Beca

Pavement Economic Analysis

Whole of Life Costs

Prepared for Waka Kotahi NZ Transport Agency
Prepared by Beca Limited

1 July 2022

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Contents

Appendices

Revision History

Revision Nº	Prepared By	Description	Date
1.0	John Hallett / Lucien Zhang	Draft for Client's Comments & Peer Reviews	03/06/2022
2.0	John Hallett / Lucien Zhang	Updated regarding to review feedbacks	01/07/2022

Document Acceptance

Action	Name	Signed	Date
Prepared by	John Hallett / Lucien Zhang		03/06/2022
Reviewed by	Mike Tapper / Robert Tutty		03/06/2022
Approved by	Mike Tapper		03/06/2022
on behalf of	Beca Limited		

Executive Summary

Economic whole of life (WOL) analyses are carried out to calculate a Net Present Value (NPV) to determine the difference between the present values of the various pavement treatment options available, over a 30 year analysis period. In essence it assesses which strategy (i.e. maintain, heavy maintenance, renewal option) provides the best return on investment for the Agency, and its stakeholders. The outcomes of the analyses are very sensitive to many of the inputs which are largely subjective and based on the experience of the design engineer.

The Waka Kotahi NZ Transport Agency (Waka Kotahi) "Review of State Highway Pavement Delivery" (1) report identified several opportunities for improvement. The report states that with respect to the Network Outcomes Contract (NOC) environment "the principles and economics of WOL maintenance regimes are not well understood across the industry".

Waka Kotahi commissioned Beca Consultants to review of the WOL Cost analysis for pavements with a view to determining a consistent and evidence-based approach to WOL cost analysis for pavements, especially in the NOC environment. The report details the examination of data in RAMM regarding seal life cycles and pavement maintenance requirements under different traffic loading environments, pavement condition scenarios and risk profile of the pavement treatment.

Where trends have been identified, these generally validate what was previously considered anecdotal evidence of pavement WOL periodic and reactive maintenance requirements. The exception is the level of maintenance effort following rehabilitation treatments has historically been considered as negligible, however, there is good evidence to indicate that is not the case for high-risk treatment options. The results of the analyses carried out can be used to help standardise inputs into the WOL cost analysis and NPV calculation and example analyses using the suggested inputs have been provided. The proposed inputs should be considered as providing a consistent starting point for an NPV calculation and local knowledge should be used to alter these where appropriate.

Outputs from the analyses carried out in this project have resulted in the recommendations for the following:

- Resurface cycle time for the do-minimum option
- Surfacing cycle times following different rehabilitation treatment options
- Maintenance costs calculation for the do-minimum option
- Maintenance costs calculation after rehabilitation treatment options
- Flow charts on how to apply the above outputs in the NPV process

The report does not recommend any change to the procedure specified in the Monetised Benefits and Costs Manual (Aug. 2021) but provides guidance on how to determine future seal life cycles, pavement treatment life cycles and maintenance costs for all options including the do-minimum. This review does not address the selection of candidate pavement treatments because guidance is given regarding the choice of suitable treatments in the relevant Waka Kotahi guides and instructions, but instead focuses on determining suitable maintenance strategies for each option considered in the NPV.

Should Waka Kotahi choose to update the NPV instructions and spread sheet application provided, this report provides a specification for that process.

1 Background

Economic whole of life (WOL) analyses are carried out to calculate a Net Present Value (NPV) to determine the difference between the present values of the various pavement treatment options available, over a 30 year analysis period. In essence it assesses which strategy (i.e. maintain, heavy maintenance, renewal option) provides the best return on investment for the Agency, and its stakeholders. The outcomes of the analyses are very sensitive to many of the inputs which are largely subjective and based on the experience of the design engineer.

The Waka Kotahi "Review of State Highway Pavement Delivery" (1) report identified several opportunities for improvement. The report states that with respect to the Network Outcomes Contract (NOC) environment "the principles and economics of WOL maintenance regimes are not well understood across the industry". Waka Kotahi require a review of the WOL Cost Workstream to address this issue.

The procedures for the NOC's which require a net present value (NPV) to be calculated for each treatment option proposed for a rehabilitation site plus the do minimum and heavy maintenance options of patch and resurface (i.e., no rehabilitation). The NPV calculation is heavily dependent upon the estimation of the whole of life (WOL) costs for each treatment option. The need for this project is because Waka Kotahi have identified that during economic analyses carried out by pavement designers or project managers in the NOC's, erroneous outcomes can arise from:

- Use of inappropriate pavement design or treatment options
- Adopting inadequate maintenance strategies
- Use of inappropriate intervention timings
- Use of inaccurate or loaded schedule rates.

In addition, analyses can be manipulated to favour a certain treatment depending on the drivers that might be at play and in particular the capital cost of the project (budget constraint).

The Waka Kotahi Economic Evaluation Manual (EEM) has recently been superseded by the Monetised Benefits and Costs Manual (Aug. 2021) and several associated documents. Given that the Monetised Benefits and Costs Manual is a very recent edition there is little value in (or appetite for) changing the analysis strategies or procedures.

As a first stage to a possibly larger project, Waka Kotahi NZ Transport Agency wish to review the inputs used for pavement economic analyses with the intention of rationalizing the WOL principles and practices and challenging NPV sensitivities to ensure risks are minimized for best economic efficiency. This project addresses stage 1 and includes a review of all inputs into the NPV calculation but focuses on the estimation of the whole of life (WOL) costs.

Beca Consultants have been commissioned to carry out the WOL cost review.

2 Project Scope (First Stage)

The first stage of the project requires the provision of a senior pavement engineer with appropriate experience in the field of economic analyses to carry out the review with the following objective:

- Establish a set of guidelines for maintenance regimes to be adopted in economic analyses with respect to pavement types, site conditions and level of service.

The outputs desired from the review are a report that researches different options for maintenance regimes that can be used to develop a set of guidelines along with the supporting information used to support the findings.

The study focuses on the maintenance regimes/costs used as inputs for the calculation of NPV for pavement rehabilitation projects. However, the findings will be transferrable to the calculation of Benefit/Cost ratio for capital works projects where appropriate.

The intention is to primarily investigate and report findings, which may not support the development of specific models to be used in the process but simply provide a pragmatic approach to the prediction of future costs with more consistency in the process rather than a focus on accuracy. The proposed inputs should be considered as providing a consistent starting point for an NPV calculation and local knowledge should be used to alter these where appropriate.

At this stage the review has only been for thin surfaced granular pavements. Structural AC pavements need further review and the treatment of granular pavements with thin AC surfaces may benefit from some refinement.

3 Inputs into Pavement Economic Analyses

3.1 NPV Guidance and Software Availability

Guidance regarding the NPV process is currently provided by Waka Kotahi is contained in the "NPV Instructions for High-Cost Pavement Treatments, Version 1 (June 2016)" [NPV Instructions], which is accompanied by spreadsheet software for the calculation of NPV. This software will need to be updated/enhanced to assist with the NPV inputs recommended in this report.

3.2 Traffic Categorisation

The use of the ESAs/day reported in RAMM to calculate the traffic loading for each site was examined and found to be inappropriate because the ESAs/heavy vehicle (HV) values in RAMM were much lower than those reported from the Weigh in Motion (WIM) stations. The AADT and %HVs were used from RAMM to determine the traffic loading for the analyses in this project as follows:

Table 3-1 Traffic Categorisation

Category	HVs/day	Comment
1	< 250	
2	250 – 500	
3	500 – 1000	
4	1000 – 2000	Limited records in the dataset – inconsistent results from analyses
5	>= 2000	Too few records for analysis in the dataset

Where life cycles recommended later in this report are based on design ESA's, the following assumptions have been used to convert from HV's to ESA's:

Table 3-2 Variables for ESAs Calculation

Variable	Value
Growth rate	2% pa
Design period	25 years
ESA / HV	1.6

3.3 Rehabilitation Treatments

This review assumes that a need to rehabilitate the pavement has already been identified through network inspections, forward works programming, pavement repairs/preventive maintenance, and visual site investigation. As minimum three different treatment strategies are required in the NPV Instructions, and it is recommended that a further two options be used as follows.

Table 3-3 Treatment strategies

Scenario	Description	Compulsory/Recommended
1	Do Minimum	Compulsory
2	Heavy Maintenance (previously named Do Something)	Compulsory
3	Renewal No.1	Compulsory
4	Renewal No.2	Recommended
5	Renewal No.3	Recommended

3.3.1 Treatment Type Options

This review does not address the selection of candidate pavement treatments because guidance is given regarding the choice of suitable treatments in the NZ Guide to Pavement Evaluation and Treatment Design, 2018 and the Network Outcomes Contract – Pavement Design Parameters" (NOC-PDP), 28 May 2021 as well as other Waka Kotahi instructions issued from time to time for the preparation of the Annual Plan. This review focuses on determining suitable maintenance strategies for each option considered in the NPV. The NOC-PDP document has a catalogue matrix that ranks the rehabilitation treatment options as follows:

- Unlikely to be economic
- Low risk
- Medium risk
- High risk

The catalogue matrix is shown below.

As recommended in the NPV Instructions, 3 treatment options should be included in the analysis. It would seem prudent for these to include low to high-risk treatment options. Waka Kotahi policy may dictate that certain options (e.g., high risk options) are to be avoided for high demand sites, or in the case of "minor rehabilitation" then only one high risk option need be evaluated. Minor rehabilitation is defined in the recent Waka Kotahi memo to NOC Contractors regarding pavement rehabilitation.

The NOC-PDP instructions provide the following advice regarding the treatment options to be evaluated:

Some treatment options can be eliminated based on traffic criticality, early pavement failure (well before end of life), or physical constraints (e.g., high stresses, barriers, kerb and channel)."

Where the high-risk option indicates a greater NPV than the others, ***it should not automatically be assumed that it is the best option for the site***, especially for higher demand sites. The final choice of treatment needs to be agreed through collaboration between the Contractor and Waka Kotahi staff.

3.3.2 Treatment Type Longevity

From anecdotal evidence the life cycle of the treatment type depends on the risk category from which is chosen. To assist with the identification of each generic treatment type in the RAMM database, and to help determine suitable maintenance strategies post-treatment, the following guidelines have been adopted.

3.3.2.1 Low Risk Treatments

The low-risk treatments generally involve significant overlay, sometimes over a cement bound layer created from the existing basecourse. These treatments typically achieve an expected life cycle for the second coat seal (see 3.4.3) plus 2 – 3 reseals before requiring another rehabilitation treatment. The need for a following rehabilitation treatment is therefore well outside the 30-year analysis period and need not be considered in the analysis.

Table 3-4 Catalogue Matrix from NOC-PDP

25 year design traffic volume (ESAs)	Catalogue Treatment	Less than 5×10⁶	Between 5×10⁶ and 1×10⁷	Between 1×10⁷ to 2×10⁷	Between 2×10⁷ to 2.5×10⁷	Greater than 2.5×10⁷
Structural Asphalt Overlay	Minimum Total Layer thickness 105mm (need to consider the existing structure, not a greenfields design) (e.g. 55mm AC14 with 50mm DG14)	Unlikely to be economic	Unlikely to be economic	Unlikely to be economic	Low risk	Low risk
Structural Asphalt Inlay	Inlay (requires site specific design)	Unlikely to be economic	Unlikely to be economic	Low risk Unlikely to be economic	Low risk	Low risk
Foamed bitumen basecourse	1%cement/3% Bitumen 75mm make up material, stabilise to 200mm, pre-hoe	Unlikely to be economic	Unlikely to be economic	Low risk	Low risk	Medium risk
Stabilised Overlay	150mm overlay 2% stabilised over 2% cement stabilised 200mm sub-base	Unlikely to be economic	Low risk	Low Risk	Medium Risk	High Risk
Unbound aggregate overlay and bound sub-base	150mm overlay over 4% cement stabilised 200mm sub-base	Low risk	Low risk	Medium risk	High risk	High risk
In-situ Stabilisation	75mm make-up material, stabilise to 200mm, 2% cement	Low risk	Low risk	Medium risk	Medium to High risk	High risk

Table 3-5 Catalogue Matrix from NOC-PDP

25 year design traffic volume (ESAs)	Catalogue Treatment	Less than 5×10⁶	Between 5×10⁶ and 1×10⁷	Between 1×10⁷ to 2×10⁷	Between 2×10⁷ to 2.5×10⁷	Greater than 2.5×10⁷
Unbound aggregate overlay	150mm	Low risk	Low risk	Medium risk	High risk	High risk
Unbound aggregate overlay	100mm over high spot	Low risk	Medium risk	High risk	High risk	High risk
Recycle	Multiple seal layers <30% treatment depth, 2% cement, 50mm make up material, prehoe	Medium risk	High risk	High risk	High risk	High risk

3.3.2.2 Medium Risk Treatments

The medium risk treatments generally involve an overlay of approximately 100mm, sometimes including cement modification to a depth of 200mm. These treatments typically achieve an expected life cycle for the second coat seal (see 3.4.3) plus one reseal before requiring another rehabilitation treatment. The need for a following rehabilitation treatment is therefore at approximately 20 years, which is inside the 30-year analysis period and needs to be considered in the analysis.

3.3.2.3 High Risk Treatments

The high-risk treatments generally involve a recycle type of treatment with only minimal improvement to the pavement strength and current terminology is “minor rehabilitation”. These treatments have a design life of 10 years but typically achieve an expected life cycle for the second coat seal (see 3.4.3) plus one reseal before requiring another rehabilitation treatment. The need for a following rehabilitation treatment is therefore at approximately 15 years, which is well inside the 30-year analysis period and needs to be considered in the analysis.

3.3.3 Treatment Construction Cost

The construction costs for the rehabilitation treatments are generally easily established based on NOC schedule rates. The NPV Instructions note that improvements for major drainage or traffic safety should not be included in the pavement rehabilitation cost for the NPV. The exception to this is where drainage or traffic safety work is required because of the rehabilitation treatment, e.g. if a proposed overlay requires the kerb and channel or barriers to be lifted.

3.3.4 Improvements Constructed Concurrently with Rehabilitation Treatment

No pavement rehabilitation treatments should be undertaken without concurrent drainage improvements being considered; this needs to be part of the treatment selection/design process at the conception stage. Minor traffic safety improvements may also be identified and if funding is available these should be undertaken concurrently with the rehabilitation treatment.

3.4 Surface Treatments

3.4.1 Construction Cost

Future periodic surface treatments must be estimated for the do minimum and each pavement rehabilitation option. The cost of resurfacing treatments can be accurately established, from the measured area of pavement and the base rates from the NOC schedule of prices (SoP).

It is recommended that the cost used be determined for a grade 3/5 two coat seal, which is assumed to be the average treatment.

3.4.2 Resurface Cycle Times (Do Minimum Option)

The do minimum option has the advantage of knowing the past surface cycle times for the site and historically the designer has been required to estimate the future surface times based on these. It is likely that a surface treatment placed on a site that is in poor condition will achieve a shorter life cycle than the previous treatment. However, sometimes a surface treatment has achieved a “normal” life cycle because it has been stretched often uneconomically with frequent patching. For these situations, this project has attempted to establish the influential factors for determining a reseal life for chip seals with a grade 2 or 3 first chip size. The factors considered were as follows:

- Traffic loading in heavy commercial vehicles (HCV’s) [influential]
- Life of previous seal coat [not influential]
- High speed data capture (HSDC) texture depth before resurfacing [not influential]
- HSDC rutting before resurfacing [not influential]
- Pavement deflection curvature (from FWD) [influential in some regions only]
- Surface condition prior to resurfacing [influential]

Seal lengths less than 300m were excluded from the analysis because they are often required for skid resistance requirements on curves and will be required irrespective of any rehabilitation treatment requirements. The results of attempting to correlate the factors above with the achieved seal life are shown in Appendix C. The best indication of the future seal life was found by grouping the results by bands of traffic loading (see 3.2) and comparing the seal lives achieved with the surface condition prior to the surface being placed and the condition of the surface when it was resurfaced.

The surface condition index was based on the visual road rating information that was carried out annually from the early 1990's until 2013 when it was discontinued. The grouping into the surface condition based on surface condition index (SCI) is shown in Table 3-6.

Table 3-6 Surface Condition Categorisation

Surface Condition	SCI
Poor / Very Poor	> 15
Moderate	1.5 – 15
Good / Very Good	< 1.5

The results were filtered to compare poor and moderate surface conditions prior to initial resealing and only moderate condition prior to the subsequent reseal. The reason only the moderate condition seals were considered before the subsequent reseal was that seals left to progress into a poor/very poor state before resealing were likely in a sub-optimal condition for resealing and any rated as being in good condition when subsequently resealed were probably resealed too soon to be optimal.. The results are shown in Figure 3-1 and Figure 3-2.

As expected, the trend in seal life is downwards as traffic increases. There is variability in the very heavy band which is expected because the low number of seals populated in this band will not have produced reliable and consistent results. The influence of surface condition prior to placing the seals indicates that seals placed on a moderate condition surface prior to resealing achieve approximately a 1 year longer economic life than those placed on a poor/very poor condition surface for the majority traffic loadings (250 – 1000 HVs/day). This is noted out of interest only because it can be assumed that all existing surfaces will be in poor condition for sites chosen for a rehabilitation treatment. Therefore, the estimation of a future seal life for the do-minimum option can be assumed to vary from 11 years in the low traffic band through to 8 years in the high traffic band. These values have been extrapolated to give the values shown in Table 3-4 for the NOC-PDP traffic loading categories. If the existing seal life is less than this, the life achieved less 1 or 2 years should be adopted depending on the designers' experience with the site.

It is recommended that the reseal life for the do-minimum option be set to the lesser of either 1 or 2 years less than that achieved by the existing seal coat if it is a grade 2 – 4 chip or the values shown in Table 3-7. The traffic loading bands in Table 3-7 have been approximately aligned with those on the NOC-PDP.

Table 3-7 Default Seal Life for Do-Minimum Option

NOC-PDP Category	Design 25yr MESA	Default Seal Lives	Approx. HVs/day
1	< 5	10	< 500
2	5 – 10	9	500 – 1000
3	10 – 20	8	1000 – 2000
4	20 – 25	7	2000 – 2700
5	> 25	6	> 2700

It is not recommended that a second cycle of repair and seal be used in the analysis because it is very likely that the structural condition of the pavement will have deteriorated further, and a rehabilitation treatment will be justified.

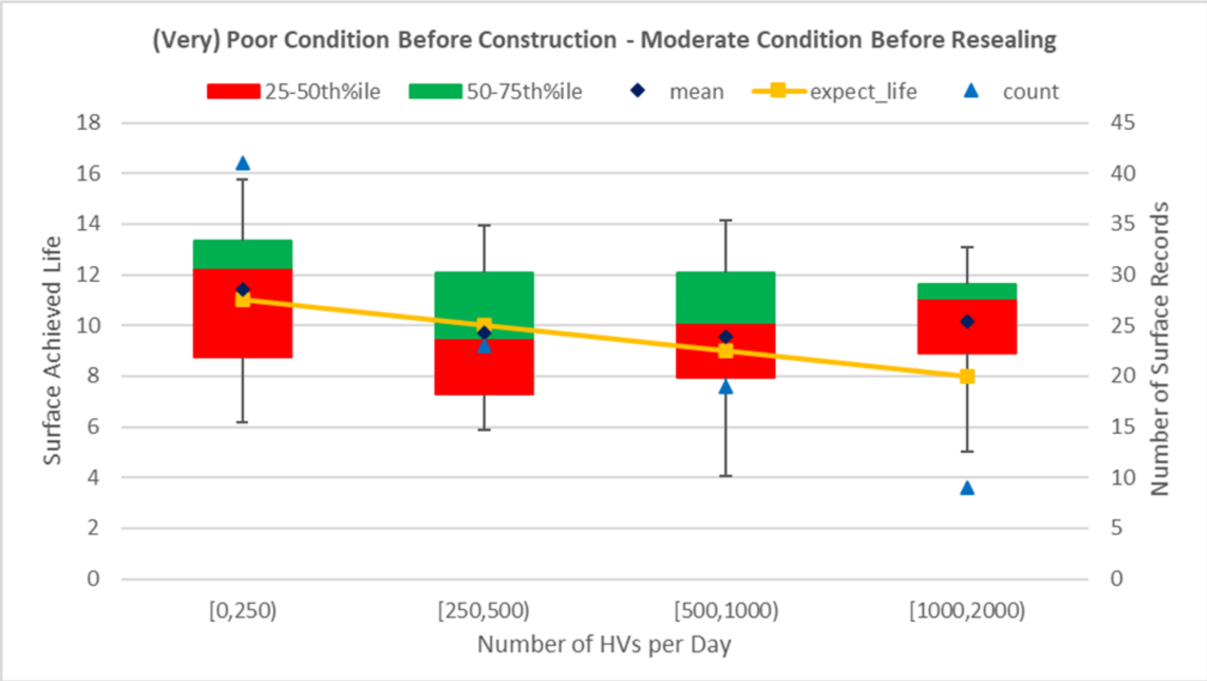


Figure 3-1 Seal life achieved when a reseal is placed over an existing seal in poor/very poor condition and ending when resealed in a moderate condition

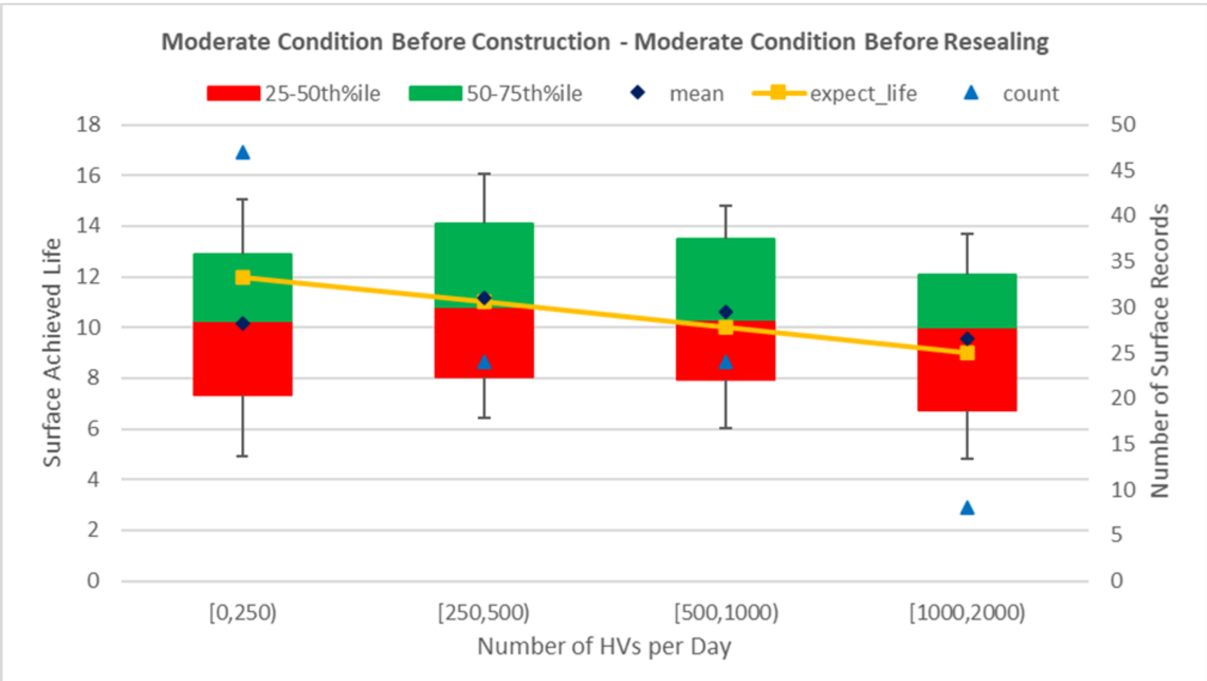


Figure 3-2 Seal life achieved when a reseal is placed over an existing seal in moderate condition and ending when resealed in a moderate condition

3.4.3 Resurface Cycle Times (After Rehabilitation)

2nd Coat Seals are applied shortly after 1st Coat seals and 1 year after is assumed for the analysis. The second coat seal life distribution plot for lengths >300m is shown in Figure 3-3. Figure 3-4 shows the distribution in the various traffic bands. The second coat seal life usually indicates the likely reseal cycle after a rehabilitation treatment.

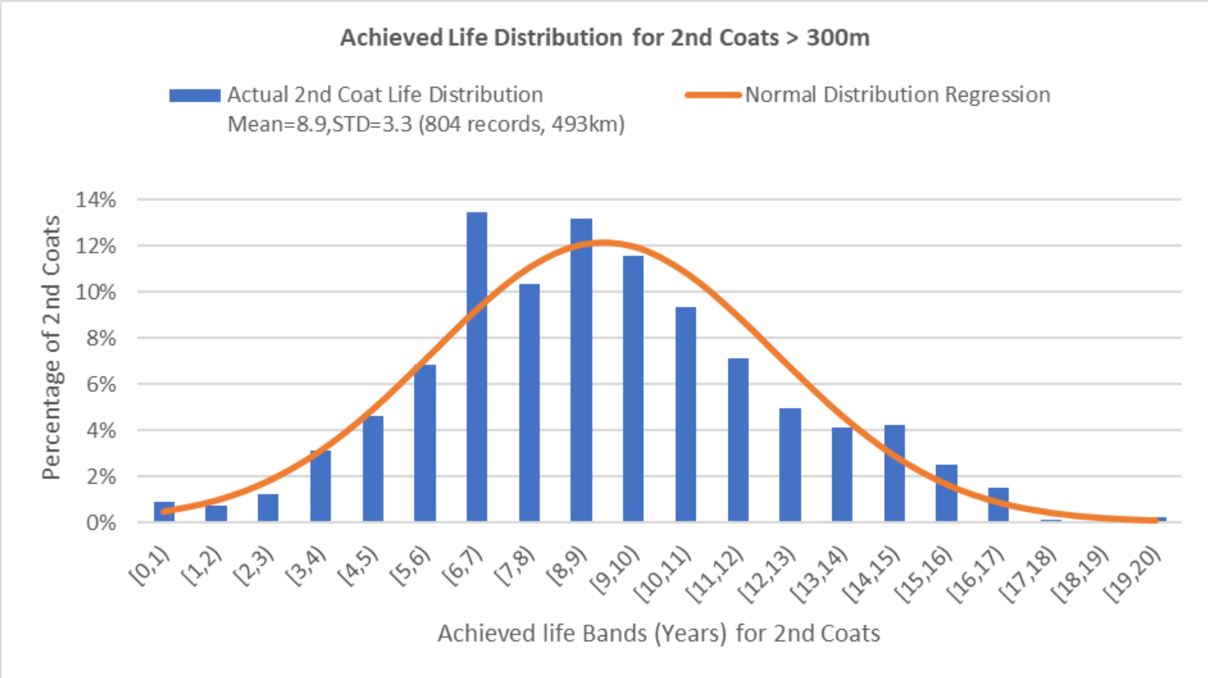


Figure 3-3 Distribution of second coat seal lives (>300m length)

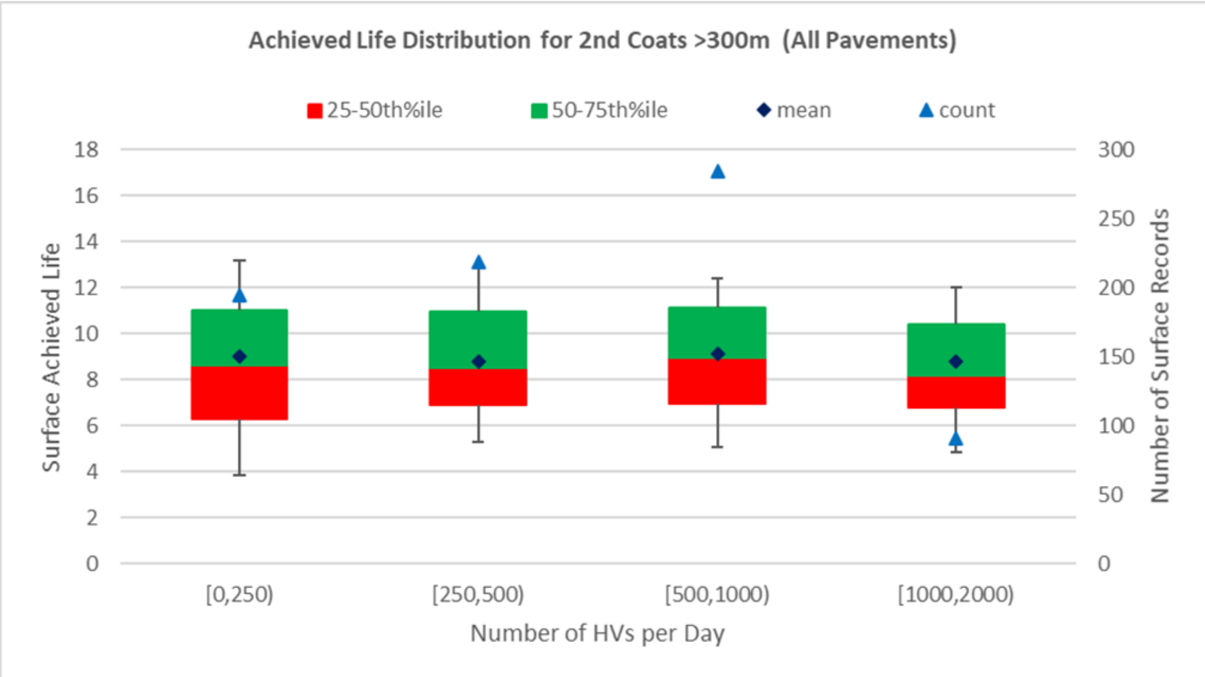


Figure 3-4 Distribution of second coat seal lives (>300m length) in traffic bands

The second coat seals placed on short rehabilitation treatment lengths distribution plot is shown in Figure 3-5 and Figure 3-6 and these demonstrate that the short length treatments perform worse than the longer lengths.

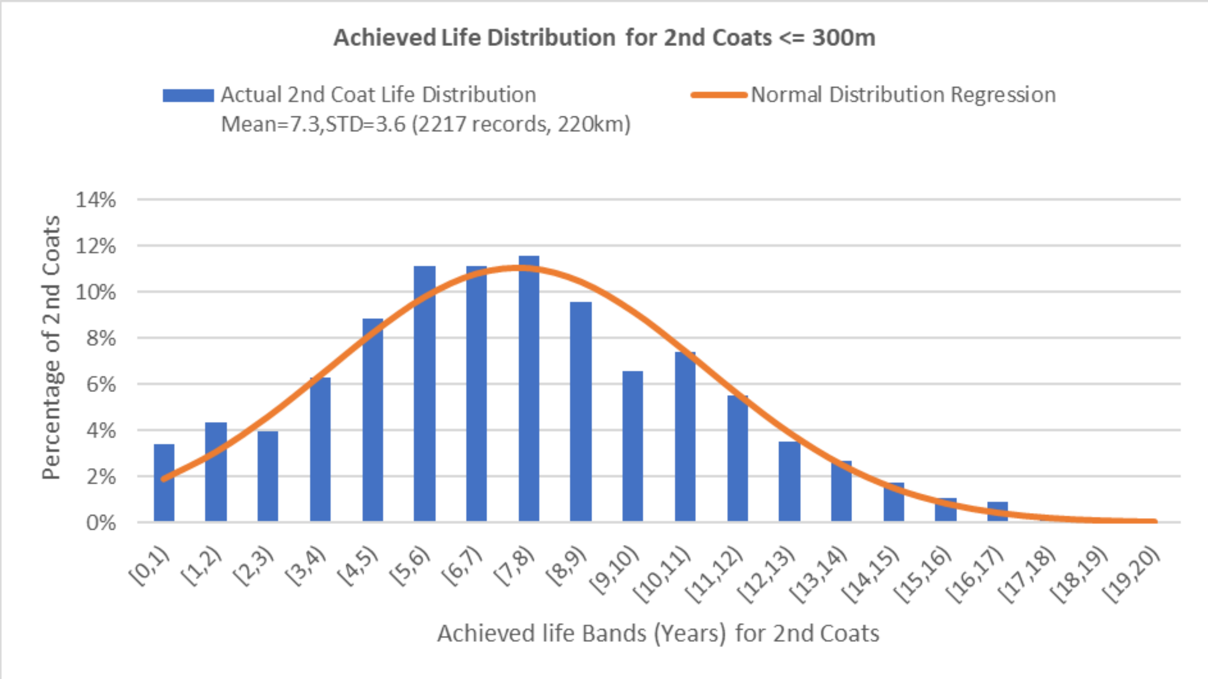


Figure 3-5 Distribution of second coat seal lives (<= 300m length)

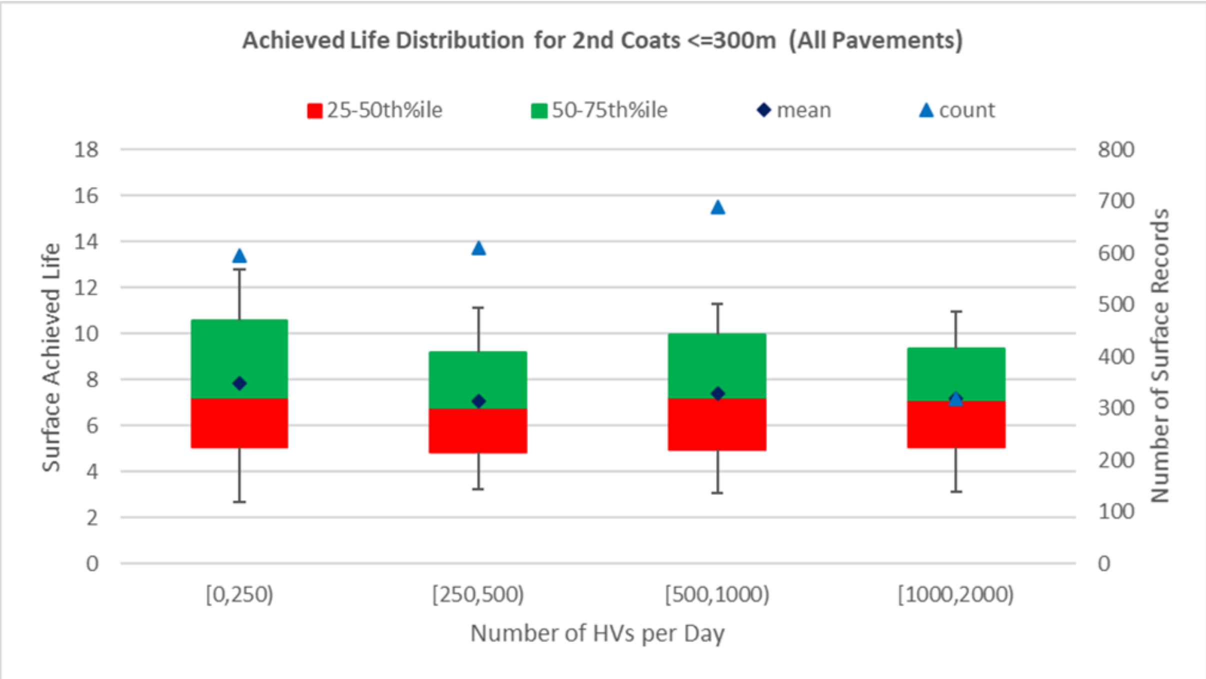


Figure 3-6 Distribution of second coat seal lives (<= 300m length)

Figure 3-3 shows an unexpectedly high standard deviation in rehabilitation second coat seal lives. Approximately 25% of the rehabilitated pavements have low seal lives (< 6 years) which indicates many rehabilitation treatments are not achieving the strength required for longevity. There is also the possibility that some second coat seals are not well constructed.

The traffic appears to have no significant impact on the life of the second coat seals. They are more likely dependent upon the integrity of the rehabilitation treatment. However, there is no indicator in the RAMM data to easily distinguish between low/moderate/high risk rehabilitation treatments. The pavement deflection curvature was examined to see if low curvature pavements (i.e., high strength / low risk) performed better than the higher deflection curvature pavements in regard to second coat seal life.

The strength categories of the pavements are defined as below.

Table 3-8 Pavement strength categories

Strength Category	90th%ile Curvature Range
Strong	<= 0.25mm
Moderate	> 0.25mm and <= 0.35mm
Weak	> 0.35mm

A slight trend is evident, with stronger pavement producing a second coat life 1 year longer than weak pavements, however, the deflection curvature does not appear to be a strong indicator of second coat seal life achieved.

The RAMM database was interrogated to compare the average life of the second coat seals for high-risk treatments verses low risk treatments as described in the catalogue matrix of the NOC-PDP document.

The data was filtered to examine the second coat lives achieved for pavements that had received a high-risk treatment and those that had received a low-risk treatment. The high-risk treatment examined was the recycle treatment of 50mm make up material and modify with 2% cement, and the low-risk treatment was >=150mm of granular M/4 AP40 overlay. The risk designation was determined from the catalogue matrix for pavements carrying 5 - 10 MESA.

The analysis was categorised by length as well as by traffic bands and the results are shown in Figure 3-7 - Figure 3-14.

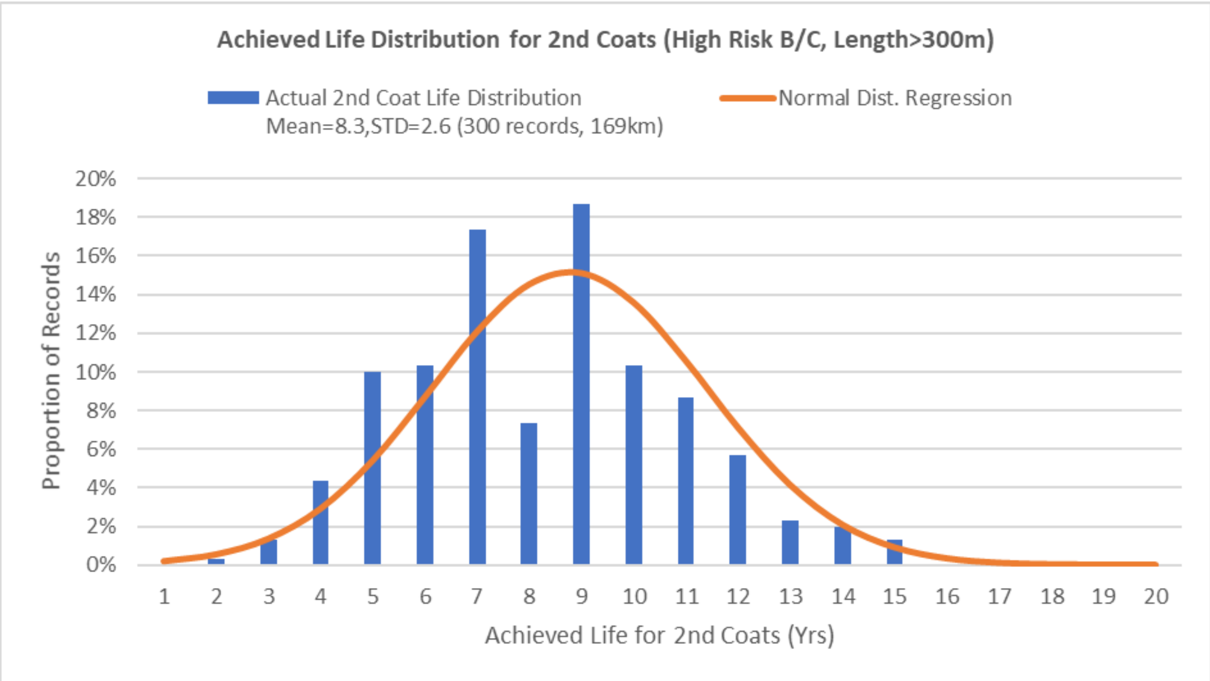


Figure 3-7 Second coat life achieved for high-risk treatments, length > 300m

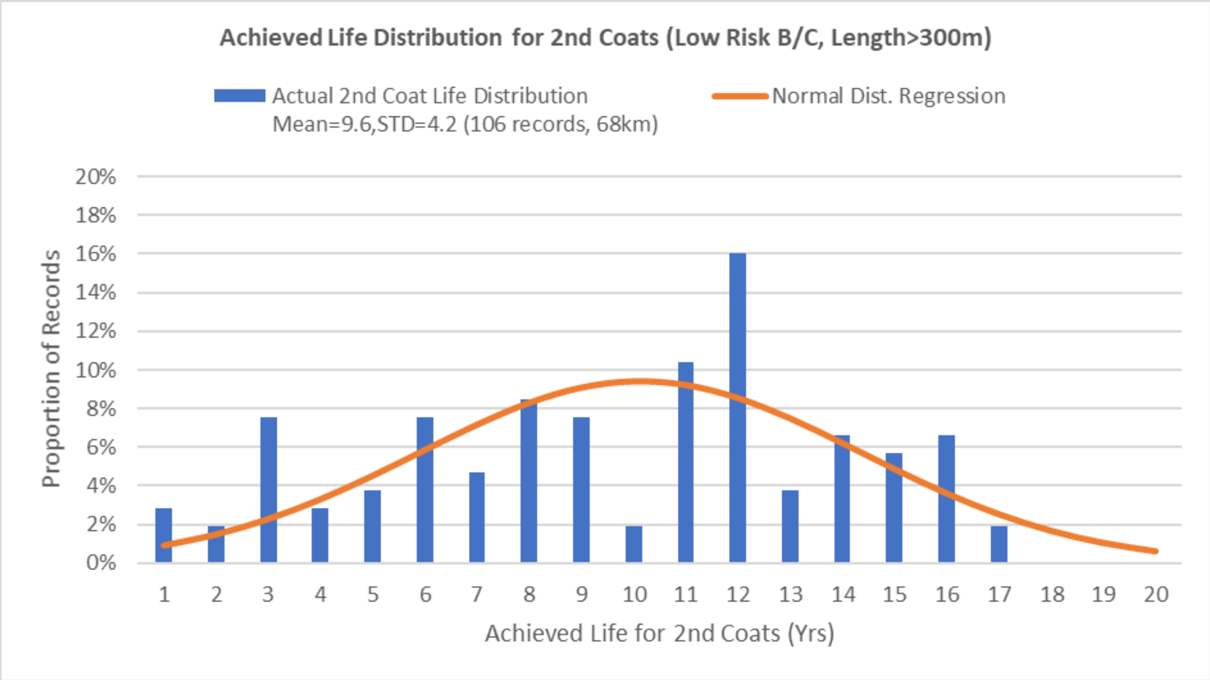


Figure 3-8 Second coat life achieved for low-risk treatments, length > 300m

The distribution is skewed by the very low numbers at 10 years life achieved and it would be appropriate to assume a second coat life of 11-12 years for low-risk treatment.

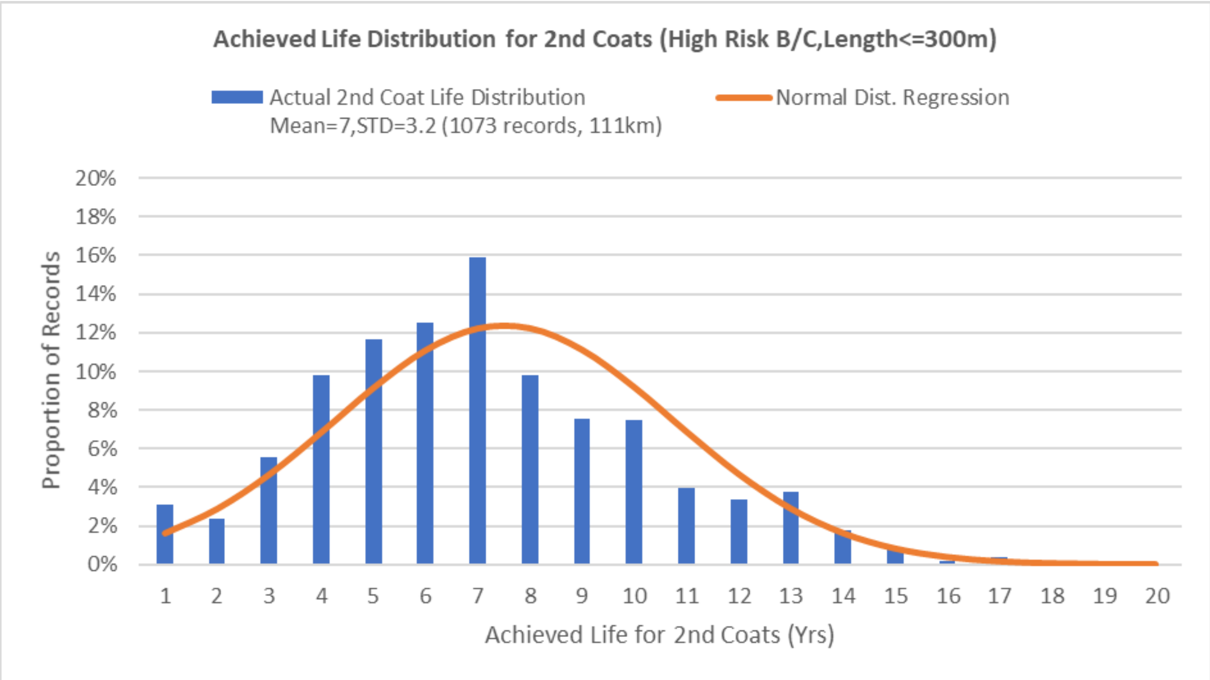


Figure 3-9 Second coat life achieved for high-risk treatments, length <= 300m

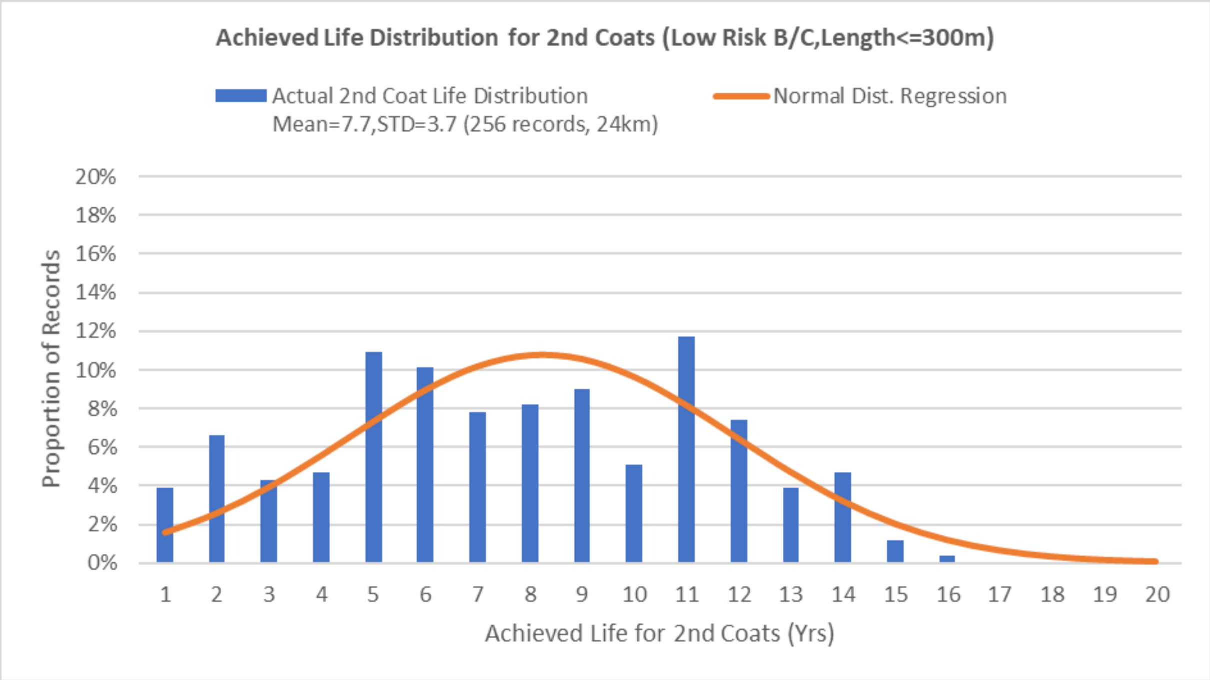


Figure 3-10 Second coat life achieved for low-risk treatments, length <= 300m

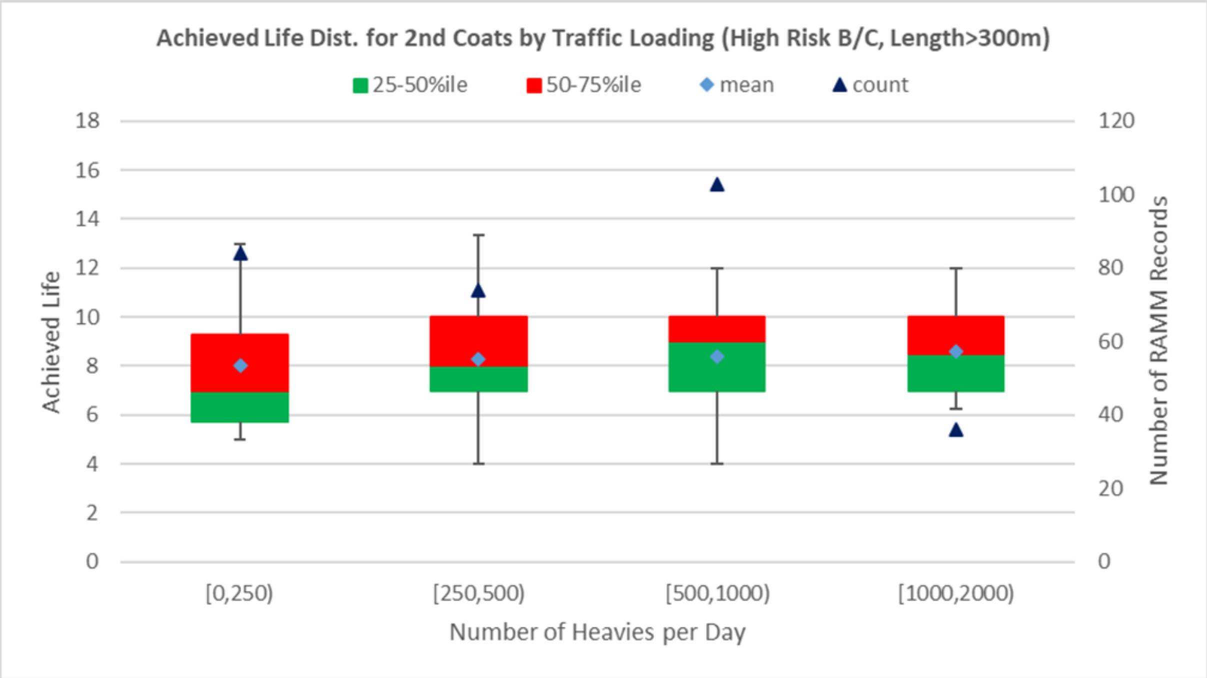


Figure 3-11 Second coat life achieved for high-risk treatments by traffic loading, length > 300m

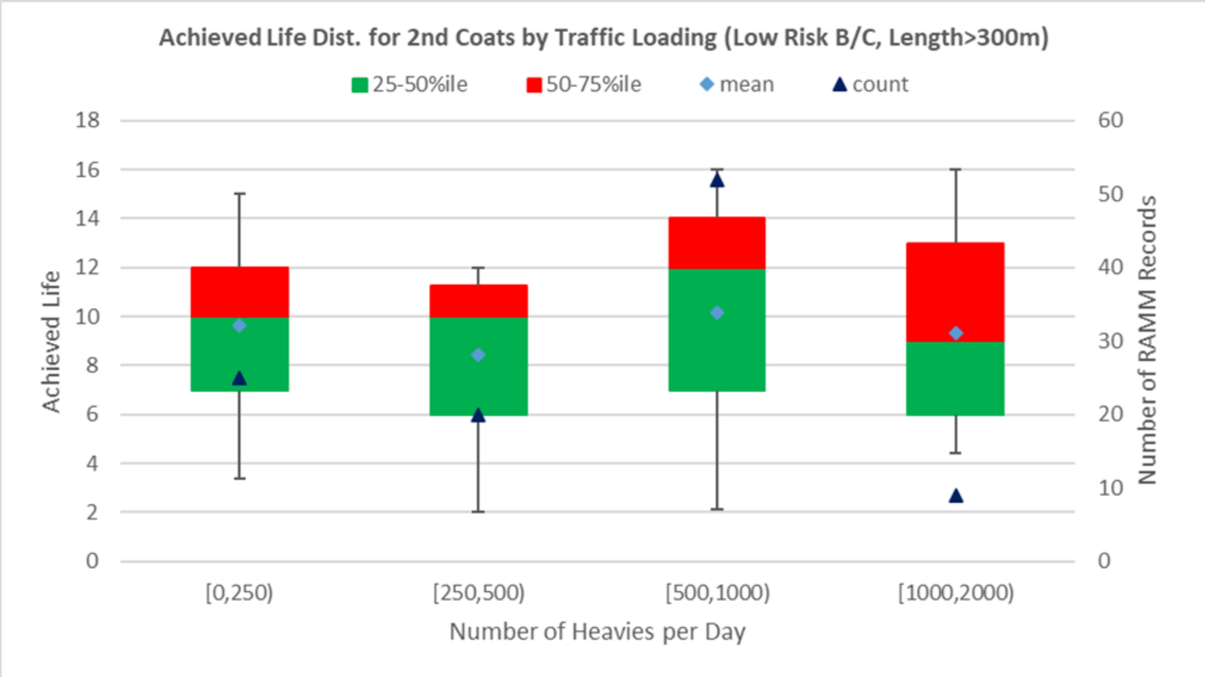


Figure 3-12 Second coat life achieved for low-risk treatments by traffic loading, length > 300m

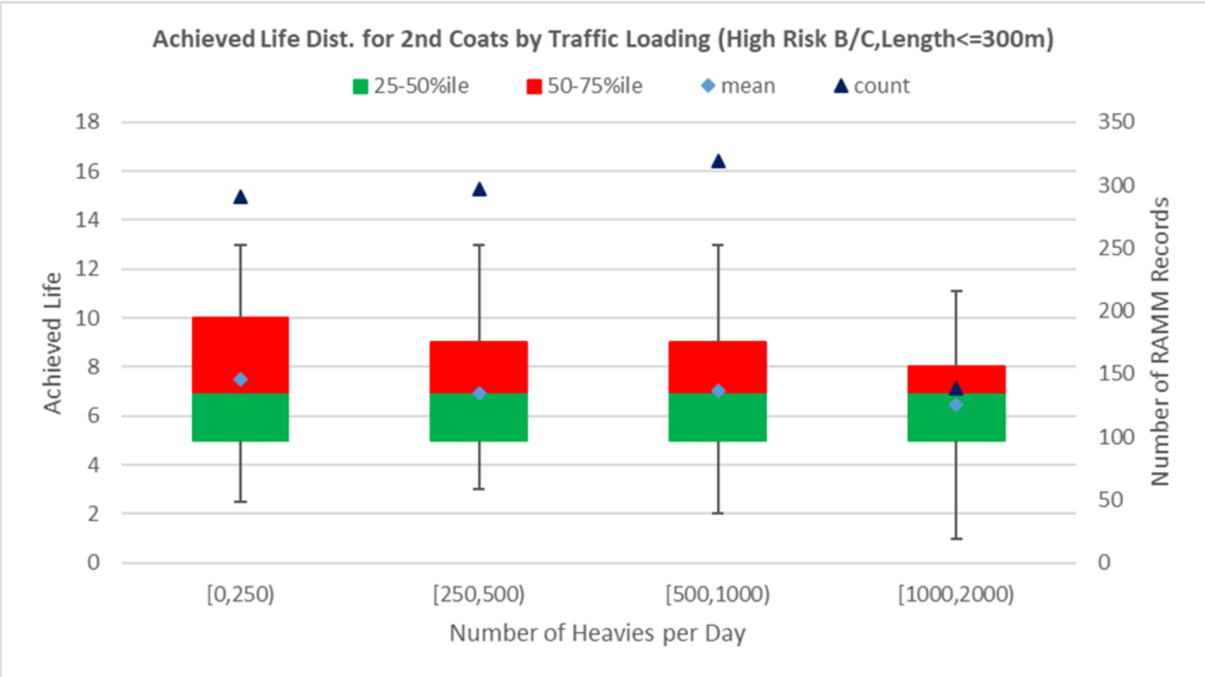


Figure 3-13 Second coat life achieved for high-risk treatments by traffic loading, length <= 300m

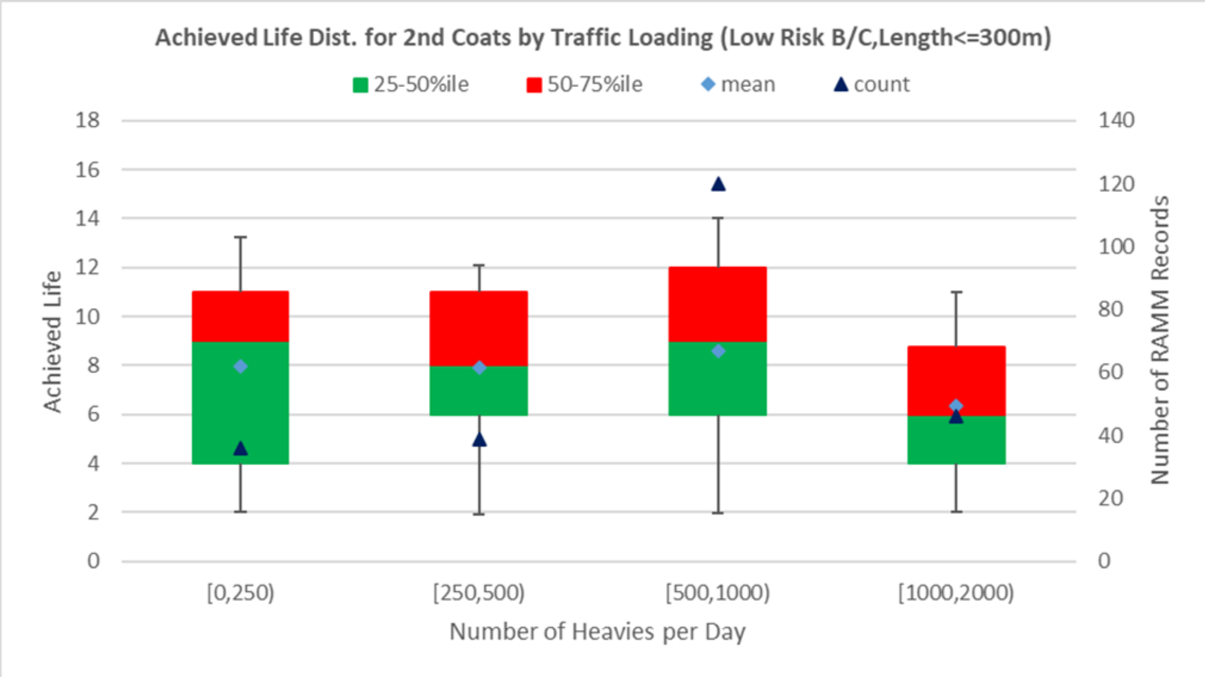


Figure 3-14 Second coat life achieved for low-risk treatments by traffic loading, length <= 300m

For the traffic loading categories analysed, the traffic loading appears to make no significant difference to the second coat life achieved. This is intuitively correct because the treatments should be designed to cope with the traffic loading imposed. The most significant factor is the risk profile of the treatment. The standard deviations are high but that may be a result of the quality of construction.

For very heavily loaded pavements, the traffic loading will significantly impact the life of chip seal surfaces, and it is usually more economic to construct heavy duty pavements with asphalt concrete surfaces. This scenario has not been included in the first stage of this project.

The outcomes of the data analysis above lack sufficient precision to warrant splits between short (<300m) site and longer (>300m) sites. It is recommended that a default second coat life be set as follows.

Table 3-9 Default second coat life by treatment risk

Treatment	Default second coat life
High risk treatment	7 years
Medium risk treatment	10 years
Low risk treatment	12 years

It is recommended that further iterations of surface treatment after a second coat seal have life cycles set to the same as the second coat seal.

4 Reactive Maintenance Proposal

4.1 Immediate Maintenance Requirement

The current process to determine the immediate maintenance cost should remain as presently recommended in the NPV guide and be based on a measure of the defects present in the current pavement that need to be remediated for the "do minimum" (repair and resurface) option. The need for remediation should be based on meeting the performance standards required in the NOCs for normal pre-seal maintenance requirements. The cost can be calculated using the current contract rates in the NOC for pavement maintenance.

The defects should be measured and recorded in a diagrammatic representation of the site.

This part of the financial analysis process is carried out in approximately the middle of the financial year (year 0) and therefore some of the maintenance required to keep the pavement in a condition that meets the NOC performance requirements will have been carried out. However, from the maintenance identified and measured up, any maintenance considered necessary to be carried out prior to winter should be included in year 0 and the remainder in year 1 for the do-minimum option, but not for the rehabilitation options. Any maintenance considered necessary to be carried out in the remainder of year 0 is considered to be historic and not part of future maintenance costs for the do-minimum option.

4.2 Historical Maintenance Achievement

The site maintenance achievement for the previous ten years should be downloaded from the RAMM software, and the quantities of each maintenance type used to calculate the maintenance costs for the pavement, surface and shoulders using the base unit rates from the NOC schedule of prices (SoP). The surfacing history should also be downloaded and only the maintenance achievement since the last resurface treatment considered.

4.3 Future Reactive Maintenance Costs

Future reactive maintenance costs must be estimated for the do-minimum and each pavement option. The do-minimum option has the advantage of knowing the past costs for the site and it is therefore possible to allocate a trend from the average maintenance effort over 5 years prior to the proposed rehabilitation.

4.3.1 Maintenance Costs for Do-Minimum Option

A set of 46 rehabilitation sites was used to examine the progression of pavement maintenance costs within the surfacing cycle prior to the NPV calculation for the rehabilitation project. Traditionally a linear progression from the historical costs has been used to determine the future maintenance costs within the following re-surfacing treatment for the do-minimum option. The analysis shows, statistically, an exponential regression fits the progression better than a linear regression (see Figure 4-1).

4.3.1.1 Profiling of Sites Based on Past Maintenance Effort

The variation between sites is significant and therefore the sites were profiled dependent upon the % area of pavement and shoulders that had been treated and scheduled for treatment over the 5 years prior to and including the year of the proposed rehabilitation treatment. The costs in the year of the treatment (year 1) need to be included for the do-minimum option. The profiling of pavements based on maintenance effort is as follows.

Table 4-1 Maintenance Profiles

Maintenance Profile	5yr Average of % Fault Area	Number of NPVs
Moderate	< 10%	20
High	10 – 20%	17
Very High	20 – 100%	9

Regression curves based on mean values were fitted for the three profiles adopted as shown in Figure 4-2 - Figure 4-4. The regression curves are distinctly different for each profile and therefore the regression shape for each profile has been used in the calculation of the maintenance costs for a 10-year period prior to a rehabilitation treatment. Rather than adopt a single set of values for each profile, the costs are adjusted for each individual site based on the cost of the maintenance identified for year 0 and year 1 in the NPV process plus costs recorded in the RAMM database for years -1, -2, and -3. The year 1 in the NPV process refers to 0 years prior to a rehabilitation in Figure 4-1 to Figure 4-4.

The map of the years in the NPVs process and the years in the charts below are showing in the following table.

Table 4-2 The map of years in NPVs analysis and years in the analysis

Year in NPVs Process	Year in Figure4-1 – Figure 4-4
0	1
1	0
2	-1
3	-2
4	-3

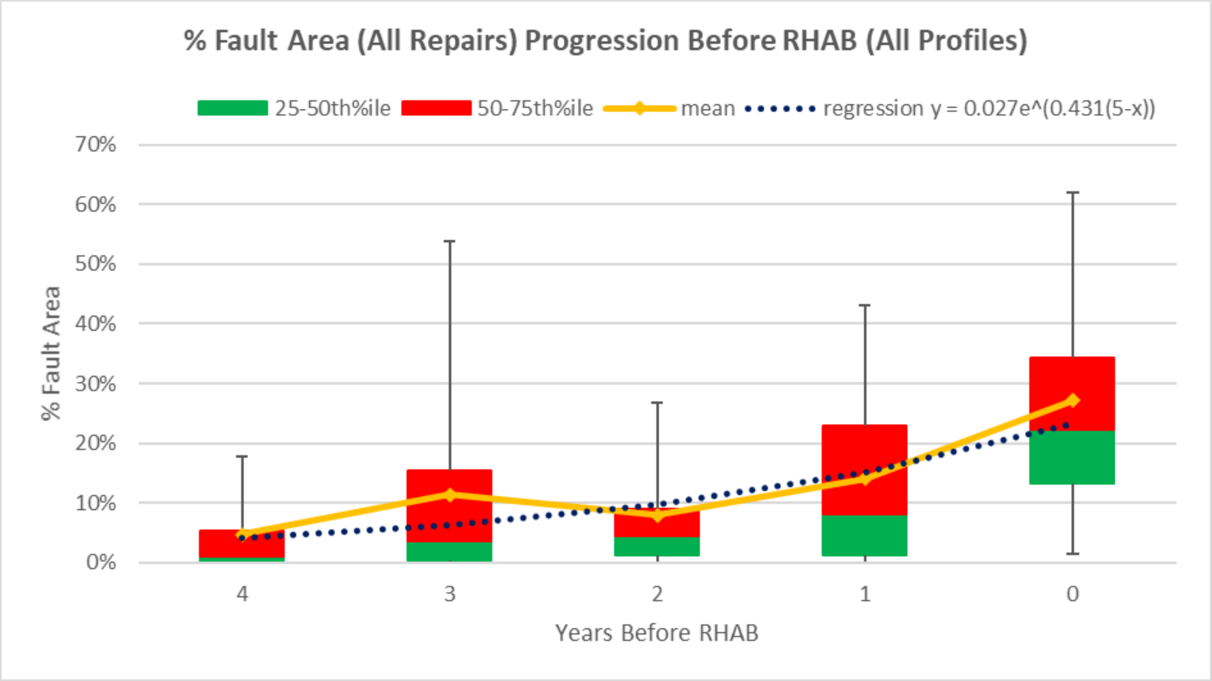


Figure 4-1 Maintenance effort progression prior to a rehabilitation for 46 sites (all profiles)

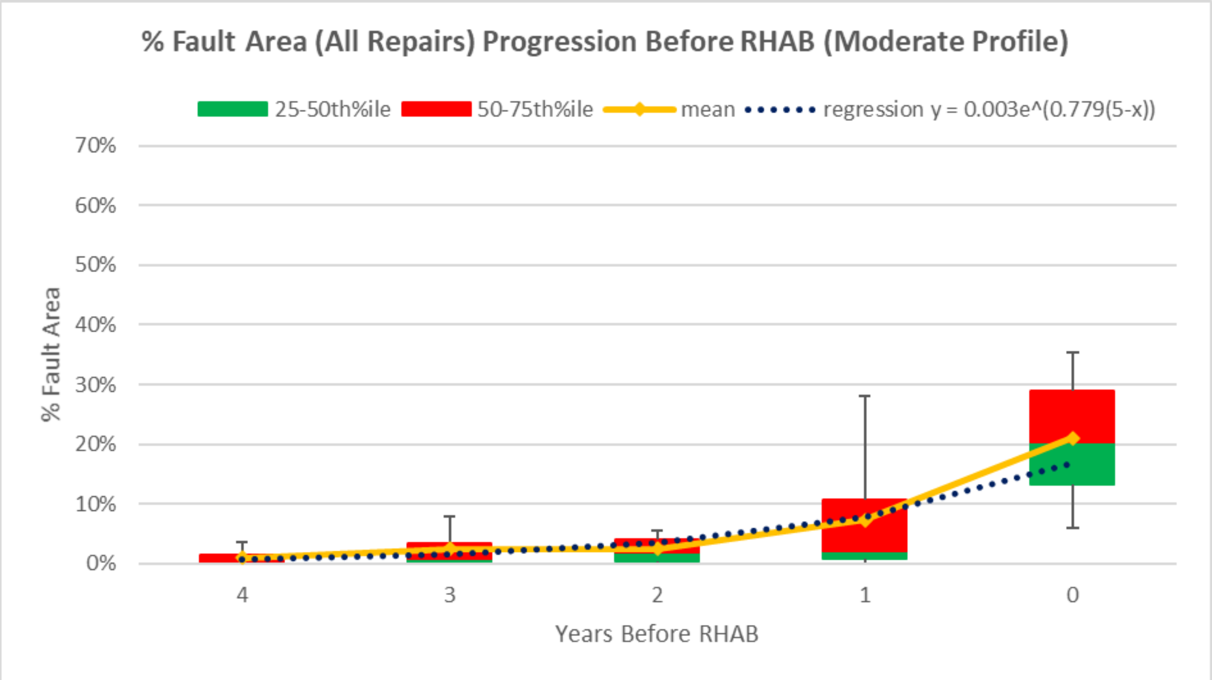


Figure 4-2 Maintenance effort progression prior to a rehabilitation for moderate maintenance profile

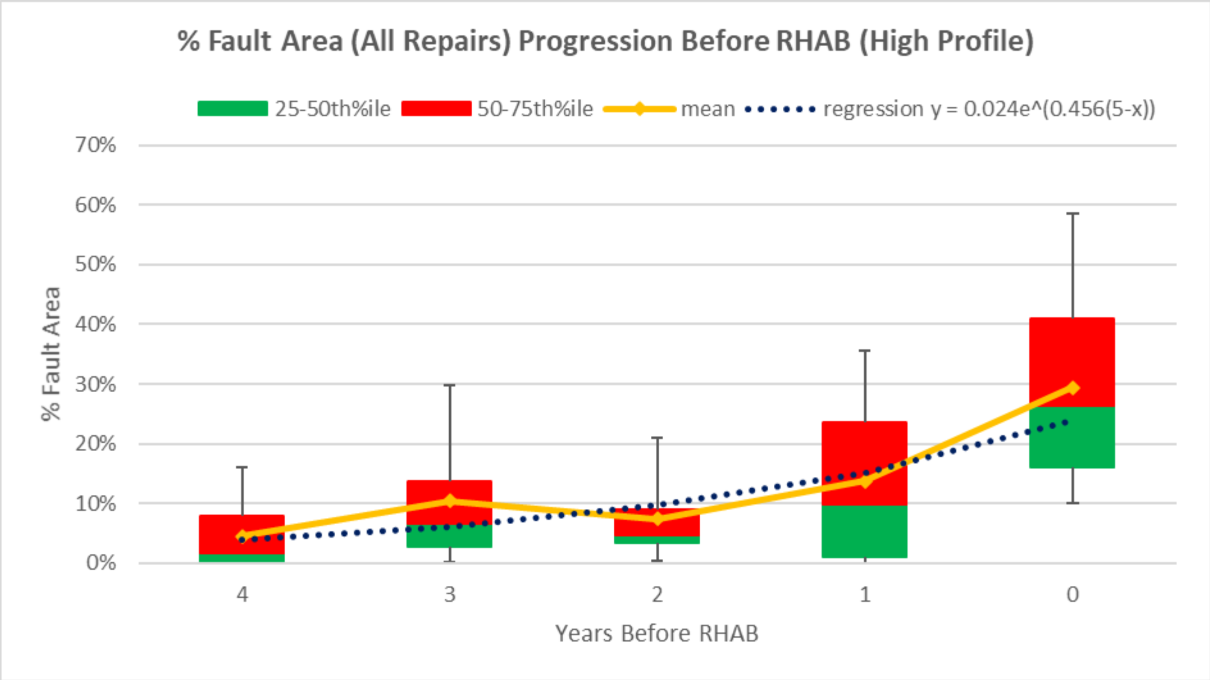


Figure 4-3 Maintenance effort progression prior to a rehabilitation for high maintenance profile

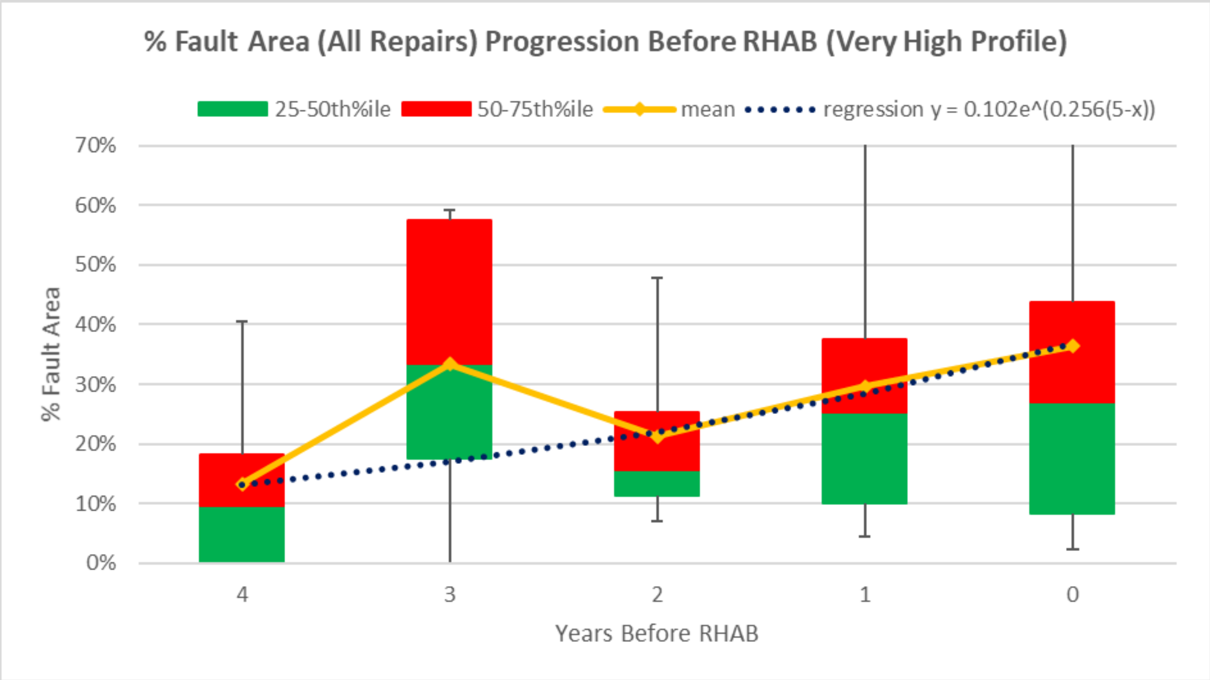


Figure 4-4 Maintenance effort progression prior to a rehabilitation for very high maintenance profile

4.3.1.2 Cost Curve Fitting for Each Site

The do-minimum cost curve is an exponential equation defined as $y = a * e^{b(5-x)}$, where the y is the maintenance cost, x is the number of years before rehabilitation, and a, b are coefficients.

The b value in the function determines the progression rate of a maintenance cost curve. The three different b values used in the calculation are based on those obtained for each maintenance effort profile, which are 0.779, 0.456 and 0.256 for moderate, high, and very high profiles respectively. These b values were calculated from the mean value regressions.

Which b value to use is determined by the 5-year average % fault area bands as shown in Table 4-1.

The coefficient a is then calculated separately for pavement (PA), surface (SU), and shoulder (SH) maintenance groups.

The coefficient a is calculated by the following equation.

$$a = \frac{Total\ 5yr\ Maint.Area\ for\ the\ cost\ group}{\sum_{i=1}^{5} e^{b(5-i)}}$$

The coefficient a calculated from this equation will have the total maintenance area (5 years before RHAB) calculated from the do-minimum curve same to the total maintenance area (5 years before RHAB) populated in the NPVs spreadsheet.

Once the a values are calculated for PA, SU, and SH maintenance groups, the maintenance cost area is calculated based on the exponential equation for a 10-year period before rehabilitation for each maintenance group.

The weighted average costs for PA, SU and SH maintenance groups are then calculated based on the quantities populated in the NPV spreadsheet 5 years before RHAB (year -3 to year 1).

These weighted average costs are then used to convert the maintenance cost area calculated based on the exponential equation to dollar figures.

Finally, the dollar figures for PA, SU, and SH maintenance groups are summed up to be the do-minimum cost curve showing in the NPVs template.

A k factor was added in the NPVs template to adjust the a values calculated from the equation above. The k is set to 1 by default. The k factor is a linear amplifier of the maintenance cost from the do-minimum cost curve. For example, k = 1.1 means the maintenance cost is increased by 10%. The k factor is introduced in the calculation to allow Waka Kotahi to put more focus on the reactive maintenance.

4.3.2 Maintenance Costs for Rehabilitation Options

Experience has shown that maintenance costs are generally higher for rehabilitated pavements that only achieve a short second coat seal life. The maintenance costs in the RAMM database were examined for second coat seals greater than 300m in length which achieved lives that fell into the life cycle bands shown in Table 4-2.

Table 4-3 2nd coat seal life categories

2nd Coat Seal Life Category	Life Band
Short	4 – 7 years
Medium	8 – 11 years
Long	12 – 15 years

The graphs for each second coat seal life category are shown in Figure 4-5 - Figure 4-7 and summarised in Figure 4-8.

The results indicate maintenance costs for the short life second coat seals are significantly greater than for the medium to long life second coat seals. Therefore, the life achieved for a second coat seal is a good indicator of the efficacy of the rehabilitation treatment. Because the life cycle of second coat seals is related to the risk profile of the treatment it can also be concluded that the maintenance costs for the high risk treatments are significantly greater than for low risk treatments.

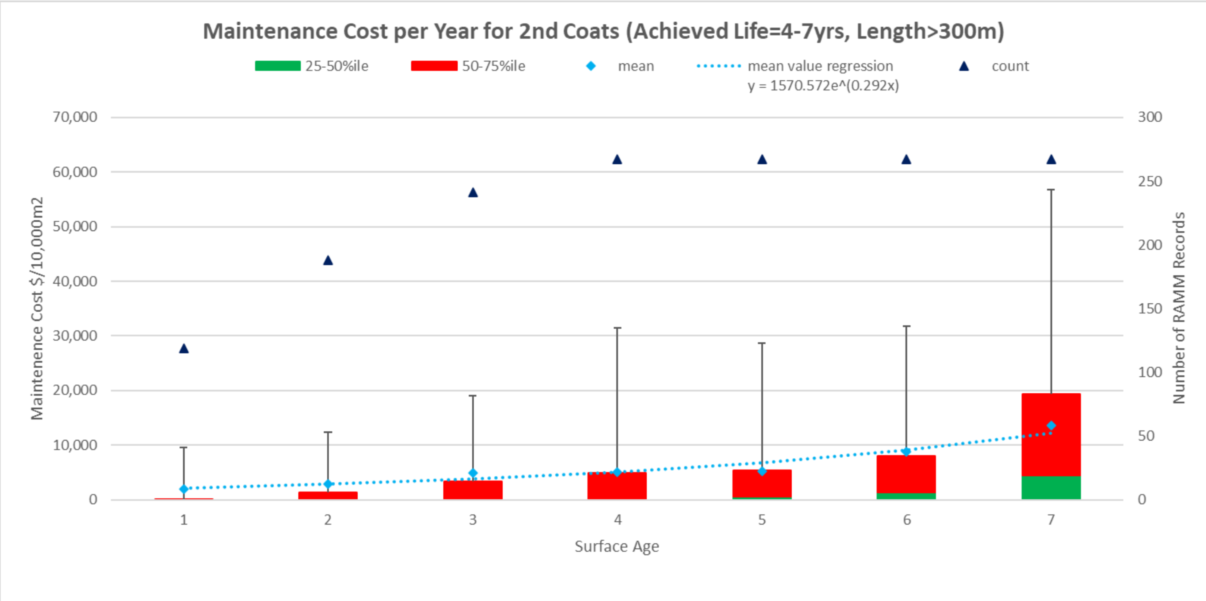


Figure 4-5 Maintenance costs for 2nd coat seals based on 4-7 years life achieved

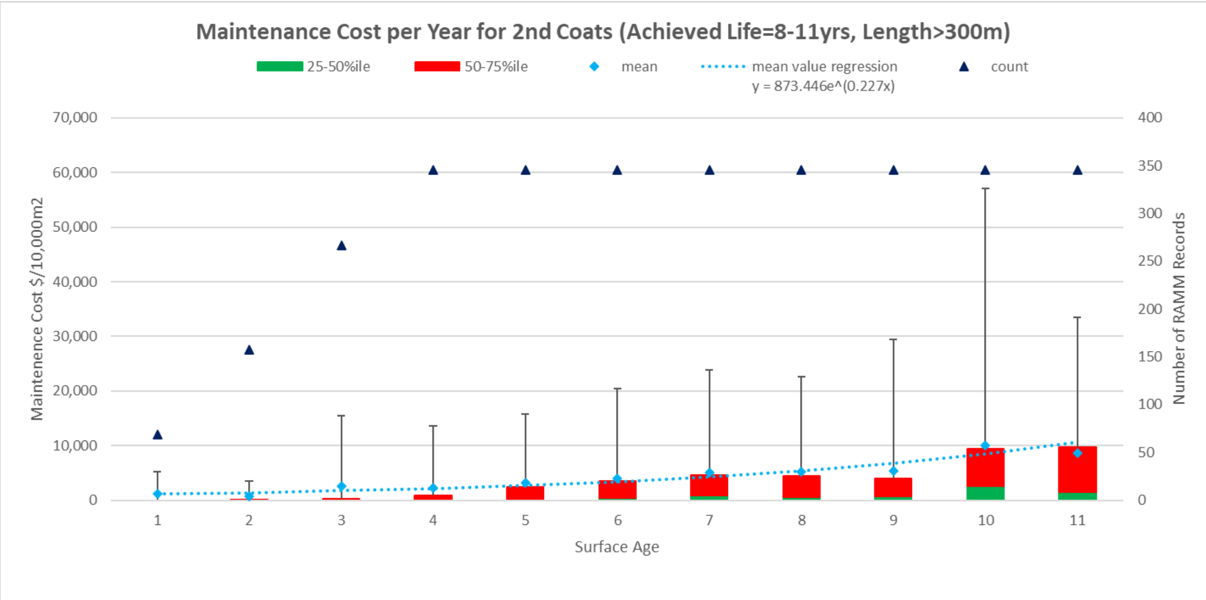


Figure 4-6 Maintenance costs for 2nd coat seals based on 8-11 years life achieved

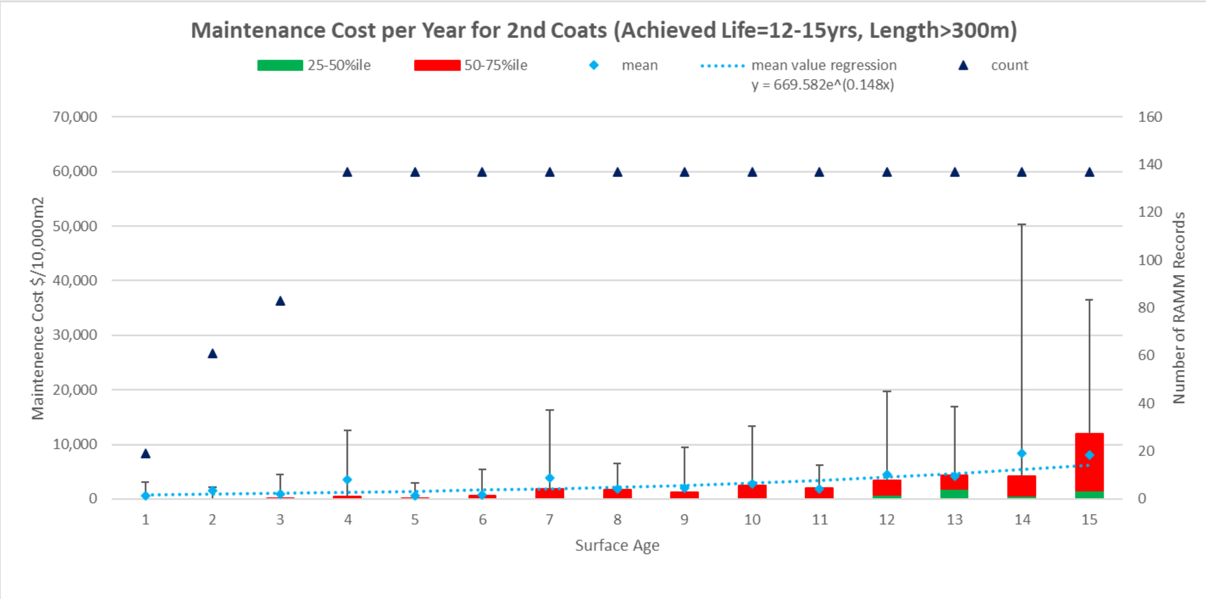


Figure 4-7 Maintenance costs for 2nd coat seals based on 12-15 years life achieved

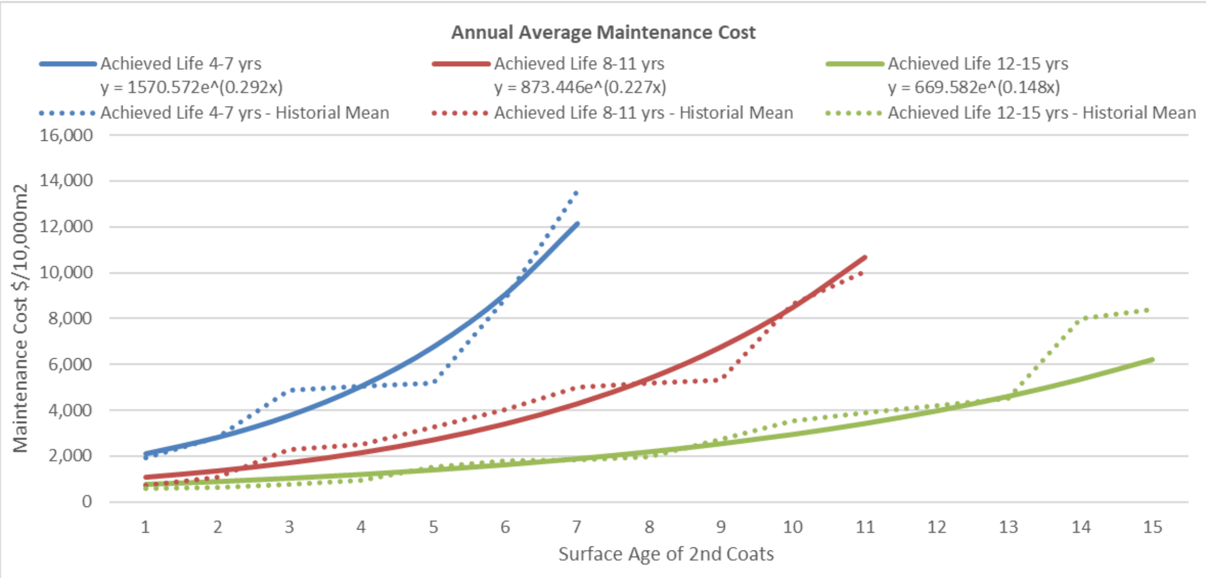


Figure 4-8 Maintenance costs for 2nd coat seals based on life achieved

5 Recommended Economic Analysis Procedure for a Rehabilitation Treatment

The process of calculating an NPV for a rehabilitation treatment for a granular pavement with a thin surface is summarised as follows.

5.1 Background

5.1.1 Forward Work Programme

The forward programme contains a long-term programme of resurfacing and rehabilitation treatments spread over the next 10 years. This programme is set by Waka Kotahi and reviewed every 3 years.

5.1.2 Annual Plan

The annual plan process starts in November for the following financial year (FY) with the examination of the network by Waka Kotahi review and prioritisation team (RAPT) accompanied by Waka Kotahi regional staff and representatives from the NOC contractor teams. Sites scheduled for a rehabilitation or resurface treatment in the FWP are examined and based on the performance of the site over the previous year, the rehabilitation programme for the next FY is decided. However, each rehabilitation site must have a financial analysis carried out to determine if it is economically justified. The justification is provided in the form of a calculated net present value (NPV).

The annual plan rehabilitation programme must be finalised by 15th March and must include the NPV. There is no time for investigation and design before the NPV calculation and therefore the maintenance regimes suggested above should be adopted unless better information exists.

Design of rehabilitation work commences with the investigation of the pavement (test pits and initial laboratory testing) in April – June and designs are completed in July – October. With better treatment information available following design work, it is normal for the NPV to be re-examined to make sure it is still appropriate, and it is considered a pass/fail assessment.

5.1.3 Annual Plan Minimum NPV Requirements

The Waka Kotahi AP instructions SM018 (2016) includes the following instructions.

> "*A low NPV (< $10,000) is considered negligible over the 30 year analysis period and may still result in the proposed option being rejected. This is due to the variables in producing the NPV and the minimal return on investment the option is likely to provide over the long term. As a guide, a treatment option will be considered to be robust where the NPV is greater than $25,000. The following table should be used as a guide;*"

Classification	Minimum NPV
National	$5,000
Arterial	$10,000
Regional	$10,000
Primary Collector	$25,000
Secondary Collector	$25,000
Access	$25,000

This guide is embedded in the spread sheet application for calculating NPVs and provides a significant barrier to obtaining a pass assessment for rehabilitation on Primary, Secondary and Access designated highways. This is understandable when budgets are restricted because it is appropriate to keep the higher use highways in a good functional state. However, the restriction is not so appropriate for short length rehabilitation treatments which have become the norm and it would be more appropriate to have the minimum NPV apply per kilometre of highway.

5.2 Summary of Inputs for NPV

Based on the analyses and recommendations in this report, a summary of inputs into the NPV process follows.

5.2.1 Timing

- Year 0 – the financial year in which the NPV is being calculated
- Year 1 – the financial year following year 0 in which the treatment is carried out

5.2.2 Do-Minimum Option

This option requires the designer to determine the following.

a) Cost to repair the existing surface to a standard acceptable for a resurface treatment

This cost should be based on a measure of the defects present in the current pavement that need to be remediated for the "do minimum" (repair and resurface) option. The need for remediation should be based on meeting the performance standards required in the NOCs for normal pre-seal maintenance requirements. The cost can be calculated using the current contract rates in the NOC for pavement maintenance.

b) Cost of the surface treatment

The cost of resurfacing treatments can be accurately established, from the measured area of pavement and the base rates from the NOC schedule of prices (SoP).

It is recommended that the cost used be determined for a grade 3/5 two coat seal, which is assumed to be the average treatment.

c) Life of the surface treatment

It is recommended that the reseal life for the do minimum option be set to the lesser of either 1 year less than that achieved by the existing seal coat if it is a grade 2 – 4 chip or the values shown in Table 3-7.

d) Cost of annual maintenance during the life of the surface treatment

From the maintenance measured in a), any maintenance considered necessary to be carried out prior to winter should be included in year 0 and the remainder in year 1 for the do-minimum option, but not for the rehabilitation options.

For years -1 to -3, the maintenance effort from RAMM should be downloaded for these years and input into the spread sheet application, which will calculate the maintenance cost curve for the do-minimum re-surface.

e) Cost of a minimalist rehabilitation (high-risk) option

From the NOC-PDP catalogue matrix, choose the highest risk, least cost practical option. This would normally be the recycle option. Estimate the cost of this treatment including the first coat seal.

f) Life of the second coat seal

The default second coat life is estimated from the risk rating for the treatment as shown in Table 5-1. For the do-minimum option the high-risk treatment is the do-minimum which has a default life of 7 years.

Table 5-1 Default Seal Life for Second Coat Seals

Treatment Risk	Expected 2nd Coat Life
High	7 years
Medium	10 years
Low	12 years

g) Cost of the 2nd coat seal

This is the same cost as calculated in b) above.

h) Cost of annual maintenance during the life of the second coat seal

The annual maintenance for the life of the second coat seal is estimated as described in 4.3.2 above within the spread sheet application, which will calculate the maintenance cost curve for the high-risk treatment second coat surface.

i) Cost of the resurface after the second coat

This is the same cost as calculated in b) above.

j) Life of the reseal

This is the same life as calculated in f) above.

k) Cost of annual maintenance during the life of the surface treatment

This is the same cost as calculated in h) above.

l) Repeat procedure from e) for a 30-year period

The flow diagram for do-minimum option shows below. Note that 2 high risk rehabilitation treatments will be required in the 30 year analysis period.

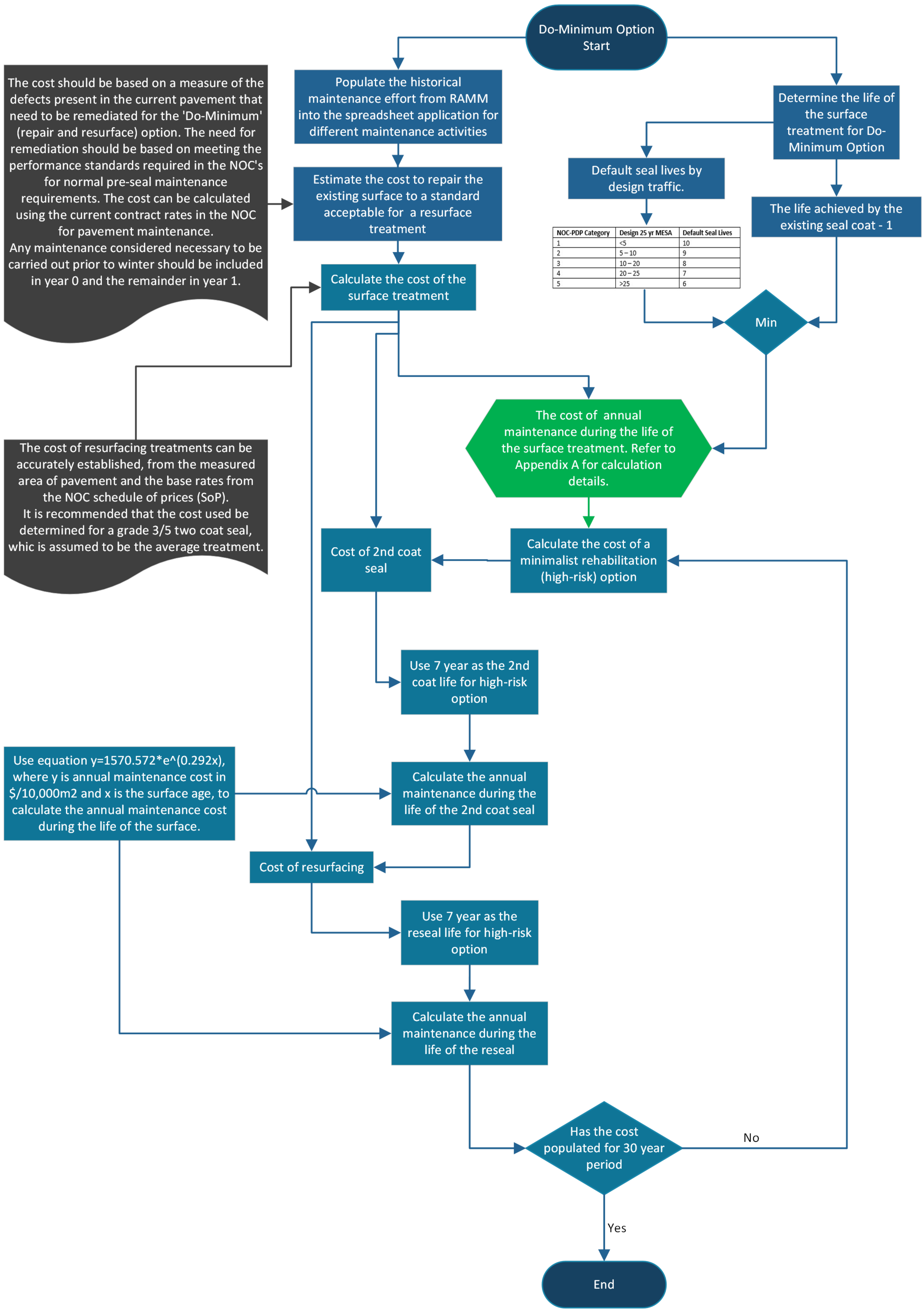


Figure 5-1 Flow Diagram for Do-Minimum Option

5.2.3 Heavy Maintenance Option

This option is halfway between the do-minimum and a high-risk rehabilitation treatment. The assumption is that significant structural repairs will be carried out (e.g. digout and stabilisation repairs) to strengthen the weakest 10 – 20% of the pavement and for a resurface treatment to be placed. It is assumed that maintenance costs will be the same for the do-minimum option.

There is no objective way to determine the life cycle of surface treatment or the maintenance costs that may be incurred over the life of the surface treatment. It is assumed that the treatment will last 7 years at which time a rehabilitation treatment will be required. This is a minimalist approach, and therefore it is assumed that a high-risk rehabilitation treatment will follow the heavy maintenance and resurface. The resurfacing cycle times and costs will be the same for the high-risk option following the rehabilitation treatment.

The flow diagram for heavy maintenance option shows below. Note that 2 high risk rehabilitation treatments will be required in the 30 year analysis period.

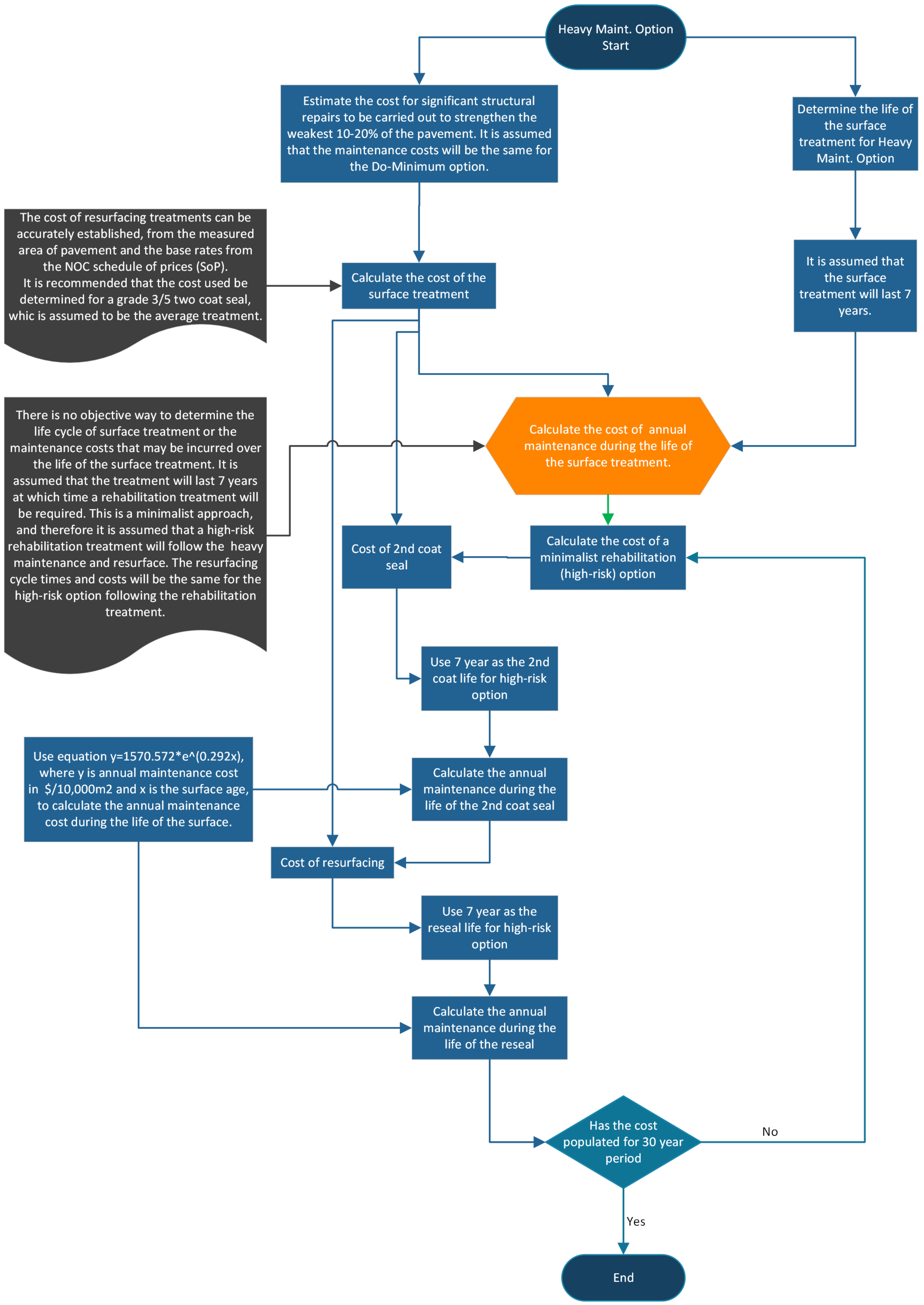


Figure 5-2 Flow Diagram for Heavy Maintenance Option

5.2.4 High-risk Rehabilitation Option

This option requires the designer to determine the following.

a) Cost of a high-risk rehabilitation option

From the NOC-PDP catalogue matrix, choose the highest risk, least cost practical option. This would normally be the recycle option. Estimate the cost of this treatment including the first coat seal.

b) Life of the second coat seal

The default second coat life is estimated from the risk rating for the treatment as shown in Table 5-1. The high-risk treatment second coat seal has a default life of 7 years.

c) Cost of the 2nd coat seal

The cost of resurfacing treatments can be accurately established, from the measured area of pavement and the base rates from the NOC SoP for a 3/5 grade chip seal.

d) Cost of annual maintenance during the life of the second coat seal

The annual maintenance for the life of the second coat seal is estimated as described in 4.3.2 above within the spread sheet application, which will calculate the maintenance cost curve for the high-risk treatment second coat surface.

e) Life of the resurface after the second coat

This is the same as b) above.

f) Cost of the resurface after the second coat

This is the same cost as calculated in c) above.

g) Cost of annual maintenance during the life of the surface treatment

This is the same cost as calculated in d) above.

h) Repeat procedure from a) for a 30-year period

The flow diagram for high-risk rehabilitation option shows below. Note that 2 high risk rehabilitation treatments will be required in the 30 year analysis period.

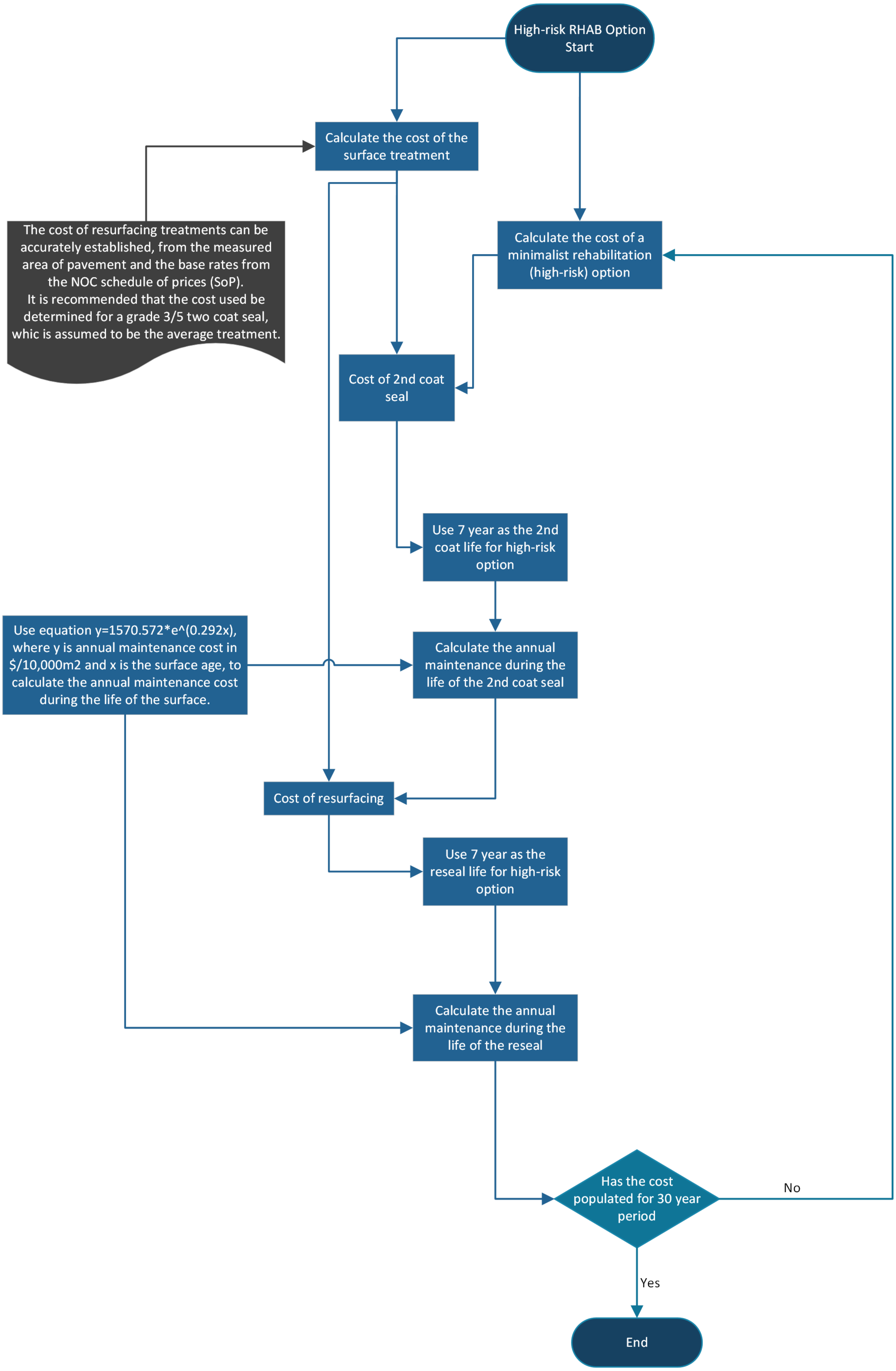


Figure 5-3 Flow Diagram for High-risk Option

5.2.5 Medium-risk Rehabilitation Option

This option requires the designer to determine the following.

a) Cost of a medium-risk rehabilitation option

From the NOC-PDP catalogue matrix, choose a medium-risk, practical option.

b) Life of the second coat seal

The default second coat life is estimated from the risk rating for the treatment as shown in Table 5.2. The medium-risk treatment second coat seal has a default life of 10 years.

c) Cost of the 2nd coat seal

The cost of resurfacing treatments can be accurately established, from the measured area of pavement and the base rates from the NOC SoP for a 3/5 grade chip seal.

d) Cost of annual maintenance during the life of the second coat seal

The annual maintenance for the life of the second coat seal is estimated as described in 4.3.2 above within the spread sheet application, which will calculate the maintenance cost curve for the medium-risk treatment second coat surface.

e) Life of the resurface after the second coat

This is the same as b) above.

f) Cost of the resurface after the second coat

This is the same cost as calculated in c) above.

g) Cost of annual maintenance during the life of the surface treatment

This is the same cost as calculated in d) above.

h) Repeat procedure from a) for a 30-year period.

The flow diagram for medium-risk shows below. Note that 2 medium risk rehabilitation treatments will be required in the 30 year analysis period.

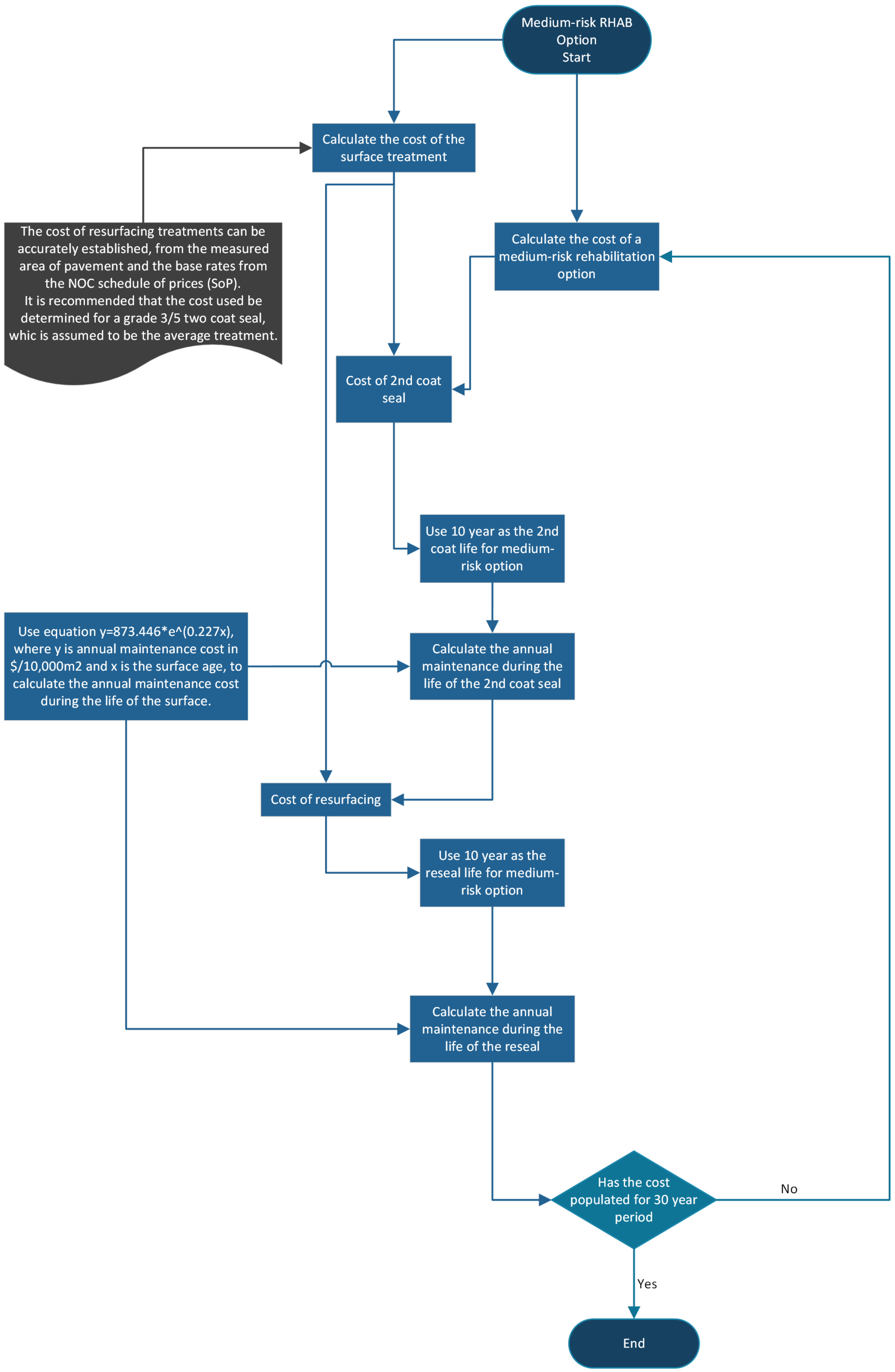


Figure 5-4 Flow Diagram for Medium-risk Option

5.2.6 Low-risk Rehabilitation Option

This option requires the designer to determine the following.

a) Cost of a low-risk rehabilitation option

From the NOC-PDP catalogue matrix, choose a low-risk, practical option.

b) Life of the second coat seal

The default second coat life is estimated from the risk rating for the treatment as shown in Table 5-1. The low-risk treatment second coat seal has a default life of 12 years.

c) Cost of the second coat seal

The cost of resurfacing treatments can be accurately established, from the measured area of pavement and the base rates from the NOC SoP for a 3/5 grade chip seal.

d) Cost of annual maintenance during the life of the second coat seal

The annual maintenance for the life of the second coat seal is estimated as described in 4.3.2 above within the spread sheet application, which will calculate the maintenance cost curve for the low-risk treatment second coat surface.

e) Life of the resurface after the second coat

This is the same as b) above.

f) Cost of the resurface after the second coat

This is the same cost as calculated in c) above.

g) Cost of annual maintenance during the life of the surface treatment

This is the same cost as calculated in d) above.

h) Repeat procedure from e) for a 30-year period.

Flow diagram for low-risk option shows below. Note that 1 low risk rehabilitation treatment will be required in the 30 year analysis period.

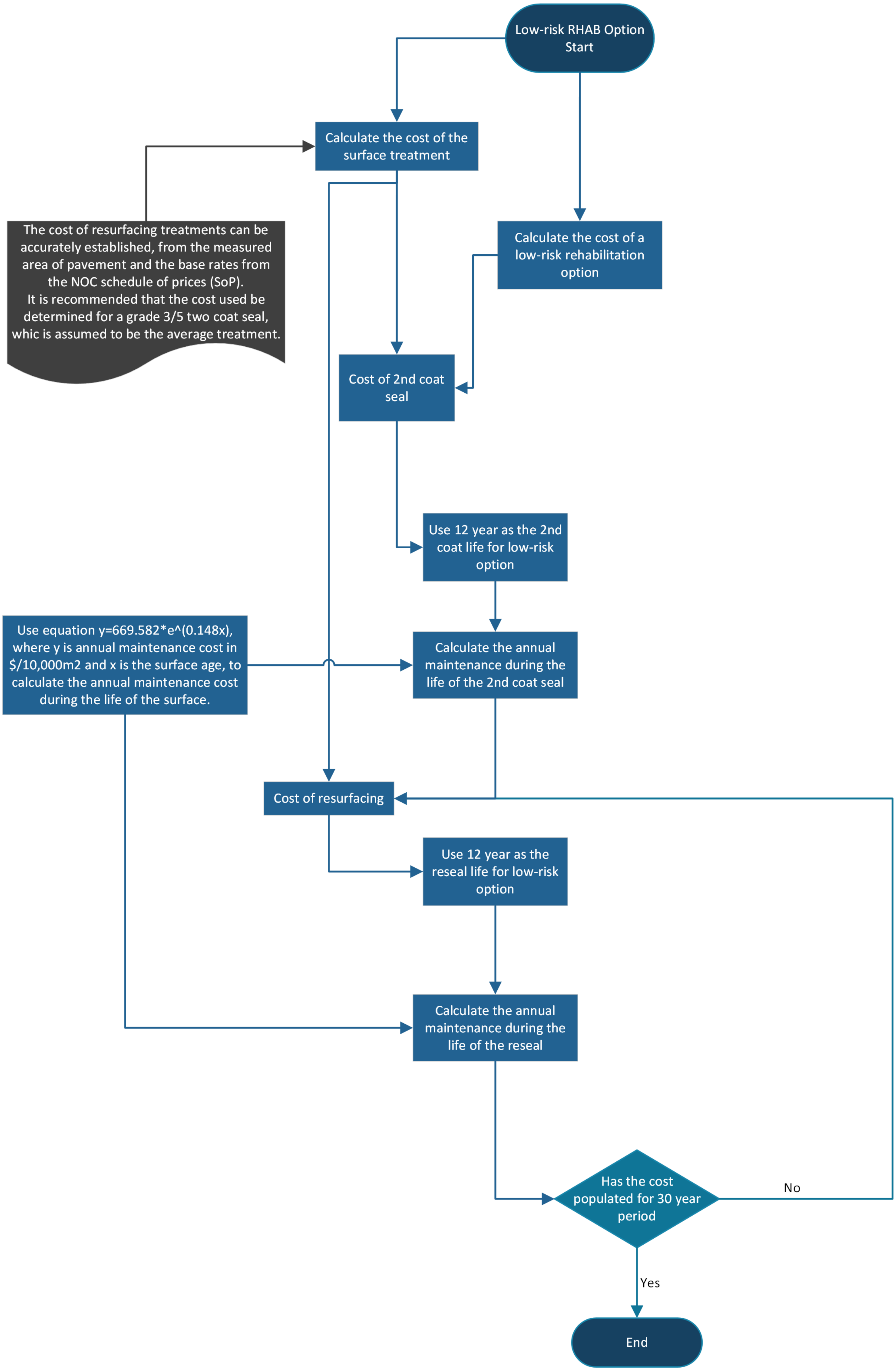


Figure 5-5 Flow Diagram for Low-risk Option

6 Trial NPV Calculations

The procedure above was trialled on three sites from the East Waikato NOC with the results shown in Table 6-1.

Table 6-1 Trial NPV Examples

Site	25yr ESAs	Treatment	Risk	PV	NPV	Pass / Fail
SH 2 Ford Rd Regional Length 175m	1.8×10^7	Do-minimum	N/A	$210,886		
		Heavy Maintenance	N/A	$206,422	$4,465	Fail
		Recycle	High	$183,096	$27,970	Pass
		100mm O/L	Med	$179,916	$30,971	Pass
		150 CM O/L + 200 CBSB	Low	$175,563	$35,323	Pass
SH 25 Harbour Rd Primary Collector Length 300m	5.7×10^6	Do-minimum	N/A	$175,419		
		Heavy Maintenance	N/A	$191,148	-$15,729	Fail
		Recycle	High	$163,718	$11,701	Fail[1]
		100mm O/L	Med	$168,026	$7,392	Fail[1]
		150mm O/L	Low	$144,823	$30,596	Pass
SH 27 Canyon Arterial Length 610m	1.4×10^7	Do-minimum[2]	N/A	$403,714		
		Heavy Maintenance	N/A	$469,271	-$65,556	Fail
		Recycle	High	$372194	$31,520	Pass
		100mm O/L	Med	$366,742	$36,972	Pass
		150mm O/L + 200 CBSB	Low	$377,400	$26,314	Pass

7 Levels of Service

The project scope requires LOS to be considered when establishing guidelines for maintenance regimes to be adopted in the NPV analysis. If this was to be done within the NPV analysis it would require pavement functionality to be incorporated in the process, such as roughness, rutting, texture, skid, and deflection. However, Waka Kotahi present policy is to only include Agency costs in the analysis except for travel time delays for highly trafficked routes. LOS are only considered when pavement treatments are chosen to provide the LOS required for specific sections of highway. Examples of how Waka Kotahi have put such policy into practice are as follows:

- OGPA or SMA surfaces on motorways and expressways
- SMA surfaces on high volume urban sections of highway

[1] These "Fail" because the site is on a Primary Collector Highway which requires a minimum NPV of $25,000, which is difficult to obtain for a short length rehabilitation.

[2] The do minimum from the Canyon Site was quite low because the existing seal coat had achieved a life of 10 years, thus a seal life of 8 years was assumed from the suggested guide for this option of repair and re-seal. This is likely optimistic for this site which had extensive and severe rutting.

LOS should be considered when developing the FWP where the required quantity and type of treatments is driven by the need to obtain or retain target LOS. The desired LOS for the network may necessitate the treatment of sections of highway that do not require a significant level of pavement maintenance. In such cases a negative NPV may result for the proposed treatment, but the treatment would be justified to obtain the LOS required.

8 Network vs Project

It can be seen from the summary of NPV calculations that sometimes the highest NPV is provided by the high-risk/medium-risk options. However, it is wise to be circumspect before automatically choosing the higher risk options. The NPV may indicate good returns for such a choice but there is no connection between the project level analysis and the network level of service (LOS) provided to the road user. The financial analysis at the project level does not consider the functional requirements of the network that impact the road user. Increased road roughness causes increased vehicle operating costs and more frequent operations on the highway increases travel time delays and risk of accidents.

The disconnect between site level and network level analysis can be demonstrated in the graphs below which show the results of the annual road roughness and rutting surveys. The results show a general deterioration from the time the NOC contracts were implemented, and the RAPT teams began to stretch seal lives. The NPV process does nothing to keep the network in a steady performance state and may be better used as a priority ranking tool with the network performance requirements driving the projects in the AP.

A further consideration is the longer-term impact on the annual rehabilitation programme. If the higher risk options are chosen, they have shorter pavement life cycles than the low-risk treatments. Currently only 1% – 2% of the network is rehabilitated each year which indicates pavement life cycles of 30 – 80 years have historically been the norm. This has been achieved because the Ministry of Works originally constructed pavements conservatively (low risk), with light traffic and with conservative maintenance regimes. This is no longer the situation. Heavy traffic is much heavier with the use of high productivity motor vehicles (HPMVs) and more frequent. Traditional unbound granular pavement materials are less suitable for the heavier traffic and much of the pavement stock is aging with some pavements having been recycled up to 3 times. If the life cycle of the rehabilitated pavements continues to be squeezed, it is likely that the annual rehabilitation programme will at a future stage have to double compared to what has been the norm for the past 30 years.

Figure 8-1 Roughness & Rutting Progression for Access Highways

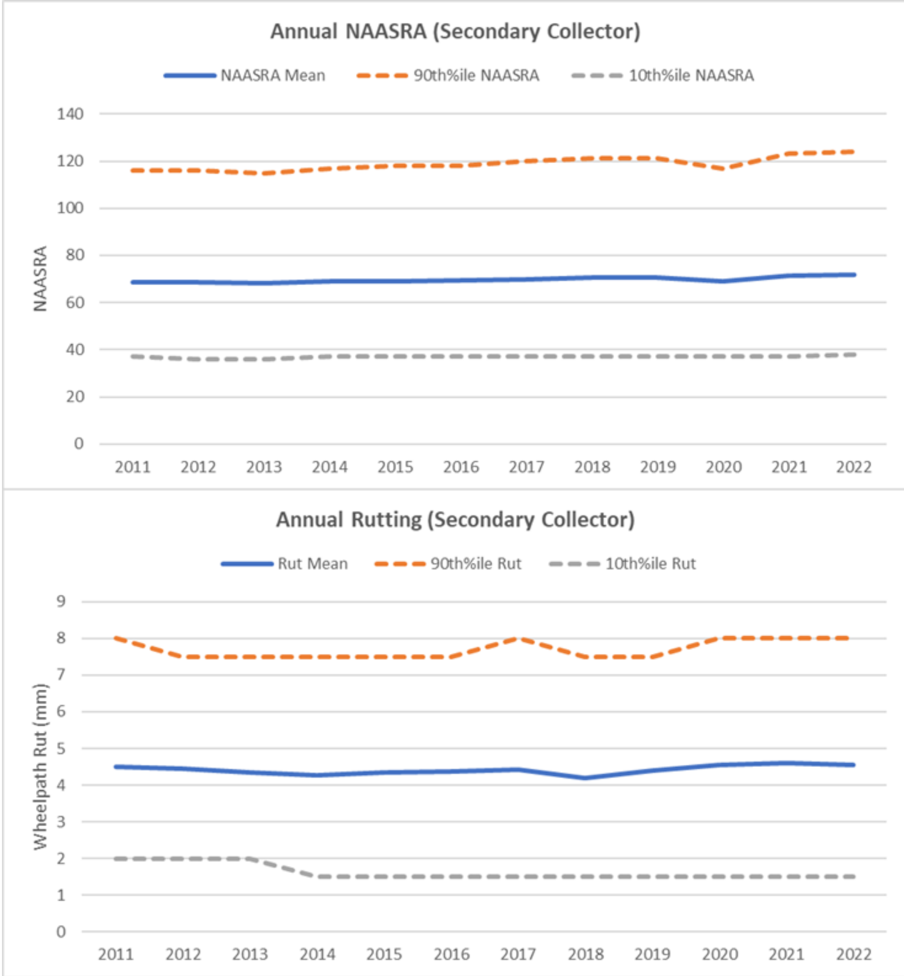


Figure 8-2 Roughness & Rutting Progression for Secondary Collector Highways

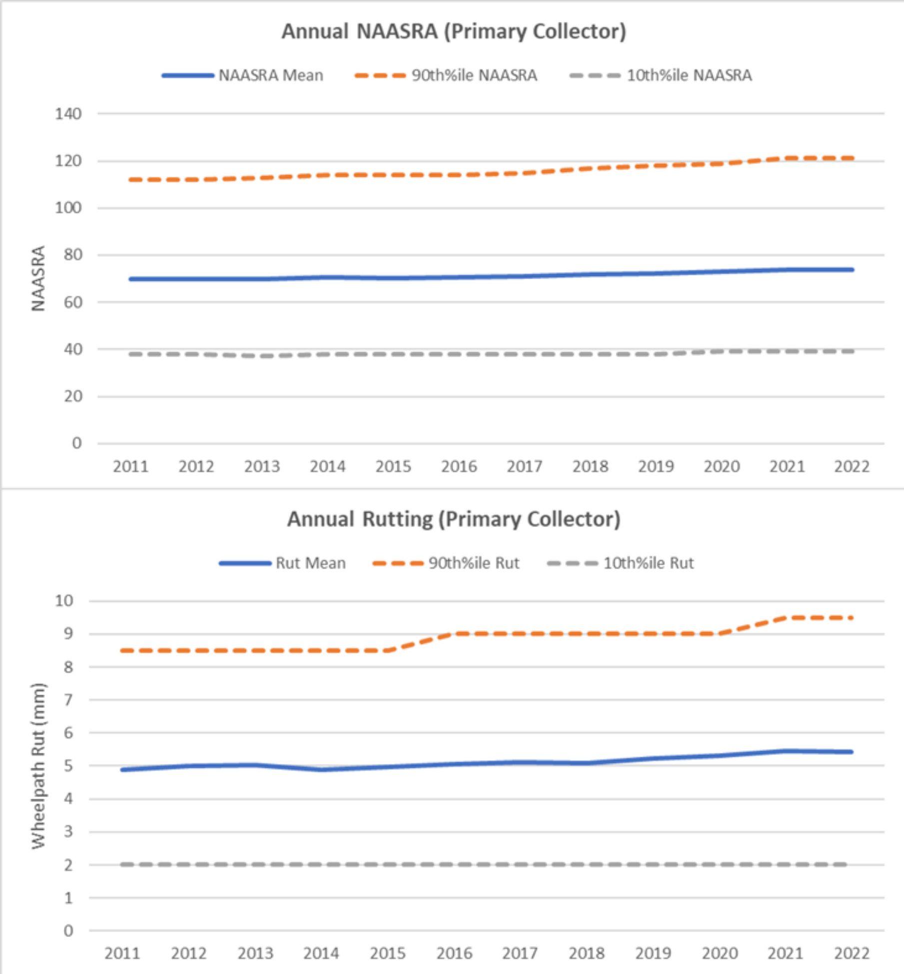


Figure 8-3 Roughness & Rutting Progression for Primary Collector Highways

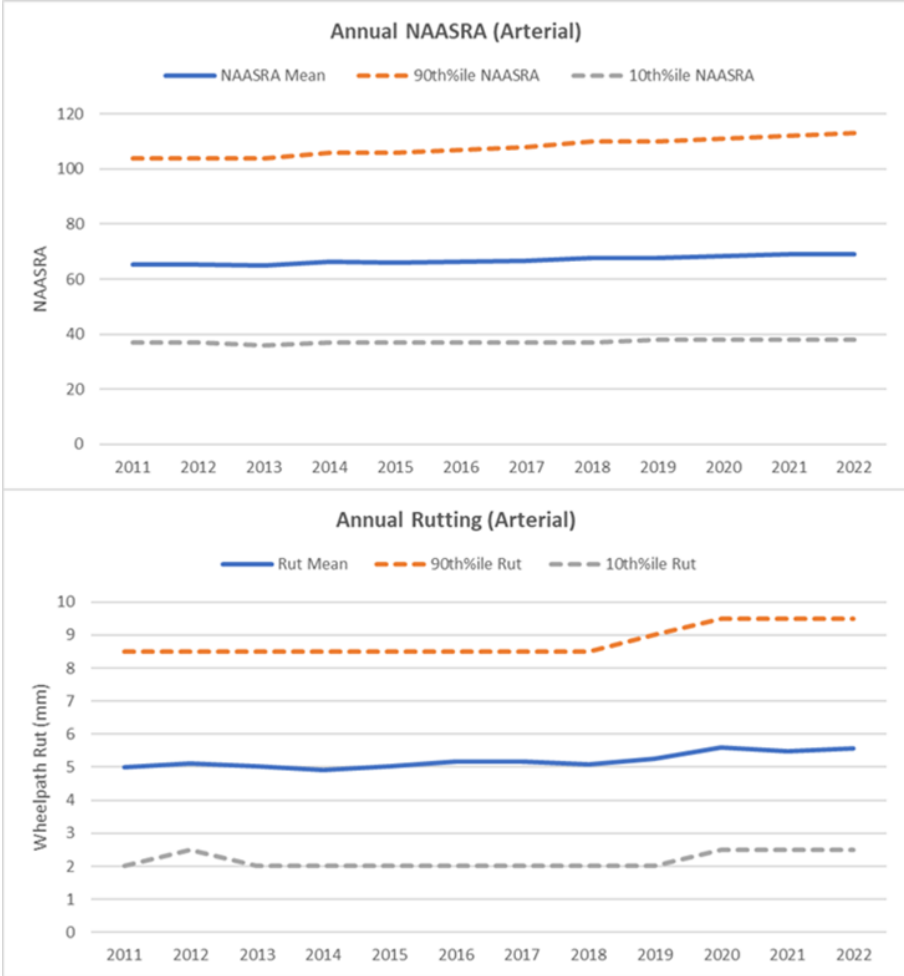


Figure 8-4 Roughness & Rutting Progression for Arterial Highways

Figure 8-5 Roughness & Rutting Progression for Regional Highways

Figure 8-6 Roughness & Rutting Progression for National Highways

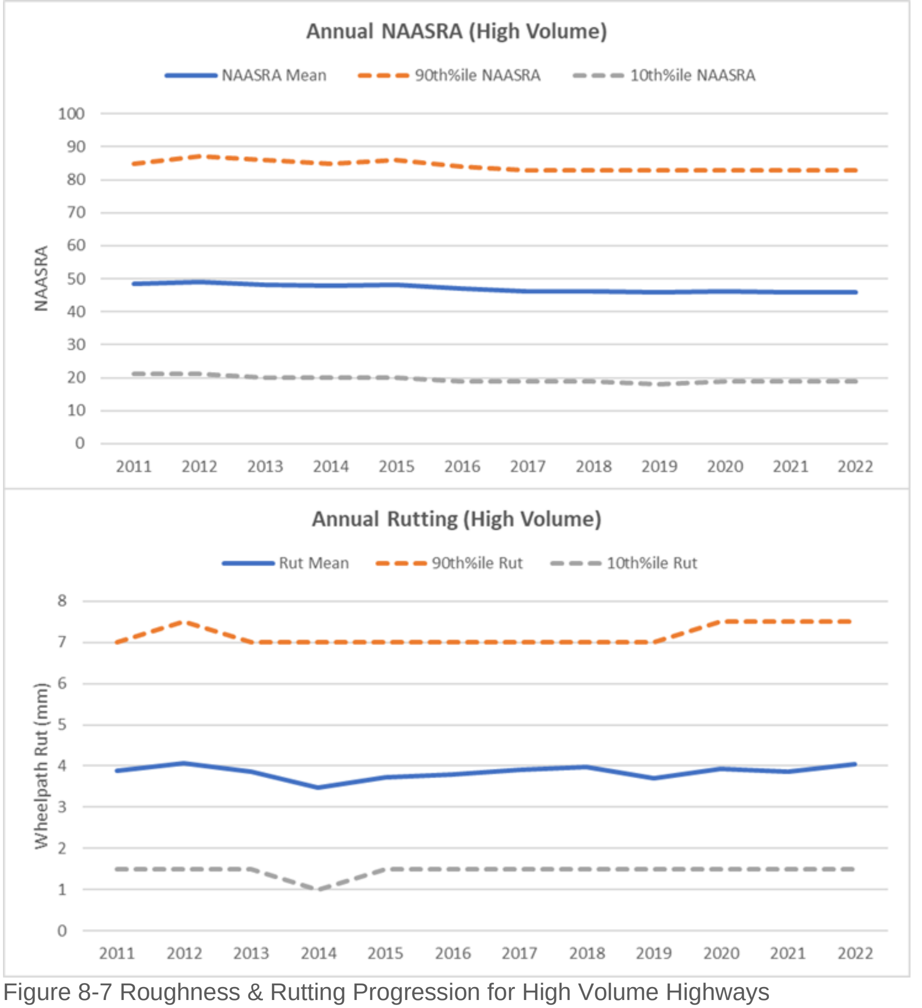


Figure 8-7 Roughness & Rutting Progression for High Volume Highways

9 References

1. Crossen, Cruden, & Fisher. (January 2020). *Review of State Highway Pavement Delivery for NZ Transport Agency.*

A

Appendix A – Maintenance Cost Curve Calculation for Do-Minimum

The annual maintenance costs during the seal life pre-rehabilitation (for do-minimum option) are calculated from the steps below.

The process shall be mostly streamlined in the NPV spreadsheet template. The following steps are to explain the calculation details, which are not necessarily what need to be followed exactly for the users who use the NPV spreadsheet template to work out the NPVs.

a) Populating the historical maintenance efforts (quantities)

The historical maintenance efforts need populated in the **Site Details** in the NPV spreadsheet template. The actual historical maintenance quantities for different maintenance activities can be retrieved from the mc_cost table in RAMM database for the NPV site.

b) Populating the unit rates for different maintenance activities

Populating the unit rates in the **Site Details** tab in the NPV spreadsheet template. The unit rates for different maintenance activities are from NOC schedule of prices (SoP) for each NOC specifically.

c) Estimating the maintenance quantities to repair the existing surface to a standard acceptable for a resurface treatment

The maintenance quantities for different maintenance activities should be based on a measure of the defects present in the current pavement that need to be remediated for the “do-minimum” (repair and resurface) option. The need for remediation should be based on meeting the performance standards required in the NOC’s for normal pre-seal maintenance requirements. The estimated maintenance quantities should be populated under year 0 and year 1 in the **Site Details** tab. Year 0 and year 1 are defined as below.

- Year 0 – the financial year in which the NPV is being calculated
- Year 1 – the financial year in which the treatment is carried out.

Any maintenance considered necessary to be carried out prior to winter should be included in year 0 and the remainder in year 1 for the “do-minimum” option, but not for the rehabilitation options.

d) Determining the maintenance quantity progression curve

We denote here that the last three financial years, excluding year 0 which is the current financial year, are year -3, year -2, and year -1. The historical maintenance quantities for year -3 to year -1 are populated in step a) mentioned above. The future maintenance quantities for year 0 and year 1 are estimated in step c).

The total maintenance quantity [3] for these 5 years are used to calculate the 5 year average percentage fault area of the site using the equation below.

$$5yr\ Avg\ \%\ Fault\ Area = \frac{5yr\ Total\ Maint.Qty\ for\ All\ Activities}{Site\ Area\ \times 5} \times 100$$

The 5 year average percentage fault area is used to categorise the maintenance profile described in Table 4-1 Maintenance Profiles.

The maintenance quantity progression curve is $y = ae^{b(5-x)}$, where y is the annual maintenance quantity and x is the number of years before the rehabilitation treatment.

The coefficient b is different across maintenance profiles showing in the table below.

Maintenance Profile	Coefficient b
Moderate	0.799

[3] The shoulder maintenance quantity is recorded in meters in the spreadsheet. To convert the quantity in square meters, it is assumed that the width of shoulder maintenance is 1 meter.

High	0.456
Very High	0.256

Once the coefficient b is determined by the maintenance profile, the coefficient a is calculated separately for different cost groups from the equation below.

$$a = \frac{Total\ 5yr\ Maint.Area\ for\ the\ cost\ group}{\sum_{i=1}^{5} e^{b(5-i)}}$$

Where the 5 year period is from year -3 to year 1.

The table below shows the relationship between maintenance activities and cost groups.

Maintenance Activity	Cost Group
In situ stabilisation	Pavement
Digouts (all pavements)	Pavement
Milling	Pavement
Minor levelling	Pavement
Rip and remake	Pavement
Fill cracks	Surface
Seal cracks	Surface
Surfacing defect repairs	Surface
Waterblasting	Surface
Shoulder maintenance	Shoulder

At the end of this step, three maintenance quantity progression curves are calculated with

- The same b value for all cost groups
- Different a values for each cost group

e) Calculating the maintenance cost progression curve

The maintenance cost progression curve is calculated based on the maintenance quantity progression curves calculated in d).

Firstly, three different cost progression curves are calculated by multiplying the weighted average cost for each cost group and the maintenance quantity from the maintenance quantity progression curves. Where the weighted average cost for each cost group is calculated from the equation below.

$$Weighted\ Avg\ Cost\ for\ the\ Cost\ Group = \frac{Total\ 5yr\ maint.cost\ for\ the\ cost\ group}{Total\ 5yr\ maint.quantity\ (m2)\ for\ the\ cost\ group}$$

Where the 5 year period is from year -3 to year 1.

The final maintenance cost progression curve is the sum of the three maintenance cost progression curves for different cost groups.

B

Appendix B – Work Examples

Three work examples are demonstrated in this appendix. The calculation details are explained in the "Notes" columns only for the first example, as all the three examples follow the same process.

a) 025-0156 3.1-3.4km Boat Harbour

Site Details

The actual historical maintenance efforts are retrieved from mc_cost table in RAMM.

Refer to step **c) in Appendix A** for Year 0 and Year 1 quantities.

	Actual Historic									Year 0	Year 1
Maintenance Quantities	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22
In situ stabilisation (m2)	0	0	0	0	0	0	45	0	0	120	200
Digouts (all pavements) (m2)	0	0	0	0	0	0	0	0	0	8	
Milling (m2)	0	0	0	0	0	0	0	0	0		
Minor levelling (m2)	0	0	0	0	0	0	0	0	6		
Rip and Remake (m2)	0	0	0	0	0	0	0	0	0		
Fill cracks (m2)	0	0	0	0	0	0	0	0	0		
Seal cracks (m2)	0	0	0	0	0	0	0	0	0		
Surfacing defect repairs (m2)	0	0	7	0	20	0	0	5	0	30	60
Waterblasting (m2)	0	0	0	0	0	0	0	0	0		
Shoulder maintenance (m)	0	0	0	0	91	0	20	1	0	80	

Base Unit Rates			
In situ stabilisation	70	$/m2	Refer to NOC SoP Item 2.4.2 (weighted average)
Digouts	100	$/m2	Refer to NOC SoP Item 2.4.1 (weighted average)
Milling	100	$/m2	Refer to NOC SoP Item 2.4.5 (weighted average)
Minor levelling	50	$/m2	Refer to NOC SoP Item 2.4.4 (weighted average)
Rip and Remake	70	$/m2	Refer to NOC SoP Item 2.4.3 (weighted average)
Fill cracks	20	$/m2	Refer to NOC SoP Item 2.4.7
Seal cracks	20	$/m2	Refer to NOC SoP Item 2.4.6
Surfacing defect repairs	20	$/m2	
Waterblasting	8	$/m2	Refer to NOC SoP Item 2.4.9
Shoulder maintenance	10	$/m	

Template for Do-Minimum and Heavy Maintenance Options

Calculation details are in the "Notes" columns.

			DO MINIMUM									HEAVY MAINTENANCE									
Year		SPPWF	Rehab	Notes	Resurf	Notes	Annual Maint (Pave)	Notes	Cycle year	Notes	Discounted Total Costs	Rehab	Notes	Resurf	Notes	Annual Maint (Pave)	Notes	Cycle Year	Notes	Discounted Total Costs
2021/22	1	0.9615			$16,800	Refer to step **c) in 5.3.2** for surface treatment cost.	$16,583	Refer to step **a) in 5.3.2.** This is the remediation cost when rehab is not planned in the year. The cost is calculated from the maintenance cost curve where x = 0. See **Appendix A** for the maintenance cost curve calculation.			$32,099	$50,261	Refer to **5.3.3** for the cost of heavy maint.	$16,800	Refer to step **c) in 5.3.2** for surface treatment cost.					$64,482
2022/23	2	0.9246					$679	Same as below with x = 4	1		$628					$137	Same as below with x = 6	1		$127
2023/24	3	0.8890					$1,509	Same as below with x = 3	2		$1,341					$305	Same as below with x = 5	2		$271
2024/25	4	0.8548					$3,355	Same as below with x = 2	3		$2,868					$679	Same as below with x = 4	3		$580
2025/26	5	0.8219					$7,459	This is calculated from the maintenance cost curve (refer to **Appendix A**), where x = 1, which means the maintenance cost 1 year prior to rehab.	4	Refer to step **c) in 5.3.2** for the life of the surface treatment.	$6,131					$1,509	Same as below with x = 3	4		$1,240
2026/27	6	0.7903	$65,688	Refer to step **e) in 5.3.2** for the rehab cost.					6		$51,914					$3,355	Same as below with x = 2	5		$2,652
2027/28	7	0.7599			$16,800	Refer to step **c) in 5.3.2** for surface treatment cost.					$12,767					$7,459	This is calculated from the maintenance cost curve (refer to **Appendix A**), where x = 1, which means the maintenance cost 1 year prior to rehab.	6		$5,668
2028/29	8	0.7307					$631	Refer to **Figure 4-9** for maintenance cost equation for seals with 4-7 years of life. Let x = 1 to calculate the maintenance cost. The cost calculated from the equation is in $/10,000m2. **It needs to be adjusted to the site area.**	1		$461	$65,688	Refer to **5.3.3** for the cost of rehab.					7	Refer to **5.3.3** for the life of the surface treatment.	$47,998
2029/30	9	0.7026					$845	Same as above with x = 2	2		$594			$16,800	Refer to step **c) in 5.3.2** for surface treatment cost.					$11,803
2030/31	10	0.6756					$1,132	Same as above with x = 3	3		$765					$631	Refer to **Figure 4-9** for maintenance cost equation for seals with 4-7 years of life. Let x = 1 to calculate the maintenance cost. The cost calculated from the equation is in $/10,000m2. **It needs to be adjusted to the site area.**	1		$426
2031/32	11	0.6496					$1,515	Same as above with x = 4	4		$984					$845	Same as above with x = 2	2		$549
2032/33	12	0.6246					$2,029	Same as above with x = 5	5		$1,268					$1,132	Same as above with x = 3	3		$707
2033/34	13	0.6006					$2,718	Same as above with x = 6	6		$1,632					$1,515	Same as above with x = 4	4		$910
2034/35	14	0.5775			$16,800	Refer to step **c) in 5.3.2** for surface treatment cost.	$3,639	Same as above with x = 7	7	Refer to step **f) in 5.3.2** for the life of the second coat.	$11,803					$2,029	Same as above with x = 5	5		$1,172
2035/36	15	0.5553					$631	Same as above with x = 1	1		$350					$2,718	Same as above with x = 6	6		$1,509
2036/37	16	0.5339					$845	Same as above with x = 2	2		$451			$16,800	Refer to step **c) in 5.3.2** for surface treatment cost.	$3,639	Same as above with x = 7	7	Refer to **5.3.3** for the life of the second coat seal.	$10,913
2037/38	17	0.5134					$1,132	Same as above with x = 3	3		$581					$631	Same as above with x = 1	1		$324
2038/39	18	0.4936					$1,515	Same as above with x = 4	4		$748					$845	Same as above with x = 2	2		$417
2039/40	19	0.4746					$2,029	Same as above with x = 5	5		$963					$1,132	Same as above with x = 3	3		$537
2040/41	20	0.4564					$2,718	Same as above with x = 6	6		$1,240					$1,515	Same as above with x = 4	4		$692
2041/42	21	0.4388	$65,688	Refer to step **e) in 5.3.2** for the rehab cost.				Same as above with x = 7	7	Refer to step **j) in 5.3.2** for the life of the reseal.	$28,826					$2,029	Same as above with x = 5	5		$891
2042/43	22	0.4220			$16,800	Refer to step **c) in 5.3.2** for surface treatment cost.					$7,089					$2,718	Same as above with x = 6	6		$1,147
2043/44	23	0.4057					$631	Same as above with x = 1	1		$256	$65,688	Refer to **5.3.3** for the cost of rehab.				Same as above with x = 7	7	Refer to **5.3.3** for the life of the reseal.	$26,651
2044/45	24	0.3901					$845	Same as above with x = 2	2		$330			$16,800	Refer to step **c) in 5.3.2** for surface treatment cost.					$6,554
2045/46	25	0.3751					$1,132	Same as above with x = 3	3		$425					$631	Same as above with x = 1	1		$237
2046/47	26	0.3607					$1,515	Same as above with x = 4	4		$547					$845	Same as above with x = 2	2		$305
2047/48	27	0.3468					$2,029	Same as above with x = 5	5		$704					$1,132	Same as above with x = 3	3		$392
2048/49	28	0.3335					$2,718	Same as above with x = 6	6		$906					$1,515	Same as above with x = 4	4		$505
2049/50	29	0.3207			$16,800	Refer to step **c) in 5.3.2** for surface treatment cost.	$3,639	Same as above with x = 7	7	Refer to step **f) in 5.3.2** for the life of the second coat.	$6,554					$2,029	Same as above with x = 5	5		$651
2050/51	30	0.3083					$631	Same as above with x = 1	1		$195					$2,718	Same as above with x = 6	6		$838
							2290.1811			**Discounted Total Cost**	$175,419								**Discounted Total Cost**	$191,148

Template for Low, Medium, and High Risk Rehabilitation Options

RENEWAL No.1 Low Risk

Year		SPPWF	Rehab	Notes	Resurf	Notes	Annual Maint (Pave)	Notes	Cycle Year	Notes	Discounted Total Costs
2021/22	1	0.9615	$109,480	Refer to step **a) in 5.3.6** for the rehab cost.							$105,269
2022/23	2	0.9246			$16,800	Refer to step **c) in 5.3.6** for surface treatment cost.					$15,533
2023/24	3	0.8890					$233	Refer to **Figure 4-9** for maintenance cost equation for seals with 12-15 years of life. Let x = 1 to calculate the maintenance cost. The cost calculated from the equation is in $/10,000m2. **It needs to be adjusted to the site area.**	1		$207
2024/25	4	0.8548					$270	Same as above with x = 2	2		$231
2025/26	5	0.8219					$313	Same as above with x = 3	3		$258
2026/27	6	0.7903					$363	Same as above with x = 4	4		$287
2027/28	7	0.7599					$421	Same as above with x = 5	5		$320
2028/29	8	0.7307					$488	Same as above with x = 6	6		$357
2029/30	9	0.7026					$566	Same as above with x = 7	7		$398
2030/31	10	0.6756					$657	Same as above with x = 8	8		$444
2031/32	11	0.6496					$762	Same as above with x = 9	9		$495
2032/33	12	0.6246					$883	Same as above with x = 10	10		$552
2033/34	13	0.6006					$1,024	Same as above with x = 11	11		$615
2034/35	14	0.5775			$16,800	Refer to step **f) in 5.3.6** for surface treatment cost.	$1,187	Same as above with x = 12	12	Refer to step **b) in 5.3.6** for the life of second coat seal.	$10,387
2035/36	15	0.5553					$233	Refer to **Figure 4-9** for maintenance cost equation for seals with 12-15 years of life. Let x = 1 to calculate the maintenance cost. The cost calculated from the equation is in $/10,000m2. **It needs to be adjusted to the site area.**	1		$129
2036/37	16	0.5339					$270	Same as above with x = 2	2		$144
2037/38	17	0.5134					$313	Same as above with x = 3	3		$161
2038/39	18	0.4936					$363	Same as above with x = 4	4		$179
2039/40	19	0.4746					$421	Same as above with x = 5	5		$200
2040/41	20	0.4564					$488	Same as above with x = 6	6		$223
2041/42	21	0.4388					$566	Same as above with x = 7	7		$249
2042/43	22	0.4220					$657	Same as above with x = 8	8		$277
2043/44	23	0.4057					$762	Same as above with x = 9	9		$309
2044/45	24	0.3901					$883	Same as above with x = 10	10		$344
2045/46	25	0.3751					$1,024	Same as above with x = 11	11		$384
2046/47	26	0.3607			$16,800	Refer to step **f) in 5.3.6** for surface treatment cost.	$1,187	Same as above with x = 12	12	Refer to step **e) in 5.3.6** for the life of reseal.	$6,488
2047/48	27	0.3468					$233	Refer to **Figure 4-9** for maintenance cost equation for seals with 12-15 years of life. Let x = 1 to calculate the maintenance cost. The cost calculated from the equation is in $/10,000m2. **It needs to be adjusted to the site area.**	1		$81
2048/49	28	0.3335					$270	Same as above with x = 2	2		$90
2049/50	29	0.3207					$313	Same as above with x = 3	3		$100
2050/51	30	0.3083					$363	Same as above with x = 4	4		$112
										Discounted Total Cost	$144,823

RENEWAL No.2 - Medium Risk

Year		SPPWF	Rehab	Notes	Resurf	Notes	Annual Maint (Pave)	Notes	Cycle Year	Notes	Discounted Total Costs
2021/22	1	0.9615	$87,776	Refer to step **a) in 5.3.5** for the rehab cost.							$84,400
2022/23	2	0.9246			$16,800	Refer to step **c) in 5.3.5** for surface treatment cost.					$15,533
2023/24	3	0.8890					329	Refer to **Figure 4-9** for maintenance cost equation for seals with 8-11 years of life. Let x = 1 to calculate the maintenance cost. The cost calculated from the equation is in $/10,000m2. **It needs to be adjusted to the site area.**	1		$292
2024/25	4	0.8548					412	Same as above with x = 2	2		$353
2025/26	5	0.8219					517	Same as above with x = 3	3		$425
2026/27	6	0.7903					649	Same as above with x = 4	4		$513
2027/28	7	0.7599					815	Same as above with x = 5	5		$619
2028/29	8	0.7307					1,022	Same as above with x = 6	6		$747
2029/30	9	0.7026					1,283	Same as above with x = 7	7		$901
2030/31	10	0.6756					1,610	Same as above with x = 8	8		$1,088
2031/32	11	0.6496					2,020	Same as above with x = 9	9		$1,312
2032/33	12	0.6246			$16,800	Refer to step **f) in 5.3.5** for surface treatment cost.	2,535	Same as above with x = 10	10	**5.3.5** for the life of second coat seal.	$12,077
2033/34	13	0.6006					329	Refer to **Figure 4-9** for maintenance cost equation for seals with 8-11 years of life. Let x = 1 to calculate the maintenance cost. The cost calculated from the equation is in $/10,000m2. **It needs to be adjusted to the site area.**	1		$197
2034/35	14	0.5775					412	Same as above with x = 2	2		$238
2035/36	15	0.5553					517	Same as above with x = 3	3		$287
2036/37	16	0.5339					649	Same as above with x = 4	4		$347
2037/38	17	0.5134					815	Same as above with x = 5	5		$418
2038/39	18	0.4936					1,022	Same as above with x = 6	6		$505
2039/40	19	0.4746					1,283	Same as above with x = 7	7		$609
2040/41	20	0.4564					1,610	Same as above with x = 8	8		$735
2041/42	21	0.4388					2,020	Same as above with x = 9	9		$887
2042/43	22	0.4220	$87,776	Refer to step **a) in 5.3.5** for the rehab cost.				Same as above with x = 10	10	Refer to step **e) in 5.3.5** for the life of reseal.	$37,038
2043/44	23	0.4057			$16,800	Refer to step **c) in 5.3.5** for surface treatment cost.					$6,816
2044/45	24	0.3901					329	Refer to **Figure 4-9** for maintenance cost equation for seals with 8-11 years of life. Let x = 1 to calculate the maintenance cost. The cost calculated from the equation is in $/10,000m2. **It needs to be adjusted to the site area.**	1		$128
2045/46	25	0.3751					412	Same as above with x = 2	2		$155
2046/47	26	0.3607					517	Same as above with x = 3	3		$187
2047/48	27	0.3468					649	Same as above with x = 4	4		$225
2048/49	28	0.3335					815	Same as above with x = 5	5		$272
2049/50	29	0.3207					1,022	Same as above with x = 6	6		$328
2050/51	30	0.3083					1,283	Same as above with x = 7	7		$396
										Discounted Total Cost	$168,026

RENEWAL No.3m - High Risk

Year		SPPWF	Rehab	Notes	Resurf	Notes	Annual Maint (Pave)	Notes	Cycle Year	Notes	Discounted Total Costs
2021/22	1	0.9615	$65,688	Refer to step **a) in 5.3.4** for the rehab cost.							$63,162
2022/23	2	0.9246			$16,800	Refer to step **c) in 5.3.4** for surface treatment cost.					$15,533
2023/24	3	0.8890					$631	Refer to **Figure 4-9** for maintenance cost equation for seals with 4-7 years of life. Let x = 1 to calculate the maintenance cost. The cost calculated from the equation is in $/10,000m2. **It needs to be adjusted to the site area.**	1		$561
2024/25	4	0.8548					$845	Same as above with x = 2	2		$722
2025/26	5	0.8219					$1,132	Same as above with x = 3	3		$930
2026/27	6	0.7903					$1,515	Same as above with x = 4	4		$1,198
2027/28	7	0.7599					$2,029	Same as above with x = 5	5		$1,542
2028/29	8	0.7307					$2,718	Same as above with x = 6	6		$1,986
2029/30	9	0.7026			$16,800	Refer to step **f) in 5.3.4** for surface treatment cost.	$3,639	Same as above with x = 7	7	Refer to step **b) in 5.3.4** for the life of second coat seal.	$14,360
2030/31	10	0.6756					$631	Refer to **Figure 4-9** for maintenance cost equation for seals with 4-7 years of life. Let x = 1 to calculate the maintenance cost. The cost calculated from the equation is in $/10,000m2. **It needs to be adjusted to the site area.**	1		$426
2031/32	11	0.6496					$845	Same as above with x = 2	2		$549
2032/33	12	0.6246					$1,132	Same as above with x = 3	3		$707
2033/34	13	0.6006					$1,515	Same as above with x = 4	4		$910
2034/35	14	0.5775					$2,029	Same as above with x = 5	5		$1,172
2035/36	15	0.5553					$2,718	Same as above with x = 6	6		$1,509
2036/37	16	0.5339	$65,688					Same as above with x = 7	7	Refer to step **e) in 5.3.4** for the life of reseal.	$35,071
2037/38	17	0.5134			$16,800	Refer to step **c) in 5.3.4** for surface treatment cost.					$8,625
2038/39	18	0.4936					$631	Refer to **Figure 4-9** for maintenance cost equation for seals with 4-7 years of life. Let x = 1 to calculate the maintenance cost. The cost calculated from the equation is in $/10,000m2. **It needs to be adjusted to the site area.**	1		$312
2039/40	19	0.4746					$845	Same as above with x = 2	2		$401
2040/41	20	0.4564					$1,132	Same as above with x = 3	3		$517
2041/42	21	0.4388					$1,515	Same as above with x = 4	4		$665
2042/43	22	0.4220					$2,029	Same as above with x = 5	5		$856
2043/44	23	0.4057					$2,718	Same as above with x = 6	6		$1,103
2044/45	24	0.3901			$16,800	Refer to step **f) in 5.3.4** for surface treatment cost.	$3,639	Same as above with x = 7	7	Refer to step **b) in 5.3.4** for the life of second coat seal.	$7,974
2045/46	25	0.3751					$631	Refer to **Figure 4-9** for maintenance cost equation for seals with 4-7 years of life. Let x = 1 to calculate the maintenance cost. The cost calculated from the equation is in $/10,000m2. **It needs to be adjusted to the site area.**	1		$237
2046/47	26	0.3607					$845	Same as above with x = 2	2		$305
2047/48	27	0.3468					$1,132	Same as above with x = 3	3		$392
2048/49	28	0.3335					$1,515	Same as above with x = 4	4		$505
2049/50	29	0.3207					$2,029	Same as above with x = 5	5		$651
2050/51	30	0.3083					$2,718	Same as above with x = 6	6		$838
										Discounted Total Cost	$163,718

b) 002-0093 3.935 – 4.11km Ford Rd

Site Details

Maintenance Quantities	Actual Historic 2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	Year 0 2018/19	Year 1 2019/20
In situ stabilisation (m2)	87	0	0	0	22	0	60	307	65		138
Digouts (all pavements) (m2)	33	0	0	0	0	0	0	0	0		231
Milling (m2)	0	0	0	36	0	0	0	0	0		
Minor levelling (m2)	0	0	0	0	0	0	0	24	0		
Rip and Remake (m2)	0	0	0	0	0	0	0	0	0		
Fill cracks (m2)	0	0	0	0	0	0	0	0	0		
Seal cracks (m2)	0	0	0	0	0	0	0	0	0		
Surfacing defect repairs (m2)	2	0	15	0	0	9	90	65	13		
Waterblasting (m2)	0	0	0	0	0	0	0	0	0	100	380
Shoulder maintenance (m)	0	0	0	0	0	0	0	0	0		

Base Unit Rates			
In situ stabilisation	42	$/m2	Refer to NOC SoP Item 2.4.2 (weighted average)
Digouts	67	$/m2	Refer to NOC SoP Item 2.4.1 (weighted average)
Milling	70	$/m2	Refer to NOC SoP Item 2.4.5 (weighted average)
Minor levelling	38	$/m2	Refer to NOC SoP Item 2.4.4 (weighted average)
Rip and Remake	29	$/m2	Refer to NOC SoP Item 2.4.3 (weighted average)
Fill cracks	9	$/m2	Refer to NOC SoP Item 2.4.7
Seal cracks	8	$/m2	Refer to NOC SoP Item 2.4.6
Surfacing defect repairs	11	$/m2	
Waterblasting	6	$/m2	Refer to NOC SoP Item 2.4.9
Shoulder maintenance	18	$/m	

Template for Treatment Options

			DO MINIMUM						HEAVY MAINTENANCE					
Year		SPPWF	Rehab	Resurf	Annual Maint (Pave)	Cycle year		Discounted Total Costs	Rehab	Resurf	Annual Maint (Pave)	Cycle year		Discounted Total Costs
2021/22	1	0.9615		$16,000	$18,194			$32,879	$37,800	$16,000				$51,731
2022/23	2	0.9246			$7,309	1		$6,758			$1,179	1		$1,090
2023/24	3	0.8890			$11,531	2		$10,251			$1,861	2		$1,654
2024/25	4	0.8548	$80,000					$68,384			$2,936	3		$2,510
2025/26	5	0.8219		$16,000				$13,151			$4,632	4		$3,807
2026/27	6	0.7903			$631	1		$499			$7,309	5		$5,776
2027/28	7	0.7599			$845	2		$642			$11,531	6		$8,763
2028/29	8	0.7307			$1,132	3		$827	$80,000			7		$58,455
2029/30	9	0.7026			$1,515	4		$1,065		$16,000				$11,241
2030/31	10	0.6756			$2,029	5		$1,371			$631	1		$426
2031/32	11	0.6496			$2,718	6		$1,765			$845	2		$549
2032/33	12	0.6246		$16,000	$3,639	7		$12,267			$1,132	3		$707
2033/34	13	0.6006			$631	1		$379			$1,515	4		$910
2034/35	14	0.5775			$845	2		$488			$2,029	5		$1,172
2035/36	15	0.5553			$1,132	3		$628			$2,718	6		$1,509
2036/37	16	0.5339			$1,515	4		$809		$16,000	$3,639	7		$10,485
2037/38	17	0.5134			$2,029	5		$1,042			$631	1		$324
2038/39	18	0.4936			$2,718	6		$1,341			$845	2		$417
2039/40	19	0.4746	$80,000			7		$37,971			$1,132	3		$537
2040/41	20	0.4564		$16,000				$7,302			$1,515	4		$692
2041/42	21	0.4388			$631	1		$277			$2,029	5		$891
2042/43	22	0.4220			$845	2		$357			$2,718	6		$1,147
2043/44	23	0.4057			$1,132	3		$459	$80,000			7		$32,458
2044/45	24	0.3901			$1,515	4		$591		$16,000				$6,242
2045/46	25	0.3751			$2,029	5		$761			$631	1		$237
2046/47	26	0.3607			$2,718	6		$980			$845	2		$305
2047/48	27	0.3468		$16,000	$3,639	7		$6,811			$1,132	3		$392
2048/49	28	0.3335			$631	1		$210			$1,515	4		$505
2049/50	29	0.3207			$845	2		$271			$2,029	5		$651
2050/51	30	0.3083			$1,132	3		$349			$2,718	6		$838
						Discounted Total Cost		$210,886				Discounted Total Cost		$206,422

	RENEWAL No.1 Low Risk						RENEWAL No.2 - Medium Risk						RENEWAL No.3m - High Risk					
Year	Rehab	Resurf	Annual Maint (Pave)	Cycle Year		Discounted Total Costs	Rehab	Resurf	Annual Maint (Pave)	Cycle Year		Discounted Total Costs	Rehab	Resurf	Annual Maint (Pave)	Cycle Year		Discounted Total Costs
2021/22	$143,000					$137,500	$97,500					$93,750	$80,000					$76,923
2022/23		$16,000				$14,793		$16,000				$14,793		$16,000				$14,793
2023/24			$233	1		$207			329	1		$292			$631	1		$561
2024/25			$270	2		$231			412	2		$353			$845	2		$722
2025/26			$313	3		$258			517	3		$425			$1,132	3		$930
2026/27			$363	4		$287			649	4		$513			$1,515	4		$1,198
2027/28			$421	5		$320			815	5		$619			$2,029	5		$1,542
2028/29			$488	6		$357			1,022	6		$747			$2,718	6		$1,986
2029/30			$566	7		$398			1,283	7		$901		$16,000	$3,639	7		$13,798
2030/31			$657	8		$444			1,610	8		$1,088			$631	1		$426
2031/32			$762	9		$495			2,020	9		$1,312			$845	2		$549
2032/33			$883	10		$552		$16,000	2,535	10		$11,577			$1,132	3		$707
2033/34			$1,024	11		$615			329	1		$197			$1,515	4		$910
2034/35		$16,000	$1,187	12		$9,925			412	2		$238			$2,029	5		$1,172
2035/36			$233	1		$129			517	3		$287			$2,718	6		$1,509
2036/37			$270	2		$144			649	4		$347	$80,000			7		$42,713
2037/38			$313	3		$161			815	5		$418		$16,000				$8,214
2038/39			$363	4		$179			1,022	6		$505			$631	1		$312
2039/40			$421	5		$200			1,283	7		$609			$845	2		$401
2040/41			$488	6		$223			1,610	8		$735			$1,132	3		$517
2041/42			$566	7		$249			2,020	9		$887			$1,515	4		$665
2042/43			$657	8		$277	$97,500			10		$41,141			$2,029	5		$856
2043/44			$762	9		$309		$16,000				$6,492			$2,718	6		$1,103
2044/45			$883	10		$344			329	1		$128		$16,000	$3,639	7		$7,662
2045/46			$1,024	11		$384			412	2		$155			$631	1		$237
2046/47		$16,000	$1,187	12		$6,199			517	3		$187			$845	2		$305
2047/48			$233	1		$81			649	4		$225			$1,132	3		$392
2048/49			$270	2		$90			815	5		$272			$1,515	4		$505
2049/50			$313	3		$100			1,022	6		$328			$2,029	5		$651
2050/51			$363	4		$112			1,283	7		$396			$2,718	6		$838
				Discounted Total Cost		$175,563				Discounted Total Cost		$179,916				Discounted Total Cost		$183,096

c) 027-0027 14.39 – 15.0 km Canyon

Site Details

	Actual Historic									Year 0	Year 1
Maintenance Quantities	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21
In situ stabilisation (m2)	0	15	0	0	29	0	0	312	120	200	1600
Digouts (all pavements) (m2)	0	0	0	0	0	0	0	0	0		
Milling (m2)	0	0	0	0	0	0	0	0	0		
Minor levelling (m2)	0	0	0	0	0	0	0	0	0		
Rip and Remake (m2)	0	0	0	0	0	0	0	0	0		
Fill cracks (m2)	0	0	0	0	0	0	0	0	0		
Seal cracks (m2)	0	0	0	0	0	0	307	0	0		
Surfacing defect repairs (m2)	0	0	0	0	0	6	4	7	21	20	5
Waterblasting (m2)	0	143	13	0	35	0	0	0	0		
Shoulder maintenance (m)	0	0	0	0	0	0	670	0	376		
Base Unit Rates											
In situ stabilisation	50	$/m2	Refer to NOC SoP Item 2.4.2 (w eighted average)								
Digouts	72	$/m2	Refer to NOC SoP Item 2.4.1 (w eighted average)								
Milling	110	$/m2	Refer to NOC SoP Item 2.4.5 (w eighted average)								
Minor levelling	58	$/m2	Refer to NOC SoP Item 2.4.4 (w eighted average)								
Rip and Remake		$/m2	Refer to NOC SoP Item 2.4.3 (w eighted average)								
Fill cracks	20	$/m2	Refer to NOC SoP Item 2.4.7								
Seal cracks	12	$/m2	Refer to NOC SoP Item 2.4.6								
Surfacing defect repairs	50	$/m2									
Waterblasting	6	$/m2	Refer to NOC SoP Item 2.4.9								
Shoulder maintenance	10	$/m									

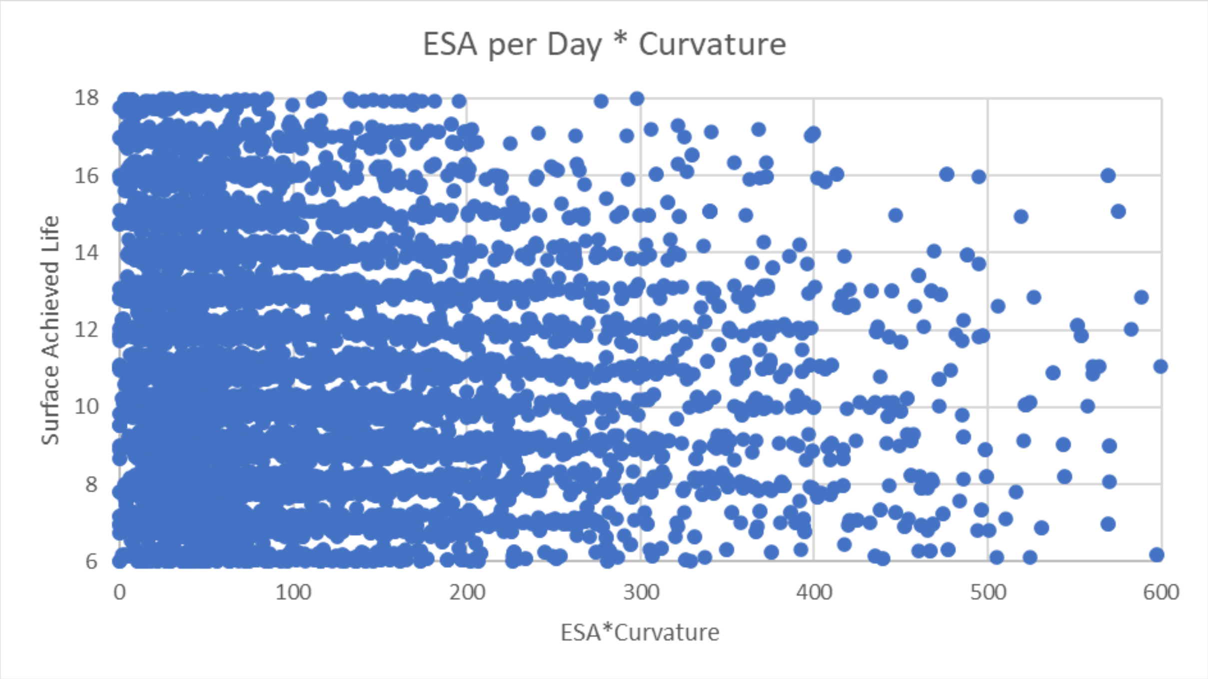
Template for Treatment Options

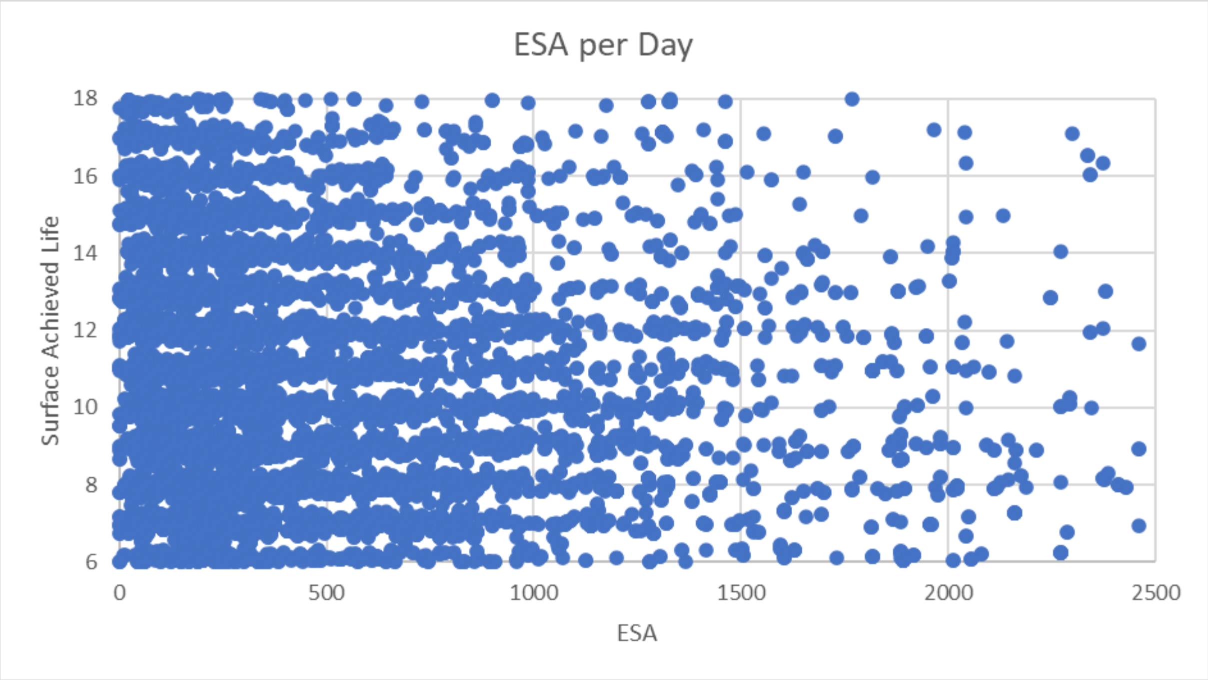
			DO MINIMUM						HEAVY MAINTENANCE					
Year		SPPWF	Rehab	Resurf	Annual Maint (Pave)	Year		Discounted Total Costs	Rehab	Resurf	Annual Maint (Pave)	Year		Discounted Total Costs
2020/21	1	0.9615		$32,574	$52,454			$81,758	$117,933	$32,574				$144,718
2021/22	2	0.9246			$2,155	1		$1,992			$2,155	1		$1,993
2022/23	3	0.8890			$3,401	2		$3,023			$3,401	2		$3,025
2023/24	4	0.8548			$5,365	3		$4,586			$5,365	3		$4,589
2024/25	5	0.8219			$8,465	4		$6,958			$8,465	4		$6,961
2025/26	6	0.7903			$13,356	5		$10,555			$13,356	5		$10,559
2026/27	7	0.7599			$21,072	6		$16,013			$21,072	6		$16,018
2027/28	8	0.7307			$33,246	7		$24,293			$33,246	7		$24,298
2028/29	9	0.7026	$162,500			8		$114,170	$162,500			8		$114,176
2029/30	10	0.6756		$32,574				$22,006		$32,574				$22,006
2030/31	11	0.6496			$1,283	1		$833			$1,283	1		$834
2031/32	12	0.6246			$1,718	2		$1,073			$1,718	2		$1,074
2032/33	13	0.6006			$2,301	3		$1,382			$2,301	3		$1,383
2033/34	14	0.5775			$3,081	4		$1,779			$3,081	4		$1,781
2034/35	15	0.5553			$4,125	5		$2,291			$4,125	5		$2,293
2035/36	16	0.5339			$5,524	6		$2,949			$5,524	6		$2,953
2036/37	17	0.5134		$32,574	$7,398	7		$20,520		$32,574	$7,398	7		$20,524
2037/38	18	0.4936			$1,283	1		$633			$1,283	1		$634
2038/39	19	0.4746			$1,718	2		$815			$1,718	2		$816
2039/40	20	0.4564			$2,301	3		$1,050			$2,301	3		$1,051
2040/41	21	0.4388			$3,081	4		$1,352			$3,081	4		$1,354
2041/42	22	0.4220			$4,125	5		$1,741			$4,125	5		$1,743
2042/43	23	0.4057			$5,524	6		$2,241	$162,500		$5,524	6		$68,174
2043/44	24	0.3901	$162,500			7		$63,395				7		$3
2044/45	25	0.3751		$32,574				$12,219		$32,574				$12,219
2045/46	26	0.3607			$1,283	1		$463			$1,283	1		$463
2046/47	27	0.3468			$1,718	2		$596			$1,718	2		$597
2047/48	28	0.3335			$2,301	3		$767			$2,301	3		$768
2048/49	29	0.3207			$3,081	4		$988			$3,081	4		$989
2049/50	30	0.3083			$4,125	5		$1,272			$4,125	5		$1,273
					1879	Discounted Total Cost		$403,714				Discounted Total Cost		$469,271

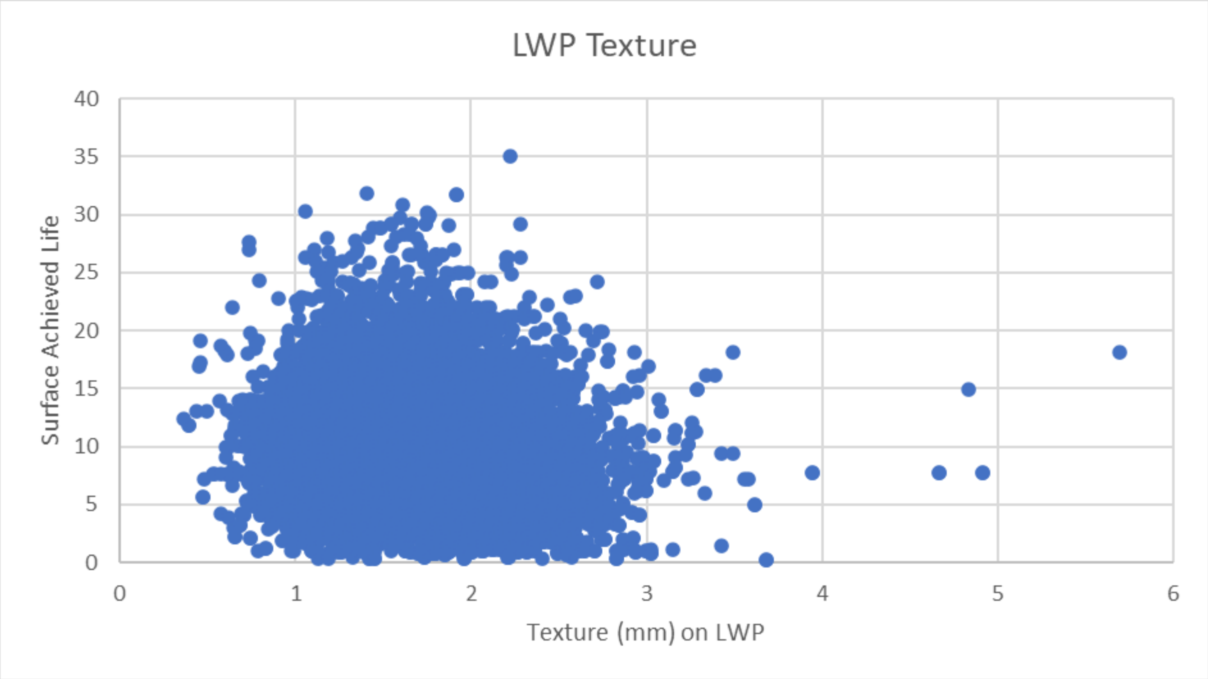
			RENEWAL No.1 - Low Risk						RENEWAL No.2 - Medium Risk						RENEWAL No.3 - High Risk					
Year		SPPWF	Rehab	Resurf	Annual Maint (Pave)	Year		Discounted Total Costs	Rehab	Resurf	Annual Maint (Pave)	Year		Discounted Total Costs	Rehab	Resurf	Annual Maint (Pave)	Year		Discounted Total Costs
2020/21	1	0.9615	$311,700					$299,712	$203,000					$195,192	$162,500					$156,250
2021/22	2	0.9246		$32,574				$30,116		$32,574				$30,116		$32,574				$30,116
2022/23	3	0.8890			$474	1		$422			$669	1		$595			$1,283	1		$1,141
2023/24	4	0.8548			$549	2		$471			$839	2		$719			$1,718	2		$1,470
2024/25	5	0.8219			$637	3		$526			$1,053	3		$868			$2,301	3		$1,893
2025/26	6	0.7903			$738	4		$587			$1,321	4		$1,047			$3,081	4		$2,438
2026/27	7	0.7599			$856	5		$654			$1,658	5		$1,263			$4,125	5		$3,139
2027/28	8	0.7307			$993	6		$730			$2,080	6		$1,524			$5,524	6		$4,041
2028/29	9	0.7026			$1,151	7		$814			$2,610	7		$1,839		$32,574	$7,398	7		$28,088
2029/30	10	0.6756			$1,335	8		$907			$3,275	8		$2,218			$1,283	1		$867
2030/31	11	0.6496			$1,547	9		$1,011			$4,110	9		$2,675			$1,718	2		$1,117
2031/32	12	0.6246			$1,794	10		$1,127			$5,157	10		$3,227			$2,301	3		$1,439
2032/33	13	0.6006			$2,081	11		$1,256		$32,574				$19,563			$3,081	4		$1,853
2033/34	14	0.5775		$32,574	$2,412	12		$20,211			$669	1		$387			$4,125	5		$2,385
2034/35	15	0.5553			$474	1		$264			$839	2		$467			$5,524	6		$3,071
2035/36	16	0.5339			$549	2		$294			$1,053	3		$564	$162,500			7		$86,764
2036/37	17	0.5134			$637	3		$328			$1,321	4		$680		$32,574				$16,723
2037/38	18	0.4936			$738	4		$366			$1,658	5		$821			$1,283	1		$634
2038/39	19	0.4746			$856	5		$409			$2,080	6		$990			$1,718	2		$816
2039/40	20	0.4564			$993	6		$456			$2,610	7		$1,194			$2,301	3		$1,051
2040/41	21	0.4388			$1,151	7		$508			$3,275	8		$1,441			$3,081	4		$1,354
2041/42	22	0.4220			$1,335	8		$567			$4,110	9		$1,738			$4,125	5		$1,743
2042/43	23	0.4057			$1,547	9		$632	$203,000			10		$82,367			$5,524	6		$2,244
2043/44	24	0.3901			$1,794	10		$704		$32,574				$12,708		$32,574	$7,398	7		$15,597
2044/45	25	0.3751			$2,081	11		$785			$669	1		$251			$1,283	1		$482
2045/46	26	0.3607			$2,412	12		$874			$839	2		$303			$1,718	2		$620
2046/47	27	0.3468		$32,574	$2,412	12		$12,138			$1,053	3		$366			$2,301	3		$799
2047/48	28	0.3335			$474	1		$158			$1,321	4		$442			$3,081	4		$1,029
2048/49	29	0.3207			$549	2		$177			$1,658	5		$533			$4,125	5		$1,324
2049/50	30	0.3083			$637	3		$197			$2,080	6		$643			$5,524	6		$1,705
						Discounted Total Cost		$377,400				Discounted Total Cost		$366,742				Discounted Total Cost		$372,194

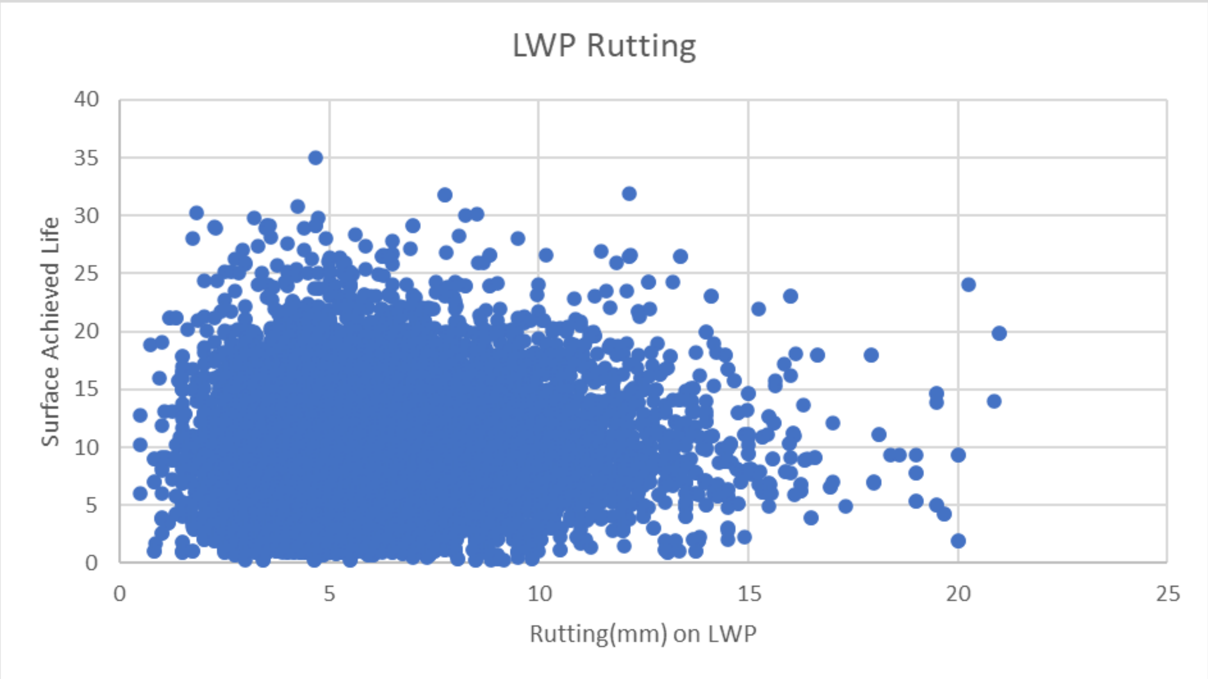
C

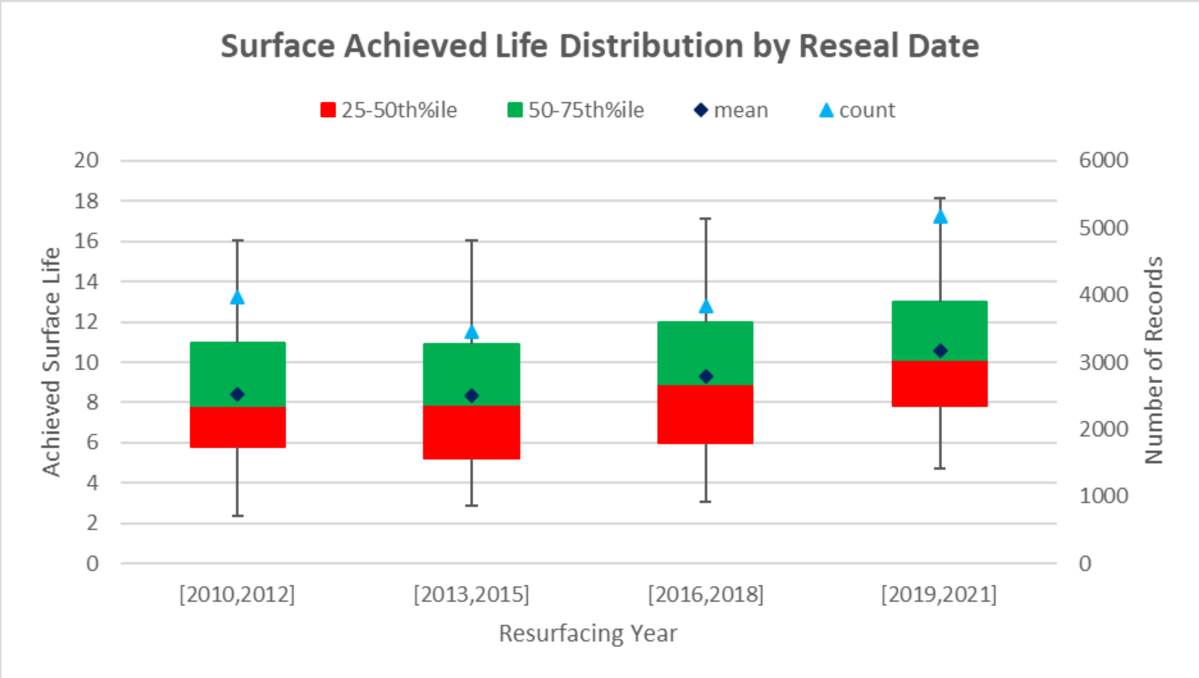
Appendix C – Achieved Seal Life vs Other Conditions

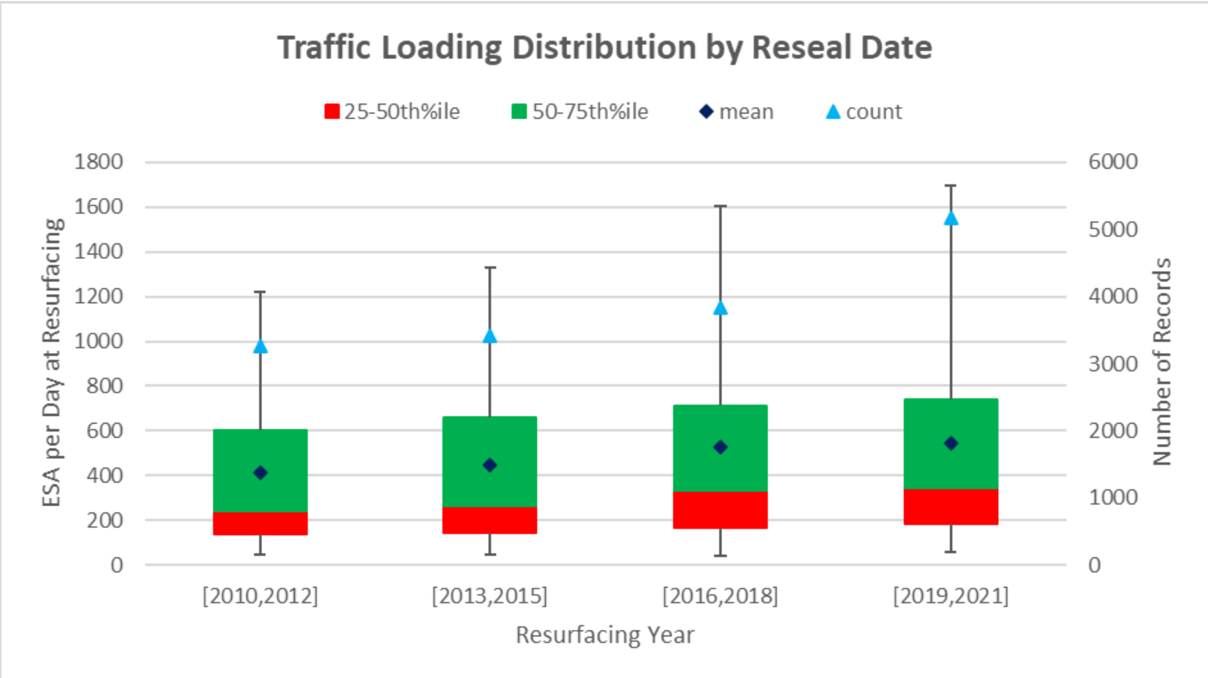

ESA per Day * Curvature
Surface Achieved Life
ESA*Curvature
18
16
14
12
10
8
6
0
100
200
300
400
500
600

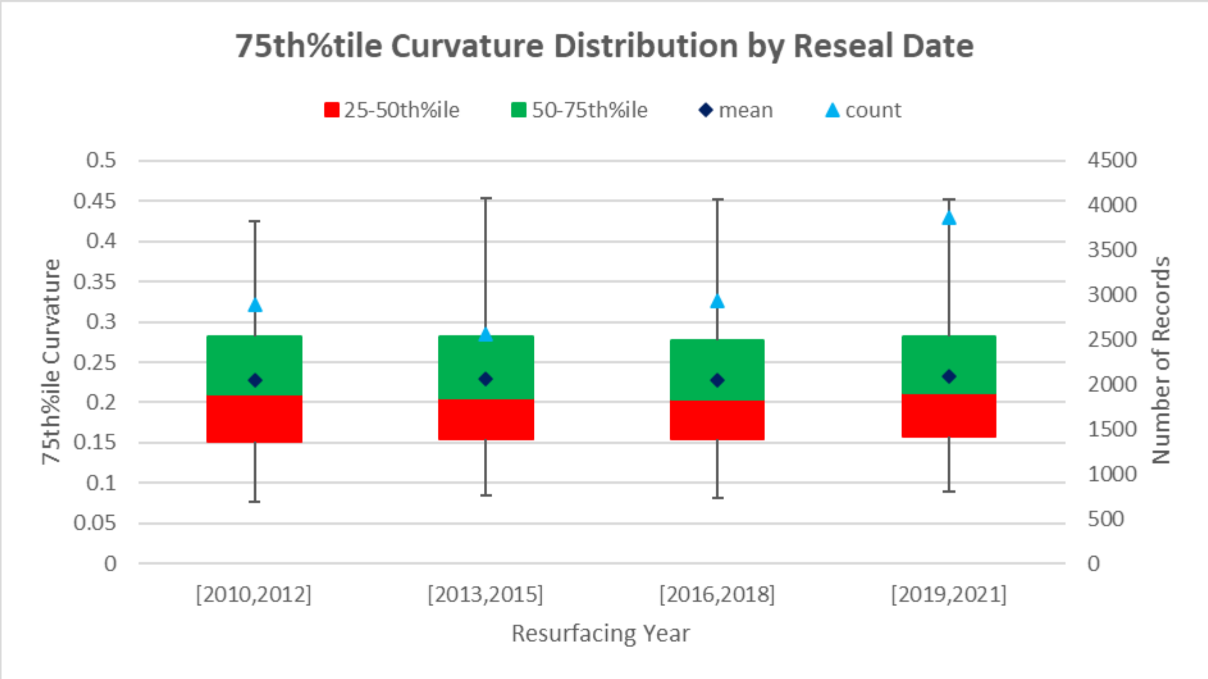

ESA per Day
Surface Achieved Life
ESA
18
16
14
12
10
8
6
0
500
1000
1500
2000
2500

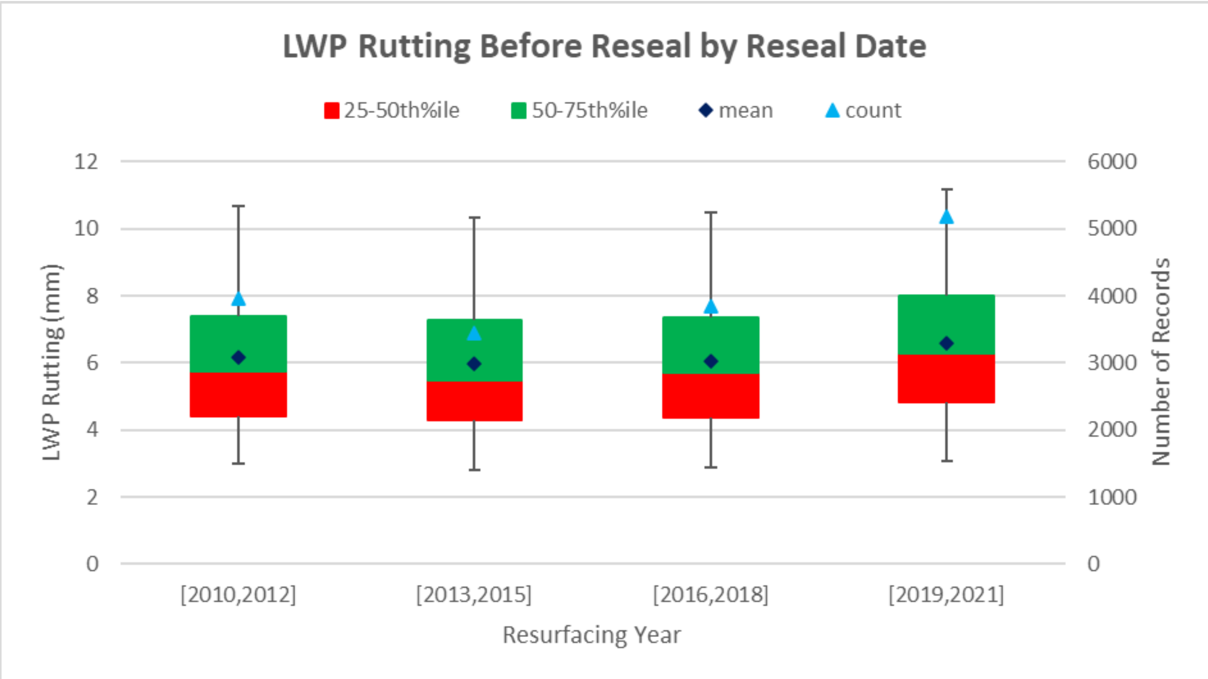

LWP Texture
Surface Achieved Life
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
Texture (mm) on LWP

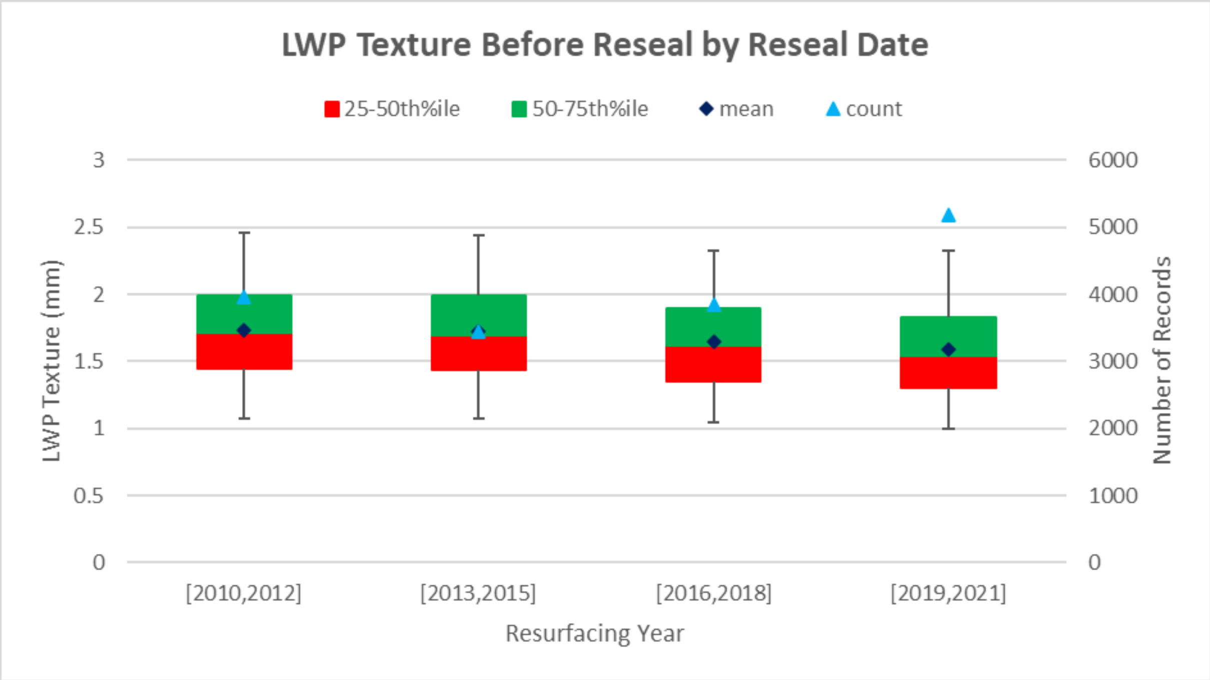

LWP Rutting
Surface Achieved Life
40
35
30
25
20
15
10
5
0
0
5
10
15
20
25
Rutting(mm) on LWP


Surface Achieved Life Distribution by Reseal Date
25-50th%ile
50-75th%ile
mean
count
Achieved Surface Life
Number of Records
20
18
16
14
12
10
8
6
4
2
0
6000
5000
4000
3000
2000
1000
0
[2010,2012]
[2013,2015]
[2016,2018]
[2019,2021]
Resurfacing Year


Traffic Loading Distribution by Reseal Date
25-50th%ile
50-75th%ile
mean
count
ESA per Day at Resurfacing
Number of Records
1800
1600
1400
1200
1000
800
600
400
200
0
6000
5000
4000
3000
2000
1000
0
[2010,2012]
[2013,2015]
[2016,2018]
[2019,2021]
Resurfacing Year


75th%tile Curvature Distribution by Reseal Date
25-50th%ile
50-75th%ile
mean
count
75th%ile Curvature
Number of Records
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
4500
4000
3500
3000
2500
2000
1500
1000
500
0
[2010,2012]
[2013,2015]
[2016,2018]
[2019,2021]
Resurfacing Year


LWP Rutting Before Reseal by Reseal Date
25-50th%ile
50-75th%ile
mean
count
LWP Rutting (mm)
Number of Records
12
10
8
6
4
2
0
6000
5000
4000
3000
2000
1000
0
[2010,2012]
[2013,2015]
[2016,2018]
[2019,2021]
Resurfacing Year


LWP Texture Before Reseal by Reseal Date
25-50th%ile
50-75th%ile
mean
count
LWP Texture (mm)
Number of Records
3
2.5
2
1.5
1
0.5
0
6000
5000
4000
3000
2000
1000
0
[2010,2012]
[2013,2015]
[2016,2018]
[2019,2021]
Resurfacing Year

D

Appendix D – Surface Achieved Life Distribution by NOC Regions

The following two tables show the average surface achieved life and standard deviation of surface achieved life for resurfacings and second coats respectively.

The dataset for resurfacing and second coat records is based on the following conditions according to RAMM surface_structure table.

- Surface records that are marked as resealed since 01/01/2010
- The width of the surface records is greater than 75% of the treatment length width.

Resurfacings	Surface Length > 300m				Surface Length <= 300m			
cway_area	total_length (km)	num_records	mean_life	std	total_length (km)	num_records	mean_life	std
(EC) MARLBOROUGH	123.9	205	9.4	4.1	55.0	464	7.7	2.8
(NOC) BOP EAST	453.1	707	9.7	3.4	136.0	925	8.6	3.0
(NOC) BOP WEST	48.8	88	7.5	2.8	28.2	231	8.1	1.7
(NOC) CENTRAL WAIKATO	260.8	391	9.0	4.6	70.1	525	7.6	4.0
(NOC) COASTAL OTAGO	449.9	477	11.9	4.5	68.2	534	10.0	4.2
(NOC) EAST WAIKATO	246.6	409	10.9	3.5	142.5	1018	9.8	2.2
(NOC) HAWKES BAY	142.4	238	9.1	3.3	88.9	689	9.6	2.0
(NOC) MANAWATU-WHANGANUI	151.8	236	11.0	4.2	63.1	458	9.1	3.0
(NOC) NELSON-TASMAN	194.5	336	8.8	4.4	165.0	1262	7.4	2.2
(NOC) NORTH CANTERBURY	271.8	375	11.4	4.1	76.7	585	10.2	3.3
(NOC) NORTHLAND	364.5	618	10.6	5.1	264.4	1954	8.3	2.9
(NOC) OTAGO CENTRAL	383.0	414	10.4	3.4	53.1	402	10.0	3.4
(NOC) SOUTH CANTERBURY	361.5	372	10.9	3.4	59.3	468	9.1	3.0
(NOC) SOUTHLAND	240.8	289	11.6	5.3	62.4	483	9.5	4.1
(NOC) TAIRAWHITI ROADS NORTHERN	99.9	151	7.3	2.3	53.2	359	7.2	1.5
(NOC) TAIRAWHITI ROADS WESTERN	92.3	150	8.2	2.5	36.8	256	8.5	1.9
(NOC) TARANAKI	189.8	333	11.4	4.0	99.7	753	9.9	2.7
(NOC) WELLINGTON	70.7	109	11.3	4.8	23.0	186	9.9	3.7
(NOC) WEST COAST	345.6	356	12.3	3.6	38.8	297	10.3	3.9
(NOC) WEST WAIKATO	129.4	251	9.7	3.9	85.6	632	9.1	2.5
AUCK ALLIANCE	11.2	22	9.9	3.2	10.3	87	8.0	1.6
MILFORD	24.5	29	13.8	7.2	10.9	84	10.1	4.2

2nd Coats	Surface Length > 300m				Surface Length <= 300m			
cway_area	total_length (km)	num_records	mean_life	std	total_length (km)	num_records	mean_life	std
(EC) MARLBOROUGH	3.0	7	3.9	2.3	2.6	45	3.6	3.4
(NOC) BOP EAST	58.4	100	9.3	2.7	14.4	102	8.4	4.2
(NOC) BOP WEST	8.8	15	6.6	2.7	3.7	32	5.5	2.7
(NOC) CENTRAL WAIKATO	54.3	72	9.6	4.1	12.8	167	7.2	3.8
(NOC) COASTAL OTAGO	32.5	44	9.2	2.8	9.3	89	6.9	4.0
(NOC) EAST WAIKATO	22.8	41	9.3	2.4	22.1	235	8.0	3.6
(NOC) HAWKES BAY	17.6	36	8.4	2.2	17.1	151	7.7	2.7
(NOC) MANAWATU-WHANGANUI	17.7	21	11.1	3.0	8.4	92	5.7	3.8
(NOC) NELSON-TASMAN	5.4	8	9.7	2.0	2.3	28	4.6	3.3
(NOC) NORTH CANTERBURY	17.5	30	7.3	1.8	9.5	115	5.9	2.6
(NOC) NORTHLAND	55.6	89	9.5	3.6	26.1	269	7.0	3.5
(NOC) OTAGO CENTRAL	33.5	43	10.1	3.7	6.3	49	10.6	3.5
(NOC) SOUTH CANTERBURY	16.5	13	9.6	2.1	2.7	40	6.0	3.0
(NOC) SOUTHLAND	34.2	51	9.3	3.7	7.6	100	5.9	4.0
(NOC) TAIRAWHITI ROADS NORTHERN	36.6	68	6.9	2.0	19.4	167	7.0	2.5
(NOC) TAIRAWHITI ROADS WESTERN	20.7	35	8.1	2.9	7.3	65	8.1	3.6
(NOC) TARANAKI	63.4	106	9.5	3.5	27.1	324	8.2	3.3
(NOC) WELLINGTON	10.3	18	12.4	1.3	1.6	13	10.4	4.2
(NOC) WEST COAST	3.8	6	7.5	1.1	2.2	28	6.3	3.7
(NOC) WEST WAIKATO	50.5	101	9.1	2.9	45.3	432	7.9	3.4
AUCK ALLIANCE	16.3	19	4.9	2.0	2.3	28	5.3	1.7
MILFORD	1.2	2	7.0	0.0	0.3	3	2.3	3.3

E

Appendix E – RAMM SQLs

Dataset for reseal conditions prior to both surface date and reseal date

```
IF OBJECT_ID('tempdb.dbo.#temp_cs') IS NOT NULL
DROP TABLE #temp_cs;
IF OBJECT_ID('tempdb.dbo.#temp_rating_survey') IS NOT NULL
DROP TABLE #temp_rating_survey;
IF OBJECT_ID('tempdb.dbo.#temp_rating_results') IS NOT NULL
DROP TABLE #temp_rating_results;

-- Returns the proportion (0~1) of the length of a record overlapping to a section
-- e.g. DBO.OVERLAPRATIO(0, 100, 80, 120) returns 0.5
IF OBJECT_ID('DBO.OVERLAPRATIO') IS NOT NULL
DROP FUNCTION DBO.OVERLAPRATIO;
CREATE FUNCTION DBO.OVERLAPRATIO(@section_start INTEGER, @section_end INTEGER,
@record_start INTEGER, @record_end INTEGER)
RETURNS FLOAT
AS BEGIN
 DECLARE @res FLOAT
 DECLARE @max_start INTEGER
 DECLARE @min_end INTEGER
 IF @section_start > @record_start
  BEGIN
   SET @max_start = @section_start
  END
 ELSE
  BEGIN
   SET @max_start = @record_start
  END
 IF @section_end < @record_end
  BEGIN
   SET @min_end = @section_end
  END
 ELSE
  BEGIN
   SET @min_end = @record_end
  END
```

```
  DECLARE @ol INTEGER
  SET @ol = @min_end - @max_start
  IF @ol > 0
    BEGIN
      SET @res = CAST(@ol AS FLOAT) / (@record_end - @record_start)
    END
  ELSE IF @ol = 0 AND @record_start = @record_end
    BEGIN
      SET @res = 1.0
    END
  ELSE
    BEGIN
      SET @res = 0
    END
  RETURN @res
END;

IF OBJECT_ID('DBO.FINYR') IS NOT NULL
DROP FUNCTION DBO.FINYR;
CREATE FUNCTION DBO.FINYR (@in_date DATE)
RETURNS VARCHAR(7)
AS BEGIN
  DECLARE @t_year INTEGER
  DECLARE @t_month INTEGER
  DECLARE @res VARCHAR(7)
  SET @t_year = YEAR(@in_date)
  SET @t_month = MONTH(@in_date)
  IF @t_month < 7
    SET @t_year = @t_year - 1
  SET @res = CONCAT(@t_year, '/', FORMAT((@t_year + 1) % 100, '00'))
  RETURN @res
END;
```

```
SELECT DISTINCT cs.surf_structure_id, cw.carr_way_no, cs.road_id, cs.start_m, cs.end_m, cs.length_m, cs.surf_width, tl.tl_width, tl.tl_lanes,
    cs.full_width_flag, cs.surf_material, cs.surf_function, sm.surf_category, cs.chip_size, cs.surface_date, cs.reseal_date,
    DBO.FINYR(cs.surface_date) AS surf_finyr, DBO.FINYR(cs.reseal_date) AS resurf_finyr
INTO #temp_cs
FROM surface_structure AS cs
JOIN surf_material AS sm
ON cs.surf_material = sm.surf_material
JOIN treatment_length AS tl
ON cs.road_id = tl.road_id AND cs.start_m >= tl.tl_start_m AND cs.start_m < tl.tl_end_m AND cs.surf_function = 'R'
--AND cs.length_m > 300
AND cs.reseal_date >= '2010-01-01'
JOIN carr_way AS cw
ON cw.road_id = cs.road_id AND cs.start_m >= cw.carrway_start_m AND cs.start_m < cw.carrway_end_m
WHERE cs.full_width_flag = 'Y' OR (cs.surf_width IS NOT NULL AND cs.surf_width / tl.tl_width > 0.75)
AND cs.surf_structure_set = 'D' AND cs.surf_sectioning = 'N' AND cs.major_surface = 'N';


SELECT DISTINCT t.surf_structure_id, t.road_id, t.start_m, t.end_m, t.rating_date_prev, rb.survey_number AS survey_prev,
t.rating_date, ra.survey_number AS survey
INTO #temp_rating_survey
FROM
(SELECT cs.surf_structure_id, cs.road_id, cs.start_m, cs.end_m, MAX(rb.rating_date) AS rating_date_prev, MAX(ra.rating_date) AS rating_date
FROM #temp_cs AS cs
JOIN rating AS rb
ON cs.road_id = rb.road_id AND cs.start_m < rb.insp_end_m AND cs.end_m > rb.insp_start_m
AND rb.rating_date < cs.surface_date
JOIN rating AS ra
ON cs.road_id = ra.road_id AND cs.start_m < ra.insp_end_m AND cs.end_m > ra.insp_start_m
AND ra.rating_date < cs.reseal_date AND ra.rating_date > cs.surface_date
GROUP BY cs.surf_structure_id, cs.road_id, cs.start_m, cs.end_m) AS t
JOIN rating AS rb
```

```
ON t.road_id = rb.road_id AND t.start_m < rb.insp_end_m AND t.end_m > rb.insp_start_m
AND rb.rating_date = t.rating_date_prev
JOIN rating AS ra
ON t.road_id = ra.road_id AND t.start_m < ra.insp_end_m AND t.end_m > ra.insp_start_m
AND ra.rating_date = t.rating_date;


SELECT cs.surf_structure_id, cs.road_id, cs.start_m, cs.end_m, cs.rating_date_prev, cs.survey_prev,
cs.rating_date, cs.survey,
SUM(DBO.OVERLAPRATIO(cs.start_m, cs.end_m, rb.start_m, rb.end_m) * rb.insp_length_m) AS
insp_length_prev,
SUM(DBO.OVERLAPRATIO(cs.start_m, cs.end_m, rb.start_m, rb.end_m) * rb.alligator) AS alligator_prev,
SUM(DBO.OVERLAPRATIO(cs.start_m, cs.end_m, rb.start_m, rb.end_m) * rb.scabbing) AS scabbing_prev,
SUM(DBO.OVERLAPRATIO(cs.start_m, cs.end_m, rb.start_m, rb.end_m) * rb.holes) AS holes_prev,
SUM(DBO.OVERLAPRATIO(cs.start_m, cs.end_m, rb.start_m, rb.end_m) * rb.patch) AS patch_prev,
SUM(DBO.OVERLAPRATIO(cs.start_m, cs.end_m, rb.start_m, rb.end_m) * rb.flushing) AS flushing_prev,
SUM(DBO.OVERLAPRATIO(cs.start_m, cs.end_m, ra.start_m, ra.end_m) * ra.insp_length_m) AS
insp_length,
SUM(DBO.OVERLAPRATIO(cs.start_m, cs.end_m, ra.start_m, ra.end_m) * ra.alligator) AS alligator,
SUM(DBO.OVERLAPRATIO(cs.start_m, cs.end_m, ra.start_m, ra.end_m) * ra.scabbing) AS scabbing,
SUM(DBO.OVERLAPRATIO(cs.start_m, cs.end_m, ra.start_m, ra.end_m) * ra.holes) AS holes,
SUM(DBO.OVERLAPRATIO(cs.start_m, cs.end_m, ra.start_m, ra.end_m) * ra.patch) AS patch,
SUM(DBO.OVERLAPRATIO(cs.start_m, cs.end_m, ra.start_m, ra.end_m) * ra.flushing) AS flushing
INTO #temp_rating_results
FROM #temp_rating_survey AS cs
JOIN rating AS rb
ON cs.road_id = rb.road_id AND cs.start_m < rb.insp_end_m AND cs.end_m > rb.insp_start_m
AND cs.survey_prev = rb.survey_number
JOIN rating AS ra
ON cs.road_id = ra.road_id AND cs.start_m < ra.insp_end_m AND cs.end_m > ra.insp_start_m
AND cs.survey = ra.survey_number
GROUP BY cs.surf_structure_id, cs.road_id, cs.start_m, cs.end_m, cs.rating_date_prev, cs.survey_prev,
cs.rating_date, cs.survey;
```

```
SELECT cs.surf_structure_id, cs.carr_way_no, cs.road_id, cs.start_m, cs.end_m, cs.length_m,
cs.surf_width, cs.tl_width, cs.tl_lanes,
    cs.full_width_flag, cs.surf_material, cs.surf_function, cs.surf_category, cs.chip_size, cs.surface_date,
cs.reseal_date,
    cs.surf_finyr, cs.resurf_finyr, rr.rating_date_prev, rr.survey_prev, rr.rating_date, rr.survey,
    rr.insp_length_prev, rr.alligator_prev, rr.scabbing_prev, rr.holes_prev, rr.patch_prev, rr.flushing_prev,
    rr.insp_length, rr.alligator, rr.scabbing, rr.holes, rr.patch, rr.flushing,
    tb.adt AS adt_prev, tb.pcheavy AS pcheavy_prev, ta.adt, ta.pcheavy
FROM #temp_cs AS cs
JOIN #temp_rating_results AS rr
ON cs.surf_structure_id = rr.surf_structure_id
JOIN traffic_loading_dtl AS tb
ON tb.tload_asset_type = 'CWAYY' AND tb.tload_asset_id = cs.carr_way_no AND tb.financial_year =
cs.surf_finyr AND tb.count_status = 'E'
JOIN traffic_loading_dtl AS ta
ON ta.tload_asset_type = 'CWAYY' AND ta.tload_asset_id = cs.carr_way_no AND ta.financial_year =
cs.resurf_finyr AND ta.count_status = 'E';
```

Dataset for second coats analysis

```
IF OBJECT_ID('tempdb.dbo.#temp_cs') IS NOT NULL
DROP TABLE #temp_cs;

SELECT DISTINCT cs.surf_structure_id, cw.carr_way_no, cs.road_id, cs.start_m, cs.end_m, cs.length_m,
cs.surf_width, tl.tl_width, tl.tl_lanes,
    cs.full_width_flag, cs.surf_material, cs.surf_function, sm.surf_category, cs.chip_size, cs.surface_date,
cs.reseal_date,
    DBO.FINYR(cs.surface_date) AS surf_finyr, DBO.FINYR(cs.reseal_date) AS resurf_finyr,
MAX(pl.layer_date) AS layer_date
INTO #temp_cs
FROM surface_structure AS cs
JOIN surf_material AS sm
ON cs.surf_material = sm.surf_material
JOIN treatment_length AS tl
ON cs.road_id = tl.road_id AND cs.start_m >= tl.tl_start_m AND cs.start_m < tl.tl_end_m AND
cs.surf_function = '2'
--AND cs.length_m > 300
AND cs.reseal_date >= '2010-01-01'
JOIN carr_way AS cw
```

```
ON cw.road_id = cs.road_id AND cs.start_m >= cw.carrway_start_m AND cs.start_m < cw.carrway_end_m

JOIN pave_layer AS pl

ON pl.layer_subgrade = 'L' AND pl.road_id = cs.road_id

AND ((CASE WHEN cs.end_m > pl.end_m THEN cs.end_m ELSE pl.end_m END) - (CASE WHEN cs.start_m < pl.start_m THEN cs.start_m ELSE pl.start_m END)) * 2 >= cs.length_m

AND pl.layer_date < cs.surface_date AND (pl.full_width_flag = 'Y' OR pl.width IS NOT NULL AND pl.width / tl.tl_width > 0.75)

WHERE cs.full_width_flag = 'Y' OR (cs.surf_width IS NOT NULL AND cs.surf_width / tl.tl_width > 0.75)

AND cs.surf_structure_set = 'D' AND cs.surf_sectioning = 'N' AND cs.major_surface = 'N'

GROUP BY cs.surf_structure_id, cw.carr_way_no, cs.road_id, cs.start_m, cs.end_m, cs.length_m, cs.surf_width, tl.tl_width, tl.tl_lanes,

   cs.full_width_flag, cs.surf_material, cs.surf_function, sm.surf_category, cs.chip_size, cs.surface_date, cs.reseal_date,

   DBO.FINYR(cs.surface_date), DBO.FINYR(cs.reseal_date);


SELECT DISTINCT cs.surf_structure_id, cs.carr_way_no, cs.road_id, cs.start_m, cs.end_m, cs.length_m, cs.surf_width, cs.tl_width, cs.tl_lanes,

   cs.full_width_flag, cs.surf_material, cs.surf_function, cs.surf_category, cs.chip_size, cs.surface_date, cs.reseal_date,

   cs.surf_finyr, cs.resurf_finyr, cs.layer_date,

   tb.adt AS adt_prev, tb.pcheavy AS pcheavy_prev, ta.adt, ta.pcheavy,

   PERCENTILE_CONT(0.75) WITHIN GROUP (ORDER BY (CAST(f.disp0_reading AS DECIMAL)*(566 / CAST(f.pressure AS DECIMAL)))/1000.0)

                    OVER (PARTITION BY cs.surf_structure_id) AS fwd_d0_75th,

   PERCENTILE_CONT(0.75) WITHIN GROUP (ORDER BY (CAST((f.disp0_reading - f.disp1_reading) AS DECIMAL)*(566 / CAST(f.pressure AS DECIMAL)))/1000.0)

                    OVER (PARTITION BY cs.surf_structure_id) AS fwd_cur_75th,

   PERCENTILE_CONT(0.9) WITHIN GROUP (ORDER BY (CAST(f.disp0_reading AS DECIMAL)*(566 / CAST(f.pressure AS DECIMAL)))/1000.0)

                    OVER (PARTITION BY cs.surf_structure_id) AS fwd_d0_90th,

   PERCENTILE_CONT(0.9) WITHIN GROUP (ORDER BY (CAST((f.disp0_reading - f.disp1_reading) AS DECIMAL)*(566 / CAST(f.pressure AS DECIMAL)))/1000.0)

                    OVER (PARTITION BY cs.surf_structure_id) AS fwd_cur_90th

FROM #temp_cs AS cs

JOIN traffic_loading_dtl AS tb

ON tb.tload_asset_type = 'CWAYY' AND tb.tload_asset_id = cs.carr_way_no AND tb.financial_year = cs.surf_finyr AND tb.count_status = 'E'

JOIN traffic_loading_dtl AS ta
```

```
ON ta.tload_asset_type = 'CWAYY' AND ta.tload_asset_id = cs.carr_way_no AND ta.financial_year = cs.resurf_finyr AND ta.count_status = 'E'

LEFT JOIN falling_weight AS f

ON cs.road_id = f.road_id AND f.location >= cs.start_m AND f.location <= cs.end_m AND f.pressure > 0 AND f.pressure < 1000

AND f.reading_date < cs.reseal_date AND f.reading_date > cs.layer_date;
```

Dataset for annual maintenance cost during lives of second coats

```
IF OBJECT_ID('tempdb.dbo.#pave_layer') IS NOT NULL

DROP TABLE #pave_layer;

IF OBJECT_ID('tempdb.dbo.#mc_cost') IS NOT NULL

DROP TABLE #mc_cost;

IF OBJECT_ID('tempdb.dbo.#temp_cs') IS NOT NULL

DROP TABLE #temp_cs;

IF OBJECT_ID('tempdb.dbo.#temp_sec_coats') IS NOT NULL

DROP TABLE #temp_sec_coats;

IF OBJECT_ID('tempdb.dbo.#temp_sec_coats_') IS NOT NULL

DROP TABLE #temp_sec_coats_;


IF OBJECT_ID('DBO.FINYRADD') IS NOT NULL

DROP FUNCTION DBO.FINYRADD;

CREATE FUNCTION DBO.FINYRADD(@finyr VARCHAR(7), @offset INTEGER)

RETURNS VARCHAR(7)

AS BEGIN

  DECLARE @t_year INTEGER

  SET @t_year = CAST(SUBSTRING(@finyr, 1, 4) AS INTEGER) + @offset

  DECLARE @res VARCHAR(7)

  SET @res = CONCAT(@t_year, '/', FORMAT((@t_year + 1) % 100, '00'))

  RETURN @res

END;


IF OBJECT_ID('DBO.FINYR') IS NOT NULL

DROP FUNCTION DBO.FINYR;

CREATE FUNCTION DBO.FINYR (@in_date DATE)

RETURNS VARCHAR(7)
```

```
AS BEGIN
  DECLARE @t_year INTEGER
  DECLARE @t_month INTEGER
  DECLARE @res VARCHAR(7)
  SET @t_year = YEAR(@in_date)
  SET @t_month = MONTH(@in_date)
  IF @t_month < 7
    SET @t_year = @t_year - 1
  SET @res = CONCAT(@t_year, '/', FORMAT((@t_year + 1) % 100, '00'))
  RETURN @res
END;

IF OBJECT_ID('DBO.OVERLAPRATIO') IS NOT NULL
DROP FUNCTION DBO.OVERLAPRATIO;
CREATE FUNCTION DBO.OVERLAPRATIO(@section_start INTEGER, @section_end INTEGER,
@record_start INTEGER, @record_end INTEGER)
RETURNS FLOAT
AS BEGIN
  DECLARE @res FLOAT
  IF @section_start IS NULL OR @section_end IS NULL OR @record_start IS NULL OR @record_end IS
NULL
    BEGIN
        SET @res = 0
    END
  ELSE
    BEGIN
      DECLARE @max_start INTEGER
      DECLARE @min_end INTEGER
      IF @section_start > @record_start
        BEGIN
          SET @max_start = @section_start
        END
      ELSE
        BEGIN
          SET @max_start = @record_start
```

```
      END
     IF @section_end < @record_end
      BEGIN
       SET @min_end = @section_end
      END
     ELSE
      BEGIN
       SET @min_end = @record_end
      END
     DECLARE @ol INTEGER
     SET @ol = @min_end - @max_start
     IF @ol > 0
      BEGIN
       SET @res = CAST(@ol AS FLOAT) / (@record_end - @record_start)
      END
     ELSE IF @ol = 0 AND @record_start = @record_end
      BEGIN
       SET @res = 1.0
      END
     ELSE
      BEGIN
       SET @res = 0
      END
    END
  RETURN @res
END;

CREATE TABLE #yr_offset
(
  yr INTEGER
);

INSERT INTO #yr_offset (yr)
VALUES
(1), (2), (3), (4), (5), (6), (7), (8), (9), (10), (11), (12), (13), (14), (15), (16), (17), (18), (19), (20);
```

```
CREATE TABLE #cost_groups
(
  cost_group VARCHAR(5)
);

INSERT INTO #cost_groups (cost_group)
VALUES
('PA'), ('SU'), ('SH');

SELECT DISTINCT cs.surf_structure_id, cw.carr_way_no, cs.road_id, cs.start_m, cs.end_m, cs.length_m,
cs.surf_width, tl.tl_width, tl.tl_lanes,
    cs.full_width_flag, cs.surf_material, cs.surf_function, sm.surf_category, cs.chip_size, cs.surface_date,
cs.reseal_date,
    DBO.FINYR(cs.surface_date) AS surf_finyr, DBO.FINYR(cs.reseal_date) AS resurf_finyr,
MAX(pl.layer_date) AS layer_date
INTO #temp_cs
FROM surface_structure AS cs
JOIN surf_material AS sm
ON cs.surf_material = sm.surf_material
JOIN treatment_length AS tl
ON cs.road_id = tl.road_id AND cs.start_m >= tl.tl_start_m AND cs.start_m < tl.tl_end_m AND
cs.surf_function = '2'
--AND cs.length_m > 300
AND cs.reseal_date >= '2010-01-01'
JOIN carr_way AS cw
ON cw.road_id = cs.road_id AND cs.start_m >= cw.carrway_start_m AND cs.start_m < cw.carrway_end_m
--JOIN pave_layer AS pl
--ON pl.layer_subgrade = 'L' AND pl.road_id = cs.road_id
JOIN pave_structure as pl
--ON pl.structure_set = 'D' AND pl.dtims_layer IS NULL AND pl.layer_no = '1' AND pl.pave_material IN ('M4',
'M4AP40') AND pl.reconstructed = 'U' AND pl.thickness >= 150 AND pl.road_id = cs.road_id
ON pl.structure_set = 'D' AND pl.dtims_layer IS NULL AND pl.layer_no = '1' AND pl.pave_material = 'COMP'
AND pl.road_id = cs.road_id
AND ((CASE WHEN cs.end_m > pl.end_m THEN cs.end_m ELSE pl.end_m END) - (CASE WHEN
cs.start_m < pl.start_m THEN cs.start_m ELSE pl.start_m END)) * 2 >= cs.length_m
```

AND pl.layer_date < cs.surface_date AND (pl.full_width_flag = 'Y' OR pl.width IS NOT NULL AND pl.width / tl.tl_width > 0.75)

WHERE cs.full_width_flag = 'Y' OR (cs.surf_width IS NOT NULL AND cs.surf_width / tl.tl_width > 0.75)

AND cs.surf_structure_set = 'D' AND cs.surf_sectioning = 'N' AND cs.major_surface = 'N'

GROUP BY cs.surf_structure_id, cw.carr_way_no, cs.road_id, cs.start_m, cs.end_m, cs.length_m, cs.surf_width, tl.tl_width, tl.tl_lanes,

cs.full_width_flag, cs.surf_material, cs.surf_function, sm.surf_category, cs.chip_size, cs.surface_date, cs.reseal_date,

DBO.FINYR(cs.surface_date), DBO.FINYR(cs.reseal_date);

SELECT DISTINCT cs.surf_structure_id, cs.carr_way_no, cs.road_id, cs.start_m, cs.end_m, cs.length_m, cs.surf_width, cs.tl_width, cs.tl_lanes,

cs.full_width_flag, cs.surf_material, cs.surf_function, cs.surf_category, cs.chip_size, cs.surface_date, cs.reseal_date,

cs.surf_finyr, cs.resurf_finyr, cs.layer_date,

tb.adt AS adt_prev, tb.pcheavy AS pcheavy_prev, ta.adt, ta.pcheavy,

PERCENTILE_CONT(0.75) WITHIN GROUP (ORDER BY (CAST(f.disp0_reading AS DECIMAL)*(566 / CAST(f.pressure AS DECIMAL)))/1000.0)

OVER (PARTITION BY cs.surf_structure_id) AS fwd_d0_75th,

PERCENTILE_CONT(0.75) WITHIN GROUP (ORDER BY (CAST((f.disp0_reading - f.disp1_reading) AS DECIMAL)*(566 / CAST(f.pressure AS DECIMAL)))/1000.0)

OVER (PARTITION BY cs.surf_structure_id) AS fwd_cur_75th,

PERCENTILE_CONT(0.9) WITHIN GROUP (ORDER BY (CAST(f.disp0_reading AS DECIMAL)*(566 / CAST(f.pressure AS DECIMAL)))/1000.0)

OVER (PARTITION BY cs.surf_structure_id) AS fwd_d0_90th,

PERCENTILE_CONT(0.9) WITHIN GROUP (ORDER BY (CAST((f.disp0_reading - f.disp1_reading) AS DECIMAL)*(566 / CAST(f.pressure AS DECIMAL)))/1000.0)

OVER (PARTITION BY cs.surf_structure_id) AS fwd_cur_90th

INTO #temp_sec_coats

FROM #temp_cs AS cs

JOIN traffic_loading_dtl AS tb

ON tb.tload_asset_type = 'CWAYY' AND tb.tload_asset_id = cs.carr_way_no AND tb.financial_year = cs.surf_finyr AND tb.count_status = 'E'

JOIN traffic_loading_dtl AS ta

ON ta.tload_asset_type = 'CWAYY' AND ta.tload_asset_id = cs.carr_way_no AND ta.financial_year = cs.resurf_finyr AND ta.count_status = 'E'

LEFT JOIN falling_weight AS f

```
ON cs.road_id = f.road_id AND f.location >= cs.start_m AND f.location <= cs.end_m AND f.pressure > 0
AND f.pressure < 1000
AND f.reading_date < cs.reseal_date AND f.reading_date > cs.layer_date;

SELECT cs.surf_structure_id, cs.carr_way_no, cs.road_id, cs.start_m, cs.end_m, cs.length_m,
cs.surf_width, cs.tl_width, cs.tl_lanes,
   cs.full_width_flag, cs.surf_material, cs.surf_function, cs.surf_category, cs.chip_size, cs.surface_date,
cs.reseal_date,
   cs.surf_finyr, cs.resurf_finyr, cs.layer_date,
   cs.adt_prev, cs.pcheavy_prev, cs.adt, cs.pcheavy,
   cs.fwd_d0_75th, cs.fwd_cur_75th, cs.fwd_d0_90th, cs.fwd_cur_90th,
   DBO.FINYR(cs.surface_date) AS fyr_sealed, ocv.category_id,
   yo.yr, DBO.FINYRADD(DBO.FINYR(cs.surface_date), yo.yr) AS finyr, cg.cost_group
INTO #temp_sec_coats_
FROM #temp_sec_coats AS cs
JOIN onrc_cway_view AS ocv
ON ocv.carr_way_no = cs.carr_way_no
JOIN #yr_offset AS yo
ON cs.surf_structure_id IS NOT NULL
JOIN #cost_groups AS cg
ON cs.surf_structure_id IS NOT NULL;

SELECT road_id, start_m,
(CASE WHEN start_m = end_m THEN start_m + 1 ELSE end_m END) AS end_m,
financial_year, transaction_date, cost_group, cost_amount
INTO #mc_cost
FROM mc_cost
WHERE cost_group IN ('PA', 'SU', 'SH');

SELECT cs.surf_structure_id, cs.carr_way_no, cw.cway_area, cs.road_id, rn.road_name, cs.start_m,
cs.end_m, cs.length_m, cs.surf_width, cs.tl_width, cs.tl_lanes,
   cs.full_width_flag, cs.surf_material, cs.surf_function, cs.surf_category, cs.chip_size, cs.surface_date,
cs.reseal_date,
   cs.surf_finyr, cs.resurf_finyr, cs.layer_date,
   cs.adt_prev, cs.pcheavy_prev, cs.adt, cs.pcheavy,
   cs.fwd_d0_75th, cs.fwd_cur_75th, cs.fwd_d0_90th, cs.fwd_cur_90th,
```

```
   cs.fyr_sealed, cs. category_id,
   cs.yr, cs.finyr, cs.cost_group,
   SUM(mc.cost_amount * DBO.OVERLAPRATIO(cs.start_m, cs.end_m, mc.start_m, mc.end_m)) AS
cost_amount
FROM #temp_sec_coats_ AS cs
JOIN carr_way As cw
ON cs.carr_way_no = cw.carr_way_no
JOIN roadnames AS rn
ON cs.road_id = rn.road_id
LEFT JOIN #mc_cost AS mc
ON cs.road_id = mc.road_id AND cs.finyr = mc.financial_year AND
cs.start_m < mc.end_m AND cs.end_m > mc.start_m AND cs.cost_group = mc.cost_group AND
mc.transaction_date > cs.surface_date AND mc.transaction_date < cs.reseal_date
GROUP BY cs.surf_structure_id, cs.carr_way_no, cw.cway_area, cs.road_id, rn.road_name, cs.start_m,
cs.end_m, cs.length_m, cs.surf_width, cs.tl_width, cs.tl_lanes,
   cs.full_width_flag, cs.surf_material, cs.surf_function, cs.surf_category, cs.chip_size, cs.surface_date,
cs.reseal_date,
   cs.surf_finyr, cs.resurf_finyr, cs.layer_date,
   cs.adt_prev, cs.pcheavy_prev, cs.adt, cs.pcheavy,
   cs.fwd_d0_75th, cs.fwd_cur_75th, cs.fwd_d0_90th, cs.fwd_cur_90th,
   cs.fyr_sealed, cs.category_id,
   cs.yr, cs.finyr, cs.cost_group;

DROP FUNCTION DBO.FINYRADD;
DROP FUNCTION DBO.FINYR;
DROP FUNCTION DBO.OVERLAPRATIO;
```