THE CHANGING FACE OF ROAD MAINTENANCE ENGINEERING

Interactive Road Maintenance Engineering

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Paper Summary

Over the past twenty-five years, the Road Maintenance Industry has seen numerous software packages marketed ostensibly that are a “best practise” road management philosophy, to asset managers responsible for the multi million dollar road reserve asset. Many of these so-called solutions, pay little or no attention the actual deficiencies on the network, maintenance practises undertaken by the authority, customer requirements, and most importantly the overriding management philosophy, for managing the pavement network.

In this paper the authors, examine:

1. The development of a method for acquiring network maintenance segments based on measured condition data, rather than the traditional fixed reference segments.
2. The optimisation methods, fundamental to the development of the long term maintenance planning and demonstrate the use, benefits and drawbacks of the primary three different optimisation/prioritisation methods, namely: the ranking, benefit-cost/economic analysis, used to determine budgeted works programme.
3. Additionally, describe the method and more importantly the implications of developing an optimal maintenance strategy for any section of pavement.
4. The impact elasticity of input parameters used to produce the long term budget and maintenance strategies in terms of data collection, works effect models,
5. Once this works program has been developed, an interactive methodology is shown to provide the Road Maintenance Engineer with the tools to measure the effect, in terms of Key Performance Measures and Budget, of moving the budget produced works program into an effective the effect operational works program.

The method described in this paper, are based on the method developed over the past nine years on the ten year Performance Specified Maintenance Contract in the Sydney Metropolitan Area and 5 years on the New Zealand PSMC contract.

INTRODUCTION

The adoption and development of Road Management Plans as a tool for local government authorities is becoming more important on a yearly basis as local authorities more away from more reactive maintenance strategies into long-term maintenance strategies that have accompanying long term strategic goals. To help achieve these goals in the pavement area, more authorities are starting to use and investigate Pavement Management Systems (PMS). However, this is being done with little understanding of what "best practise" means to the local government authority.

The term best practice has been used ostensibly in the field of pavement management systems and on many occasions it has been used to describe a single type of analysis. However, this begs the question; can a single type of analysis method be truly best practice, when every authority has different sets of goals, different maintenance practices, different user requirement and different needs? It is in this context that the optimisation/prioritisation methods, maintenance strategies, definition of maintenance sections, data collection and budget requirements used in pavement management systems that need to be explained. Throughout this paper the operationally proven works programme and asset valuation software PARMMS ® Road Manager is used for the purposes of demonstrating how the local authorities pavement management strategy can be placed into the pavement management software.

To gain an understanding of the sensitivity of the process to changes in inputs, a review of the impact elasticity of the input parameters used to determine budget requirements in order to achieve the network owner's philosophy, is also shown.

Finally, the paper covers the method for converting, the PMS produced works programs into Operational Works Programs and yearly work packages.

This paper is not intended to cover the in-depth technical requirements, models or use of any pavement management software.

Objective

This paper provides potential and current PMS users an outline of the process used to establish the budget and budgeted works program, configured to produce a customized multi-year works programs, which adheres to the agencies specific goals and philosophy. And finally, show a method to convert the budgeted works programs into a useable RMP with efficient work packages.

When using any PMS system it needs to be remembered they are simply, *"a systematic method of information collection and decision making, necessary for the optimisation of resources, for the maintenance and rehabilitation of pavements;"* [1] the philosophy that is used to produce the RMP is then the authorities philosophy for management of the road network, incorporates a software package, it is not the software package.

Given the philosophy used in is authority specific, it needs to be incorporated into the PMS by using customised: optimisation/prioritisation procedures, treatment selection processes and risk or treatment levels. This philosophy, that is incorporated in the PMS is then the intellectual property of the authority, and is specific to the authority i.e. no two agencies will have the same philosophy and therefore, no two agencies will predict that same outcome for a given budget and thus not two agencies should have the same PMS.

DETERMINING THE PHILOSOPHYAND ESTABLISHING KPI

The most important step in setting up any pavement management system, is determining the overall driving philosophy of the system. When developing the philosophy for maintaining a road network, the authority must consider what are the deficiencies in their network (i.e. the area of cracking is high), what are the user requirements (i.e. remove rough sections of road), what are the owner's expectations (i.e. best condition for the available budget), and what budget is available. Additionally, the authority must consider the application and validation of the philosophy. It is of little use developing a governing philosophy when it can be neither measured nor applied.

It is advisable that once philosophy is establish, the performance of the network gets measured against that philosophy, it is the measurement of the network condition against this philosophy that should become the Key Performance Indicators (KPI) of this network. For PSMC type contracts, the overriding philosophy is supplied in the contract documents, usually in terms of maximum condition for a section of pavement and the overall average condition of the network or sub networks.

Because of the importance of the process, it is recommended that the governing philosophy that directs the use of the pavement management system, becomes the responsibility of not only the senior managers of the authority but the political decision makers as well.

IMPLEMENTATION OF THE ROAD MANAGEMENT PLAN

The following steps outline the method for developing a RMP they are shown in no particular order; it is up to the authority to determine the order taken in establishing the RMP. In some case steps may not be needed, in others step may be taken concurrently.

Performance Prediction

Ideally the performance prediction equations used in the PMS should be derived or calibrated with data from Australia and New Zealand even more ideally the equations should be calibrated to sub-regions within Australia. On implementation of the PMS system the validity of the supplied models should be checked using a desktop calibration and adjusted if needed by experienced and professional engineers. Once the PMS is established on a network, the calibration of the models to each authority's local conditions should be using data collected form LTPP sites, collected over multiple years.

Contrary to popular belief, the models on the whole have relatively low impact elasticity, due to the continued calibration and validation of the models (dependant on the amount of global default values). However to ensure accurate results for the RMP in terms of budget and predicted outcomes, it is recommended that the models are maintained in calibration by continued use of the LTPP site data on a bi-yearly basis. Due to the technical nature of this calibration it is recommended that the calibration of the models remain the responsibility of the Pavement Engineer.

Selecting Optimisation/Prioritisation Philosophy

There are three methods of optimisation/prioritisation available, priority programming, optimisation programming and the fuzzy logic failure plane approach, the choice of which method to use should solely be controlled by the governing philosophy of the road authority.

For example, the pure optimisation methods should be chosen when the authority has an objective function, such as lowering overall roughness of their network. This approach must then select the works program that results in the lowest roughness for a given budget. However, it needs to be noted that economic approaches may not examine all contributing factors and ignore social issues (i.e. may defer unsafe sections of pavement due, say, rut depth even though those sections may be in an unacceptable condition). Currently an authority has the, mutually exclusive, choice of optimising on roughness, rutting, cracking and total area of defects.

The priority programming approach, produces works programs by treating pavement sections on a worst first approach (e.g. treat worst skid resistance sections of pavement first or treat sections with the highest routine maintenance per square meter first), this approach does not consider cost. In RM the priority approach employed is totally up to the authority and may be a complex interaction, equation based approach, using any of the 50 program fields. It should be noted that this approach on most occasions will not produce the lowest network condition for a given budget and will produce completely different works programs dependent on the prioritisation method chosen.

The final method, the failure plane approach, was developed around limiting the amount of failed pavement sections. With the "Fuzzy Logic" processes; the system weighs up the three contributing factors leading to the pavement failure. The factors used in this feature include roughness, rutting and cracking, and determine the highest priority by examining the distance of each attribute from the failure surface. This approach will develop works programs primarily revolving around sections of failed pavements and will do little in terms of preventative maintenance.

The following table, Table 1, shows for a small network a comparison of the ranking and optimisation philosophy. In the table six sections of pavement are shown, each of the same traffic class, each with their selected rehabilitation treatment and cost. If the pavement manager had a budget of $50, he could treat 3 sections of pavement with the economic approach giving a network condition of 67.5 and only the reconstruction option with the ranking approach giving a network condition of 96.2.

ROUGHNESS	TREATMENT	COST	ROUGHNESS IMPROVEMENT	B/C RATIO	OPTIMISATION METHOD	
					BC	Ranking
120	IS Stabilisation	25	75	3.0	45	120
70	Thin Mill and Resheet	7.5	25	3.3	45	70
90	Mill and Resheet	15	45	3.0	45	90
180	Reconstruction	50	135	2.7	180	45
50	Reseal	3	3	1.0	50	50
40	Reseal	3	0	0.0	40	40
Average					67.5	69.2

Cleary, form a purely economic point of view the economic approach has given the manger more return for the moneys spent. If the economic approach was chosen, for this example the section requiring reconstruction would not be give priority until it reached a roughness of 200NRM. This begs the question, is treating a section with roughness of 70 in priority over a section with roughness of 200NRM, best practise? It is up to you.

The optimisation/prioritisation process used in the PMS, by far, has the highest impact elasticity on the produced works programs and predicted budget requirements. And therefore, to ensure credible results in terms of budget and predicted outcomes this process has to match the maintenance philosophy undertaken by the authority. Due to the highly sensitive nature of this parameter, it is suggested that this process becomes the responsibility of management to ensure that the philosophy built into the PMS matches the governing philosophy of the authority.

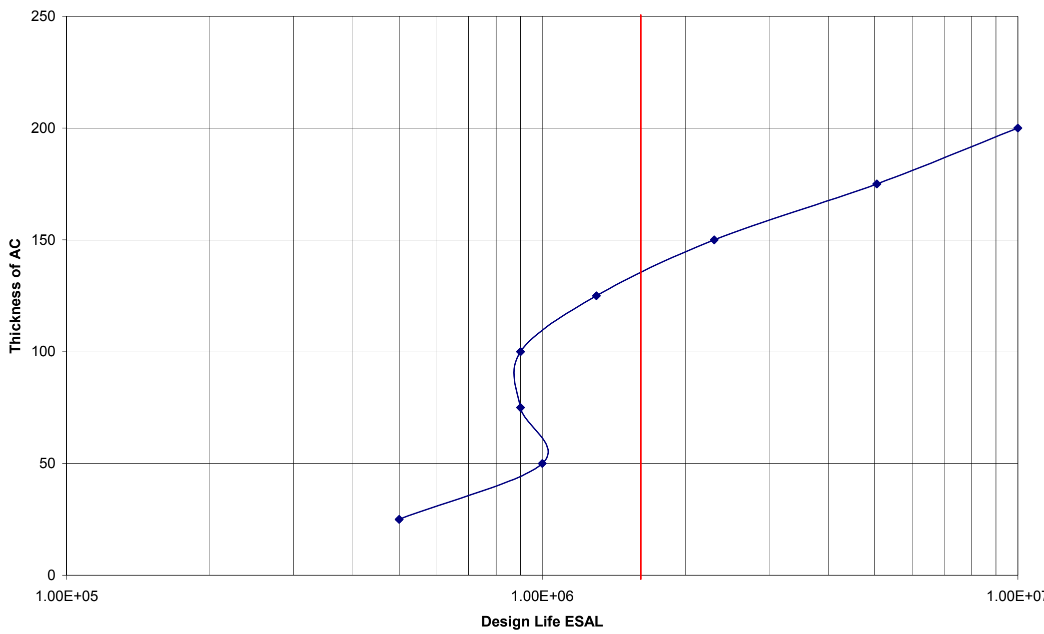
Determination of Maintenance Strategies (Project Level Optimisation)

The determination of the most appropriate maintenance strategy to be used on a section of pavement, based o it current condition can be achieved through the use of structural design risk levels or separate treatment select processes. In this approach the three alternative scenarios are cycled through the PMS system, for each year of the analysis period each scenario is costed independently.

The Three alternate scenarios are:

- Routine Maintenance: That is, only allow routine treatments such as crack sealing and patching until roughness reaches a predetermined terminal value then reconstruct.
- High Risk, Rehabilitate: Design all sections of pavement with a relatively high risk of failure, which is user defined (40-60%). For example, probability 50% uses the mean value to compute the structural capacity, which in turn is used to calculate the overlay required. This treatment option will be less expensive than the low risk option, but will introduce more frequent maintenance treatments due to the lower structural capacity.
- Low Risk, Redesign: Design all sections of pavement. A network designed with a low risk of failure, which is user defined (80-95%). For example, probability 95% will use the Mean plus two (2) standard deviations to compute the structural deficit, causing higher initial expenditure but less frequent maintenance.

Each alternative is then costed for the analytical period, at a user defined discount factor (4, 7 or 10%). The solution with the lowest whole of life cost is chosen as the “ideal” strategy. An example of how risk levels work is shown in the following figure, Figure 1. The figure shows the pavement life vs. asphalt thickness required on an 300mm granular pavement with sub-grade of 40MPa.



If the example is taken for a pavement with a 20year design traffic loading of 1.8×10^6 ESA, for the high-risk option, it would be expected that a 50mm asphalt layer would be calculated, if however the low risk option is chosen a 140mm asphalt thickness would be required. In such cases, it may be beneficial from an economic point of view, to treat the section twice in the 20year period with the 50mm overlay rather than the single treatment of 140mm.

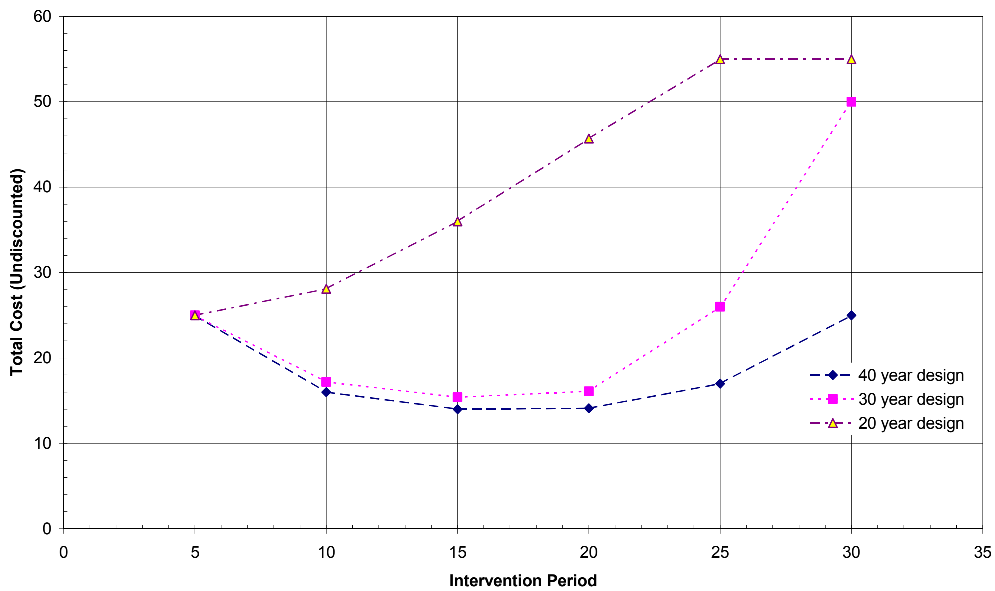
In setting up the use of risk levels the overall philosophy of the network should be considered, for example:

- If the philosophy requires all outcomes to be designed to meet a 20-year design life, then the high-risk level should not be included.
- If the philosophy is to remove all rough sections of pavement regardless of cost then the routine maintenance option should not be included.

The effect of the risk levels chosen on the operational works programs and the predicted network outcomes are relatively low. It is therefore recommended that the determination of risk levels remain the responsibility of the Pavement Engineer.

Multi Year Optimisation

Beyond, optimisation at the network and project level it is also possible to optimise on a multi year basis, in this approach if a project is selected either by economic optimisation or prioritisation the section still may be not treated if a better economic return can be achieved through deferring that treatment for an extra year. The figure following, Figure 2 shows an example of multi year economic optimisation for a single section of pavement. In the figure three asphalt pavements are investigated, one designed for 20 years, one for 30 and one for 40.



What the figure shows is that the optimal intervention period is highly a function of the overall pavement structure, additionally if the 40 year pavement structure is taken as an example and by the economic approach, the pavement is selected at year 12, it still may be deferred as economically the section will have a higher B/C ratio in year 13. is this best practice?

Determining Available Treatments, Costs and Works Effects

Before implementation of the PMS and periodically during the operation of the PMS the maintenance engineer needs to develop/inspect the treatments within the PMS and ensure that the treatments, cost and works effects models within the system are current and representative of the maintenance philosophy employed. If during the operation of the PMS the maintenance engineer adds a treatment option, then the decision matrix must also be revised to include this treatment.

Of all the input parameters used in the RM system by far the most sensitive and therefore the parameter with the highest impact elasticity is the works effects models. For example a works effects models that assumes a roughness of 40 NAASRA counts can be attained, from a HMA overlay when only 60 NAASRA counts is achieved then:

- The budget could be out by as much as 50%.
- Condition Profile could be out as much as 10%

For this reason it is imperative that works effects models are kept current, in general the upkeep of the works effects models should be the responsibility of both the Maintenance Engineer and the Pavement Engineer, due to the highly sensitive nature of this parameter.

Treatment Selection Philosophy

It is essential that the decision process used in the PMS matches the management style of the authority using it. As additional personnel use the PMS system, additional requirements will be identified. Therefore, the PMS decision process needs to evolve to be consistent with current management philosophy in terms of treatment selection and options, to maintain the credibility of the system. This implies, the authority using the PMS must take ownership and assume responsibility for the treatment selection process. The determination of the most appropriate treatment selection process can be best achieved by a cooperative effort between managers, maintenance engineers and pavement engineers to arrive at the correct design process.

To match the ever changing maintenance philosophy, the treatment section process that is used in the PMS must, be user customized and must resolve the most appropriate treatment by using both condition data and attributers of the pavement section.

This predicted budget is highly sensitive to the selection of the correct treatment .The resolution decision process should be regularly revised and checked by managers, maintenance engineers and pavement engineers to ensure that the predicted treatments still match the current philosophy.

The treatment selection process ranks third behind priority settings and works effects models for the greatest impact elasticity on budget. Therefore, to ensure credible results in terms of budget and predicted outcomes it has to be kept current. In general the treatment selection process should be the responsibility of both the pavement engineer and the maintenance engineer.

Data Collection Priorities

The data collection process and the inclusion of various elements within the network will most often be staged. In this process the most important pavements should be included in the first stage, the secondary important pavements in the second stage and so on until all data is collected for the whole network. The process should then be repeated on a rolling basis to ensure data is kept within its useful age range. Noting that RM has a step to ensure if condition data was collected from a previous years survey, it can be “synchronized” to the current date, using the built in deterioration models.

- Before any data is collected it must be ensured that all data is collected in accordance with the methods mentioned in the PMS user manual. It is little use in collecting data that cannot be used.

The impact elasticity of data collection methods along with the use of global default values is highly dependant on whether the data will trigger and action or if the data is used to measure outcomes. If the data is used for either of these two processes it should be given the highest priority in the collection process. If the data is not used directly to trigger an action or measure an outcome, it still may indirectly contribute to the condition measurement that triggers an action or that is used to measure an outcome (i.e. area of cracking contributes to roughness), in such cases the data should be given a secondary priority. A full list of the condition measurements that interact with other condition measurements refer to the RM users guide.

Sectioning Methodology

Most agencies will have a fixed referencing system by which all assets and condition data can be referenced, this system should be a consistent time stable system and may include; a) link, block b) network/road c) road, mile post referencing system etc.

However, If the data has been collected at levels below that of the fixed referencing system then it is provides an authority with the ability to dynamically segment the network, below the fixed referencing system level. This method is based on determining areas of "like" pavement condition, using a cumulative difference approach. In this method, it is possible to select the pavement condition measurements used, the level of significance used in the segmentation and the minimum segment interval, to create maintenance sub-sections. If dynamic segmentation is chosen then it must be remembered that segments may not remain constant and may change on a yearly basis.

In general the sectioning methodology employed has relatively low impact elasticity in terms of predicted budget requirement. However, the impact elasticity for the predicted works programs is fairly high. It is recommended therefore that the sectioning methodology becomes the responsibility of both the Pavement Engineer and Maintenance Engineer.

Establishing a Feedback Loop

After the implementation of the RMP, current condition and cost data should always be used. To make this possible a feed back loop should be established so that: condition information, cost data, the performance prediction models and the works effect models are maintained in calibration, so the system provides useable representative results.

The establishment of the feed back loop controls the majority of the previously mentioned processes. It is therefore recommended that the establishment and control of the feed back loop remains the responsibility of Management.

Adjusting and Improving the RMP to Keep Up with Changing Capabilities and Needs

Pavement management techniques and methods continue to evolve with advancing technology and data collection techniques. Computer speed increases, enables more complex optimisation procedures, and storage and interpretation of larger data sets. However, this can only be achieved through continuing feed back and support for the authority using the system.

This is a cooperative effort between the PMS provider and the authority.

The Operational Works Program in Practice

In general pavement management systems cannot completely model the decision process used by an experienced Maintenance Engineer. Some adjustment of the Works Program will nearly always be required to bring the produced works program into an Operational Works Program. This will generally, require shifting work and changing treatments into efficient work packages.

Predicted budgetary outcomes are sensitive to changes in the Works Program. RM enables the Asset manager to determine the effect of bringing different sections of road to the same period of construction or treatment by changing and/or shifting selected treatments forward or backwards by a maximum of three years to produce the Operational Works Program and examine the effects for both cost and Key Performance Indicators. The sensitivity of these changes should be monitored during this process.

It must be emphasised that the Works Program produced by RM is a function of input variables and a decision making process designed to replicate the treatment selection philosophy adopted by the authority. These so called candidate sections will additionally require verification in the field by an experienced Maintenance Engineer and therefore are the responsibility of the Maintenance Engineer in conjunction with the Pavement Engineer. Any changes in treatments must be monitored for the effect on the network condition and budget.

Once the proposed treatments are placed in efficient works packages, verified and designed, they become the basis of the scheduled Operational Works Program with its associated budget.

CONCLUSION

The general adoption of Road Management Plans for the maintenance and rehabilitation of Local Government road has created a need for systems that are accurate, fully user definable and versatile.

This paper considers the impact elasticity (sensitivity) of input parameters for a range of outputs and their influence on both budgetary and key performance indicator criteria.

A method is discussed for moving outcomes from a computer solution to coincide with political, environmental and operational contingencies to produce a fully costed operational works programme.

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Author Biography

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Bevan Sullivan joined Pavement Management Services in 1996 following service with The Australian Defence Forces and completion of his BE degree. He initially served for two years as Pavement Management's "implant Engineer" to the RTA – Transfield Services Performance Specified Maintenance Contract. Following this position Bevan implemented the Pavement Management Engineering methodology to Transit New Zealand's PSMC in the North Island of New Zealand and TNC 4 in association with Macmahon contractors in Western Australia.

Following a visit to Australia in 1999 by Prof Mathew Witczak the doyen of asphalt technology Bevan was invited to assist the Professor at Arizona State University with his research into the prestigious AASHTO Pavement Design guide. This he undertook, not only introducing new asphalt technology but gaining a highly awarded Master of Science degree in Civil Engineering/

Since returning to Pavement Management Bevan has been promoted to Principal Engineer and is responsible for Research and Development as well as training of engineering colleagues.

His contribution to this paper is the result of that R&D.

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John Yeaman founded Pavement Management Services P/L in 1980 to provide all the components necessary to engineer road maintenance management, following twenty years experience with road materials and specialist road maintenance products. . During the past twenty plus years he has been responsible for the implementation and validation of most of the technology of pavement management in use today, attested by the many awards to Pavement Management by peak engineering bodies both nationally and internationally. His contribution to the science was further recognised by his nomination to the prestigious Australian Academy of Technological Sciences and Engineering in 2003 .Dr Yeaman continues to play an active role in the development of Pavement Management both in Australia and overseas and provides mentoring to young engineers entering the profession through his involvement with Engineers Australia