HOW TO RUN A SUCCESSFUL LONG-TERM PERFORMANCE BASED NETWORK MAINTENANCE CONTRACT - *An Analysis of the North Auckland State Highway Network Performance Specified Maintenance Contract 005 (PSMC 005)*

Abstract

Network PSMCs are being rolled out across all states in Australia. The PSMC environment drives the contractor to find innovative solutions to reduce costs and increase margins. The use of Asphalt surfaces represents one of the most beneficial work groups when developing an optimal forward work programme, either by way of innovative materials and technologies, treatment timing or maintenance techniques.

The North Auckland network contract (PSMC005), which has been managed successfully for the past 10 years, represents a wealth of knowledge that provides valuable insight into the issues surrounding the setting up and running of PSMC's.

This paper will aim to capture that knowledge. It will present the history surrounding the Contract setup and the Key Performance Measures (KPM's) incorporated into the specifications. It will discuss the development of the optimised pavement maintenance strategy and the subsequent network performance over the contract period. Other contract management issues will also be discussed to demonstrate how PSMC005 required an integrated approach to ensure its success.

1. Background

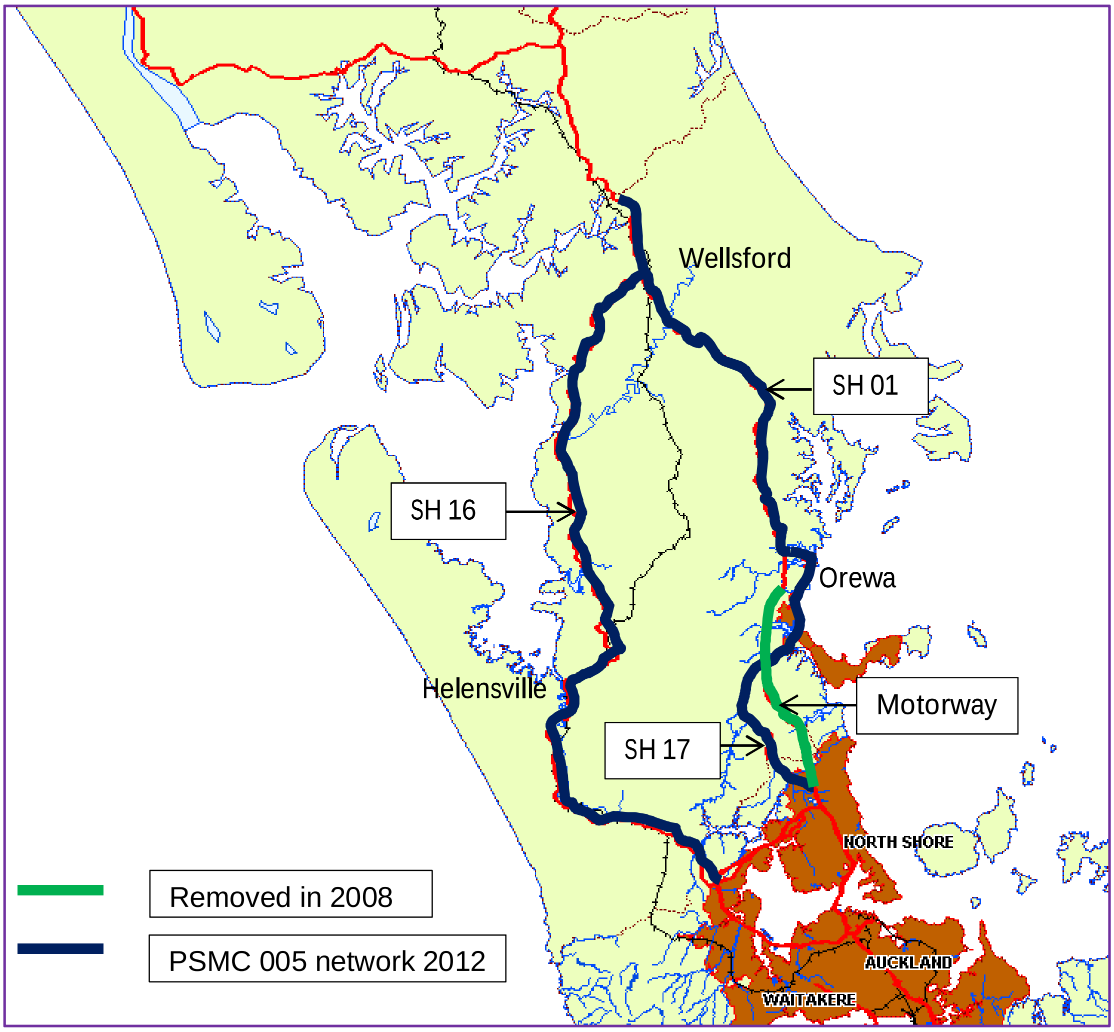
The New Zealand Transport Agency (NZTA) is the controlling and funding authority for State Highways in New Zealand (NZ) that total approximately 11,000 km in length and are divided into approximately 25 network management areas. Each management area administers two or three network maintenance contracts. Traditionally these contracts were procured on a measure and value basis and contractor activities for all but routine maintenance were controlled by the Network Management Consultant working in behalf of the NZTA. At the time of letting PSMC 005 the NZTA's predecessor Transit New Zealand was the State Highway road controlling authority (RCA), however, for the sake of simplicity NZTA will be referred to as the RCA throughout this paper.

Performance Specified Maintenance Contracts (PSMC's) were introduced as an alternative maintenance model for New Zealand State Highway networks in 1999. PSMC 005 was let in 2003 at which time approximately 10% of the NZ state highway network maintenance budget was expended through PSMC contracts. PSMC 005 was a ten year contract and was completed in March 2013.

2. Location

PSMC 005 was located to the north and north east of the City of Auckland and included a section of the Auckland Northern Motorway from Albany to Silverdale, (see Figure 1).

Figure 1 – Extent of PSMC 005 Contract



3. Description of the Network

3.1. Extent

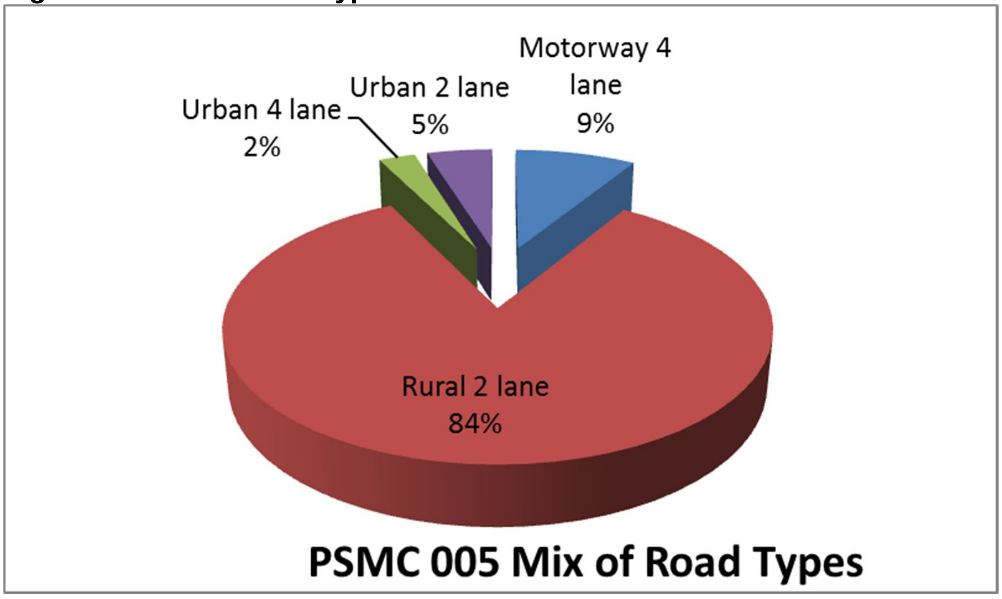
The network originally consisted of approximately 422 lane km but this was reduced to 361 lane km in October 2008 after the Northern Gateway project was completed and the Auckland Motorway Alliance took control of the motorway section between Orewa and Oteha Valley Road.

3.2. Environment

The network consisted of rural two lane highways while the urban highways were a mixture of two and four lanes. The motorway was four lanes with short sections of five lanes. The mix of highway types is shown in Figure 2.

The climate is temperate (oceanic) with monthly rainfall varying from 65 – 145 mm.

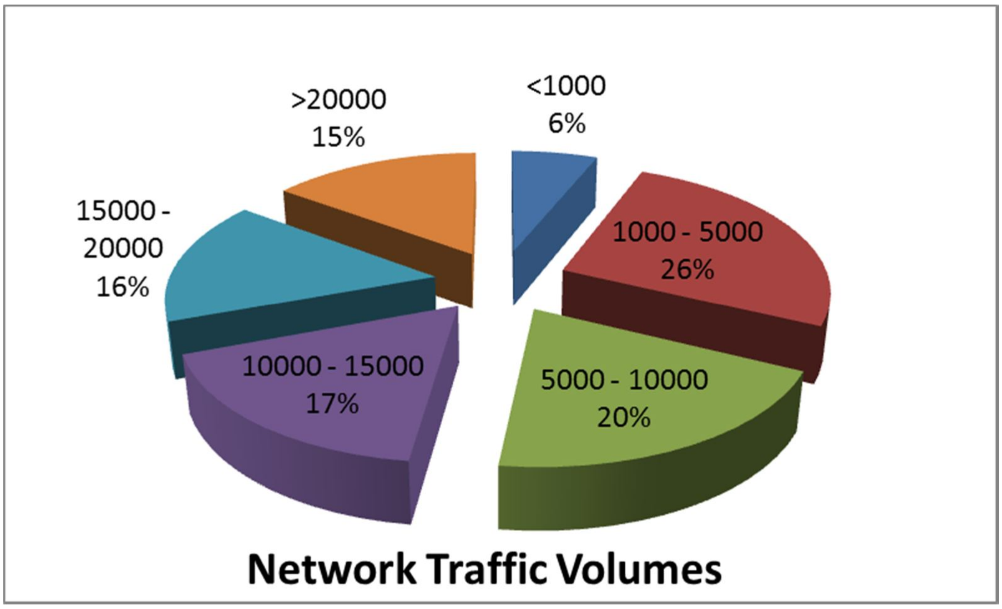
Figure 2 – Mix of Road Types



3.3. Traffic

The network was relatively heavily trafficked with only 32% of the length having a traffic volume less than 5000 vpd. The remainder of the network had a relatively even spread of traffic volumes from 5000 – 30000 vpd, (see Figure 3). The traffic growth rate was approximately 2% per annum and the percentage of HCV's varied from 5% in the urban sections to 15% in the rural areas.

Figure 3 – Network Traffic Volumes



3.4. Physical Pavement Assets

Pavement

All pavements in the PSMC 005 network were unbound granular (UBG) pavements with various aggregates from differing sources in the district ranging from weak Waitakere andesite's in the west to the stronger greywacke aggregates from the north. The motorway sections of pavement had been constructed with lime stabilised subgrades and others parts of the network had cement modified basecourse layers, which had been constructed as rehabilitation treatments.

The section of SH01N north of Orewa has some of the most heavily trafficked two lane highway in the country with thin surfaced flexible pavement carrying 10,000 - 18,000 vehicles per day (vpd) with 7 – 10% heavy commercial vehicles (HCV's). SH16 between Helensville and Wellsford also brought challenges in regard to sections of fragile pavement that were experiencing steadily increasing loads from heavy traffic and in particular logging trucks.

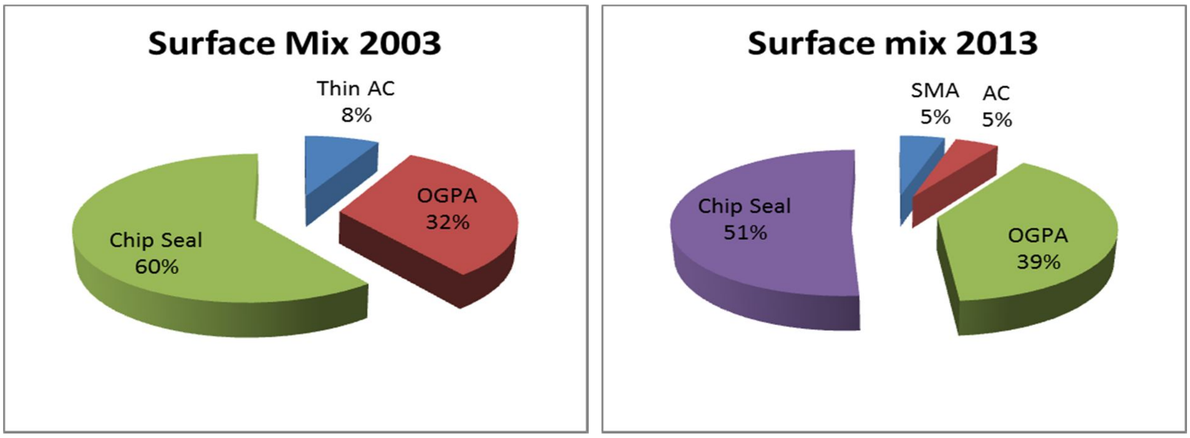
Surfacing

In 2003 the surfaces were primarily either chip seal for the lesser trafficked highways (SH 16, SH 17, north SH01) or open graded porous asphalt (OGPA) over a chip seal for the heavier trafficked highways (south SH01, motorway). Chip seals were typically two coat grade 5/3 (10mm/16mm) reseals and second coats. The OGPA was typically a 14mm top size mix and there were short sections of thin asphaltic concrete (AC) with a 15 – 20mm top size mix in some urban situations.

Over the 10 year period of the contract there was a trend away from the chip seals for the sections of SH 01 that carried greater than 10,000 vehicles per day (vpd) because the client had specified the need for OGPA on the heavily trafficked sections of highway to improve ride and reduce water spray and noise. Stone mastic asphalt (SMA) was introduced to replace OGPA on sections of heavily trafficked highway with steep grades and tight curves because of its superior stability. SMA was also used to replace existing AC 14 in places because of the greater macrotexture that could be achieved.

The mix of surface types at the start and end of the contract is shown in Figure 4.

Figure 4 – Mix of Surface Types



4. Historical Maintenance Information

Records for pavement rehabilitation and surfacing have been kept in the Road Asset and Maintenance Management (RAMM) database since the early 1990's and maintenance costs since 1998/99.

4.1. Previous maintenance contract types

Prior to 1988, NZ State Highways were managed and maintained on behalf of the National Roads Board by the Ministry of Works and Development (MWD). Maintenance work was usually carried out as day labour with some surfacing and rehabilitation work carried out by contract. Capital works were also carried out by MWD or contractors. In 1988 the Ministry of Works was corporatized and the National Roads Board became Transit New Zealand (TNZ) in 1989. At approximately this time all maintenance work was outsourced to contractors. The contracts used from 1989 until the PSMC could generally be described as measure and value contracts which were administered by a Network Management Consultant (NMC) on behalf of TNZ. The NMC to a large extent controlled what work was carried out on the network.

4.2. Maintenance Records

General (routine and reactive) maintenance costs for the NZ State Highway network have been recorded since 1998/99 and recorded in the RAMM database. The costs reported later in this paper have been adjusted to remove the influence of inflation and different rates for maintenance work between the different contracts.

Pavement construction, rehabilitation and resurfacing records in the RAMM database date back to 1970's. Records prior to 1990 were extracted from paper records and vary in quality and completeness, although resurfacing records are generally good.

5. Maintenance Delivery Environment

5.1. Contract form and delivery team structure

Description

The PSMC concept is quite simple – the contractor maintains the road network over a relatively long time period, to a set standard, for a lump sum amount. The lump sum is paid out in equal monthly amounts. The contract is underpinned by minimum quantities of pavement rehabilitation and resurfacing treatment to provide confidence for the client that the asset will be preserved. The contractor sets these quantities in the tender document.

Commercial framework for pain/gain

The NZTA contract had no mechanism for pain/gain as generally found in alliance contracts. There were no financial penalties specified for not meeting the KPM requirements of the contract, however, the contract could be cancelled if the contractor proved to be incapable of meeting those requirements. This effectively provided a large financial incentive for the contractor to succeed in meeting the specified performance levels because the cost to establish for the contract had to be recouped over the

10 year period of the contract and this would be lost if the contract did not continue for the full contract period.

The PSMC 005 lead contractor made the decision to set up a collaborative team to tender and deliver the contract. The three parties who were considered key to the delivery of the contract provided services at minimum cost and shared in any profit annually. The functions of each party included the following:

- Lead Contractor – Client liaison, public relations, general maintenance and pavement rehabilitation (significant subcontractor involvement in rehabilitation).
- Surfacing Contractor – Chip seal and asphaltic concrete surfacing design and construction.
- Professional Services – Road asset management, pavement design, traffic engineering, safety improvements, network inspection and annual planning inputs.

All three parties were involved in the determination of the forward work programme for the 10 year contract period and agreed the degree of risk needing to be priced. There was a fine balance between pricing too much risk and not winning the contract, or providing for too little risk and losing money. Also a major factor in the tender process was to provide the client with confidence that the level of rehabilitation and resurfacing proposed was adequate to preserve the asset.

Other specialist sub-contractors, (e.g. pavement stabilisation) and material supply contracts were procured on the basis of sole source contracts. These sub-contractors had to perform well to keep the sole source supply.

NZTA Objectives

The PSMC form of contract was introduced by the NZTA to compare outcomes with traditional and hybrid contracts. The main drivers appear to have been:

- Reduce the cost of highway maintenance
- Provide a level of performance that would satisfy road users
- Provide funding certainty
- Provide confidence that the asset is being preserved

Network objectives/outcomes

The client objectives were for the network to deliver a desired level of service, similar to that existing prior to the PSMC contract, with safe and satisfied users of the highways in the network. The outcomes required were those set in the KPM's to be met annually.

The Contractor objectives were closely aligned with those of the client and every effort was made to collaborate with the client and have all parties in a team environment. It was recognised by all parties that litigious or adversarial behaviour would not achieve the objectives of the contract.

During the tender period the Contractor Team Leader stated that the objective was to provide sound road asset management practice and if that was achieved the KPM's should easily be met.

Procurement method

The NZTA pro-forma for PSMC contract documents was well established at the time of the PSMC 005 tender and the bidding process was regarded as one of the most successful in the world [1]. One of the major requirements for a successful PSMC contract is that it includes a robust bidding process and contract document. The PSMC 005 contract document was open to interpretation in places but it did cover off the major risk items.

The PSMC 005 was competitively bid on a weighted price/attributes basis. The Contractor was expected to predict the need for resurfacing and rehabilitation and the routine and reactive maintenance required to meet the specified key performance indicators (KPM's) and take most of the risk for predicted pavement behaviour over the 10 year contract period. The client took the risk for increased traffic loading above a specified amount and for slips that moved greater than 100mm per year. The maintenance of bridge structures was not included in the contract other than for cleaning drainage outlets, etc.

5.2. Performance Specification Setup (Pavements)

Network Objectives/Outcomes

The development of the KPM's was carried out by the client prior to the time of tender. The network was split into 5 sub-networks (SN) based on the hierarchy of the highway and maintenance regime as follows:

- SN 1 – Motorway, very heavily trafficked pavement with stabilised subgrade, UBG pavement and OGPA surface.
- SN 2 - Rural two lane (pockets of urban), very heavily trafficked, UBG pavement and OGPA surface
- SN 3 - Rural two lane (pockets of urban), heavily trafficked, UBG pavement and chip seal surface
- SN 4 - Rural two lane (pockets of urban), lightly/moderately trafficked, UBG pavement and chip seal surface
- SN 5 – Urban/rural mix, heavily trafficked, UBG pavement, mixture of AC, OGPA and chip seal surfaces

The sub-networks are shown in Table 1.

Table 1 – PSMC 005 sub-networks

State Highway	Description	Sub-Network	Location	
			Start Route Position	End Route Position
01N	Ross Rd - Wellsford	3	RS 336	RS 346
01N	Wellsford - Warkworth	3	RS 346	363/2.344
01N	Warkworth - Puhoi	2	363/2.344	373/7.928
01N	Puhoi - Silverdale	2	373/7.928	RS 398
01N*	Silverdale - Oteha Vly	1	RS 398	398/11.53
01A*	Silverdale - Orewa	1	RS 0	RS 6

State Highway	Description	Sub-Network	Location	
			Start Route Position	End Route Position
016	Huapai - Kaukapakapa	3	19/10.255	47/11.132
016	Kaukapakapa - Wellsford	4	47/11.132	RS 107
017	Silverdale - Greville Rd	5	RS 16	RS 33

* Removed in October 2008

The objectives of the KPM's was to give the client some certainty that the level of service provided to the road users was not diminished during the contract and that the pavements in the network had a similar average remaining life at the end of the contract when compared to the start.

KPM Development

The KPM's were based around the following desired outcomes:

- Operational – e.g. pothole filling, drainage cleaning, litter, vegetation control, etc.
- Functional - e.g. ride, rutting
- Structural - e.g. average granular overlay for 25 year life, minimum cumulative rehabilitation and resurface quantities
- Safety – e.g. macro texture, skid resistance, signs and markings

The method used to determine the pavement KPM values seemed not to be very sophisticated. The KPM's for each SN reflected the existing conditions prior to hand over to the PSMC contractor. A benchmark survey was carried out at the beginning of the contract and the KPM's set in the tender documents were adjusted on the basis of the results.

The pavement related KPM's specified average values to be obtained for each SN and also restricted the total length that could exceed a maximum or minimum value. This prevented the Contractor from reaching the desired average KPM value by balancing very poor sections with very good sections of pavement.

A brief summary of the KPM requirements is as follows:

- Roughness – Measured as NAASRA counts/km (NAASRA) and reported at 20m intervals.
  - Mean NAASRA
  - Percentage with Roughness > NAASRA Threshold
    - Sub-Network 1 >100
    - Sub-Network 2 >110
    - Sub-Network 3 >120
    - Sub-Network 4 >130
    - Sub-Network 5 >120
    - Urban > 150

Readings with certain event codes, e.g. "Railway Crossing" were excluded

- Texture – Measured as mean profile depth (MPD) for each wheel path and reported at 10m intervals.
  - Minimum Mean Texture Depth for Chip Seal Surfaces
  - Minimum Mean Texture Depth for Asphaltic Surfaces
  - Maximum Percentage Wheel Path with Mean Texture Depth < 0.5mm for Chipseal Surfaces
  - Maximum Percentage Wheel Path with Mean Texture Depth < 0.5mm for Asphaltic Surfaces
- Skid Resistance Measured as Equilibrium SCRIM Coefficient (ESC) for each wheel path using a SCRIM machine and reported at 10m intervals.
  - Skid Resistance (Site Category 1) - Maximum Percentage with ESC < 0.45
  - Skid Resistance (Site Category 2) - Maximum Percentage with ESC < 0.40
  - Skid Resistance (Site Category 3) - Maximum Percentage with ESC < 0.35
  - Skid Resistance (Site Category 4) - Maximum Percentage with ESC < 0.30
  - Skid Resistance (Site Category 5) - Maximum Percentage with ESC < 0.25
- Rutting – Measured as rut depth in each wheel path and reported at 20m intervals
  - Percentage Wheel Path with Depth > 20mm
- Surfacing
  - Surfacing Life Index*****
  - Minimum Resurfacing Length
- Structural Condition
  - Structural Condition Index******
  - Minimum Rehabilitation Length
- Network Safety Calculations
  - Network Safety Index

* The Surfacing Life Index was the average remaining life of the surfaces based on a table of expected surface life cycles determined by surface type and traffic volume.

** The Structural Condition Index was determined every 3 years from a network FWD survey and back analysis to determine the theoretical volume of granular overlay required to bring every treatment length to a minimum 25 year life based on AUSTROADS subgrade strain criteria.

There KPM resets used in modelling of the pavement performance for the network after a treatment were decided by the Contractor during the tender period. These had to accurately reflect what the Contractor could consistently achieve during the contract period. Examples of some of the resets used are shown in Table 2.

Table 2 – Examples of KPM Resets

Treatment	Surface	KPM	Reset
Rehabilitation	Chip Seal	Roughness	65 NAASRA counts/km
Rehabilitation	OGPA/SMA	Roughness	40 NAASRA counts/km
Rehabilitation	All	Rutting	4 mm after 12 months
Rehabilitation	All	Overlay for 25 year life	0 m^3
Resurface	Chip Seal	Macrotexture	2.0 mm mean profile depth
Resurface	OGPA	Macrotecture	1.0 mm mean profile depth

6. Development of the Delivery Mechanism for the Contract

6.1. Challenges

Economic / funding environment

The economics were challengingly simple: provide a competitively priced and robust FWP of well-defined, accurately timed treatments that meet the KPM's for 10 years. Then provide an accurate prediction and price for the amount of reactive maintenance resulting from the implementation of the FWP.

The easiest challenge regarding economics was the pricing of the routine maintenance, professional services and management items because these were relatively static for the duration of the contract.

The funding mechanism for the contract was delightfully simple for the client and required the lump sum for 10 years be paid out annually as 12 monthly payments. The annual amount was adjusted for inflation each year. This uniform income for the Contractor required an accurate prediction of cash flow be made so that any "lumpiness" in the expenditure could be accommodated by borrowing and the cost of this estimated.

It is obvious that a very accurate prediction of pavement treatment types and timing is not possible for a 10 year period and significant risk was transferred to the Contractor in this regard. The challenge was to innovate in order to decrease risk and increase margin.

Client expectations

At the time of tender for the PSMC contract it became obvious that the network had been historically well maintained and presented no immediate challenges in regard to unexpected pavement behaviour. The client expectations were that the level of service previously provided to the road users would continue and in some cases e.g. skid resistance, would improve. These expectations were enshrined in the KPM's. The contract specifications also required a high level of professional services be provided to the client in regard to annual planning requirements. Activities outside the maintenance of the network, e.g. traffic safety improvements, major drainage improvements, geotechnical design for slip repairs, etc. were commissioned and paid separately. The Client expectations were also that the Contractor would also provide a well-resourced interface between the Client and public.

Initial pre-conceptions and practices

A particular challenge was to remove the traditional siloes around maintenance activities, whereby separate budgets were kept for general maintenance (routine and reactive), resurfacing and rehabilitation. All parties had to be made aware that that all pavement activities were inter-related, e.g. the timing and type of a surface treatment impacted reactive maintenance costs and KPM's. A holistic approach was required that gave the maximum benefit to meeting the KPM's at the least cost over the life of the contract.

A further challenge was to remove the conventional wisdom of that time: that all maintenance activities are provided by specialist services. It was common practice in NZ in 2002 to carry out all maintenance activities under contract. In general the maintenance activities were carried out by specialist crews and often specialist contractors. These specialist activities included pot hole and edge break repairs, structural pavement repairs, sign maintenance/replacement, line marking, street light maintenance, drainage cleaning, drainage repairs, water cutting, vegetation control, road sweeping, etc. To enable the pricing of a 10 year contract to be competitive the staff had to be flexible and trained to do all but very specialist activities with specialist equipment, e.g. water cutting

Identifying pavement management knowledge gaps

Data

The PSMC was generally data rich, especially in regard to surfacing, traffic, condition measures and pavement inventory items. As previously described, there was a large effort in year 2 of the contract to record any asset items not previously recorded because they were not easily located. There was a continuing effort through the contract period to keep complete and accurate records.

It is not feasible to have detailed data for everything on the network and the occasional unpleasant surprise will eventuate. A memorable surprise was that a significant length of OGPA that was recorded as being a standard mix and placed in 2001 only performed well until 2005 and then started to ravel extensively. Although the replacement for this mix was scheduled in the contract period it had to be brought forward. This change affected the surface average life KPM and the contract economics.

Condition / Performance relationship

The pavement performance models used in the tender period were from the standard NZ setup of dTIMS. These continue to be a work in progress but were very useful indicators of the pavement performance when used judicially to provide an indicator of annual pavement condition. The challenge was to keep updating the models and their calibration to improve the predicted pavement performance during the contract period and to provide confidence the KPM's would either be met with the tendered FWP or show the need for FWP adjustment.

There were no realistic models available (this is still the case) to predict the performance of surface aggregates in regard to skid resistance. An annual allowance was estimated to resurface some tight sections of alignment to restore skid resistance. It was considered that skid resistance would be catered for over the period of the contract by primarily choosing a surface chip that had an appropriate PSV as prescribed in the NZTA specification T/10. However, PSV proved to be a poor indicator of skid resistance performance and many tight corners failed the skid KPM requirements when only 3 – 5 years old.

FWP – KPM/ Reactive maintenance relationship

The greatest impact on the FWP-KPM relationship is the reset values used after a treatment is carried out and these had to be set to realistically achievable values.

A further challenge was to try and predict the effect of the timing of the rehabilitation or surface treatments on reactive pavement maintenance. Traditionally the network had been well maintained and the need for rehabilitation treatments justified only after significant pavement maintenance had occurred. Consequently the maintenance regime had been geared towards doing high quality structural repairs when required because it was likely that a rehabilitation treatment could be a few years away.

6.2. Overcoming the Challenges

Value for money initiatives

The best value for money initiatives really stemmed from simply doing a very good job of what is normally considered business as usual. The management strived to obtain good quality work with a "do it once, do it right" ethic. It was recognised that value for money was often obtained by not taking the cheapest option and this was particularly evident when obtaining sub-contractor services and materials.

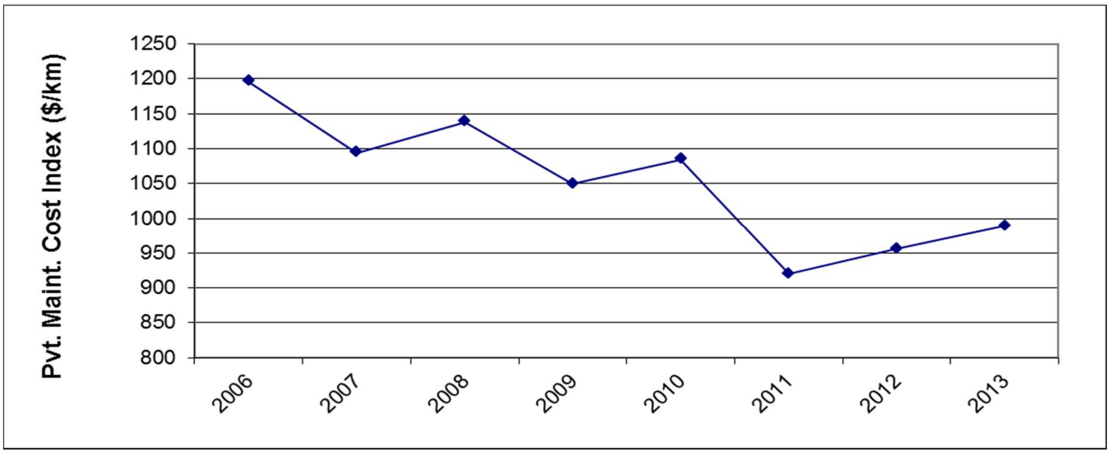
New technology, especially in regard to pavement surfaces and rehabilitation was always seriously considered to see if it could bring cost effective benefits to the contract.

Other initiatives resulted from the use of historical condition and maintenance data available to model what the future network performance might be for different FWP scenarios. The development of the FWP for the rehabilitation and resurfacing treatments was carried out by an experienced and knowledgeable team. However, no member of the tender team had previously had to guarantee the FWP for 10 years. It was the accepted norm within the industry at that time that the first 3 years of a 10 year FWP could be considered fixed but after that time the treatments and their timing became more fluid. The option of making the FWP very conservative and risk adverse would merely render the tender non-competitive and so the FWP was developed with a great deal of care and before risk was decided, two programmes were developed: optimistic and pessimistic. The amount of risk was decided by choosing a programme within the two scenarios.

The PSMC economic environment discouraged traditional thinking in regard to scheduling rehabilitation treatments only after considerable maintenance had been carried out to keep the pavement in an acceptable condition. The same applied to resurfacing, which traditionally was sometimes scheduled only after significant faults were evident. The change in PSMC thinking was because the investment in maintenance gave only a short term benefit to the KPM's and the contract would still have to fund the rehabilitation and resurfacing treatments to meet the underpinned quantities provided in the tender FWP.

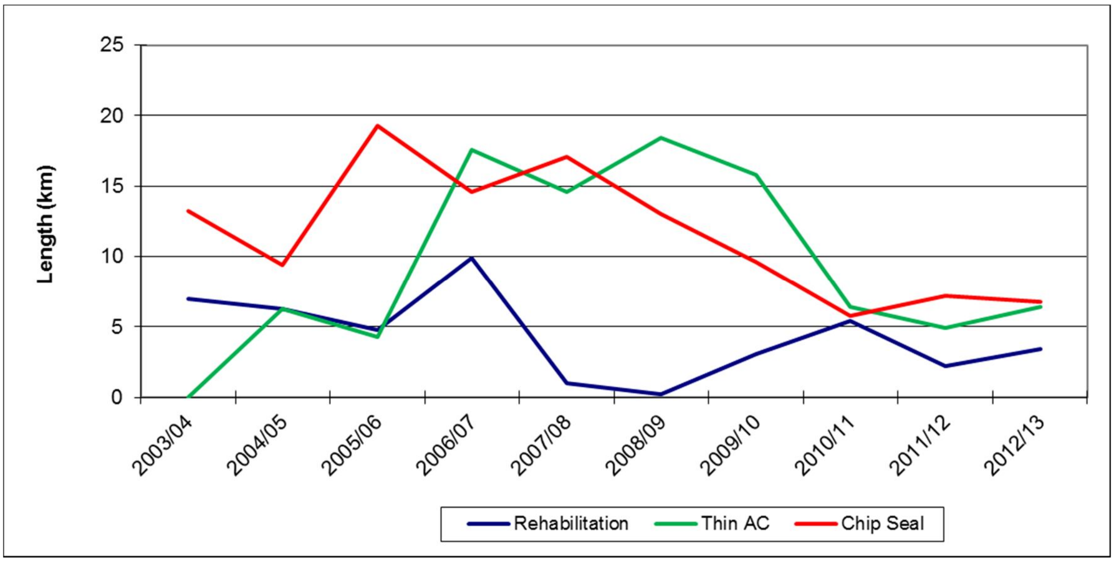
The preferred scenario was for a significant amount of the rehabilitation treatments to be carried out early in the contract period and an attempt was made to model the impact this would have on reactive maintenance. Models were used in dTIMS to try and indicate the trend in reactive maintenance after 2006 if some of the rehabilitation treatments scheduled in the first 5 years of the contract were advanced in timing. Maintenance savings were indicated as shown in Figure 5. The dollar amounts shown were simply an indicator used in the modelling. What was important was the establishment of the trend and this was calibrated to predict actual maintenance costs.

Figure 5 – Predicted Reactive Pavement Maintenance Trend



The maintenance savings were compared with the cost of finance and the decision was made to advance the rehabilitation treatments. The resulting FWP developed is shown in Figure 6. This programme was adopted for pricing, however, the underpinned quantities in the tender showed a more even spread of work over the 10 years.

Figure 6 – FWP Developed to reduce reactive maintenance costs



Client / delivery team alignment

A PSMC needs to be led by people who can operate in a partnered, innovative and ever-changing environment. It is obvious that there will always be issues that will test the relationship between client and contractor especially over the long time frame of a PSMC contract. It is important that the management board provides a strong sense of leadership and that all parties abide by the decisions of the board.

It would be impractical to try and cover off all the issues that could arise over the lifetime of a PSMC so in order to operate effectively the client and contractor must act in a spirit of partnership and openness. It is vitally important that all parties involved are taken on the journey together. If an adversarial approach is adopted all parties will quickly revert back to their traditional roles and the PSMC model will not function in this environment. (2)

Knowledge transfer (breaking the "this is how we do things" barrier)

Right from the start of the tender process an environment of sharing knowledge and experience was developed. Prior to the final tender documents being released the Contractor had assembled the main team participants and started work on the tender with a professionally lead workshop to build teamwork, help align expectations and give all parties an understanding of their role and responsibilities. Throughout the life of the contract the spirit of cooperation continued with remarkably open and frank sharing of knowledge and with a "fix the problem not the blame" attitude. When all major parties share in the profit it is of benefit to all concerned to help fix any problems that arise as quickly and as efficiently as possible because confrontation and litigation just waste time and money.

The need for all work carried out for rehabilitation and surfaces to meet the design expectations and resets used to predict the KPM's was crucial to the success of the contract. Therefore a close relationship was required between design and construction staff with the design intentions being understood by all parties. Target outcomes were given to the work managers to achieve with the clear understanding that if these were not met there was the possibility of re-work or the need to overachieve on the next project to keep the KPM's on target. Training of staff was essential and also any remaining attitude based on old ways (e.g. the best way to make a profit is to do the minimum possible to meet the specification) had to be overcome.

Staff had to be encouraged to take ownership of the network and be flexible in regard to duties, so that the crew out cleaning drainage channels had to be prepared to straighten a sign if necessary.

Pavement asset management development

There were no special asset management studies carried out during the contract. It had been anticipated that some studies may have been necessary; however, the contract provided an environment of continuing development and improvement in asset management practice.

The annual FWP inspections carried out with pavement designer/modeller, surfacing specialist, contract manager and client superintendent were very illuminating. The re-calibration of the pavement performance models was carried out every 2 - 3 years based on the changes seen in the network during the inspections and the condition surveys. During the course of the contract performance models for chip seal and OGPA performance were significantly improved and the use of deflection curvature from FWD surveys (D0 – D200) was found to be a much superior input in regard to pavement strength. It was also discovered that polished stone value (PSV) is a very poor predictor of skid resistance over the normal life expectancy of a surface treatment.

Integration

In a PSMC a holistic approach is required; the Contractor must contractually meet the KPM's, but both the Client and the Contractor share the need for satisfied road users. The expectations of the road users and the property owners adjoining the highways have to be carefully managed so that the desired commercial outcomes can be reached for the Contractor. It was understood by all parties that political expediency was not appropriate.

The benefit of a 10 year period for the PSMC is that new technology and practices can be utilised to give better outcomes for all stakeholders and old norms can be challenged, often with great effect. New knowledge gained from monitoring pavement performance and improved performance modelling can be incorporated into the pavement management system.

6.3. Successes (How we implemented the solutions and how they effected the project delivery)

Alignment of Pavement FWP Planning with Network Performance

A major factor in the success of PSMC 005 was the provision of a robust FWP that delivered the KPM's required without compromising the required commercial outcomes. The resurfacing and rehabilitation programme made up over 50% of maintenance expenditure on the PSMC005 contract and therefore represented by far the biggest risk to the contract's performance. This programme cannot be based purely on modelling inputs and outputs, as whilst the answers from the pavement modelling will provide a rough quantum work programme at a network level, they will not be able to take into account what is actually going on in the field.

It was critical that the FWP be carefully monitored to check that it was achieving its objectives and an annual pavement drive over inspection was conducted which took three days to cover the 175 centreline km network. The pavement modeller, sealing specialist, client superintendent and contract manager carefully inspected each treatment length. The inclusion of all parties in the drive over was important as it opened up the whole decision making process. An assessment was made of the current FWP treatments and the modeller's predicted programme for each treatment length and these were adjusted to suit the rate of change of pavement condition observed for each length. During the drive over inspection the forward works programme was adjusted in the field and two separate programmes were produced; an optimistic programme and a conservative programme.

The optimistic and conservative programmes were summed and priced to check they met minimum contract quantities and to assess budgetary implications. The programmes were then combined and adjusted to produce the first draft of the final annual FWP programme. The draft was then back analysed through the pavement performance models to check that it would achieve the contracts KPM's. Once all the criteria were met the programme was set up in the RAMM system and used to prepare the annual plan.

KPM's Achieved verses Targets

The following are examples of the KPM's required to be met. For the sake of brevity not all KPM's are discussed.

Underpinned FWP Quantities KPM

The target underpinned quantities are shown in Figures 7 - 8. The rehabilitation work was advanced early in the contract as discussed above to reduce reactive maintenance costs. The rehabilitation need reduced at the end of the contract because the KPM's were being met and therefore FWP was adjusted to meet the minimum KPM requirement.

The thin AC (OGPA) resurfacing slightly exceeded the KPM target, while the chip seal quite significantly exceeded the KPM target. The primary reasons for exceeding the chip seal target were because the rehabilitation lengths that were postponed were resurfaced and because many short sections of seal were placed on tight sections of alignment to improve the skid resistance. Rather than rely on PSV to select the surface chip, a known good performing chip was transported 400 km to be used in the latter part of the contract. Good performing chip existed locally but demand exceeded supply.

Figure7 – KPM for Rehabilitation Length Achievement

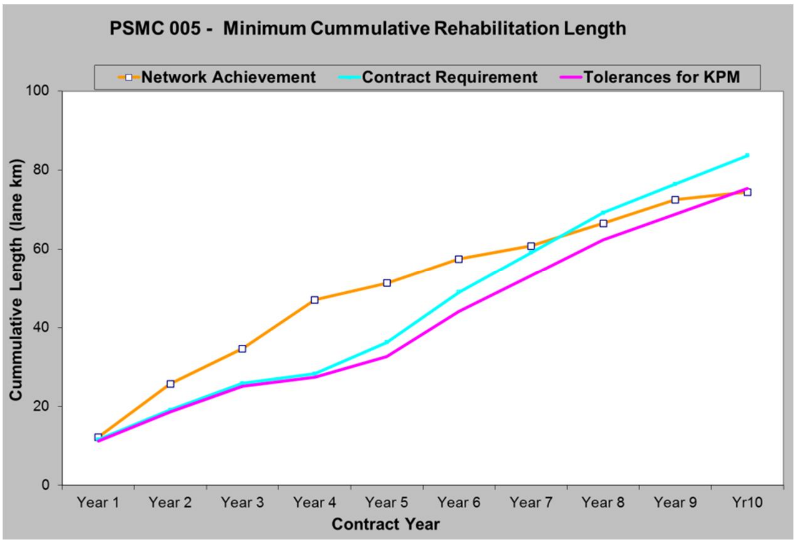
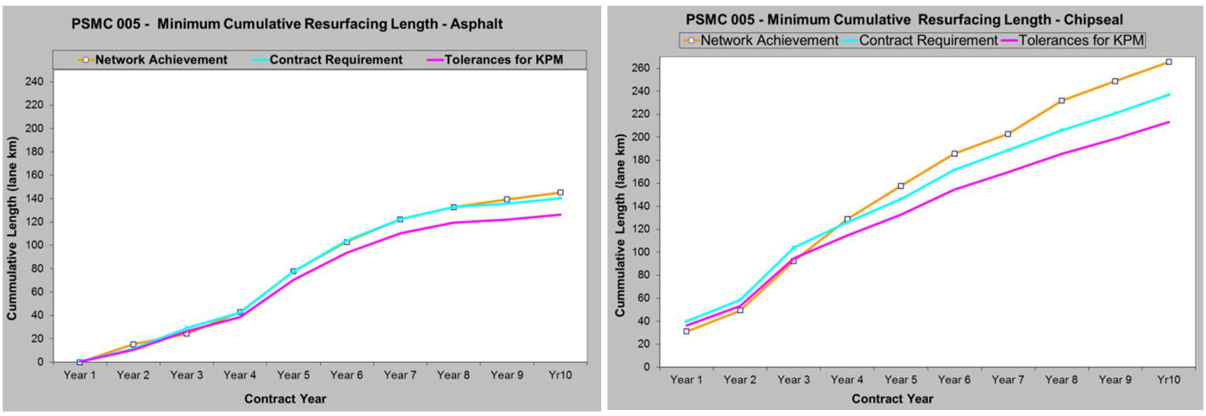


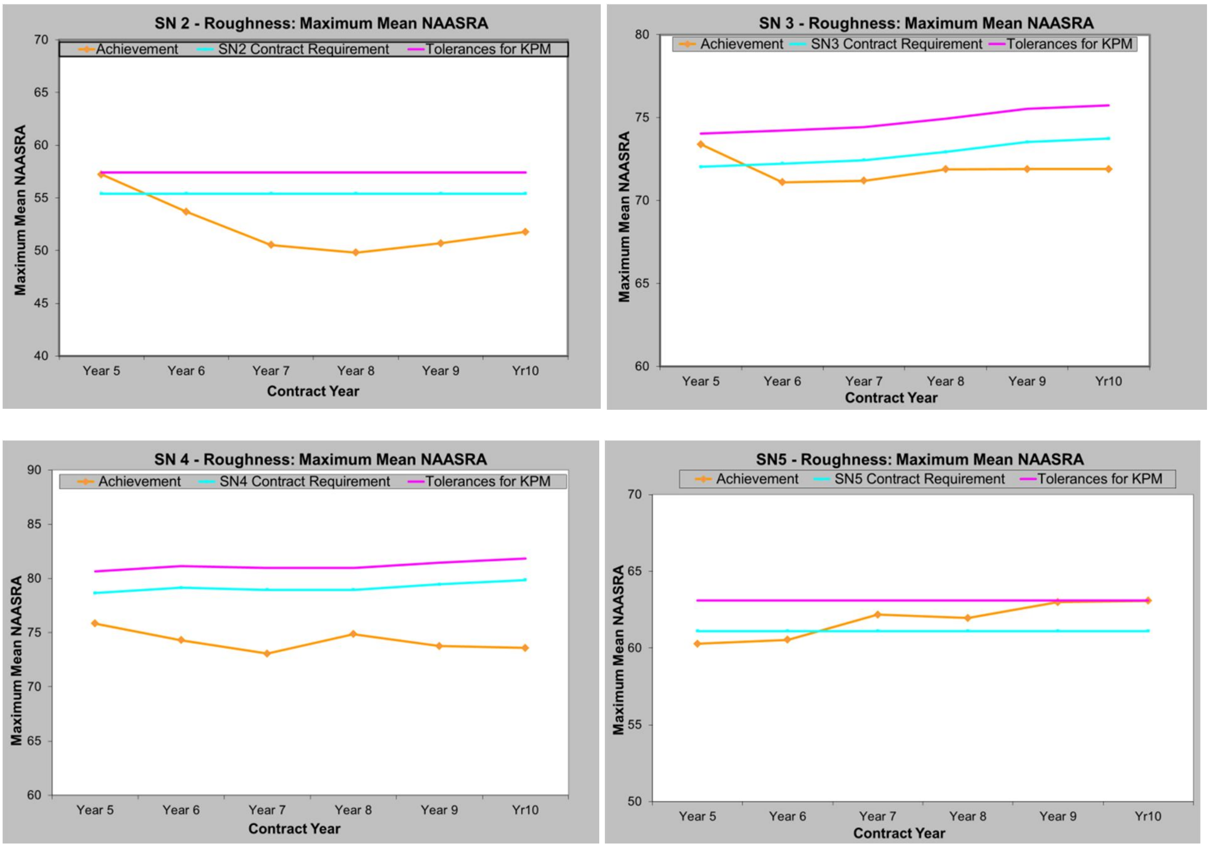
Figure 8 – KPM for Thin AC and Chip Seal Surface Length Achievement



Vehicle Ride KPM

One of the roughness KPM's was based on the mean roughness and the targets verses achievements are shown in Figure 9. Overall, the roughness KPM's were well met. The exception was SN 5 where the amount of rehabilitation and resurfacing with OGPA was minimal. In this SN the target was not met but the KPM did go above the maximum allowance. In all other SN's the targets were easily met, which indicates the construction teams performed well.

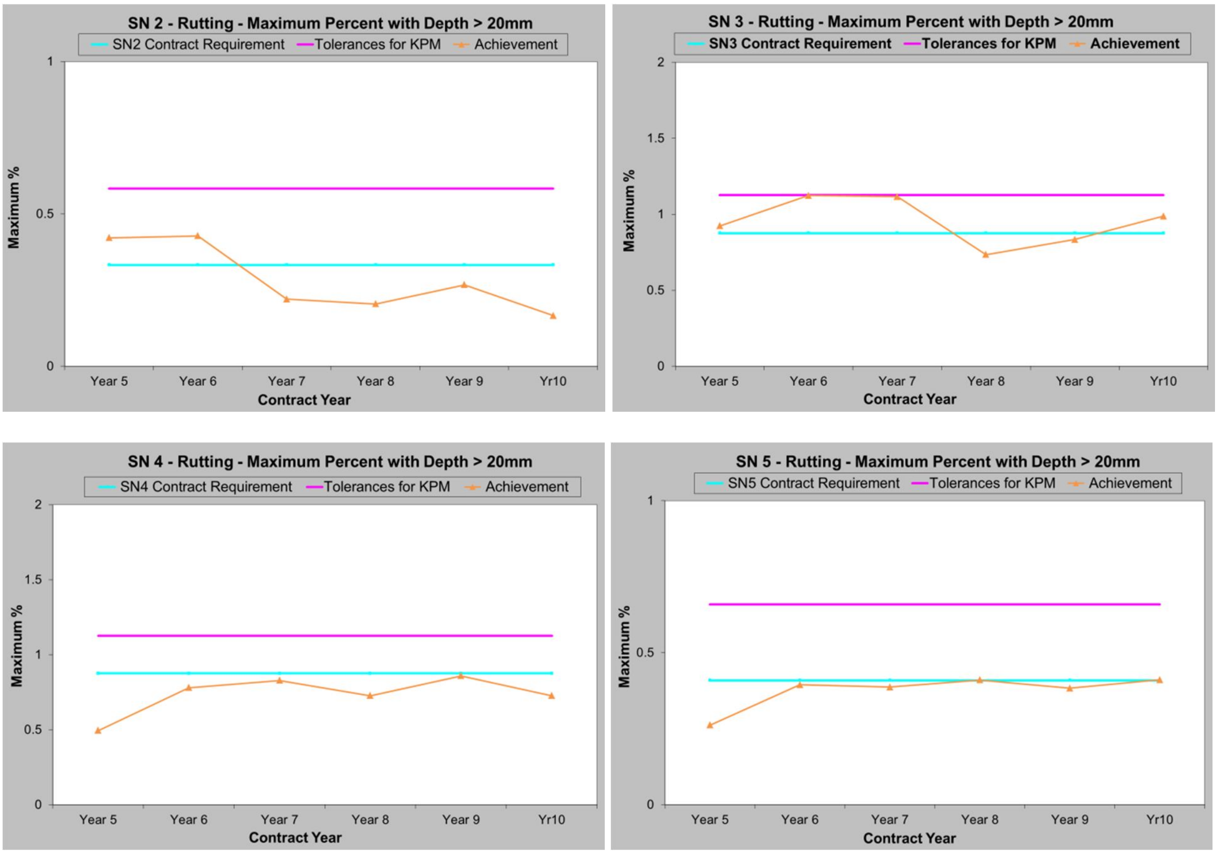
Figure 9 – Mean Roughness KPM



Rutting KPM

The example rutting KPM is shown in Figure 10. This rutting KPM was based on the length of 20m sections of wheel path with an average rut depth greater than 20mm. All SN's were close to the target values, indicating the rutting model calibrations and resets were close to the mark.

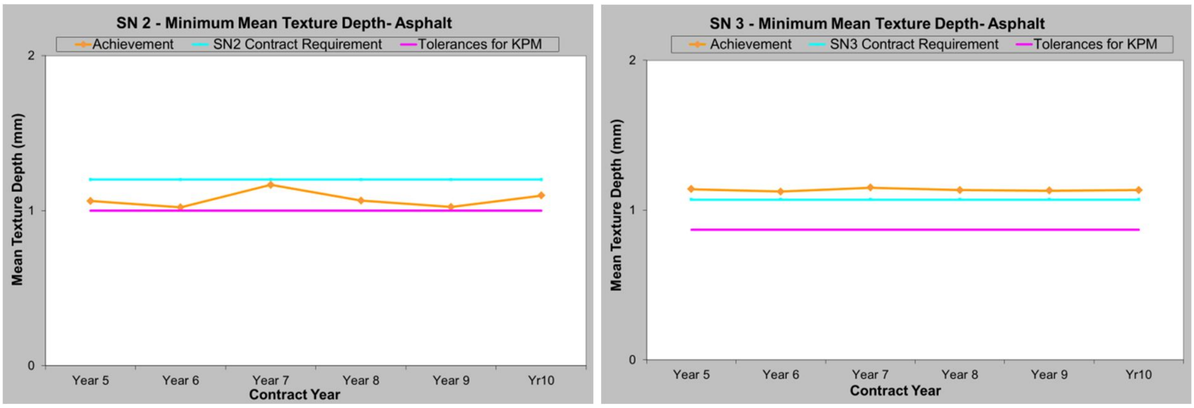
Figure 10 – Rutted Wheel Path > 20mm KPM

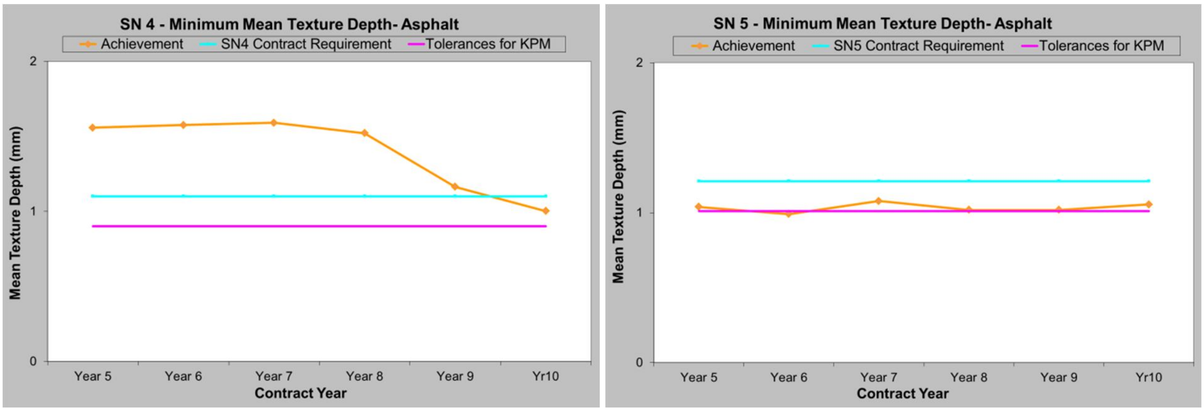


The texture depth KPM

The texture depth KPM example (Figure 11) is based on the mean profile depth of the AC surfaces in the SN. This KPM target, was only met because many of the dense grade AC surfaces were replaced with SMA when they became due for a resurface.

Figure 11 – Mean Texture Depth KPM





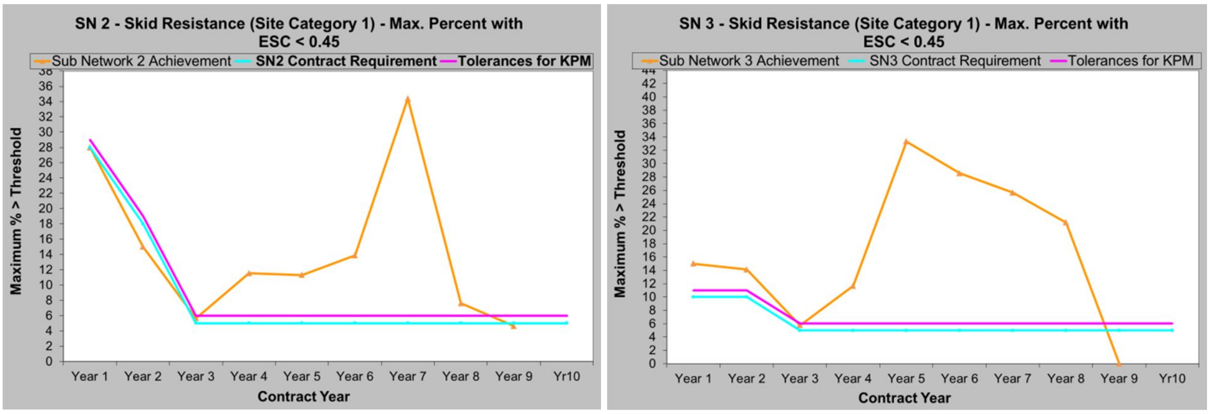
Skid Resistance KPM

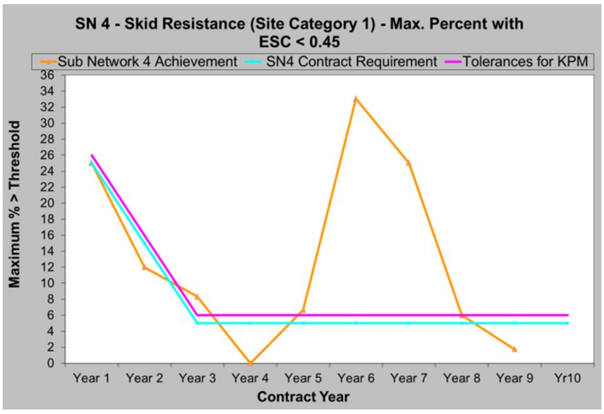
As discussed previously the skid resistance KPM was particularly difficult to meet, especially for the high use skid category sites that required a SCRIM coefficient of > 0.45 because of the reliance early in the contract on PSV as an indicator of continued skid resistance for surface aggregate. The KPM was significantly missed in the middle of the contract period when the surfaces placed early in the contract started to fail prematurely for skid resistance.

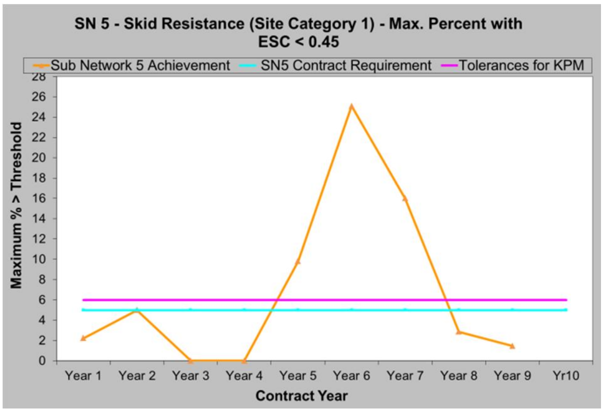
The skid resistance KPM and achievements verses targets are shown in Figure 12. The KPM is based on the percentage in each 10m section in the high use skid site category that does not have an average SCRIM coefficient > 0.45 for the 10m length.

The Client wanted the same KPM for all SN's and where the KPM at the start of the contract did not meet the desired conditions there was a period of 3 years to reduce the percentage of wheel path not meeting the requirements.

Figure 12 – Percentage Wheel Path in Skid Site Category 1with ESC < 0.45







Changes in pavement maintenance delivery methods and their effects on the network

As discussed above one of the major changes made in regard to the planning of pavement maintenance was the decision to optimise the timing of rehabilitation and resurfacing work to reduce reactive pavement maintenance. The traditional disconnect between reactive maintenance and the rehabilitation and resurfacing budgets was removed and the all maintenance activities were integrated in planning the timing and type of maintenance. The best way to demonstrate the success of this change in the way things were done is to examine the records for the 10 years in regard to pavement maintenance activities.

In October 2008 the motorway section was removed and incorporated into the Auckland Motorway Alliance and at the end of 2012 SH17 was removed from the database because the State Highway designation was revoked and the road was taken over by Auckland Transport. Therefore, for the purpose of simplicity and reporting the work of the PSMC only, SH16 and SH01 (Orewa – northern boundary) are reported for historical maintenance. This 130km section is 62% of the original contract network and is representative of the total PSMC 005. For the purpose of this paper this section of the network will be referred as the researched network.

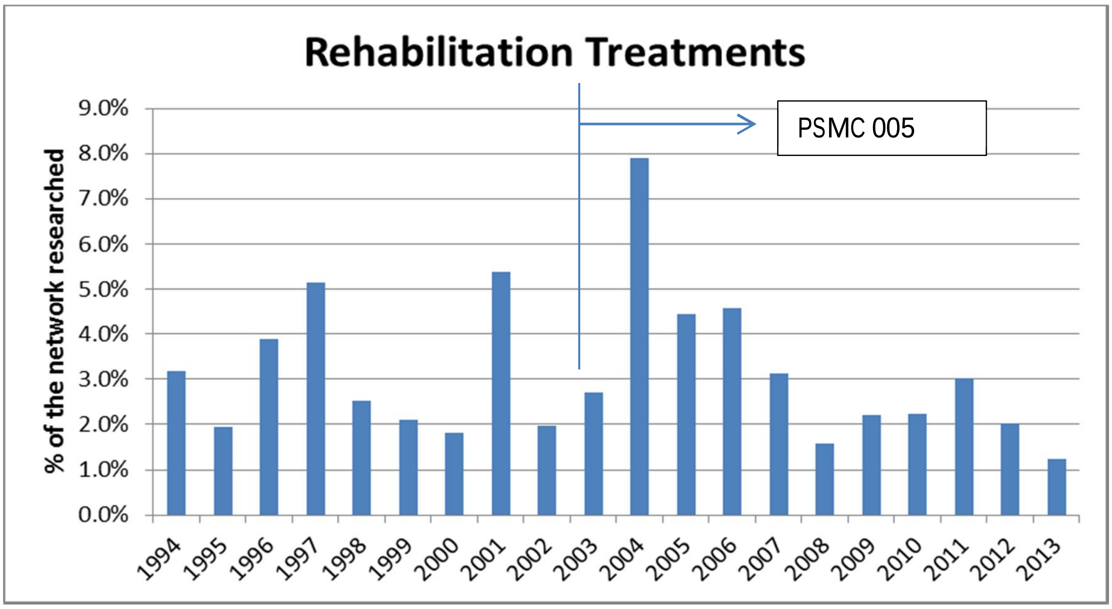
Rehabilitation Achievements

The historical annual rehabilitation treatments carried out on the researched network are shown in Figure 13 expressed as a percentage of the network length studied. The records have been reported from the database starting 10 years prior to PSMC to give context to what changes were made during the PSMC. The length of rehabilitation treatments were obtained from the first coat seal records which are considered to be more complete than the pavement structure records prior to 1998. The length of pavement rehabilitated spiked early in the PSMC contract when rehabilitation treatments were brought forward but on average the annual amount remains the same as the 10 years prior to the PSMC at 3% of the network per year.

Resurfacing Achievements

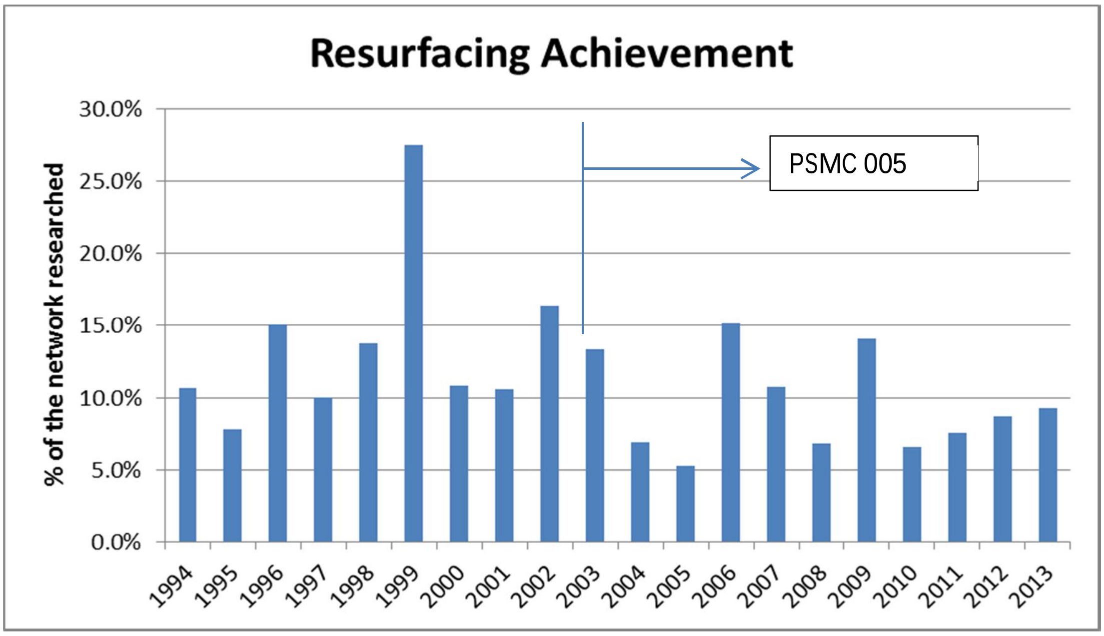
The historical annual resurfacing treatments carried out on the researched network are shown in Figure 14 expressed as a percentage of the network length studied. As with the rehabilitation the records have been reported from the database starting 10 years prior to PSMC to give context to what changes were made during the PSMC. The average annual quantity of resurfacing was greater prior to the PSMC at 13% compared with an average of 9% per annum during the PSMC.

Figure 13 – Historical Rehabilitation Achievement



It would normally be expected that the reduction in resurfacing would be accompanied by a greater number of surface faults evident on the network. However, this did not eventuate because the type of surface treatments select were optimal for each site and the advanced rehabilitation programme reduced the need to patch and seal pavements for short term benefit because a more substantial rehabilitation treatment could not be programmed because of budget constraint.

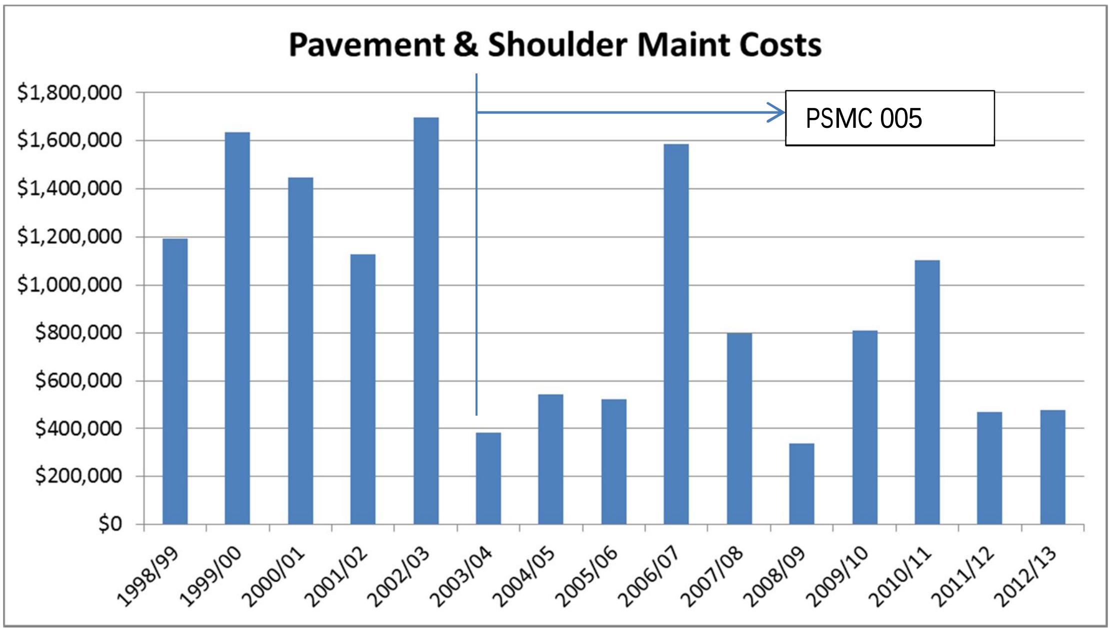
Figure 14 – Historical Resurfacing Achievement



Reactive Maintenance Costs

The PSMC Contractor did not tender rates for reactive maintenance work and only input costs were recorded. However, the location and quantity of all maintenance activities were recorded in the RAMM database as were the maintenance activities carried out after 1988/89 under previous contracts. The rates assigned in this study are those from the previous contract and the maintenance costs have been calculated by applying the rates to the quantities recorded in the RAMM system for shoulder and pavement maintenance. The results are shown in Figure 15.

Figure 15 – Pavement and Shoulder Maintenance Costs



The effect of advancing the rehabilitation treatments can be seen immediately the contract commenced. For the first 3 years reactive maintenance was kept to a minimum because those sections that were to soon receive a rehabilitation treatment would have only had sufficient maintenance carried out to keep them safe and to meet the operational KPM's. After the first 3 years maintenance did increase but on average remained low with the exception of two years that had a spike in maintenance, most probably for environmental reasons.

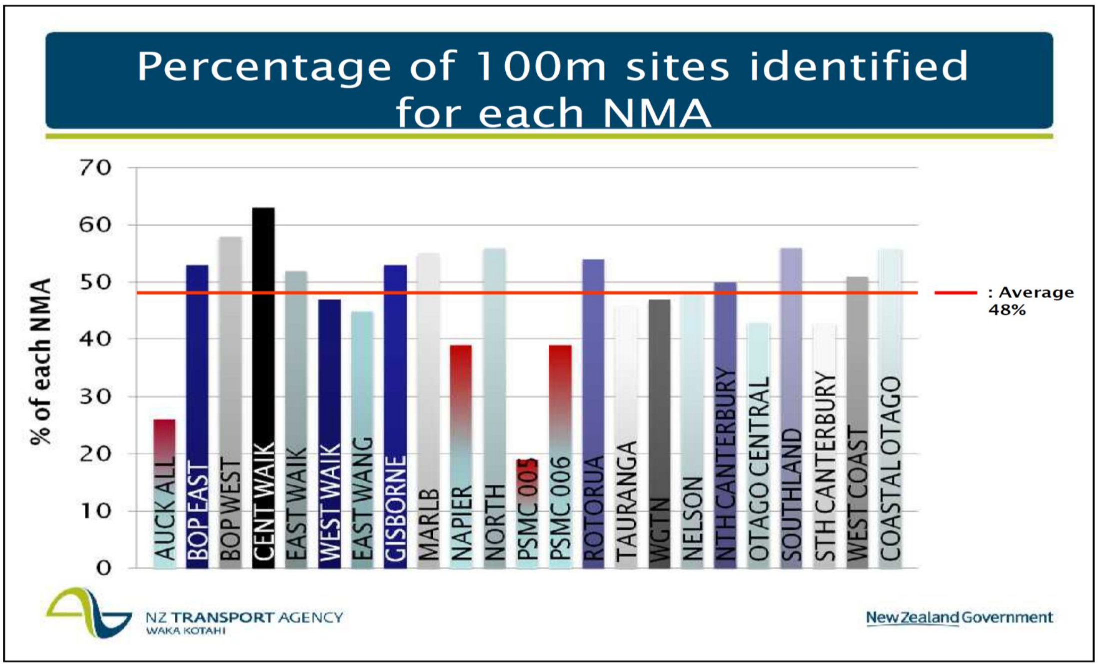
The real success of the policy can be assessed by the 50% reduction in average reactive maintenance costs. The average pavement and shoulder maintenance costs prior to the PSMC contract commencing in 2003/04 was $1.4M/year. Over the period of the PSMC the average pavement maintenance costs were $0.7M/year.

Comparison with Other State Highway Regions

A true indication of the success of the PSMC 005 was demonstrated as part of a presentation given by John Donbavand of NZTA during the 2013 NZ Institute of Highway Technology conference. NZTA had carried out an analysis of all the NZ State Highway pavements by extracting the maintenance and condition data summarised to 100m lengths. A matrix of faults and a score was developed to identify any 100m that needed an inspection to determine if it required a periodic or reactive maintenance treatment.

Treatment lengths and a suitable treatment could be determined where several closely spaced 100m lengths indicated a treatment was required. For each Network Maintenance Area (NMA) on the State Highway network the percentage of the network length that had a score that triggered the need for an inspection was reported. The average percentage reported for the NZ State Highways was 45% whereas PSMC 005 had only 19% reported, (see Figure 16). This contract was competitively tendered and the average periodic quantities are similar for the other State Highways. This suggests that the major difference was in the road asset management activities.

Figure 16 – Percentage of Network Triggered for a Pavement Maintenance Inspection



Technologies

Pavement Rehabilitation Treatments

The design criteria required under the contract were those provided in the APDG (2004) and the NZ Supplement. The design period for the rehabilitation was specified as 25 years and the post-construction remaining life had to be shown to meet the design period using an FWD survey and back analysis using ELMOD. Design life had to be based on subgrade compressive strain criteria for unbound granular pavements. Pavements with bound layers had to meet the tensile strain criteria in the bound layers as well as the subgrade compressive strain criteria.

Rehabilitation was one of the major opportunities in the PSMC to innovate and potentially increase the profit margin. Some sites were particularly challenging because of soft subgrade, lack of pavement depth, poor aggregate quality and physical restrictions that made the construction of a granular overlay difficult and costly. Several feasible rehabilitation treatments were generally considered for each rehabilitation site and a treatment chosen after consideration of criteria such as constructability under traffic, level control, proximity of suitable materials, etc. All of these factors impacted the cost of the treatment.

With agreement from the client the design norms were able to be challenged, although responsibility remained with the Contractor to achieve a 25 year design life as determined from an FWD back analysis carried out one year after construction.

An example of where design norms were successfully challenged was in the use of cement bound basecourse layers. Traditionally cement bound pavement layers were restricted to sub-base layers where a sufficiently deep base layer of either AC or unbound granular aggregate was placed over the cement bound layer to remove the possibility of environmental cracking in the cement bound layer reflecting through the surface. Quite early in the contract it was recognised that some rehabilitation sites could be rehabilitated with significant cost savings if cement bound basecourse layers could be successfully implemented.

The cement bound basecourse layers were constructed with 5 – 6% cement with the water content only just sufficient to gain good compaction. There was no opportunity to keep traffic off the pavement for a curing period, so the design allowed for the layers to be cracked. It was also hoped that the cracking would be in the form of micro-cracking and help to prevent reflective cracking in the surface. To provide mitigation of potential reflective cracking the second coat seal was placed using a binder modified with sbs. These pavements proved to be very successful with only very minor cracking in the chip seal surface showing after 9 years' service, (see Figure 17).

The cement bound basecourse pavements were monitored carefully for 4 years after which time their performance was considered as acceptable and the technique was used again on several sections before the end of the contract.

Figure 17 – Surface of Cement Bound Basecourse at Nine Years' Service

Another innovation was the use of foamed bitumen stabilisation for rehabilitation of a basecourse layer that was heavily trafficked and starting to exhibit shear failure. This technique was in its infancy in NZ when first used on a PSMC 005 rehabilitation site. The site was on SH 01 with two lanes and which carried 18,000 vpd with 10% HCV's. The operation was quick under difficult traffic conditions and the road could be opened to traffic immediately under a 50kph restricted speed limit. The traffic was able to traverse the stabilised surface for up to several days without significant deterioration, until it could be surfaced. This technique proved so successful it was used on a number of sites over the contract period.

The total length of each type of rehabilitation treatment used over the first 8 years of the contract period is shown in table 3.

Table 3 – Pavement Rehabilitation Options Constructed by Year 8

Rehabilitation Type	Length (lane km)
Unbound Granular Overlay	16.7
Cement Modified Basecourse	17.6
Foamed Bitumen Stabilised Basecourse	20.0
Cement Bound Sub-base	2.7
Cement Bound Basecourse	11.0

The performance of all rehabilitation treatments were tracked using the annual network condition surveys. The results showed that where "current thinking" embodied in the APDG was challenged and some of the design requirements relaxed, there was no corresponding reduction in pavement performance. [(3)]

Surfacing

Chip Seal

Most of the surfaces to be resealed were quite variable in texture and therefore two coat seals were predominantly used so that binder rates could be kept at a level that would not promote flushing in the wheel paths. Water cutting was employed to remove excess bitumen where flushing was present in the surface to be resealed and a polymer modified binder was usually used to help retard flushing in the new seal.

Where there were several previous seal coats present and the excess bitumen could not be removed by economically, the pavement was considered for a rehabilitation treatment, especially where other basecourse related faults were occurring. The treatment predominantly used in this situation was to stabilised the basecourse with a small amount (2% – 2.5%) of cement.

Where reflective cracking was a possibility a polymer modified binder using approximately 3 – 4% sbs polymer was applied as a sealing binder. The polymer modified sealing binders were normally polymer modified emulsions which gave better chip wetting and were less sensitive to the weather.

OGPA and SMA

OGPA was used without a polymer modified binder for straight sections of road with strong pavement layers below and low deflection curvature. Where the 90th percentile deflection curvature was high (>0.2mm), polymer would be added to the OGPA binder to achieve the desired fatigue life. In one situation the basecourse layer was stabilised to reduce the curvature prior to surfacing with OGPA.

SMA was used for heavily trafficked pavements with steep and widening alignments and sbs polymer modified binder was routinely used in this mix. SMA was also used in all urban situations where an OGPA surface was not appropriate because of turning heavy traffic.

$avings

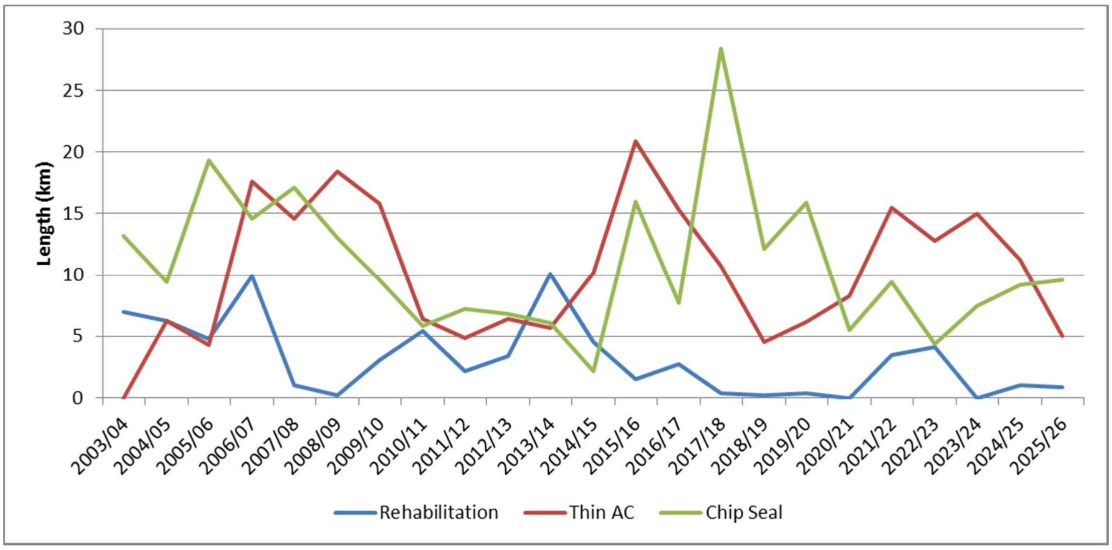
National Level

Cost savings were achieved with the use of PSMC contracts in general in NZ and in 2005 the General Manager of Transit New Zealand reported that *PSMCs "provide better services that are being delivered at much lower costs. In New Zealand, there has been a 30% decrease in professional costs and 17% decrease in physical works, while traffic grew by 53%".*

Network Level

As discussed previously, the increase in pavement rehabilitation and resurfacing early in the contract period corresponds to the reduction in reactive pavement maintenance activity and clearly shows the financial return to the PSMC contractor for implementing a well-targeted and proactive programme of both rehabilitation and resurfacing treatments. Furthermore, the increase in rehabilitation does not have to be sustained after the network attains a steady state at the higher level of performance. The reduced maintenance costs achieved post-peak in rehabilitation can be maintained provided a programme of well-timed resurfacing treatments is maintained. This is demonstrated in Figure 18 below showing the outputs from the dTIMS performance model for the PSMC 005 network.

Figure 18 - dTIMS outputs for Rehabilitation and Resurfacing Treatments



Project Level

The use of commercially available advanced technologies significantly assisted in innovating to increase profit margin. The use of polymer bitumen additives proved to be cost effective where enhanced fatigue life was required in AC mixes or crack mitigation was required in chip seal of AC surfaces. Foamed bitumen also provided a cost effective alternative to structural AC treatments where heavy traffic

Functioning of the PSMC

The PSMC environment has not introduced any radically different philosophies or approach to maintaining the highway network. It functioned well and was successful for several reasons, which include the following:

- Leadership: Strong, logical leadership from the Management Board whose decisions are supported in practice by the Contractor and Client is essential.
- Trust: The PSMC transfers a lot of risk and responsibility from the client, to the contractor. The client needs confidence that the lump sum is being spent in the best manner to provide a safe and efficient network.
- Flexibility: Have a well-trained flexible workforce, especially for general maintenance activities.
- Attitude: Do it once and do it right. Staff should have a sense of ownership towards the network with no rewards for cutting corners.
- Collaboration: Provide a collaborative and knowledge sharing environment. Fix the mistake not the blame. Take all stakeholders and especially the Client on the journey.
- Reward: Main parties share in the pain and the gain.
- Integrate: Remove silos, especially around periodic and reactive maintenance budgets. Treat the maintenance operation as a whole not as individual parts.
- Planning: Minimise reactive maintenance by optimal timing of periodic maintenance.
- Innovate: Make good use of new technologies and optimal treatments and challenge the norms in regard to design to increase profit margin. Cheapest is not always the most economical option in the longer term.

7. Lessons Learned

Over the 10 years there were many lessons learned. As the road asset engineer, the author found the lessons that were most memorable include the following:

- That the timing of periodic maintenance significantly impacts reactive maintenance requirements.
- That the use of structural number in pavement performance modelling was inadequate and could result in poor predictions of pavement performance. During the contract the models were changed to use deflection curvature (D0 - D200) as measured with the FWD.
- That the fatigue life of OGPA is strongly related to the deflection curvature and ESA's carried and the fact that the pavement had performed well under heavy traffic for many years with a chip seal surface does not mean it is suitable for an OGPA surface.
- That the stabilisation of less than premium quality aggregates is an attractive pavement rehabilitation option and the pavement performance studies carried during the contract demonstrated good performance of stabilised pavements.
- That foamed bitumen stabilisation is a very useful pavement rehabilitation technique and sometimes an alternative to structural AC, especially under heavy traffic where pavement works can cause major traffic delays.

- That cement bound pavement layers do not have to be designed to retain tensile strength to give good performance over the normal design period.
- That the use of polymer modified binder in surface treatments can provide mitigation of reflective cracking when placed on cement bound basecourse, which proved to be a viable and very cost effective pavement rehabilitation design option.

8. The Way Forward

One of the main advantages of PSMC's over a traditional network management contract is it gives the client funding confidence over the period of the contract. It also ensures that the pavement asset is preserved and unexpected budget cuts will not devalue the asset. However this has also become one of its drawbacks. It is known that NZTA are concerned with the lack of funding flexibility as the model locks both parties into a long term contract with set levels of service and funding. In the event of a reduction in the national roading budget NZTA is unable to reduce PSMC funding with the same flexibility as a traditional contract. The only significant saving that can be made is to reduce the sealing and rehabilitation quantities, which account for over 50% of the maintenance budget. Theoretically this could be done by reducing the KPM's, but this will increase reactive maintenance costs. There is currently no method to accurately predict how a reduction would increase reactive maintenance costs and it is therefore not possible to include this scenario in a contract document.

A maintenance alliance between the Client, Contractor and Professional Services Provider is possibly the best way forward. The Auckland Motorway Alliance is a good example because it has adopted many of the aspects of a PSMC that made PSMC 005 so successful but with some useful differences. It has introduced a pain/gain mechanism for meeting KPM's/budgets, complete transparency in regard to costs and allows some funding flexibility for both the Client and Contractor with a three year Target Outturn Cost planning period. The budget can be altered each three years if necessary but only with the agreement of the Alliance in regard to the alteration of the KPM's to reflect the altered budget.

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[1] Using Performance Specified Maintenance Contracts: Buyer / Seller Beware [2006]. Tighe, Manion, Yeaman, Rickards and Haas

[2] Haines J and Hallett J, PSMC 005 Programming and Funding – Transit NZ & NZIHT Roading Conference 2006.

[3] Hallett J, Performance Comparison of Pavement Rehabilitation Treatments - New Zealand Transport Agency & NZIHT Annual Conference 2012.