REG | THE ROAD EFFICIENCY GROUP

BEST PRACTICE
AMP WORKING GROUP

Case Study

Forward Works Programme Optimisation

Initiative number 2013_02

July 2013

Version No	Date	Item Affected	Description of Change
1	8/7/13		Draft Document Created
2	11/7/13		Section 2 updated and appendix B added
3	16/7/ 13		Renamed electronic file
4			Needs linkage to appendix B in the text. This (and finalisation of Executive Summary) will be added in version 3 after discussing the draft with the working group.
5	20/6/14		Closed out on all feedback and updated to new template

Executive Summary

This case study discusses the processes that can be adopted to develop an optimised forward works programme for pavement and surfacing renewals, and the tools and methodologies that are available to achieve this. It outlines the importance of starting the prioritisation process from an optimised programme, and the efficiencies that can be achieved from an optimised programme as opposed to a worst first approach.

The REG AMP Best Practice case study 2013/01outlined the process that the Transport Agency is using to verify and prioritise the upcoming renewals programme. The paper proposed that the prioritisation process should start from an optimised programme of forward works which considers the most cost effective whole of life strategies to maintain the network. This paper provides guidance on an approach that can be used to achieve that. The methodology proposed uses a multi criteria approach that utilises outputs form the New Zealand dTIMS modelling tool as one of the inputs.

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Introduction

1.1 Project Outline

Project Name:	
Project Location:	Nationwide
Project Objectives:	Understanding the tools available for achieving an optimised forward works programme for pavement and surfacing renewals that will deliver a cost effective whole of life maintenance strategy. Demonstrating how these can be applied to determine the optimal programme and the outcomes of this.
Length:	n/a
Traffic Volume:	n/a
Supplier(s):	Internal
Project Stage:	Now business as usual
Value: (cost savings)	The work has resulted in a significant reduction in the renewals quantities forecast across the state highway network for the next ten years. A follow up case study will be submitted following completion of the ongoing validation work. This paper will quantify the savings expected.
Scope of Work:	Summarises a best practice process that should form the basis for the development of long term pavement investment programmes. Typically this process will be undertaken every three years as an integral part of preparing the long term plan, but there are also advantages in carrying out an annual review.
Constraints:	Time and resources
Project commenced:	Has been developing over the fifteen years.
Key Issues:	Part of the Transport Agency Advanced Asset Management quality process.

1.2 Project Team

Name	Organisation / Role	Contact Details (Email and Telephone)
NZTA	SM 020 State Highway Asset Maintenance Management Manual describes the recommended process.	
IDS Limited	Provides dTIMS capability in New Zealand	Dr Theuns Henning t.henning@auckland.ac.nz

2 Fundamental Planning Principles

2.1 Context

The process for developing and managing the forward works programme for pavement and surfacing renewals is outlined in Transport Agency's State Highway Asset Maintenance Management Manual (SM 020). In REG AMP paper 2013_01 the process that the Transport Agency is employing to review and prioritise the renewals programme proposed that the prioritisation process should start from an optimised programme of forward works that will deliver cost effective whole of life strategies to maintain the network.

Prioritisation is necessary when the optimised work programme exceeds budget availability, but if the prioritisation process does not start from an optimised long term programme, there is a risk that the programme management may revert to a worst first strategy which is generally not efficient in whole of life cost terms. Also, prioritisation in the absence of an optimised long term programme gives no indication of the scale of any backlog that is developing.

Long term renewals programmes should be developed drawing on a range of inputs. There are many variables affecting our ability to accurately predict future needs and the most reliable forward programmes are those that consider a number of key inputs and indicators to determine the future needs. The recommended scope of these is indicated in figure 1.

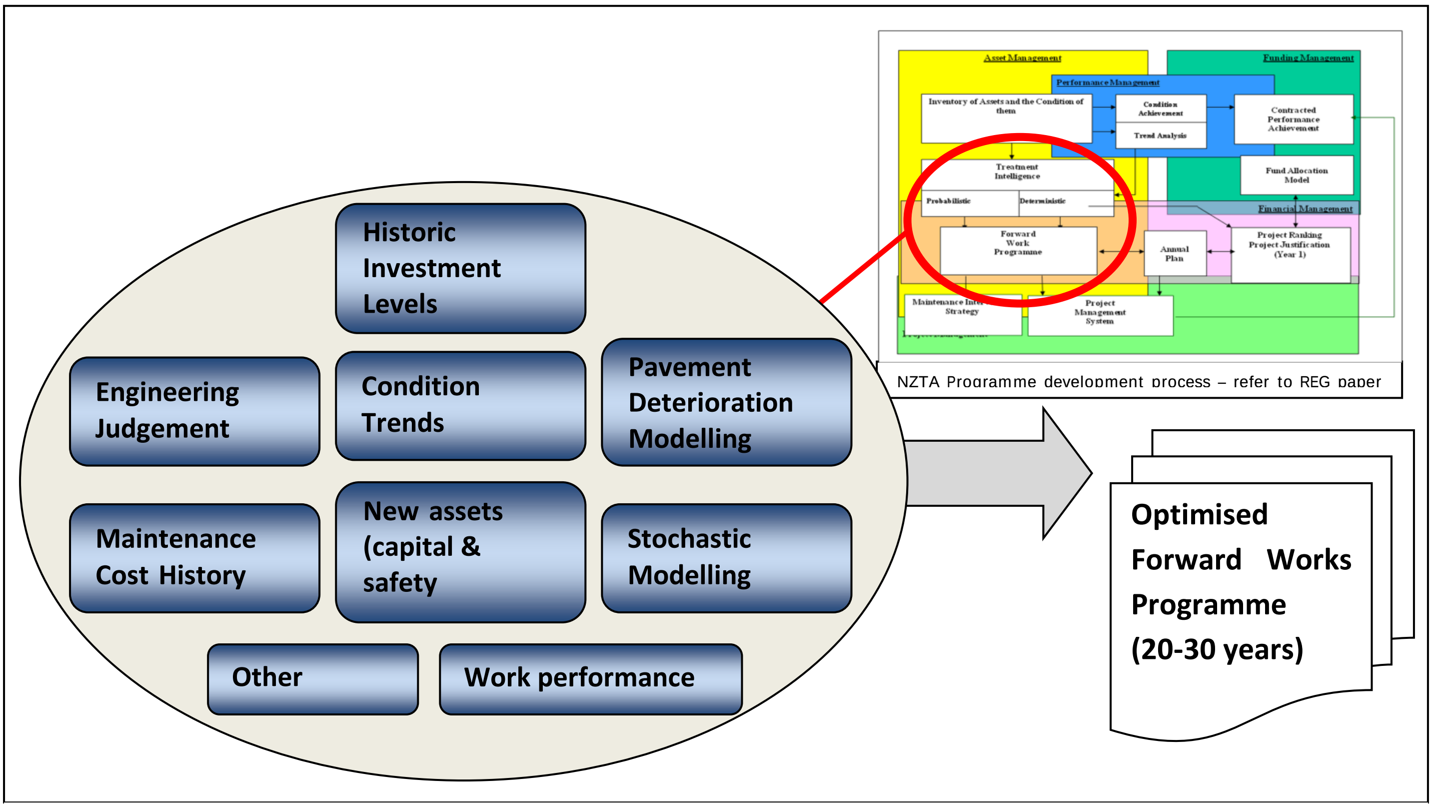


Figure 1: Inputs that should be considered in determining long term forward works programme

This paper discusses each of these inputs providing details of tools that are available in New Zealand to provide the outcomes required, and uses the Transport Agency's recent work on determining the base preservation levels for its new Network Outcome Contracts as a case study to demonstrate the application of these. Data is also presented that demonstrates the efficiency differential between a worst first programme and an optimised programme based on whole of life treatment strategies.

2.2 Planning Horizons

The planning horizons for road maintenance planning are presented in Figure 2.

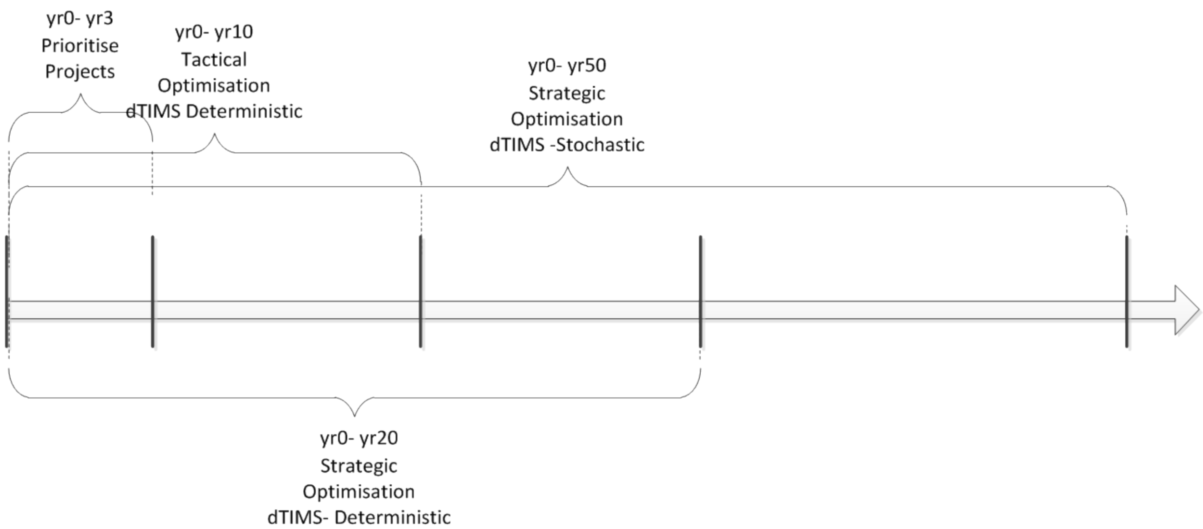


Figure 2: Planning Horizons for Road Maintenance

The respective objectives for each of the planning horizons are:

- Yr0 – Yr50 – Long-term strategic optimisation is undertaken to confirm that funding levels are sustainable in the long-term. Outputs form this level provides only the total funding level requirements. Given that deterministic models at this level would be arbitrary on individual section length an over-all network approach using stochastic modelling would be most appropriate

- Yr0 – Yr20- Strategic optimisation at this level is undertaken to test both the outcomes in terms of long-term investment levels but also starting to assess the impact of funding splits between maintenance categories. In particular the impact of the 10-year programme is tested in terms of the long-term consequences it has on the network performance. At this level more detail interventions and models are required, thus fitting the deterministic approach;

- Yr0 – Yr10 – A tactical analysis that provides details in terms of funding split between different maintenance categories and road classes. The emphasis of this analysis is ensuring that the Level of Service is maintained at the required standard for a given maintenance regime.

- Yr0-yr3 Prioritise projects for execution. These projects are determined on the basis of relative maintenance category quantities determined at tactical level. I.e. this level does not provide "the best for the network" but more a relative ranking between candidate sites which are determined from a combination of optimisation modelling and field work

2.3 Prioritisation versus optimisation

The differences between optimisation and prioritisation is summarised in Figure 2

Table 1: Optimisation vs Prioritisation

Item	Prioritisation	Optimisation	Impact
Time scale	Only relevant on current data (snapshot)	Considers maintenance needs into the future	Rate of change of condition is not considered
Number of parameter/ considerations	Only a single parameter is used	Single or multi consideration that changes with time	What is best for today, may not be the best for tomorrow
Budget constrains	Only do top ranked projects until money runs out for a year.	Timing and type of treatment is a function of annual budget constraint.	Multi-year considerations are important under constraint conditions. i.e. under constraint budgets you may do say more resurfacing and less rehabs.
Relative comparisons	A decision is based purely as a result of a project rank, thus ignoring over-all network outcomes	Outcomes are maximised for a given budget	May result in worse first approach if only ranked.

Note: a fundamental limitation to both techniques is data accuracy dependencies.

International research has proven that ranking/prioritisation methods results in a worse first approach which would be between 15-20% inefficient when compared to an optimal programme. Simply stated the optimisation ensures the "best bang for the buck" where the "bang" is determined by the user's primary objectives for a network. These claims have been theoretically tested and presented in Appendix 2. Apart from an over-all better network condition, the analysis resulted in an over-all maintenance investment saving of 20% using an optimal maintenance programme.

A limitation associated with the optimised programmes is that often "illogical" decision is being made, if viewed from a simple condition perspective. For example, a road may look like it needs a reseal now, whereas on the basis of a model the deterioration rate may suggest an imminent rehabilitation need in the short-term. In such cases an earlier than expected rehabilitation may be more cost effective.

The ideal mix therefore is to use an optimised list of potential projects for the short to medium term (up to three years) as a starting point for short-term ranking of projects.

2.4 Financial Measures

Financial considerations are important to both techniques discussed in the previous section. A definition of some of the most commonly used are listed in table 2.

Table 2: Financial Measures Definitions (NAMS, ODM Manual)

Measure	Explanation	Application
Present Value (PV)	Expenditure in year n / (1+discount rate)n (Recognises that the real cost of Spending $1,000 in ten year's time is less than the real cost of spending $1,000 now)	Applied to all cost calculations that have an time element associated to it. The discount rate has a profound impact on the outcome. A high discount rate favour deferring high investment to later years. E.g. will defer rehabilitation treatments and bring forward cheaper options such as resurfacing.
Least cost option	the cost where PV of costs is lowest	Form the basis of comparing life-cycle strategies
Net Present Value (NPV)	PV of Net Benefits – PV of Investment Costs	Used to assess minimum maintenance options form an agency perspective
Benefit Cost Ratio (BCR)	PV of Net Benefits/PV of investment costs	Mostly used when wider community benefits are considered
Internal Rate of Return	the discount rate where the discounted benefits = the discounted costs	Often used to determine the best timing of expenditure from a financial perspective
Investment Costs (Capital Costs)	Initial and intermittent capital expenditure over the project life	Each capital investment will result in future maintenance cost.
Net Benefits	Annual benefits less annual costs	Used to assess wider benefits from the community.

2.5 Historic Paradigms

There is some suggestion that some historic paradigms that form the basis for forward work programming may warrant review. When compiling and reviewing forward work programmes and validating the inputs used to develop these, it is appropriate to review the following:

- There are some indications that we may be investing too early with some renewals activities. For example:
  - Undertaking work before intervention levels would trigger treatment, and
  - Possibly being very risk averse with programming. It may be appropriate to see some work undertaken when in hindsight earlier intervention may have been preferable.

- There are some indications that we are not achieving the expected life from some renewal works. For example, chip seals not achieving default life expectations and, in some cases, the achieved life reducing over time. During programme development it is appropriate to consider mitigations that would achieve better life from assets before programming renewals.

- It is also appropriate to review the trend in outcome condition achievement against the trend in renewal investment. We are possibly not always seeing the long term improvement in condition that we would expect in response to the renewal investment.

In some cases the outcomes of deterministic modelling are treated with suspicion because they are suggesting a different paradigm or investment level to what which we are accustomed to. It is suggested that careful review of the modelling recommended strategies should be undertaken before reaching conclusions about their validity. There is evidence suggesting that some of our historic paradigms may be poorly founded. For example, it has been observed that on the long term pavement performance benchmark sites where the only work that is being carried out is reactive maintenance, the pavement and surfacing are not exhibiting the poor performance that was expected.

2.6 Programme Management – RAMM FWP functionality

The RAMM software incorporates pavement and surfacing forward works programme maintenance functionality that can be used to manage the renewals programme. This application interfaces with the modelling tools and provides a robust capability to review the reliability of renewals programmes as time passes, and record the triggers that initially suggested that renewal work was necessary, the priority assigned to it etc.

3 Case Study NZTA OMC Base Preservation Levels

3.1 Introduction

The new Transport Agency Network Outcome Contracts specify the level of investment for pavement, surfacing and drainage renewals that the client believes represent the base level required to preserve the asset. These renewal works will be bid as a lump sum based on a specimen design, but will effectively be paid by measure and value after adjustment to match the site by site design assessed to the specimen design. The Contractor is required to bid a fixed lump sum to compliment this renewal input such that the two inputs collectively deliver the specified level of service.

The contract incorporates mechanisms to vary the renewals inputs and trade off the benefits of this against the fixed maintenance lump sum. But to achieve an optimal outcome from the contracts it is critical that there is confidence in the specified quantities for renewals representing the base preservation need.

This case study provides an overview of the process used by the Transport Agency to develop the base preservation levels for pavement and surfacing renewals for use in the new OMC contracts.

3.2 Inputs and process

The following analysis and inputs were considered in the rationalisation process to derive the final Base Preservation Levels and the forward works programme that this is based on:

3.2.1 Historic Investment Levels

The RAMM database is the primary source of historic investment levels. But the RAMM database does not identify the nature of the work that results in a new pavement or surfacing record. Careful filtering of the database was required to separate out pavement and surfacing renewals from surfacing and pavement records resulting from capital and minor improvement works.

3.2.2 Condition Trends

Analysis of historic trends in the key condition outcomes that are influenced by pavement and surfacing renewal work provided valuable insight into:

- The effectiveness of the current renewals programme. Is the condition trend matching the historic trend in pavement and surfacing renewal cycles?
- Are these trends suggesting that any change to the size of the renewal programme (upwards or downwards) is warranted?
- What is the current condition suggesting about the need for any improvement (or possibly consumption potential)?

3.2.3 Performance of Work Outcomes

The performance of completed works provided a valuable insight into cycle rates that could be expected in the forward programme particularly for resurfacing work. Assessment of cycle rates for pavement renewals is not considered to be very useful as an input for establishing investment programmes.

In the work carried out by the Transport Agency two cycle rates were used in the analysis process. Measured against the current composition of the existing top surface (i.e. the current mix of seal types), the following were calculated:

- The cycle rate based on default seal lives as proposed in Chip Sealing in New Zealand (the chip sealing text book).
- The cycle rate based on the actual life achieved by seals below the current top surface. These were calculated by drilling down through all seals below the top surface down to the original second coat seal.

Assessment of the life achieved from historic RAMM seal records provided evidence suggesting that the life achieved from seals is reducing significantly over time. Changing sealing strategies and improving work quality and treatment selection processes is a mitigation that will be necessary where the proposed investment level falls below the cycle required to sustain current achieved life. Figure 2 illustrates the downward trend in seal life achievement over time.

However, in the Transport Agency work it was also found that the current condition of the top surface is very good largely as a result of sealing that has been carried out to improve SCRIM performance ahead of “end of life”. Some consumption capacity exists and the Agency will continue to carry out SCRIM improvement sealing which is specifically excluded from the base preservation assessment.

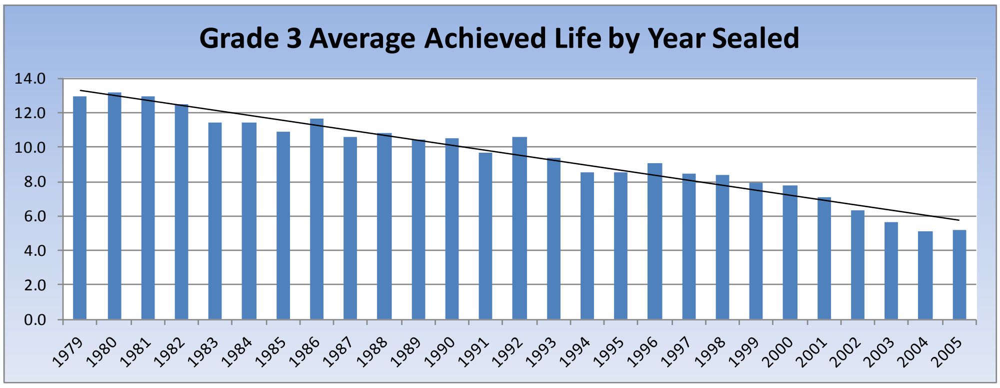


Figure 3 – Historic seal life achievement.

3.2.4 Maintenance Cost History

The Transport Agency records all routine and reactive maintenance activity data in RAMM. This data is used in the pavement deterioration model. Presentation of the maintenance cost history trend for all activities relating to pavement and surfacing maintenance produces similar indicators to condition data. Trends in maintenance costs can be considered against both the renewals investment trends and condition outcome trends as an input into the rationalisation process.

3.2.5 Pavement Deterioration Modelling

Pavement deterioration modelling outputs carried out using dTIMS was a key input into the assessment process. This case study does not provide a detailed coverage of the modelling work, but key aspects are:

a) The Modelling Task

Normally the modelling objective is to maximise network condition within a range of budget scenarios. For this work the modelling objective was to determine the minimum investment level that will sustain the asset over the long term. Essentially this was trying to determine the point where the asset condition becomes unstable.

The modelling also had to address the different level of service expectations and differential levels of risk that apply to the new classifications assigned to the state highway network.

This necessitated changes to both the standard modelling setup, and the reporting outcomes.

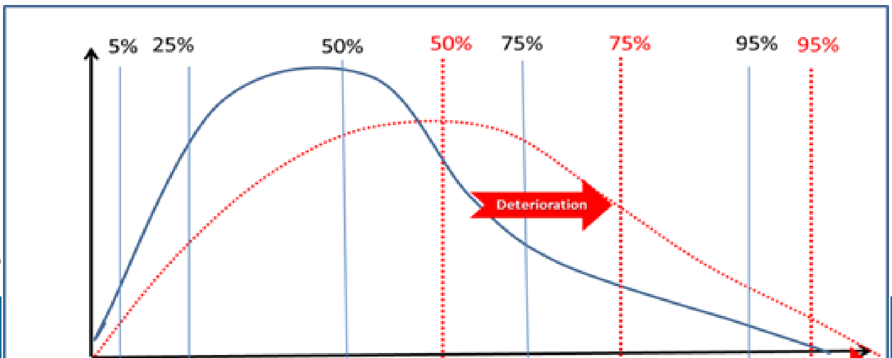
b) Model Changes

Changes carried out to the model setup included:

- Refinement of the routine maintenance cost model
- Removal of the unlimited budget assigned to routine maintenance
- Forcing the model to allow a do nothing option
- Changes on objective functions associated with road classification
- Treatment length optimisation (implemented by limiting the length to 600m maximum).

c) Assessment of Condition Outcomes

Classical condition outcome interpretation is based on analysis of average condition. For this work the analysis focussed on the change in condition distribution and considered primarily changes to the 75th percentile of all condition outcomes. This concept is illustrated in figure 4. Analysis of forecast trends in the 75th percentile condition outcomes was used to determine the level of renewals where it is believed that long term stability is being lost. This is particularly relevant to the Transport Agency analysis because the objective of the modelling work was to determine the base preservation quantities. The minimum renewal investment required to maintain the integrity of the asset without loss of stability.



An example illustrating how the 75th percentile provides an indication of condition outcomes that may not be apparent when considering average values is provided in figure 5.

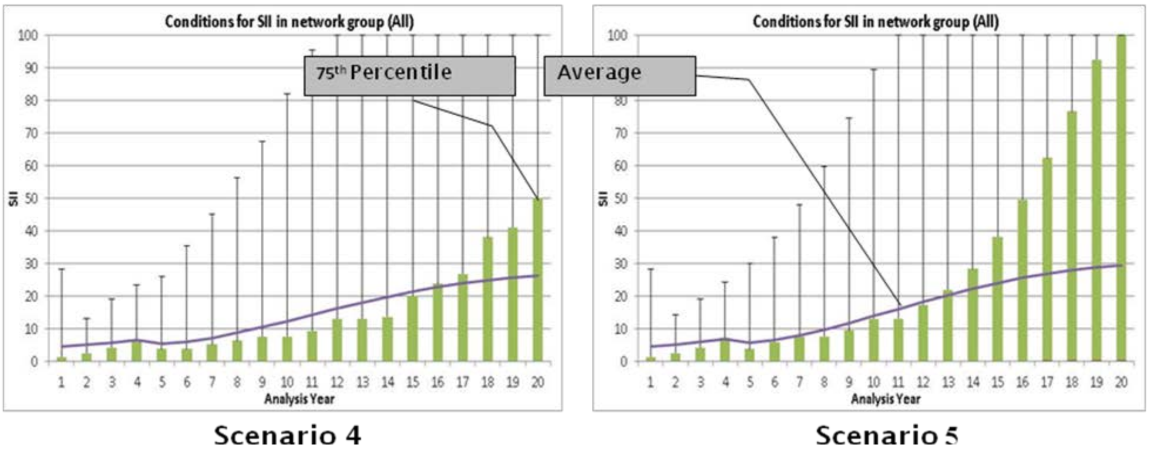


Figure 5 Illustrating average versus 75th percentile condition outcomes

d) Engineering judgement

Having assembled and analysed all of the input data, the data was then subjected to engineering judgement. A Delphi panel was briefed on the basis for all of the inputs and what analysis of these had disclosed, then network by network debated the target values until consensus was reached.

Examples of the graphical representations of the inputs considered by the Delphi panel are included in the appendices.

e) Finalisation of Outcomes

The process described has established an expectation level for the Base Preservation quantities to be used in the contracts. The final stage before finalising the quantities is a more detailed regional assessment of the forward works programme based on the expectation levels established through this analysis stage.

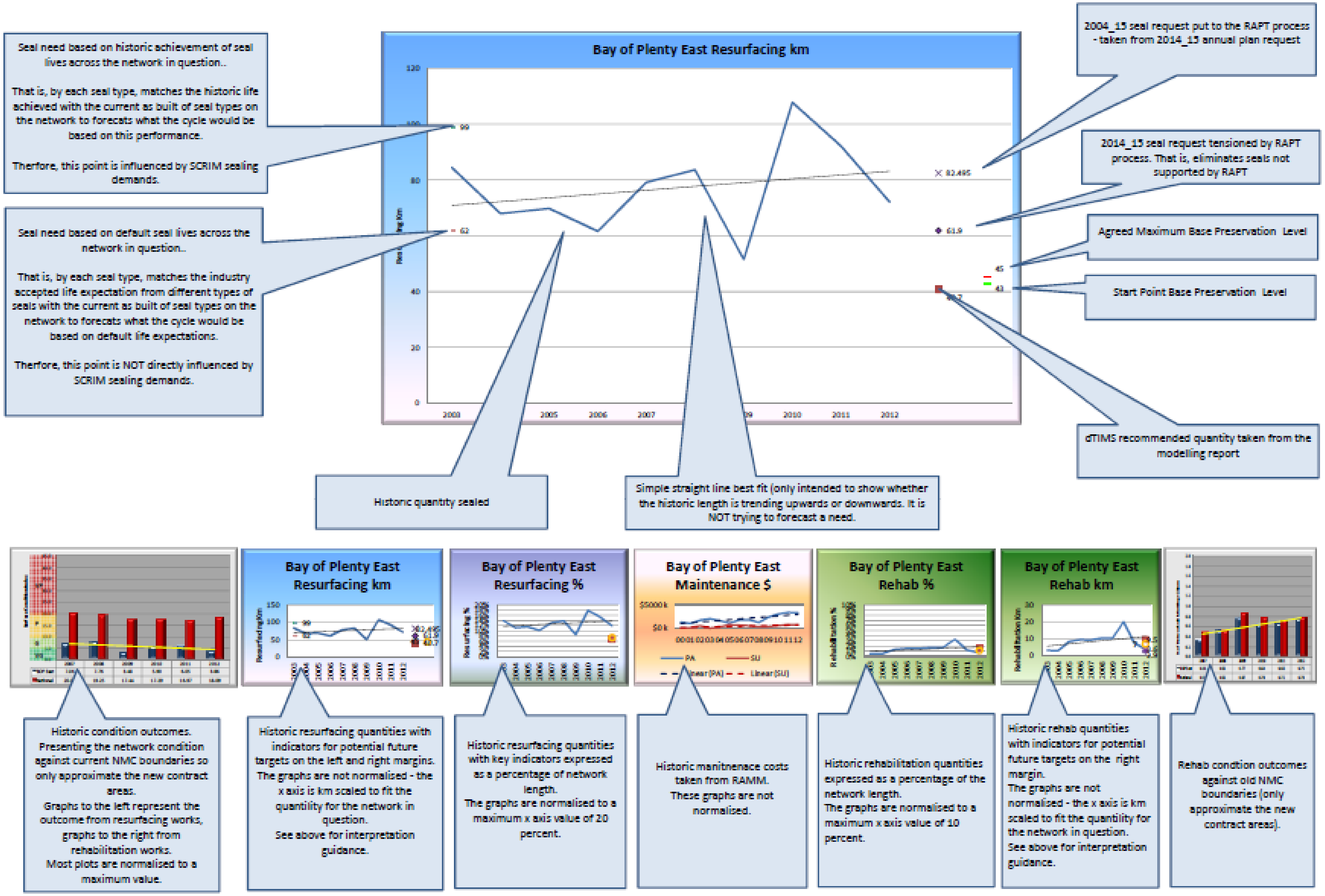
4 Recommendations

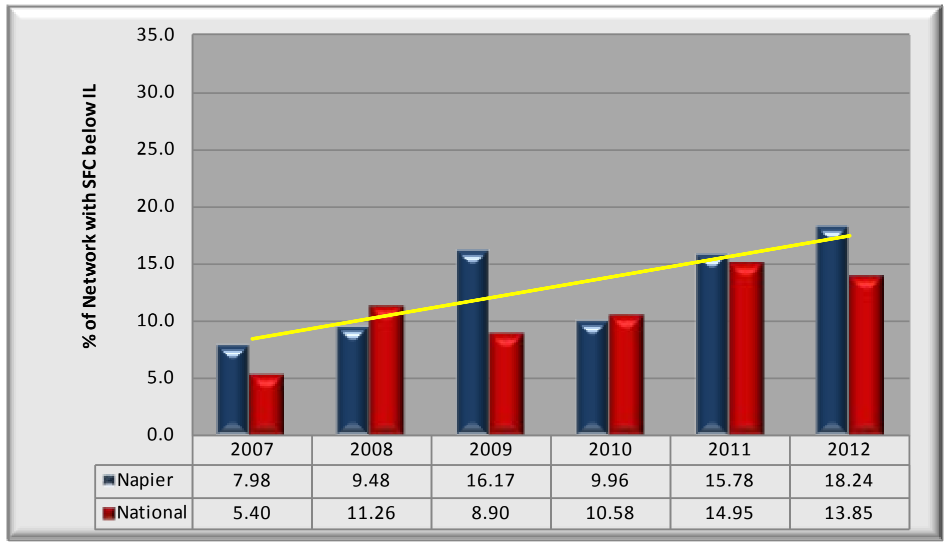
Specific Recommendations	Suggested Action to be Taken
Forward Works Programmes needs to be developed on the basis of an integrated approach using both deterioration modelling and other inputs, to determine the strategic needs, and prioritisation to confirm the short-term detail works programmes.	Advocacy within the industry
Request the RIMS Group to advance the project to develop specific guidelines on the development of optimised works programmes	Request to RIMS
Roading practitioners are encouraged to use the industry tools to achieve the outcomes as discussed in this document.	The need to achieve some enhancement to integration capability should be discussed with RIMS and IDS.
Note that the Transport Agency will produce further practice note detailing the results of the verification work that is being carried out to test the validity of the outcomes of the work detailed in this paper.	Note that an update on the validation work is expected.

Appendix A: MNO Analyses Outcomes

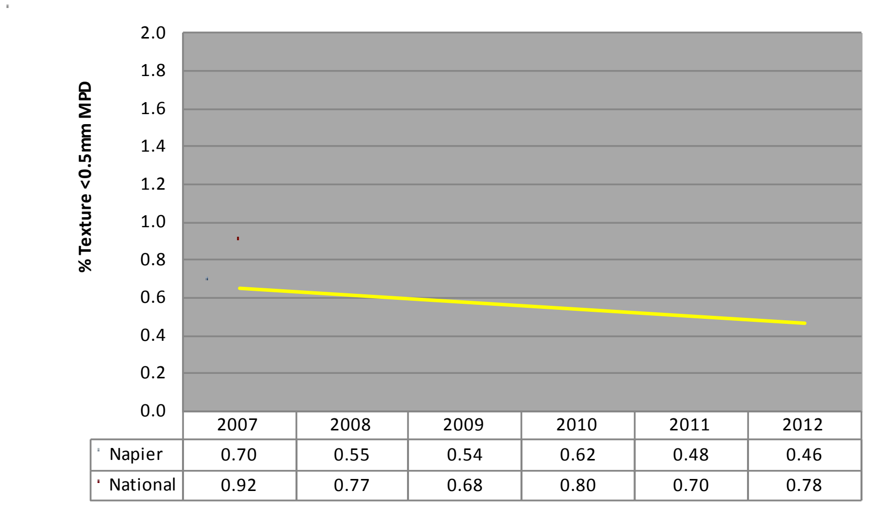
The following graphs are included as A3 landscape sized appendices.

1. Key for interpreting graphs
2. Example summary presentation of Resurfacing Renewal need
3. Example summary presentation of Pavement Renewal need
4. Explanation of potential error sources

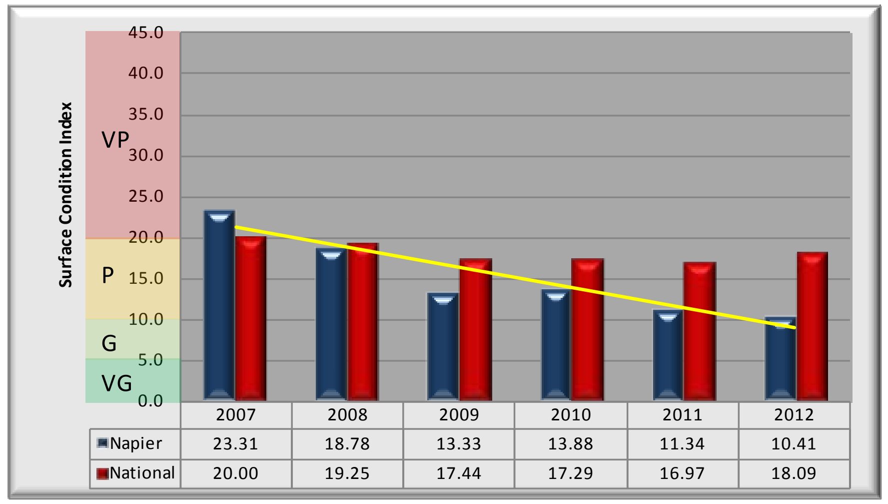

Bay of Plenty East Resurfacing km
Seal need based on historic achievement of seal lives across the network in question..
That is, by each seal type, matches the historic life achieved with the current as built of seal types on the network to forecasts what the cycle would be based on this performance.
Therfore, this point is influenced by SCRIM sealing demands.
Seal need based on default seal lives across the network in question..
That is, by each seal type, matches the industry accepted life expectation from different types of seals with the current as built of seal types on the network to forecasts what the cycle would be based on default life expectations.
Therfore, this point is NOT directly influenced by SCRIM sealing demands.
2004_15 seal request put to the RAPT process - taken from 2014_15 annual plan request
2014_15 seal request tensioned by RAPT process. That is, eliminates seals not supported by RAPT
Agreed Maximum Base Preservation Level
Start Point Base Preservation Level
dTIMS recommended quantity taken from the modelling report
Historic quantity sealed
Simple straight line best fit (only intended to show whether the historic length is trending upwards or downwards. It is NOT trying to forecast a need.
Bay of Plenty East Resurfacing km
Bay of Plenty East Resurfacing %
Bay of Plenty East Maintenance $
Bay of Plenty East Rehab %
Bay of Plenty East Rehab km
Historic condition outcomes. Presenting the network condition against current NMC boundaries so only approximate the new contract areas.
Graphs to the left represent the outcome from resurfacing works, graphs to the right from rehabilitation works.
Most plots are normalised to a maximum value.
Historic resurfacing quantities with indicators for potential future targets on the left and right margins.
The graphs are not normalised - the x axis is km scaled to fit the quantility for the network in question.
See above for interpretation guidance.
Historic resurfacing quantities with key indicators expressed as a percentage of network length.
The graphs are normalised to a maximum x axis value of 20 percent.
Historic manitnenace costs taken from RAMM.
These graphs are not normalised.
Historic rehabilitation quantities expressed as a percentage of the network length.
The graphs are normalised to a maximum x axis value of 10 percent.
Historic rehab quantities with indicators for potential future targets on the right margin.
The graphs are not normalised - the x axis is km scaled to fit the quantity for the network in question.
See above for interpretation guidance.
Rehab condtion outcomes against old NMC boundaries (only approximate the new contract areas).



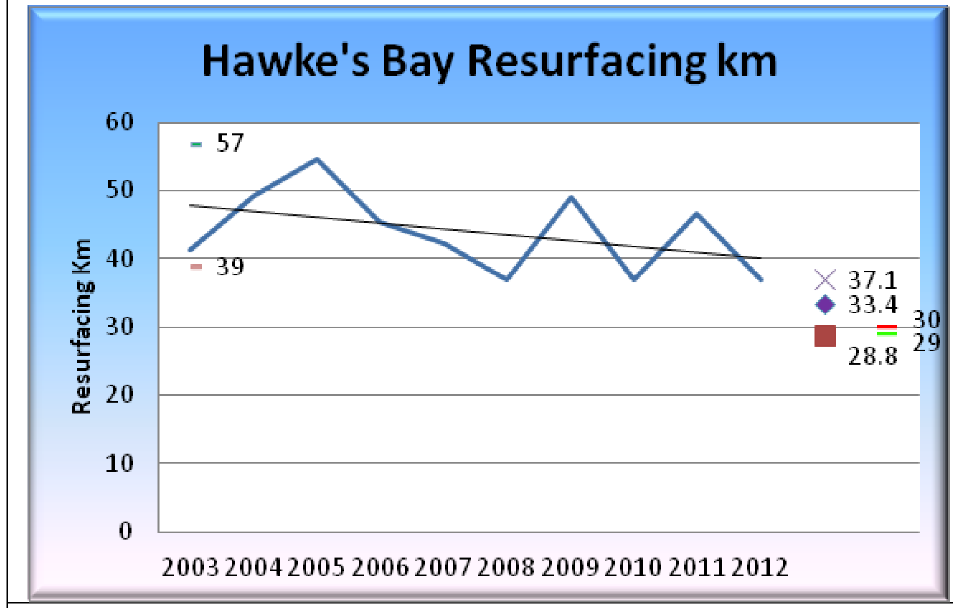
	2007	2008	2009	2010	2011	2012
Napier	7.98	9.48	16.17	9.96	15.78	18.24
National	5.40	11.26	8.90	10.58	14.95	13.85

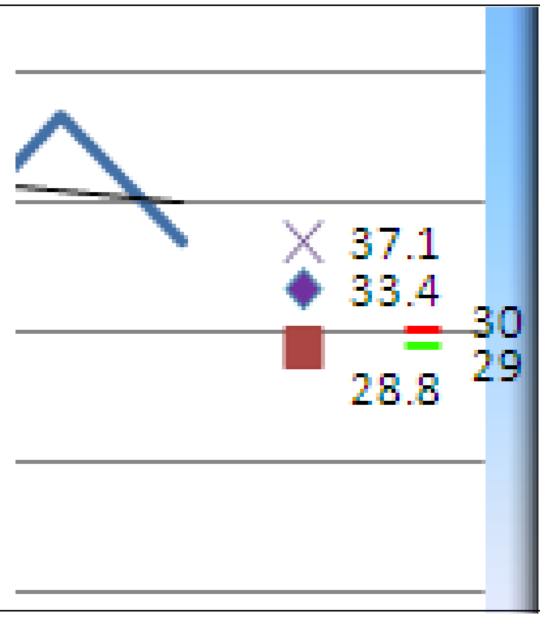


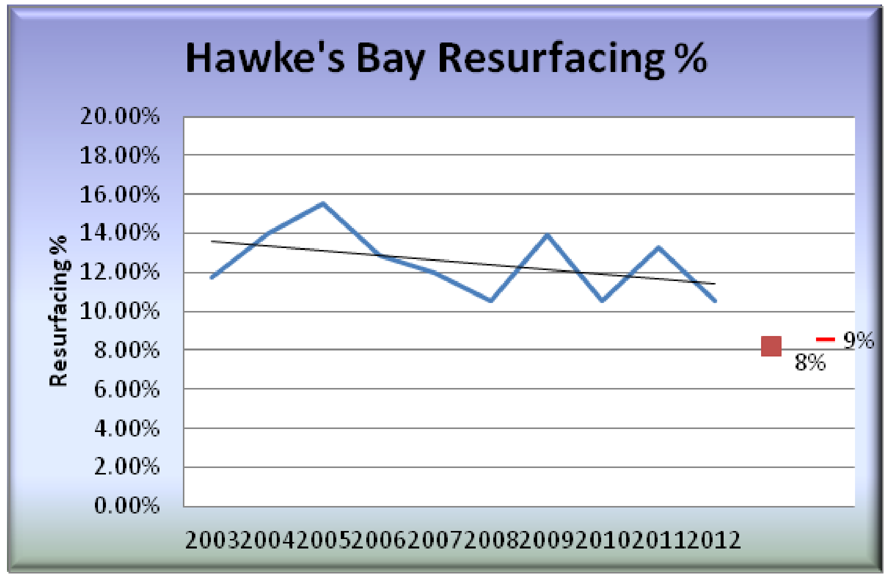
	2007	2008	2009	2010	2011	2012
Napier	0.70	0.55	0.54	0.62	0.48	0.46
National	0.92	0.77	0.68	0.80	0.70	0.78



	2007	2008	2009	2010	2011	2012
Napier	23.31	18.78	13.33	13.88	11.34	10.41
National	20.00	19.25	17.44	17.29	16.97	18.09



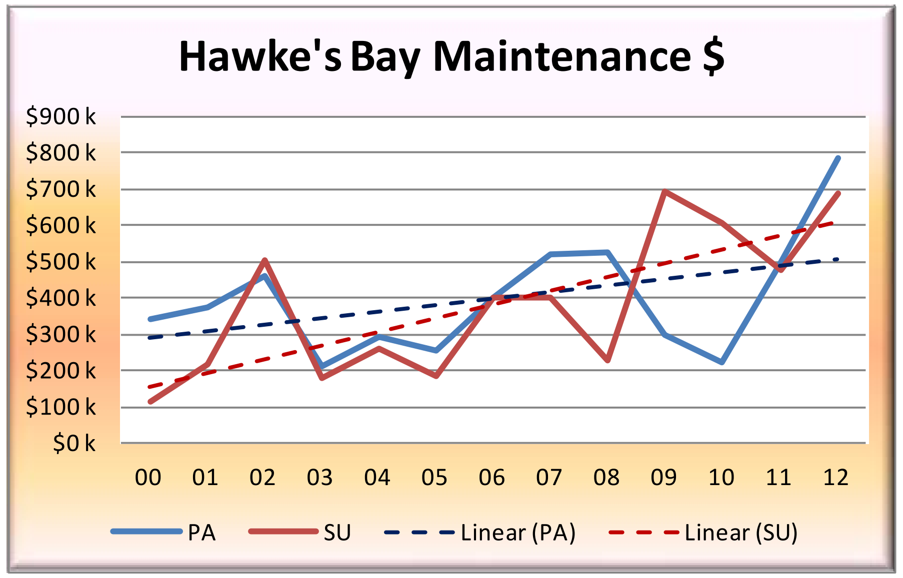




Good performing network, with a significantly improving surface condition – but reseal rates are relatively high.

It appears that SCRIM input will be required

Note that the surface routine cost has been increasing



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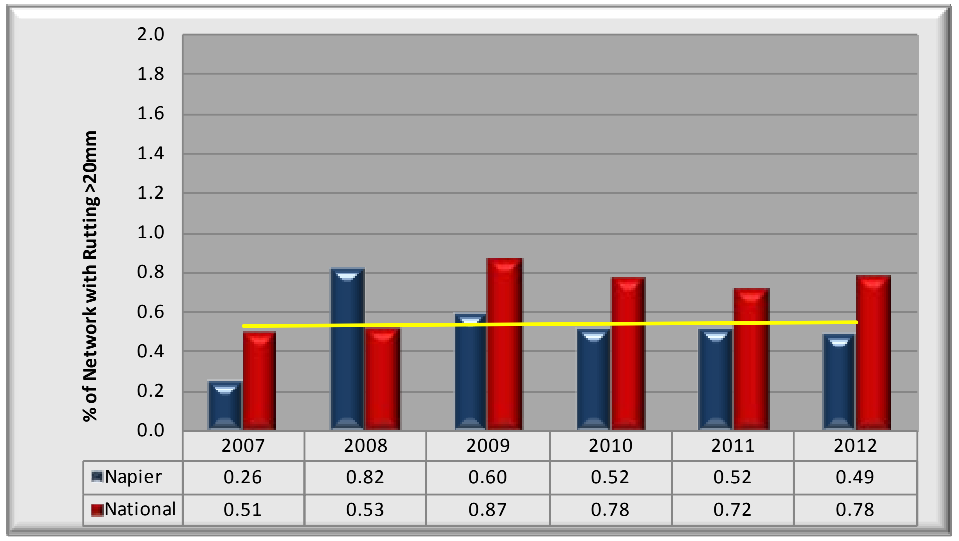
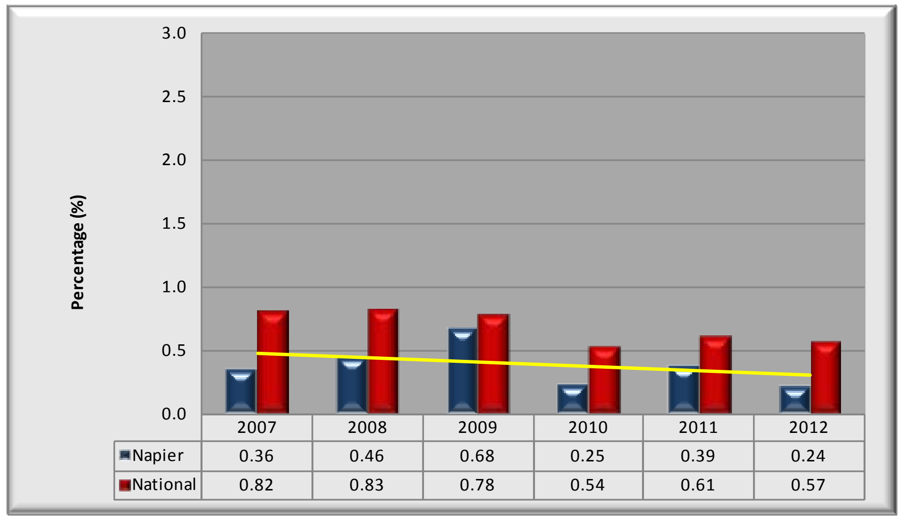
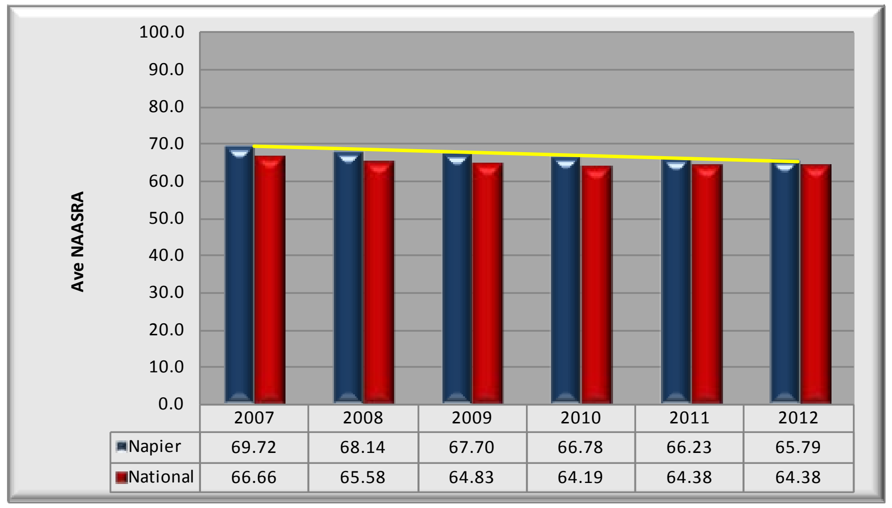
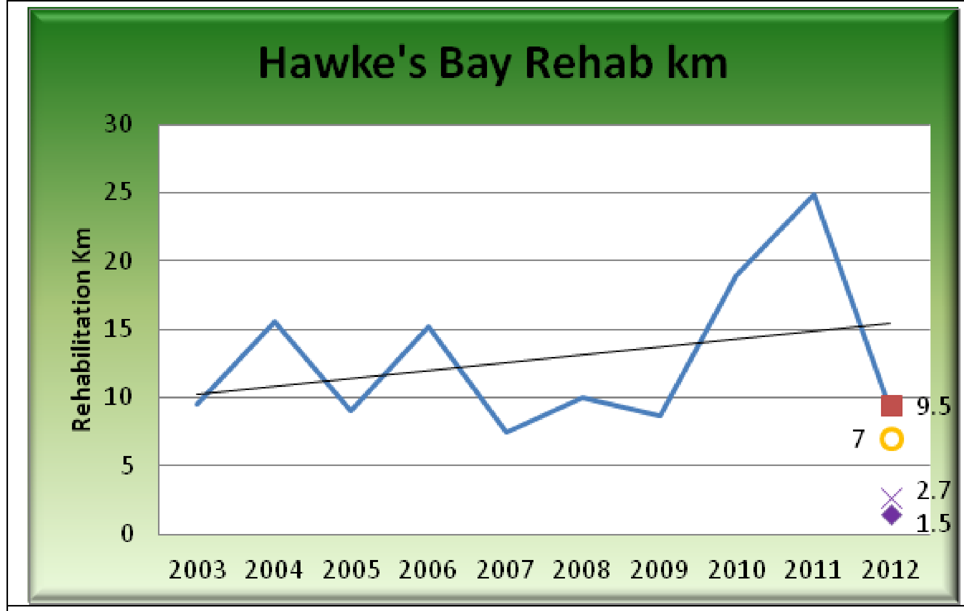
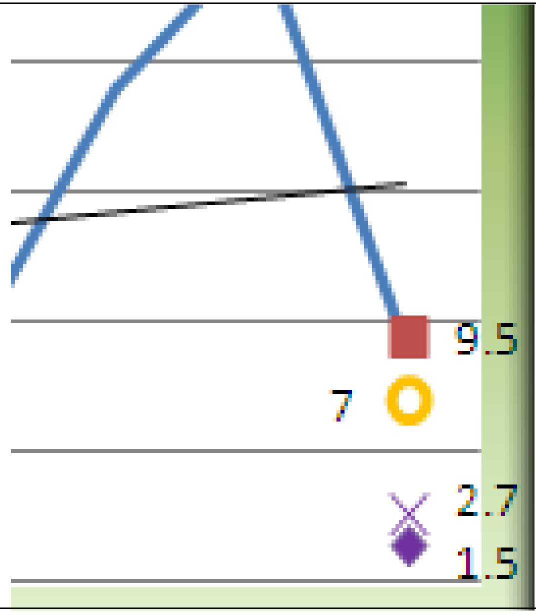
Appendix 2 – Example Summary Presentation of Reseal Renewal Need

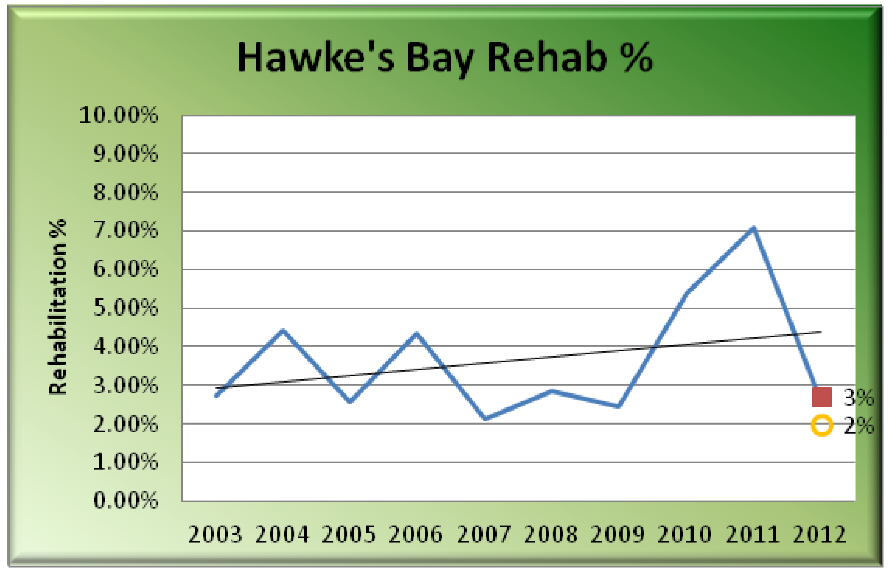








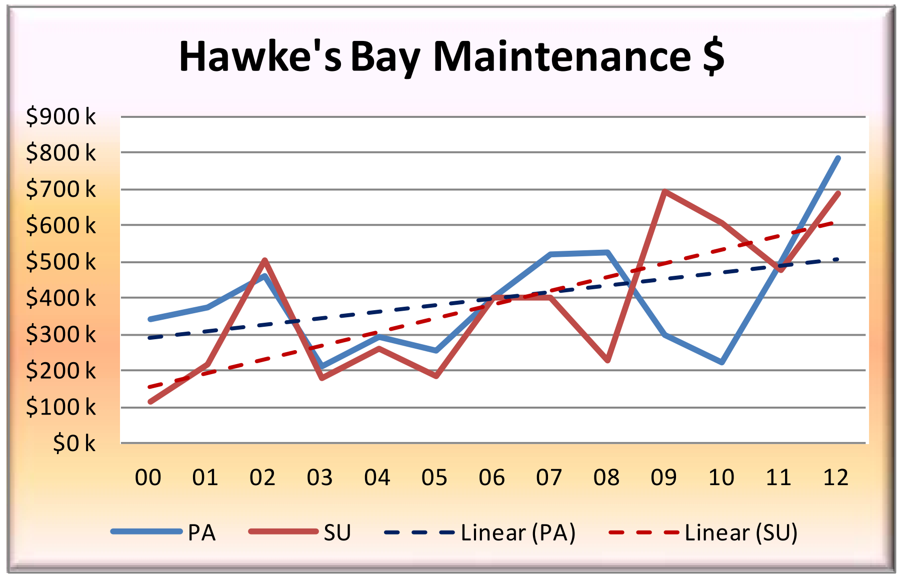


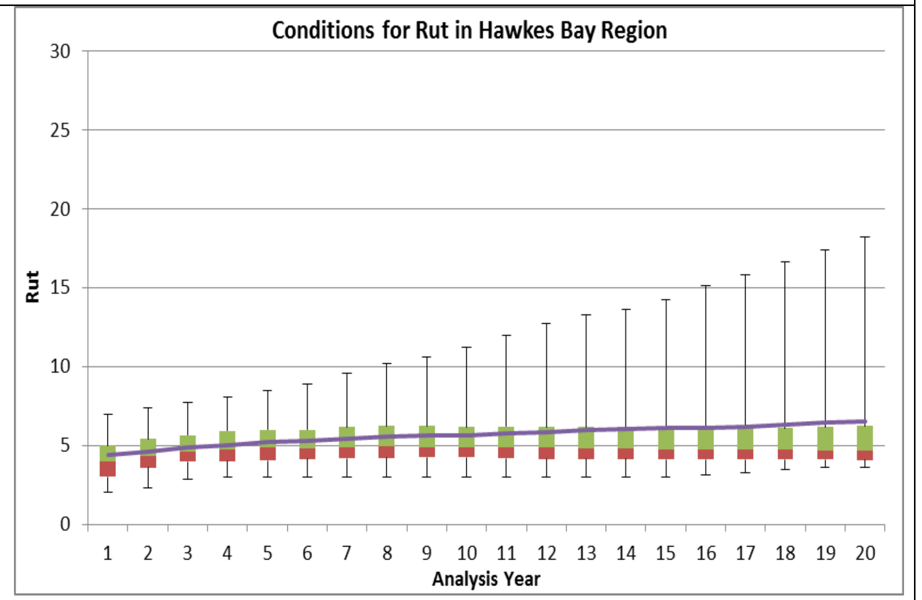


Condition appears stable but maintenance costs are increasing.

The rutting 95th percentile is increasing – but mostly relates to lower class roads.

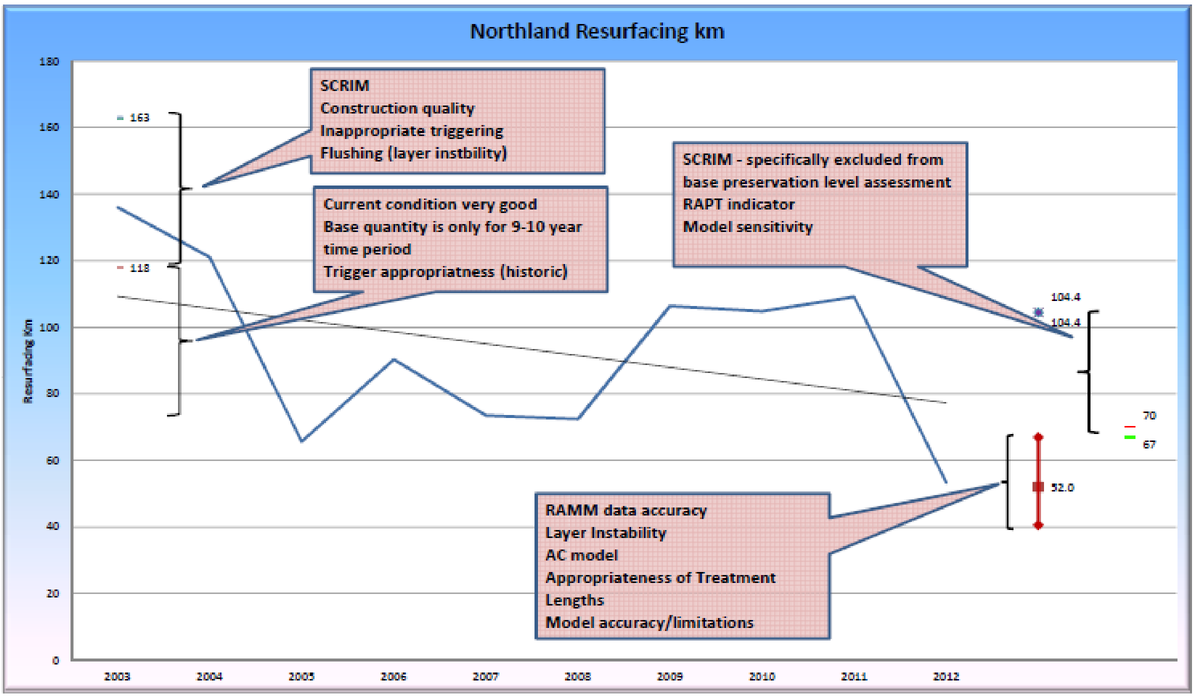
Caution on tensioning modelling outcomes too much.





Appendix 3 – Example Summary Presentation of Pavement Renewal Need

Sensitivities and Error Sources



Appendix 4 – Sensitivities and Error Sources

Appendix B: Theoretical Comparisons for Optimised programme versus Worse First

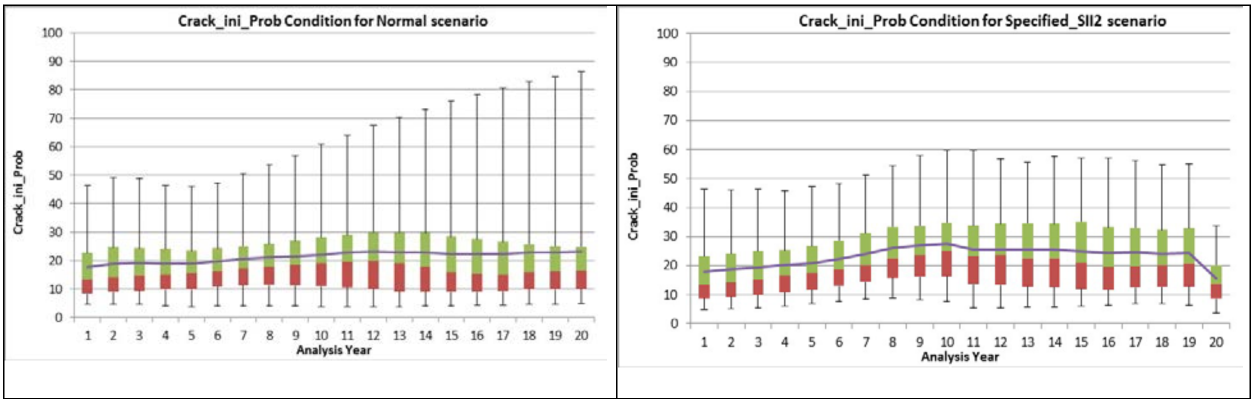
Methodology

The Transport Agency's Marlborough network was used for this study. It is the smallest SH network in NZ with 803 treatments lengths, and a total network length of 287.6 km. The budget used for the analysis is $1.5m, which is slightly higher than the minimum budget required to fund the sum of the least cost strategies.

Strategies were generated for an optimised renewal programme, and a trigger based model implemented to approximate a worst first strategy. The outcomes are presented in the graphs and commentary that follows.

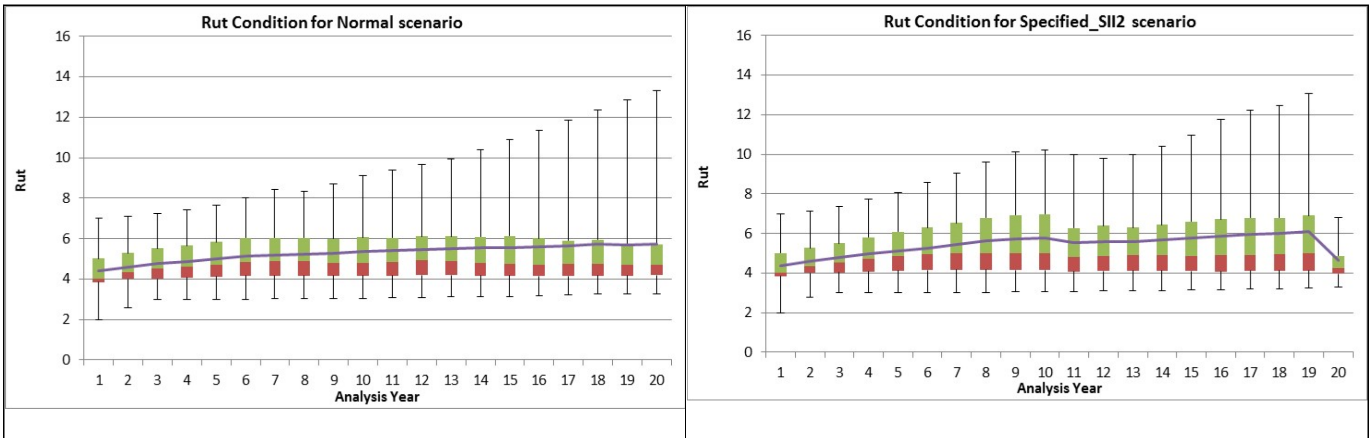
Performance Outcome

The following figures illustrate the outcomes of the condition for both surfaces and pavements.



Optimised Programme Surfacing Programme	Worse First surfacing programme

4 **Figure 2: Comparing the forecasted surfacing Performance**



Optimised Programme Pavement Programme	Worse First Pavement programme

5 **Figure 3: Comparing the forecasted Pavement Performance**

The figure illustrate expected results which are not dissimilar to comparative results of annual analyses when comparing dTIMS analysis to field programmes, that is largely based on a worse first approach. Overall the extreme conditions (95th percentiles) for both the forecasted surface and pavement conditions are better when following a worse first approach – that is, sections with the extreme conditions are treated first. However for the bulk of the network (i.e. considering the 75th percentile) the optimised programme is able to maintain better conditions for both the forecasted pavement and the surface condition.

Cost Comparison Outcome

The difference in these two planning approaches is not only observed in the condition outcomes, it is also further evident in the resulting routine maintenance cost. The average routine maintenance cost for the optimised programme over the 20-years analysis is 80% that of the worse first routine maintenance costs. This related to 10% overall investment cost savings arising from the optimal programme when considering both the routine maintenance costs and the renewal costs.