UTILISING PAVEMENT PERFORMANCE MODELLING TO JUSTIFY MAINTENANCE FUNDING

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Sean Rainsford
Fulton Hogan
29 Sir William Pickering Drive
Christchurch
New Zealand
DDI: +64 3357 0607
Fax: +64 3357 1450
E-mail: sean.rainsford@fh.co.nz

Steve McNeill
Christchurch City Council
163 – 173 Tuam St
Christchurch
New Zealand
DDI: +64 3941 8766
Fax: +64 3941 8786
E-mail: steve.mcneill@ccc.govt.nz

ABSTRACT

In New Zealand, all road maintenance is outsourced to the private sector. Funding for road network maintenance within local authorities is derived from local property taxes and subsidies from the national road fund. Any funding request has explicit methods and processes to follow for justification. This paper is a case study of the benefits of pavement performance modelling for Christchurch City Council (CCC), which has a predominately urban road network of over 1,600 km in length, with traffic levels ranging from 50 vehicles per day (vpd) to 35,000vpd. CCC has been implementing pavement performance modelling (PPM) for its sealed road network since 2002. The implementation process has included information improvement plans, Long Term Pavement Performance (LTPP) site set-up and monitoring plans, sub-network level model calibration, and investigation into varying funding levels and the long-term impact on network condition. The outputs from the pavement model are used as part of the overall process in justifying subsidies from the national road fund. The paper details the implementation phase of the project, the high level of calibration undertaken, and the outputs and benefits generated from the system.

INTRODUCTION

In New Zealand there are over 90,000km of road network to be maintained (1). All state highway and local road maintenance physical works contracts are outsourced to the private sector throughout the country. The funds for the physical work are sourced from road user charges for heavy vehicles and a share of the petrol tax that go into a dedicated national road fund. Local road controlling authorities (RCA) receive subsidies for road construction and maintenance from the national road fund if they comply with the central government funding procedures. These procedures require that the RCA's must model, using a specified software - dTIMS CT (2), their current and projected expenditure on the road, demonstrating the impact of financing levels on pavement performance. In order to do the modelling, a forward works programme must be created and regularly updated describing maintenance activities and financial forecasts. The pavement performance model evaluations are a significant part of the current transportation asset management process at the Christchurch City Council (CCC). The Pavement Performance Modelling (PPM) exercise produces forecasts of long-term funding profiles with the forecasted trends of various condition parameters. The evaluation process also produces a draft Forward Work Programme (FWP) that is used in the field for validation, and contributes to the current CCC FWP process (shown in Figure 1). The PPM for the CCC sealed road network has been modelled using the dTIMS software, utilising road inventory and condition data from the Road Assessment Maintenance Management (RAMM) database (3). The Treatment Selection Algorithm (TSA), which is produced within RAMM, is used in conjunction with the dTIMS FWP output for the purpose of developing the final works programme for the CCC road network. This paper discusses the process undertaken, the model outputs and comments on findings.

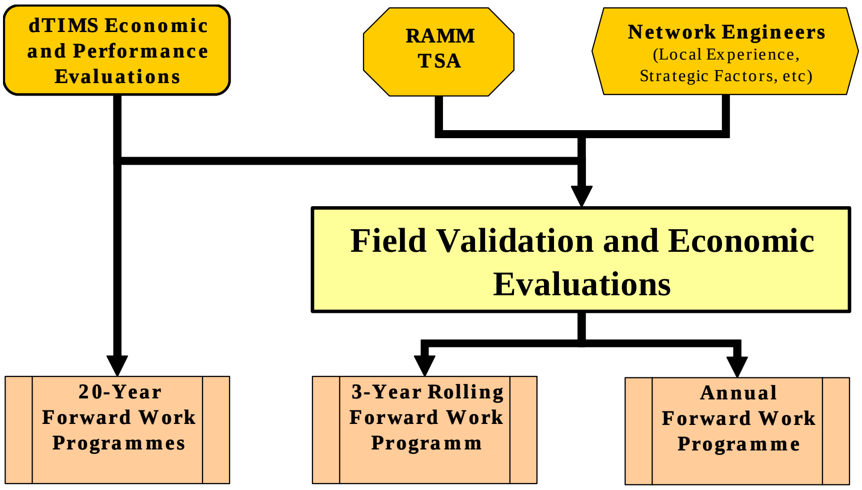

Figure 1 – CCC Forward Work Programme Process

History of PPM in CCC

CCC was one of the first road controlling authorities (RCA) to undertake the PPM initiative in New Zealand put forward by the Road Information Management Steering (RIMS) group in 1998. The RIMS group have funded the development of the pavement model template within New Zealand. The primary objective of the PPM template is to ensure consistency of the model performance and delivery for the entire New Zealand road network. The first implementation of the PPM within CCC took place in July 2001. The main purpose of this implementation was to determine the data requirements and produce an information improvement plan to achieve a robust model outcome. During the following years, steps were taken to improve the data quality held within the RAMM database. This included collection of relevant pavement performance information, such as Falling Weight Deflectometer (FWD) testing on a selection of roads within the higher trafficked areas.

The second implementation of the PPM within the council was completed in January 2003, and followed on from the previous work completed. The main purpose of the second model analysis was to align the predictions with observed performance on the CCC sealed road network. The implementation used the latest template provided by RIMS, with adjustments to match current maintenance practice, as close as practically possible, on the CCC sealed road network.

The third implementation was completed in February 2005. This model allowed for the forecasted forward work programme on the CCC road network. The model was used to ensure the programmed work would maintain the long-term needs of the road network.

Various scenarios were completed and used to optimise the predicted FWP within the forecasted maintenance expenditure levels for the council.

CCC has taken many steps in improving the PPM to align to local needs, including all facets of Pavement Management, such as data improvement, performance model calibration and network optimisation. The next step in the PPM process is to ensure that the long term needs are accurate and align with the objectives of the Asset Management Plan and the Long Term Council Community Plan (LTCCP) (4).

PPM PROCESS FOR CCC

The following section outlines the process that was undertaken by CCC for the best way forward with regards to the PPM development.

Strategy Overview

The strategy for the continuing development of the PPM within CCC consists of:

1. Data Improvements
2. Model Developments
3. System Improvements
4. Analysis
5. Refinement
6. Incorporation into Asset Management process

The above steps will form the basis for all PPM implementation within CCC, and are explained further in the following sections.

Data Improvements

The data improvements component includes the updating of relevant information for modelling purposes and development of a strategy for collection of additional information required to further improve the quality of the model predictions. The data improvement strategy will also include the possible addition of outside road feature assets, such as kerb and channel and footpaths, as these are seen as important features in driving maintenance decisions on the CCC urban network.

The CCC road network is characterised by low to medium traffic volumes with almost two-thirds (67%) of the network having less than 2,000vpd; the pavement use categories based on traffic volume are in Table 1. The CCC road network is also predominately surfaced with chip seals (Chip) – 75%; hot mix asphaltic concrete (AC) and rigid concrete pavements (Conc) make up the remainder. Figure 2 shows the distribution of the CCC road network for the pavement use categories defined in Table 1.

Table 1 - Pavement Use Category Definitions

Traffic Category	Traffic Range
Pavement Use 1	less than 100 vpd
Pavement Use 2	100 – 500 vpd
Pavement Use 3	500 – 2,000 vpd
Pavement Use 4	2,000 – 4,000 vpd
Pavement Use 5	4,000 – 10,000 vpd
Pavement Use 6	10,000 – 20,000 vpd
Pavement Use 7	greater than or = 20,000 vpd

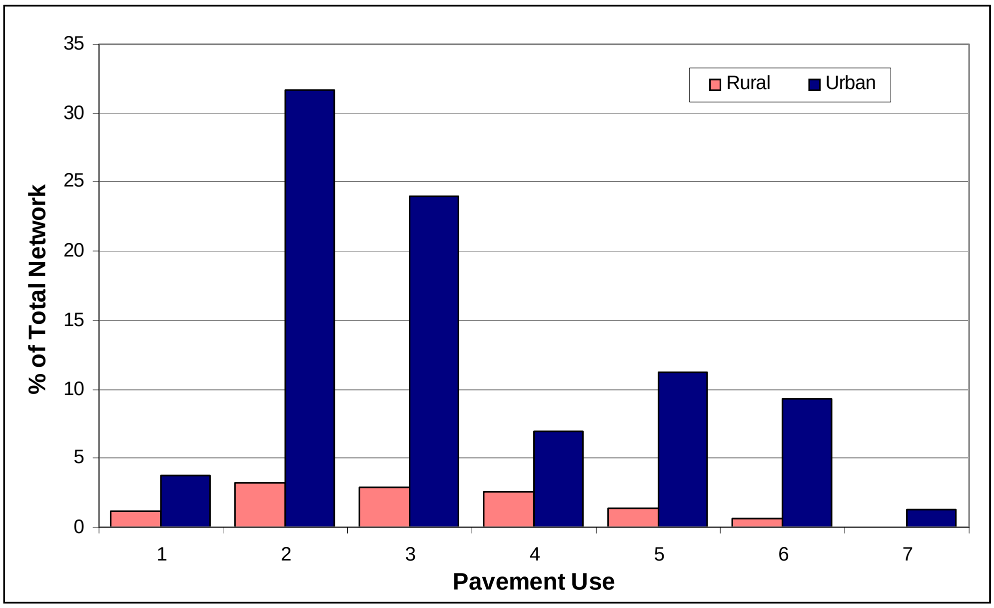

Figure 2 - CCC Traffic Distribution @ November 2006

The first step in the data improvements was to determine pavement strength numbers from the raw Benkelman beam (BB) deflection information collected. The BB information, with additional FWD information, was used to populate the pavement strength (SNP) values for the remainder of the network. The pavement strength information was aggregated to the remainder of the road network based on subgrade CBR values and pavement depth information collected previously for each road section. Geotechnical subgrade information is used for this process, thus ensuring the pavement strengths were realistic with regards to the subgrade they were built upon. Based on the pavement strength values determined, a matrix was produced to show the resulting distribution of the data across the road network, as shown in Table 2.

The outcome from this stage was a model inventory file ready for analysis. A strategy was also developed for continuing data improvements relating to Pavement Performance Modelling.

Table 2 - Pavement Strength (SNP) values used in the PPM

Surface Type	Sub network	Pavement use (Traffic Bands)						
		1	2	3	4	5	6	7
AC	BURWOOD	2.3	2.7	3.1	3.4	3.7	4.1	4.4
AC	FENDALTON	1.8	2.1	2.4	2.6	3.6	4	5.2
AC	FERRYMEAD	2.4	2.7	3	3.3	4.3	4.7	5
AC	HAGLEY	2.5	2.9	3.3	3.6	4.3	4.8	5.2
AC	HEATHCOTE	2.1	2.4	2.7	3.2	3.6	4	4.4
AC	PAPANUI	1.6	2	2.6	3	3.5	4.1	4.6
AC	PEGASUS	2.4	2.9	3.5	4.2	4.6	5.1	5.8
AC	RICCARTON	1.9	2.4	2.8	3.5	3.9	4.4	4.8
AC	SHIRLEY	2.5	2.9	3.2	3.6	3.9	4.4	4.8
AC	SPREYDON	1.8	2.5	3.2	3.8	4.4	5	5.5
AC	WAIMAIRI	1.7	2.4	3	3.5	4	4.6	5.2
AC	WIGRAM	2	2.4	2.9	3.4	4	4.6	5.1
Chip	BURWOOD	1.9	2.3	2.6	3	3.4	3.7	4
Chip	FENDALTON	1.2	1.6	2.2	2.6	3	3.5	3.8
Chip	FERRYMEAD	2.1	2.4	2.8	3.2	3.6	3.9	4.2
Chip	HAGLEY	1.8	2.1	2.6	3	3.5	4.1	4.6
Chip	HEATHCOTE	2	2.3	2.6	2.9	3.4	3.7	4.1
Chip	PAPANUI	2.1	2.4	2.7	3	3.5	3.9	4.4
Chip	PEGASUS	2.3	2.7	3	3.3	3.6	3.9	4.3
Chip	RICCARTON	2	2.4	2.7	3.1	3.7	4.1	4.8
Chip	SHIRLEY	1.8	2.1	2.3	2.6	3	3.7	4.4
Chip	SPREYDON	1.7	2.1	2.4	2.8	3.5	4.2	6
Chip	WAIMAIRI	2.2	2.6	2.9	3.2	3.9	4.4	4.7
Chip	WIGRAM	1.9	2.2	2.5	2.8	3.1	3.4	4

Model Developments

The model development component was focused on the calibration and alignment of the model to local CCC needs, including the defined level of service drivers and long-term maintenance needs. The model development consists of:

1. Determining long-term level of service objectives (intervention levels)
2. Calibrating performance curve (sub network level)
3. Treatment types, costs and decision drivers
4. Treatment effects (work effect resets)
5. Generating strategy constraints (in line with long-term objectives)
6. Optimisation method
7. Expenditure categories and levels

All assumptions and improvements to the model were documented and discussed prior to undertaking the model analysis.

Determining the long-term levels of service for the CCC road network was developed using the current distribution of the road condition within each sub network and traffic range. The CCC did not have conditional levels of service in place at the time of undertaking the PPM, although the outcome from the modelling process will be used in setting these levels of service within the CCC Asset Management Plan. The roughness constants shown in Table 3 relate to the method of calculating the level of service for the road section based on the traffic travelling upon it (5). Examples of the levels of service used in the PPM are shown in Table 3.

Table 3 - CCC Long-Term Levels of Service by Sub Network

Sub network	Roughness Constants (IRI)[5]		Maintenance Cost Index Constant	Surface Integrity Index Constant
	A_1	**A_2**		
BURWOOD	8.6	0.46	2,450	3
FENDALTON	10.2	0.53	2,630	18
FERRYMEAD	13.6	0.8	4,680	15
HAGLEY	11.6	0.55	3,080	28
HEATHCOTE	13.2	0.7	7,080	15
PAPANUI	9.5	0.4	2,690	5
PEGASUS	9.4	0.6	2,930	4
RICCARTON	10.9	0.53	8,950	25
SHIRLEY	10.4	0.5	3,850	12
SPREYDON	11.3	0.55	11,760	20
WAIMAIRI	8.9	0.4	2,510	3
WIGRAM	9.9	0.45	5,230	8

Calibration of the condition performance curves, which are based on the World Bank HDM-4 condition models, was completed doing a Level 2 calibration (6). The calibration involved the use of visual and mechanical condition information collected on the CCC road network over the past ten years. The method of capturing the condition information complied with the Land Transport New Zealand condition rating guidelines (3), and hence could be used with a high degree in confidence. This calibration was completed for the cracking and roughness models, as these were the main drivers for treatment selection on the CCC road network. Detail of the calibration process undertaken is not included in this paper due to its complexity. For more information on the Level 2 calibration process, refer to the HMD-4 calibration guidelines (6). Table 4 contains a summary of the calibration results completed for part of the CCC network within the model.

The treatment types, costs and works effect models have been aligned to current practice observed on the CCC road network since 2001. The typical treatments applied in the CCC network are particular to the urban environment of the area. Work on the calibration of the works effects models are not shown in this paper due to the sensitivity of this work not being available for public viewing (due to commercial issues).

Table 4 - CCC Condition Performance Curve Calibration

Sub network	Type	KCI	KCP	KPI	KPP	KGE	KGP	KRO	KRP
BURWOOD	AC	1.07	0.4	1	1	0.18	0.15	0.5	0.75
BURWOOD	Chip	0.65	0.1	1	1	0.45	0.25	0.5	0.75
BURWOOD	Conc	0.9	0.3	1	1	0.1	0.2	0.5	0.75
FENDALTON	AC	1.5	0.41	1	1	0.1	0.15	0.5	0.75
FENDALTON	Chip	0.52	0.29	1	1	0.3	0.25	0.5	0.75
FERRYMEAD	AC	1.02	0.31	1	1	0.6	0.15	0.5	0.75
FERRYMEAD	Chip	0.66	0.11	1	1	0.6	0.25	0.5	0.75
FERRYMEAD	Conc	0.9	0.3	1	1	0.1	0.2	0.5	0.75

Where,

KCI: Crack Initiation
KCP: Crack Progression
KPI: Pothole Initiation
KPP: Pothole Progression
KGE: Roughness Age Term
KGP: Roughness Progression
KRO: Rut Depth at Year 0
KRP: Rut Depth Progression

System Improvements

The system improvements component is related to the actual software that will be used in the PPM analysis.

All of the historic PPM work completed for CCC was undertaken in dTIMS V6.1 (2). This software had some fundamental flaws in the method of determining benefits for treatment strategies of road sections. The main flaw was the issue of the "Do-Nothing" strategy being the basis for all Net Present Value (NPV) cost calculations. This philosophy is not in line with the Land Transport NZ Economic Evaluation Manual (7) method.

Recently the RIMS group has negotiated an arrangement with the software developers for the supply of the updated system to the entire country. The updated software, dTIMS CT (concurrent transformation), is reported to have answered all issues raised by New Zealand over the last five years. This software platform formed the basis for all PPM analyses undertaken as part of the PPM process for the CCC road network. The outputs from the PPM are providing confidence that the results from the updated software more accurately align to the maintenance decision process for New Zealand and CCC.

Analysis

The analysis component focused on the model analysis methods and resulting output development. To investigate the implications of various funding scenarios, four analysis types were run for comparison and long-term need requirements:

1. Performance mode (policy driven)
2. Economic mode (economically driven by performance improvement)
3. TTC mode (economically driven by Total Transport Costs)
4. Specified mode (actual final FWP outcomes)

The first 3 analysis modes are used, with other relevant information and experience, in determining a draft long-term forward work programme (FWP) for the CCC road network. All the models are optimised to ensure that the forecasted budget requirements of CCC will provide for the long-term condition of the road network. When the long-term FWP is completed and accepted, this is put back into the model to ensure that the performance needs of the network are maintained (specified mode), and that the potential of any backlog of work is addressed within acceptable funding constraints.

The outcome of the analysis component was a report showing the resulting model outputs and long-term network condition. This report also highlights improvements to the model template and data based on the model predictions and success. The report was used as the basis for not reducing the current funding levels for the CCC road network, because any reduction in the funding would not provide for the long-term condition and maintenance of the road network.

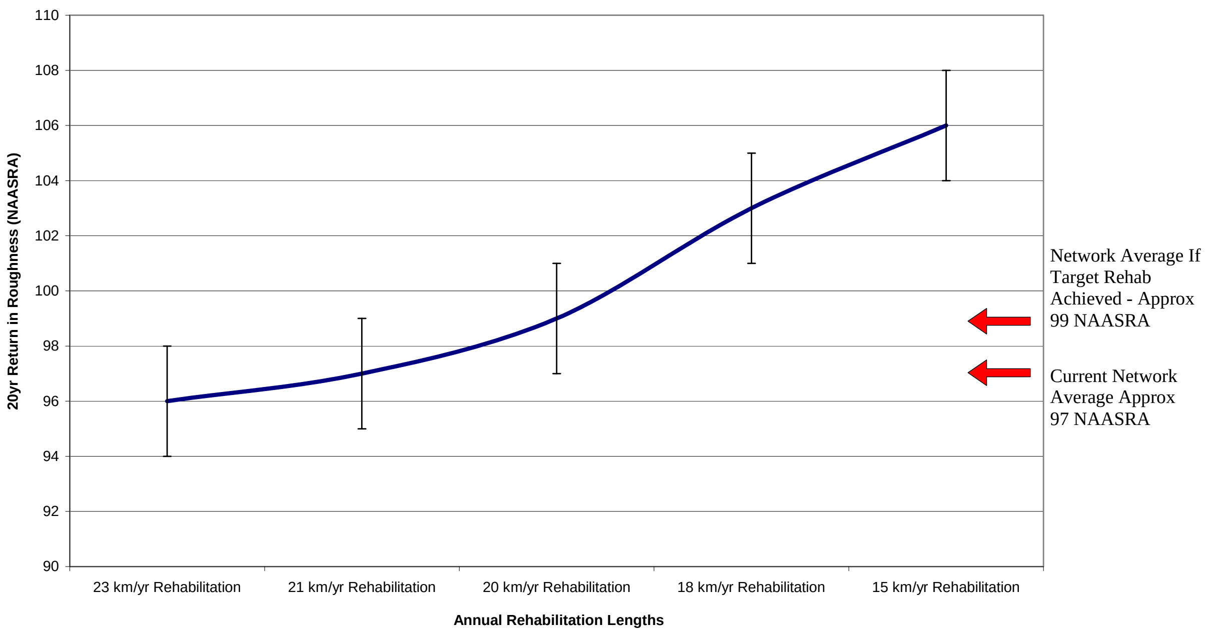

Figure 3 - CCC Rehabilitation Quantity Scenarios versus Network Roughness in 20 Years (2028)

Figure 3 shows that any reduction from the optimal amount of 20 km/yr of rehabilitation (both pavement renewal and pavement smoothing treatments) results in degradation of the network roughness, reported in NAASRA counts/km (8), which results in higher road user costs, and a potentially unsafe ride (NAASRA was the acronym for the National Association of Australian State Roading Authorities, which now includes the New Zealand highway agency and the organisation's title changed to AUSTROADS). The chart also shows that performing additional work will result in minimal improvement to the network roughness. Table 5 shows that the increase in treatment costs results in minimal savings to the maintenance of the road network, whereas a reduction in the treatment costs results in an increase in the routine maintenance costs. This result is realistic, as we would expect to see the network deteriorate in condition due to the reduction in periodic treatments, and therefore the reactive maintenance costs would increase accordingly.

Table 5 - CCC Model Output Network Cost Impact Summary

Impact on Costs	23km/yr Rehabilitation	21km/yr Rehabilitation	20km/yr Rehabilitation	18km/yr Rehabilitation	15km/yr Rehabilitation
% Increase in Agency Costs	3.4%	2.0%	n/c	-3.2%	-7.1%
% Increase in Treatment Costs	8.0%	4.6%	n/c	-7.2%	-16.5%
% Increase in Maint. Costs	-6.5%	-3.6%	n/c	5.4%	13.0%

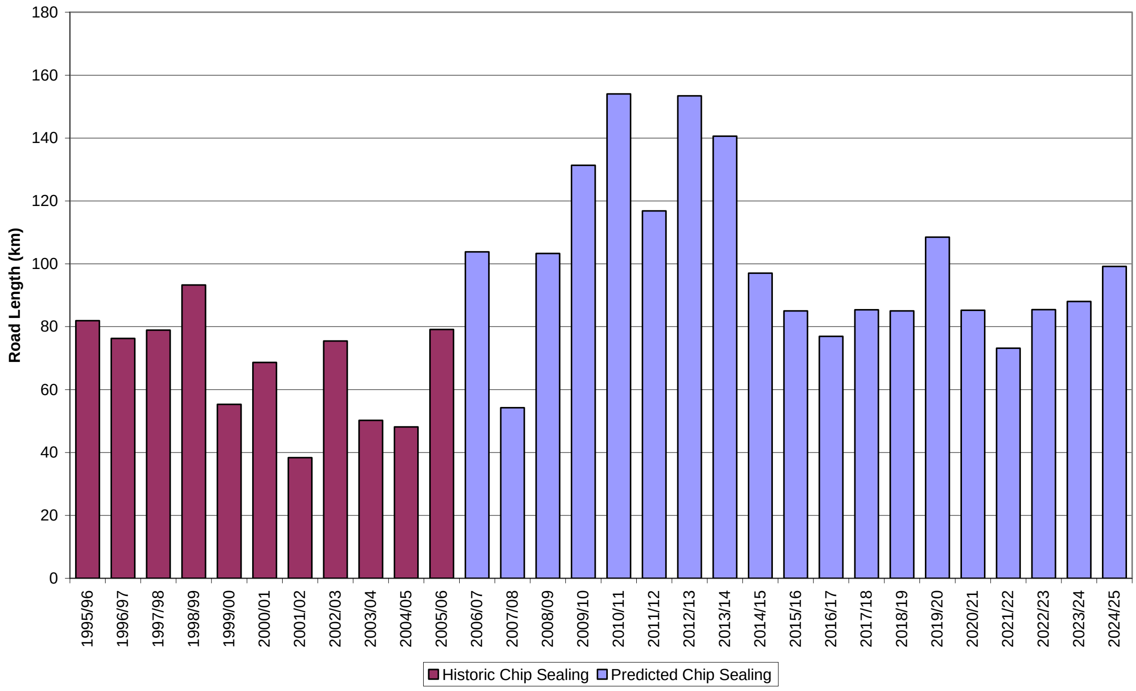

Figure 4 - CCC Comparison of Future Chip Sealing Treatments versus Predicted Requirements

Figure 4 shows that the model completed for the CCC road network also highlighted the observed backlog of chip resurfacing work required to be undertaken. This forecast from the model aligned with the understanding and experience of the outsourced road maintenance practitioners for the CCC physical works maintenance contracts. This provided confidence that the model was providing realistic outcomes for the CCC road network. Field work was undertaken by independent supervisors to assess the model predictions against their local experience. The results from this audit have yet to be received, but in discussions with the supervisors, they are satisfied with the road section predicted outputs.

Incorporation into Asset Management Process

The most important facet of the PPM and the predicted outputs is to ensure they are incorporated into the Asset Management process of CCC. Part of the process is to develop detailed field forms for use in determining the FWP. Although, with the current maintenance contract procurement method used in CCC, the emphasis of the FWP development now lies with the physical works contractor. Depending on the duration of the provided FWP by the contractor, the need for detailed information to determine the long-term FWP is still required.

CONCLUSIONS

Based on the findings to date, the PPM has been used to ensure that the provided programme for the road network is suitable to maintain the long-term condition and in line with expenditure requirements. If concerns are raised based on the model predictions, the maintenance contractor can be asked to justify the reasoning for the treatment selection. Any feedback that will help in the model predictions can be incorporated and then re-analysed to provide updated forecasts.

As part of the improvements to the PPM process for CCC, creation of long term pavement performance sites have been created within the CCC road network. Increased confidence will be placed on the predicted condition outputs from the models when results are gathered and used from these sites.

In summary, following final calibration results from data received from the long term pavement performance sites the final model will be able to be used with confidence to justify future funding requirements for the sealed road network.

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