PAVEMENT DETERIORATION MODELLING IN LONG TERM PERFORMANCE BASED CONTRACTS: HOW FAR DOES IT MITIGATE THE RISK FOR CLIENT AND CONTRACTOR?

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ABSTRACT

A recent international trend in road maintenance contracting has been towards long term performance based contracts. In New Zealand, the long term objective on the state highway network is that approximately one third of the network will be maintained using such contracts. These contracts are for 10 years, and include minor routine works through to significant pavement rehabilitation type activities. By specifying the performance requirements, rather than inputs or outputs, these contracts therefore represent a significant transfer of risk in forward works programming from client to contractor.

During the tender period, tenderers need to estimate the quantity of work that will be required to achieve the performance standards over the term of the contract. Also, clients need to satisfy themselves that any of the potential contractors have assessed this risked adequately, so that the risk of failure to maintain the network to the desired standards is minimised. Once the contract is operational, the focus will shift for both parties and there will be an on-going need to refine the predictions of road performance and maintenance requirements.

Long term forward works programming in New Zealand now uses a framework which has developed from the World Bank HDM pavement models. Transit New Zealand now specifies the use of this framework on its more traditional maintenance management contracts. To date, all contractors have adopted a similar approach when tendering for, and undertaking, long term performance based contracts.

The paper addresses a number of issues based on New Zealand experience: the role of pavement modelling in the overall tender process; the translation of organisational objectives into performance measures and the associated technical analyses; issues of data quality and how they can be managed; the degree to which calibration can be achieved; and the need for sensitivity testing to highlight the level of confidence in the outputs. Recommendations are made on where further work is required in the future in order to improve the applicability of pavement modelling techniques to the performance based contracting process.

The authors have joint experience as both advisers to tenderers and clients for such technical analyses. Based on this experience, the key risks which are identified by both clients and contractors are discussed, and conclusions are given on how pavement modelling can assist with risk mitigation. The paper will therefore be of interest to client managers, who will wish to understand the level of risk which tenderers are accepting in predicting future performance. The paper will also be of benefit to potential tenderers, in clarifying the key areas of concern from a client perspective which should be considered during the tendering process.

INTRODUCTION

Transit New Zealand is the agency responsible for management of the state highway network in New Zealand. The network consists of approximately 11,000 carriageway kilometres, and is predominantly rural and single carriageway. There are some more highly trafficked, dual carriageway sections in the densely populated areas, but in general the dominant characteristic of the network is moderate to low trafficked surface dressed (chip sealed) pavements.

Transit New Zealand has followed a similar evolution to other road agencies in recent years, in gradually shifting the risk of road management over to its suppliers. With regard to road maintenance works, the current intention is to target by expenditure a mix of maintenance procurement models of 1/3:1/3:1/3 for the traditional, hybrid, and performance specified maintenance contract (PSMC) models respectively (Transit, 2000).

The traditional procurement model involves Transit New Zealand acting as a client for both a management (professional services) contract and associated physical works contract(s). The hybrid model is similar to the traditional model in terms of the contract arrangements and relationships, but moves some way to a formalised partnership between the suppliers and defines contract outcomes in terms of performance targets as well as the more traditional work outputs. The term of both the above forms of contract is generally three years.

By contrast with the traditional and hybrid style contracts, the PSMC contracts represent a considerable shift of risk to the supplier. These contracts are for 10 years, and there is only one contracted party who is responsible for both management and physical works for a lump sum price. The contracts do not define work outputs, and all services are defined in terms of performance measures. The size of these contracts has varied between 175 and 700 carriageway kilometres.

Performance measures fall into three broad categories. Management Performance Measures (MPMs) relate to aspects of planning and management. Examples of such measures include timely provision of network control services, such as processing applications for activities within the road corridor. Operational Performance Measures (OPMs) relate to day to day activities on the network, covering issues such as routine maintenance and emergency response. Key Performance Measures (KPMs) relate to long term pavement performance and therefore define the drivers for a contractors periodic maintenance and rehabilitation programmes.

Whilst the value of the contract related to achieving the KPMs is only a portion of the contract value (typically 30 – 50%) it probably represents the highest risk area for any contractor tendering for such work. This paper considers how clients and tenderers have addressed the management of this risk related to the KPMs, through the use of pavement deterioration modelling. It aims to highlight the areas which both clients and contractors need to consider if they intend to move towards letting long term performance based contracts.

KPM DEVELOPMENT – GENERAL ISSUES

Definitions

KPMs reflect the overall condition of the primary asset, the pavement. In general, they fall into two distinct categories. First, some KPMs define the average value of a parameter which is required for the term of the contract (e.g. mean roughness). Second, other KPMs define the percentage of the network which is not allowed to exceed a certain condition (e.g. percentage of network where mean rut depth exceeds 20mm). **<u>Figure 1</u>** identifies the KPMs included within the current standard Transit New Zealand PSMC contracts.

Issues concerned with defining and managing the KPMs are discussed in more detail below.

Ensuring KPMs meet client objectives

Specifying network condition

In determining the values for each of the KPMs identified in Figure 1, Transit New Zealand has in general aimed to maintain the asset at the same level of service. The condition of the state highway network can be considered to be in a fairly steady state, and so by specifying that contractors maintain the existing conditions, this has enabled general engineering judgment and experience to be used as a validation mechanism for estimating required quantities of work to achieve the KPMs.

There are, however, issues which need to be explored with the above approach of generally maintaining existing condition. In particular, whilst a general view might be that the aim should be to maintain the network at the existing level of service, translating this into a detailed view with certain KPMs might be inappropriate. For example, the texture depth and surface life KPMs fall into this category. Resealing practice is to alternate with using small chip and large chip sizes, so that there is a natural periodicity over time in terms of texture variation. Similarly, surface life tends to fluctuate over time on a network. These fluctuations do not imply poor asset management practice, and to require they remain constant might in fact promote inefficient and ineffective practice. The issue needs thorough review at contract preparation stage, along with the definition of suitable subnetworks as described below.

The main exception to the philosophy of maintaining existing levels of service has been in the management of skid resistance, for which a significant improvement in the early years of the contract has been requested. In specifying an improvement, there is an increased challenge for a tenderer to calibrate accurately the pavement performance model. This is because less reliance can be placed on historic, empirical evidence of the quantities required to maintain steady state, and more reliance is needed on the relative impact of the key drivers which might affect achieving a KPM. Experience in this area is still limited, given the length of time the contracts have been in place. However, a tentative conclusion to date is that a tenderer is accepting significantly more risk if asked to tender for a network which is specified to change (either improve or worsen) rather than to maintain the status quo.

The need for subnetworks

Most networks comprise a variety of conditions and influencing factors (for example, urban/rural issues and traffic levels). In order to ensure the KPMs adequately reflect the clients varying objectives, and also reflect this inherent variability, the practice has been to subdivide the network into subnetworks when specifying KPMs. Considerable thought has been needed in preparation of PSMC contracts to identify an appropriate subdivision of the networks for this purpose. The following extreme examples illustrate the issues.

A network consists of some recently completed highly trafficked dual carriageway road, and also some low trafficked single carriageway roads. The former might be surfaced with thin asphaltic concrete, the latter with chip seal. If the entire network is described by a single KPM value for mean roughness over the term of the contract, then the cheapest way for a tenderer to achieve the KPM will be to rehabilitate the rougher sections of lowly trafficked road, whilst allowing the highly trafficked sections to gradually deteriorate. This would clearly not be in the client (road user) interest and so the logical solution is to set different target KPM values for the two different sections. The driver in this instance is to specify as many subnetworks as possible to match client objectives.

However, by specifying numerous subnetworks of minimal length, a new problem is introduced. In the extreme, this is illustrated by a short road of consistent construction and condition. If the pavement is currently nearing terminal condition in terms of roughness and rut depth, one would expect it to require rehabilitation during the term of the contract. In this situation, a KPM profile specified to maintain existing conditions would be inappropriate. Instead, the KPM profile would need to be show an improvement during the contract (this would be time consuming for the client, and go against the contract philosophy of the contractor managing overall network performance).

A balance between the two extremes above is therefore warranted, by considering all the factors, drivers and KPMs relevant to management of the network. Experience to date has shown this assessment needs considerable effort if robust and useful KPMs are to be specified.

The contribution of pavement deterioration modelling

In New Zealand, methodologies to predict pavement performance have largely been built on the World Bank HDM approach (Watanatada et al, 1987). Experience in New Zealand is still limited, although it is rapidly increasing due to the nationwide implementation of a consistent approach (Henning et al, 2001). In determining the risks associated with achieving the KPMs, to date all tenderers, and clients as part of their tender evaluation, have built pavement models using the HDM relationships as a starting point.

However, it is important to note that the HDM relationships only go a limited way towards addressing the KPMs. Of the KPMs shown in Figure 1, mean roughness and texture depth can be directly inferred from the HDM methodologies and rut depth exceeding 20mm can be indirectly inferred. Any pavement modelling approach therefore needs to go considerably beyond the original methodologies in identifying and interpreting the risks involved.

Mitigating the risk of inappropriate performance measures

In recognition of the above issues and uncertainties, it would not be prudent for a client to rely solely on KPMs which specify performance as the only contract criteria. Therefore, Transit New Zealand has specified that with their tender, each tenderer propose and contract to an underpinned quantity of work, as shown by the last two KPMs in Figure 1. This gives the client some security for the term of the contract should the other KPMs turn out to inadequately specify the client objectives.

TRANSLATING CONTRACT OBJECTIVES INTO TECHNICAL ANALYSES

Overall pavement modelling methodology

With the KPMs and subnetworks defined in the contract documents, the scope for pavement modelling is essentially defined.

Figure 2 illustrates the generic process which tenderers follow in order to satisfy themselves that they will achieve the KPMs over the term of the contract. The various aspects are considered in detail later in this paper, but specific attention is drawn to two key issues.

First, experience continues to confirm that there is no substitute for practical, experienced engineering judgement and understanding of pavement behaviour. In addition, a sound statistical understanding is essential to ensure that analyses are meaningful and relevant. If either of these two strands are lacking, then a tenderer is far less likely to assess the realistic risk of achieving each of the KPMs.

Second, a perception of non specialist engineers in this field sometimes appears to have been that pavement management systems and pavement deterioration modelling have somehow increased our understanding of pavement behaviour. In terms of Figure 2, this view would be represented by considering that the focus of effort when tendering is in the 'Refine model – programme development' phase. Such a view would be that on production of a Base Forward

Works Programme (FWP), a tenderer has all the information to price the risk of meeting the KPMs accordingly.

Reality and experience of those tendering for PSMCs is different. Bringing together all the experience and knowledge of a tendering team, as regards pavement behaviour and deterioration, and then designing a system which accounts for all the identified drivers is practically not achievable. By accepting that the model will never produce an all embracing answer, the focus therefore has to change. In terms of Figure 2, this reality is represented by the considerable work that is required in the ‘Refine model and programme – Audit’ phase. The nature of this work includes sensitivity analyses, modelling the predicted effects of a Base FWP and refining the model to produce answers in line with engineering knowledge and judgement. Even at the end of this process, a tenderer has to interpret the risk given that the predictions are statistical and so represent a range of probabilities of any outcome.

Whilst the above might appear a subtle shift in emphasis, it is an important one. It shifts the emphasis towards recognising that pavement modelling techniques are only as good as the engineers that carry out the analyses, and highlights the danger of accepting outputs from overly complex systems which might cloud the practical aspects of expected pavement behaviour. However, it is also important to note that experience confirms that the only credible means of managing pavement performance is through the use of pavement modelling techniques.

Defining the objectives

Given that PSMCs are lump sum contracts for delivery of the KPMs, the objective for most tenderers is clear and can be translated into the pavement modelling as an objective function which aims to minimise agency costs within the constraints of meeting the KPMs.

Translating the above objective into a software solution is not straightforward. One approach is to develop a single index, or function, which brings together the relevant pavement parameters included within all the KPMs. The software is then designed to generate various treatment strategies for each section of road on the network, and to identify the costs and benefits (in terms of achieving this index) for each strategy. The aim is then to optimise this index over the analysis period (best condition at minimum cost across the network). This approach is often referred to as the ‘efficiency frontier’, and is the same principle as the HDM approach (Kerali, 2000) and that available within the New Zealand implementation of the dTIMS system (Henning et al, 2001). However, as noted above, it is only possible to realistically model some of the KPMs and so this solution might not in practice deliver a better answer than one driven by engineering judgment of priority.

A simpler approach is to identify the KPMs which drive the need for rehabilitation or resurfacing requirements. Sections are then ranked after modelling deterioration at the end of each year, and those which are most in excess of the KPMs are given highest priority. Whilst conceptually simpler than full optimisation, and also considerably simpler in terms of software programming, the method has weaknesses in not possibly considering optimum whole of life costs. In being simpler it does, however, lend itself more to multiple sensitivity testing as required for the ‘Audit’ phase of the modelling process described above.

Experience with PSMC tenders to date is that the amount of work which a tenderer proposes to meet the KPMs appears only loosely related to their approach of defining and applying their objective function in any software solution. This suggests that other aspects (practical understanding, model calibration and data validation) are considerably more significant in identifying the optimal solution.

KEY ISSUES OF RISK

General

Risk allocation in the contract

As noted previously, PSMC contracts shift the risk of programming road maintenance to achieve defined performance wholly to the contractor. The contract does however define limits on the transferred risk. The following list notes the limitations on risk transfer which specifically relate to achieving pavement performance through the KPMs:

- Slumping of a road beyond a prescribed limit (i.e. geotechnical rather than pavement failure)
- Traffic growth in excess of a prescribed limit (currently set at 5%)
- Increases in legal axle limits

Tenderers therefore need to convince themselves that they have managed the risk, and the client also needs to be satisfied that any potential contractor has an adequate understanding of the risks associated with achieving the KPMs.

Management of risk by tenderers

The key means by which tenderers manage the risk of achieving the KPMs is by significant specialist pavement modelling input. Experience shows that successful tenderers are starting well ahead of the tendering period (i.e. well before requests for tender are issued) in terms of building their understanding of network performance and requirements. The key time consuming aspects of the approach include data validation, calibration, and sensitivity analyses as described in more detail below.

Management of risk by the client during the tender process

Given that the risk for programming road maintenance activities lies wholly with the contractor, the client needs to be satisfied that a tenderer adequately understands this risk to avoid letting a potentially unsustainable and unsuccessful contract. Transit New Zealand has managed this risk by appointing an adviser to the tender evaluation team (TET). During the tender process, this adviser monitors progress of the tenderers and in particular, confirms to the TET in advance of close of tenders that each tenderer is following a robust approach. Key aspects which are assessed by the adviser are:

- Experience of the tenderers modelling team
- Data validation processes
- Model calibration
- Sensitivity analyses
- Overall methodology

After the close of tenders, the adviser reviews the final submitted tenders and provides a formal report to the TET on the relative risks of accepting each tenderers approach (a quantitative comparison) as well as advice on how well it is considered each tenderer understands the risks (a qualitative comparison).

It is difficult for an adviser to establish properly the real issues related to achieving the KPMs. For this reason, experience to date suggests that the best way for the adviser to understand those issues is by carrying out his/her own preliminary pavement modelling. The level of investigation need not be as intense as the tenderers, but it does highlight some of the important aspects driving the network performance.

Finally, the above interactive process of evaluation enables the adviser to gain an impression of cooperation that each tenderer might be likely to offer during the contract itself.

Data issues

Confidence in the data

Probably the most important aspect which a tenderer has to consider is the validity of the existing data. In New Zealand, the nationwide uniformity of data format provided through the Road Asset Maintenance and Management system (RAMM) means that the process of data validation is less onerous than it might otherwise be. The most up to date RAMM database is issued to each tenderer, with updates as necessary during the tender period.

Notwithstanding the above advantages, significant data validation is still required by each tenderer. In general, this is best achieved out on the network and experience suggests that the most significant items which require review are those of maintenance history (which therefore affects existing inventory information such as surface type etc).

Other data items which have often been found to be questionable are those related to traffic data. Traffic data is a significant driver of the models and experience has been that tenderers often overlook such validation, probably due to a focused professional experience in pavements rather than traffic. Experience on the Transit New Zealand network is that whilst traffic volume data might be reasonable, vehicle mix data (percentage of heavy goods vehicles) is often far more questionable. Validation for such data can often be found from broader reports. For example, in New Zealand, logging traffic is often a concern and in many cases separate studies have been carried out previously addressing such issues, and the information has not been followed through into the RAMM data.

Dealing with the dynamic nature of data

Given the degree of validation that is required, it makes the process even more difficult if the tenderer is issued with an updated database during the tender period. However, this needs to be offset by the fact that often the incumbent network manager is also a tenderer for the PSMC contract about to be let, so that withholding the information from other tenderers is not an option.

Information that is particularly important for each tenderer is that concerned with any work activities being carried out during the tender period which will be completed by the time the PSMC is awarded. This can have a very significant effect on a tenderers proposed work programme and is something which needs thorough review by the client adviser to identify that tenderers understand this issue. The effect is due to the approach to contract benchmarking.

The contract defines those KPMs which will be adjusted according to a ‘benchmark’ survey at contract commencement. Benchmarking is required so that the successful contractor is measured on his performance relative to actual conditions at the start of the contract, and not on outdated conditions which might be significantly different. The KPMs which are benchmarked are noted in Figure 1, and the effects are very apparent on networks where a significant improvement is being attempted prior to contract award.

An example clarifies the issue. 10km of a 50km subnetwork are resurfaced in the run up to contract award. If a tenderer tenders without realising this information, the obvious effect will be that he might programme the need for additional unnecessary resurfacing work in the early years of the contract. However, the more subtle implication which also must not be overlooked is that, for example, the remaining surface life of the subnetwork at start of contract will now be significantly higher than is currently realised. With the intent of the contract being that the network is maintained to deliver the same KPM values at Year 10, this will mean additional work might be needed in the latter years of the contract in order to return the same value of remaining surface life KPM.

In some cases, the issue of such benchmarking has become problematic and this further emphasises the need for thorough review in advance by the client to avoid defining KPM values which are not appropriate for the long term needs of the network.

Sectioning

An important aspect which needs to be addressed by tenderers is that of sectioning. In New Zealand, forward works programming is based on the use of treatment lengths at the project level. Treatment lengths are variable lengths of road, which are determined based on their being homogeneous in terms of inventory and condition items. Treatment lengths are the basic sections which are then used to predict the required FWP based on any pavement deterioration modelling.

If conditions on treatment lengths are not adequately defined in terms of homogeneous condition and are too variable, then there is a significant impact on any pavement performance predictions. The impact is apparent in two ways. First, any estimates of work required to ensure the extreme value KPMs (‘allowable % exceeding’ KPMs) are met will be flawed, if they are based on analysis of variance of condition of the treatment lengths. Second and more importantly, any predictions of work requirements in general will be flawed as the average condition values for each length (e.g. roughness) will not be representative of the variability.

Strength – variability in estimating methodologies

A final aspect of data validation that warrants attention is that of estimating pavement strength. In preparation for tendering any PSMC contract, Transit New Zealand has completed Falling Weight Deflectometer (FWD) surveys of the entire relevant network. Given that tenderers are using the HDM methodology for pavement modelling, this information then needs to be transformed into the Modified or Adjusted Structural Number. There are a number of relationships available to achieve this transformation, and the relationship adopted will depend on availability of pavement information (layer thicknesses) as well as the users preference.

Experience in New Zealand with such relationships is that they are often significantly different in terms of cross comparison, so that one method might produce consistently different (biased) results in comparison with another. This is not an issue if only one method is used throughout the calibration and analysis process. However, in situations where a mixture of methods have been used (e.g. certain sections of the network having no pavement layer information thus for these sections using a simpler relationship) then care needs to be taken as such results will produce inconsistencies across the network.

Calibration of deterioration models

Calibration analyses

The RAMM databases hold current and past records of network condition and so they can be used as a starting point for model calibration. However, due to issues of repeatability with high speed data measurements, calibrations using such data can only be approximate at best. Also, due to the limited time available, it is not usually possible to carry out very detailed calibration studies. The approach therefore usually has two strands:

- ‘Theoretical’ calibration as far as possible by reviewing the available data and considering time series history of individual sections of road

- 'Practical' calibration which becomes an iterative process based on experience and judgement, in which a view on historic work quantities, network conditions and fundamental understanding is used to refine relationships within the model to the point where predictions appear reasonable

Experience to date with calibration

Two issues are worthy of mention with regard to calibration experience to date.

First, calibrating by definition is based on past performance. Therefore, care needs to be taken when interpreting such results in the light of potential innovation in the future. For example, calibrating the HDM models which predict time to crack initiation will be based on the performance of surfacings to date. If a contractor is anticipating innovation in this regard, and the achievement of extended surfacing lives, then due recognition of this aspect needs to be considered.

Second, experience in New Zealand with the HDM models is now beginning to suggest that calibration factors (and even model forms) might be significantly different from the original HDM equations. For example, it appears at this stage that roughness deterioration rates are significantly lower than the default HDM equations (down to possibly 20 – 30%). The perceived wisdom is that New Zealand carries out significantly more routine maintenance interventions than those countries which formed the basis for the HDM models.

Whilst the above might be true, there remains a concern that rehabilitation type activities (traditionally driven by roughness in the HDM models) are being driven by other mechanisms (pavement shear failure and unstable surfacings). If this is the case, but tenderers are only basing their predictions on the traditional HDM mechanisms, then there is a danger of underestimation of rehabilitation requirements. This is compounded by the fact that it does not appear that the models adequately reflect the need for, or impact of, routine maintenance.

In summary, the authors consider that extensive analysis of data is required in order to review calibration, but that any results need to be weighed against pragmatic experience and an understanding of the original drivers of the HDM models. Where evidence suggests network performance is significantly different from the HDM models, then careful consideration needs to be given to the consequences of such changes.

Sensitivity testing

Sensitivity testing is considered a key requirement for any pavement modelling process. This is based on the premise that pavement deterioration models by their very nature are based on a statistical distribution and error and therefore there is a probability and tolerance associated with any specific prediction.

One of the problems with sensitivity testing is that it is time consuming, particularly when a complex model is set up which might require considerable time for each analysis run. Whilst a degree of understanding is gained from detailed validation of the data and model calibration, there appears to be no substitute for multiple analysis runs to gain a better picture of the likely risks of achieving the KPMs.

Experience to date has shown that the major items requiring sensitivity review and testing are:

- traffic (primarily total volume and vehicle mix, but also growth)
- calibration factors of models (primarily roughness, cracking and texture)
- condition resets after treatments (a measure of the importance of contractors work quality)
- inventory data where this is considered to be questionable (primarily surface age)

Current concerns with regard to managing risk

This section highlights some specific issues based on pavement modelling experience to date and its contribution to the risk management process in PSMCs.

Texture prediction

Texture depth is an important KPM as it relates to safety as well as useability for the road user. To date, experience in New Zealand with predicting texture deterioration has been based on the HDM models. These models include only traffic and surface age as explanatory variables. Also, they predict a significant increase in texture for a short period after resurfacing, reverting to a long term value which only gradually deteriorates (the form is based on an exponential curve). Two aspects need to be addressed.

First, a known driver for rehabilitation type work on the network is the presence of unstable surfacings due to multiple chip seal layers on old roads. This leads to premature surface failure through flushing. The model does not include such an explanatory variable which needs to be addressed before reliability can be placed on its predictions.

Second, the raised short term texture depth predicted after resurfacing might be theoretically correct, but in a monitoring regime which is only performed on an annual basis, it exaggerates the improvement effect and might lead to a false sense of security for a tenderer. The authors consider that the model requires adjustment to reflect the realities of the monitoring process, and to produce a more stable output.

Asset consumption

The Structural Condition KPM is currently adopted to control asset consumption. It is based on the amount of overlay required on each section of the network, in order to return a 25 year design life. The criteria adopted are based on back analysis of FWD data and the Transit New Zealand supplement (May 2000) to the Austroads pavement design guide.

General experience suggests that pavement deflections do not deteriorate over time. Also, given that pavement design is relatively insensitive to small traffic changes (the relationships are logarithmic) this means that such a KPM will almost inevitably be achieved with a minimal amount of rehabilitation type work. Also, in addition to the unstable surfacing issue above, the other key driver for rehabilitation type work on the New Zealand network is often premature failure of the basecourse through shear (shoving). This phenomenon is also not predicted by the HDM models.

In summary, there is potentially a risk that the current KPMs do not adequately cover the issue of asset consumption. If asset consumption becomes an issue, and it becomes apparent that enough rehabilitation work has not been allowed for, then the problem will manifest itself in increased routine maintenance costs. Early in the contract, this might not be too significant since it might be the lowest ‘contract life cost’ for the contractor to rehabilitate a road section, rather than living with high routine maintenance costs over the term of the contract. However, in the latter years of the contract, there will be no driver for the contractor to reduce long term routine maintenance costs (except if there is a genuinely strong possibility of his being reappointed).

There is no KPM which seeks to address this latter aspect of limiting routine maintenance costs. Also, as noted previously, the model predictions for routine maintenance are considered tentative. The issue warrants further research.

SUMMARY OF CONCLUSIONS

Overview of experience to date

Transit New Zealand has now let four long term road PSMCs. During this time, both tenderers and client have gained a considerable understanding of how pavement deterioration modelling can be used to consider the risks associated with such contracts. Some valuable lessons have been learnt, and the need for further development work identified as outlined below.

Valuable lessons learnt

The status quo is less risky for tenderers to assess

If a tenderer is asked to meet KPMs which essentially represent maintaining the status quo, then network wide calibration of the models, in terms of total work quantities to deliver average conditions, is possible. This is less risky for a tenderer to assess. However, if the client wishes to change the condition of the network over time (either improve or allow deterioration), then the tenderer becomes more reliant on the detailed pavement models reflecting the relative effect of the key drivers being accurately represented. This latter approach involves a higher risk to the tenderer.

Considerable thought is required to align client and contract objectives

Considerable preparation is required by the client in advance of tendering a PSMC contract. The key issues which need to be addressed are:

- Confirming an appropriate subdivision of the network into subnetworks
- Aligning client drivers with contract specifications, and in particular checking for the impact of benchmarking and other data changes on the proposed KPMs
- Evaluating detailed technical aspects of each tenderers approach to managing the KPMs. The evaluation needs to cover both qualitative aspects (how well does a tenderer understand the risks?) and quantitative aspects (how risky is a particular tender). In the process, the client can discover how cooperative and open each tenderer is, which might serve as a guide for working with the tenderer should he be successful.

A good database of the network is essential for tenderers to understand risks

New Zealand is fortunate to have a high quality inventory of the network and significant data covering history of network conditions and maintenance activities. This is an essential basis which has allowed tenderers for PSMC contracts to make a proper assessment of the risks. If this were not the case, then tenderers would either have to significantly increase their prices to cover the risks, or Transit New Zealand would be in danger of receiving tenders which represented a high risk of non-conformance.

Pavement deterioration modelling is used for risk management for both client and tenderers

Pavement deterioration modelling is a tool which helps both the client and tenderer assess the risk of meeting the KPMs. However, rather than being seen as an expert system or decision making tool which ‘sees more than an engineers eyes’, it should rather be understood as a risk management tool. In the latter case an intensive iterative process is required which continually refines the model predictions and ‘base engineering forward works programme’ to achieve an output which demonstrates compliance with the KPMs.

The most important aspects of the modelling process are practical understanding integrated with detailed calibration of the models and data validation. This requires a combined expertise in statistics and road maintenance engineering, and detailed aspects of each have been discussed.

Further development work is required

Experience is moving us beyond the HDM pavement relationships

Experience in New Zealand suggests we might be moving well outside the original statistical basis for the HDM models. In particular, rates of roughness progression are considerably lower than the original relationships, and this is probably due to the significant amount of high quality routine maintenance which is carried out on the Transit New Zealand network.

The drivers for rehabilitation work are therefore less roughness driven, and more related to routine maintenance costs, unstable surfacings (manifested in rapid texture deterioration) and pavement shear failure. The impact of these latter issues requires refinement in the current models.

The above models relate to the issue of asset consumption and it might be that the KPMs for this aspect will require refinement in due course to ensure that client objectives are adequately defined.

Finally, care needs to be taken in the use of the HDM texture models. Their exponential form suggests very high texture for a very short initial period after construction. Whilst this may be true, it might lead to unreliable forecasts from a longer term perspective if not properly understood.

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BIOGRAPHY OF PRESENTING AUTHOR

Chris Parkman is currently Pavement Performance Analyst at Transit New Zealand where he is responsible for initiatives in the area of pavement performance management, including the on-going implementation of the dTIMS system.

Since graduation in 1988, he has worked in a number of countries gaining experience in a wide variety of backgrounds. After 3 years as a graduate engineer he completed the masters degree in highway engineering at University of Birmingham, UK. He then worked on secondment at Queensland Main Roads for one year before spending 2½ years in Belize as site materials engineer. Returning to UK in 1996, he worked for TRL where he was responsible for international asset management projects including studies on road rehabilitation, road maintenance contracting and various inputs into the international study to upgrade the World Bank HDM model.

Relocating to New Zealand in 2000, he worked for Beca Carter Hollings and Ferner before moving to Transit New Zealand in 2002.

FIGURES

Parameter	KPM	Details of measurement	Subject to bench-marking?
Roughness	Mean NAASRA	Annual with HSD	Yes
	Percent with roughness > NAASRA threshold	Annual with HSD	No
Texture	Mean texture depth	Annual, mean profile depth with HSD	Yes
	Percent with mean texture depth < lower threshold	Annual, ,mean profile depth with HSD	No
	Percent with mean texture depth > upper threshold	Annual, mean profile depth with HSD	No
Skid resistance	Percent with Sideways Force Coefficient < threshold	Annual, using SCRIM compatible machine, by site category	No
Rutting	Percent with depth > 20mm	Annual with HSD	Yes
Surface Life	Minimum surface life index	Years 8 – 10 only, an empirical index based on expected life for different surface types	Yes
Structural condition	Structural condition index	Years3, 6, 8 and 10. Volume of overlay required across network to achieve a 25 year pavement design based on FWD back analysis	Yes
Minimum resurfacing length	Resurfacing length by lane-km	Annual, proposed by tenderer, for chip seal and AC surfacings	-
Minimum rehabilitation length	Rehabilitation length by lane-km	Annual, proposed by tenderer	-

Abbreviations used in above table: *NAASRA* – National Association of Australian State Road Authorities – which has an accepted unit of measure of road roughness; *HSD* – High Speed Data – using laser profilometers; *SCRIM* – Sideways Force Coefficient Routine Investigation Machine; *FWD* – Falling Weight Deflectometer.

Figure 1: Key performance measures currently adopted

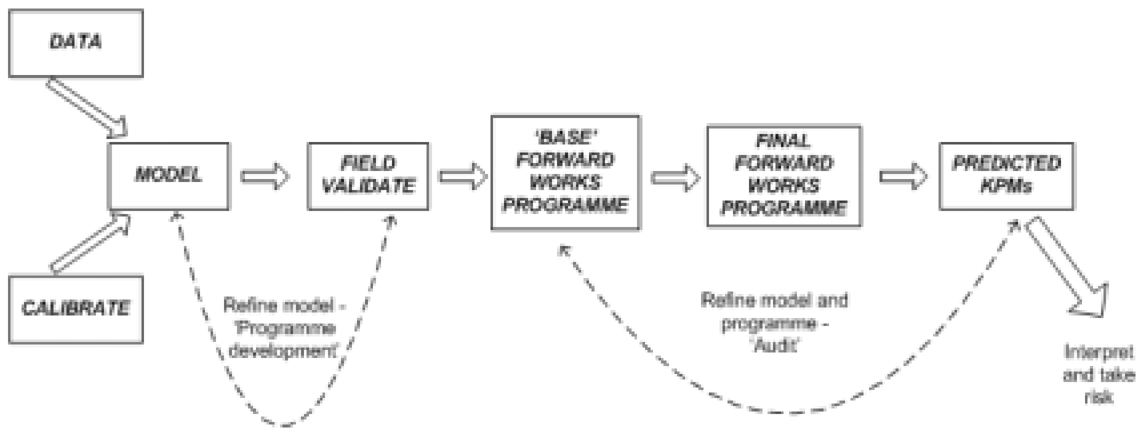

Figure 2 – Pavement modelling in the tender process