$1,105
2043/44	30		\$2,882	\$2,581	\$923	\$6,399	0.1741	\$1,062
Discounted Total Cost for Length								\$527,746

COMPARISON				
OPTION	PV over 30 year period	PV over contract period	NPV variables	
DO MINIMUM	\$521,815	\$183,410	Contract period (years)	7
DO SOMETHING	\$515,611	\$226,893	Discount rate	6%
FULL RENEWAL	\$527,746	\$463,474	Minimum EI	0.8
OPTIONS ANALYSIS				
	NPV	EI	Notes	
DO SOMETHING vs. DO MINIMUM	\$6,204	0.14	Use decision tree to rank this option.	
FULL RENEWAL vs. DO SOMETHING	-\$12,135	-0.05	Reject. NPV < 0.	

EI Calculator		
	30yr PV	Contract PV
DO MINIMUM	\$521,815	\$183,410
Treatment option	\$515,611	\$226,893
	EI	0.14

The 'Do Something' option proposed is a full length, full width pavement recycle (rip and remake) to address the unstable seal layers. No top-up material is planned. This treatment will have an approximately pavement design life of 10 years, and is considered the least whole of life cost option for the treatment length over a 30 year analysis period. The site is currently consistently failing along the entire length. Failures mainly consist of shearing, rutting and significant flushing.

	Do Minimum	Do Something	Full Renewal
RESEAL	\$33,903	\$18,523	\$18,523
RECYCLE	\$53,830	\$0	\$0
REHAB	\$7,983	\$0	\$0
TAS	\$12,177	\$807	\$807
HEAVY MAINT. & TAS	\$18,682	\$1,221	\$1,014
WATERBLAST	\$28,869	\$1,635	\$1,221
	\$45,014	\$2,050	\$1,428
	\$70,963	\$2,464	\$1,635
	\$0	\$2,879	\$1,843
	\$0	\$3,293	\$2,050
	\$807	\$3,708	\$2,257
	\$1,014	\$0	\$2,464
	\$1,221	\$0	\$2,672
	\$1,428	\$807	\$2,879
	\$1,635	\$1,014	\$3,086
	\$1,843	\$1,221	\$3,293
	\$2,050	\$1,428	\$3,501
	\$2,257	\$1,635	\$3,708
	\$2,464	\$1,843	\$3,915
	\$2,672	\$2,050	\$4,122
	\$2,879	\$2,257	\$4,329
	\$3,086	\$2,464	\$4,536
	\$3,293	\$2,672	\$4,743
	\$3,501	\$2,879	\$4,950
	\$3,708	\$3,086	\$5,157
	\$3,915	\$3,293	\$5,364
	\$4,122	\$3,501	\$5,571
	\$4,329	\$3,708	\$5,778
	\$4,536	\$3,915	\$5,985
	\$4,743	\$4,122	\$6,192
	\$4,950	\$4,329	\$6,399
	\$5,157	\$4,536	\$6,606
	\$5,364	\$4,743	\$6,813
	\$5,571	\$4,950	\$7,020
	\$5,778	\$5,157	\$7,227
	\$5,985	\$5,364	\$7,434
	\$6,192	\$5,571	\$7,641
	\$6,399	\$5,778	\$7,848
	\$6,606	\$5,985	\$8,055
	\$6,813	\$6,192	\$8,262
	\$7,020	\$6,399	\$8,469
	\$7,227	\$6,606	\$8,676
	\$7,434	\$6,813	\$8,883
	\$7,641	\$7,020	\$9,090
	\$7,848	\$7,227	\$9,297
	\$8,055	\$7,434	\$9,504
	\$8,262	\$7,641	\$9,711
	\$8,469	\$7,848	\$9,918
	\$8,676	\$8,055	\$10,125
	\$8,883	\$8,262	\$10,332
	\$9,090	\$8,469	\$10,539
	\$9,297	\$8,676	\$10,746
	\$9,504	\$8,883	\$10,953
	\$9,711	\$9,090	\$11,160
	\$9,918	\$9,297	\$11,367
	\$10,125	\$9,504	\$11,574
	\$10,332	\$9,711	\$11,781
	\$10,539	\$9,918	\$11,988
	\$10,746	\$10,125	\$12,195
	\$10,953	\$10,332	\$12,402
	\$11,160	\$10,539	\$12,609
	\$11,367	\$10,746	\$12,816
	\$11,574	\$10,953	\$13,023
	\$11,781	\$11,160	\$13,230
	\$11,988	\$11,367	\$13,437
	\$12,195	\$11,574	\$13,644
	\$12,402	\$11,781	\$13,851
	\$12,609	\$11,988	\$14,058
	\$12,816	\$12,195	\$14,265
	\$13,023	\$12,402	\$14,472
	\$13,230	\$12,609	\$14,679
	\$13,437	\$12,816	\$14,886
	\$13,644		