Abstract— Road pavement related assets can account for as much as 70% of the replacement value of all infrastructure assets owned by Local Government. The annual maintenance bill expended by Councils for the upkeep of the road pavements can run into many millions of dollars. This paper will examine how optimising the selection and timing of maintenance treatments can result in huge savings for the Road Authority. The optimisation process discussed considers the 'whole of life' costs and benefits of various treatment options performed at different stages of the asset life. As a result of the optimisation the Road Authority should be able to maintain the road network at a higher level of service with less money. Road pavements that are maintained in good condition require less routine maintenance expenditure and result in lower road user costs for the community. The paper will also examine how similar optimisation techniques can be extended and used to develop optimised works programs for all manner of infrastructure assets.

Keywords-component; PMS Road Asset Optimised HDM SMEC

I. INTRODUCTION

Road networks are one of the most important infrastructure assets that are owned and maintained by Local Government. The community relies heavily on the roads; be it for the daily commute to work, movement of freight and goods between businesses, providing transport access to shops, schools or for access by emergency services.

Road networks that are in poor condition cost the community through increased fuel usage, increased vehicle maintenance costs and increased travel times. Road pavements that are in poor condition are also more expensive to maintain. For example if a road is resurfaced soon after surface cracking starts to appear then the road will be kept waterproof and very little preparation work will be required prior to the resurfacing being applied. A shorter interval between resurfacings means more resurfacings will need to be done and paid for from the road maintenance budget. However if the resurface is delayed and the road is allowed to deteriorate further before it is applied then there is a possibility that water could be getting into the pavement layers. This could result in reduction in pavement strength and deformation of the road under the effects of the traffic axle loading. This deformation results in higher road roughness and increased vehicle operating costs. The treatment to rectify the problem may now be more expensive as it now would require a resurface with shape correction or eventually, a pavement reconstruction.

This paper will use a case study to analyse the costs and benefits of using an optimised long term works program to maintain a road network in comparison with a ‘worst roads first’ strategy which is often used when works programs are devised through a simple inspection process.

The tool used to undertake the analysis is the SMEC Pavement Management System (PMS)

II. ROAD NETWORK

The road network that this case study is based on is owned by the Wyong Shire Council. This Council lies on the coast between Sydney and Newcastle and serves a population of approximately 150,000 people.

The Wyong road network is 1,048 km long and consists of 373 km of rural roads and 675 km of urban roads. The breakdown of the network by surface type is shown in Table I.

<table>
<thead>
<tr>
<th>Table I: Breakdown of Road Network by Surface</th>
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<tr>
<td>Surface Type</td>
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<tr>
<td>Chip Seal</td>
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<tr>
<td>Asphalt</td>
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<tr>
<td>Slurry Seal</td>
</tr>
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<td>Concrete</td>
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<td>Gravel</td>
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<td>Earth</td>
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<td>Other</td>
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The works program analysis for this study did not include gravel, earth, concrete or brick paved roads.

The network was subdivided into 3,619 sections that were considered homogeneous in condition, structure, age and traffic loadings. Condition surveys recorded the amount of cracking, stripping, ravelling and potholing. Road roughness and rutting was measured using a laser profiler. Traffic counts had been carried out on 1,580 sections and where actual traffic counts were unavailable; estimates were made based on road hierarchy. Construction and treatment history information was used to establish pavement profile and age data.

Figure 1 shows the distribution of the sealed road network by surface age.
III. PREDICTION MODELS

The prediction models used in the analysis are the World Bank Highway Design and Maintenance (HDM) models [1]. These are incremental models that predict the changes from year to year in pavement distresses such as cracking, stripping, ravelling, texture, potholing, skid resistance, roughness and rutting. Incremental models are better than absolute models in that they adjust readily to new condition surveys.

The HDM models have different algorithms for different surface types. They take into consideration pavement structural strength and traffic axle loadings. The models predict the effects that various treatment options will have when applied to roads at various condition states.

The HDM model also includes a vehicle operating cost model that can predict how road user costs vary as a function of pavement condition.

The HDM models have been calibrated for Wyong Shire based on road condition data that has been collected over the last 16 years.

IV. SMEC PAVEMENT CONDITION INDEX

The SMEC Pavement Condition Index (PCI) is a summary condition score that is calculated for each road section based on the levels of each of the individual distresses. The PCI is calculated based on a deduct point system where the default score for a road pavement in perfect condition is given as 10 but then points are deducted for each different type of distress recorded based on the severity of that distress.

The formula for the calculation of the ‘deduct points’ for road roughness is also a function of the traffic level. This is because, for a low speed, low traffic road, roughness is much less of an issue. However it becomes increasingly important as the traffic volumes and traffic speeds increase.

It is possible for a road pavement with many severe distresses to have a negative PCI.

Once a PCI is calculated for each individual road section it is then possible to calculate the ‘area weighted’ average PCI for the entire network. By monitoring the network PCI on a year to year basis it is possible to check if the overall road network is improving or declining in condition. The SMEC PCI has also been used to conduct benchmark studies for all of the Councils that are running the SMEC PMS.

V. OPTIMISATION

The first stage of producing an optimised works program is to determine the costs and benefits arising for each suitable treatment option that could be applied for each section of the road network. To determine the benefits, each different treatment option is modelled for 30 years into the future. The benefits are measured on a year by year basis as the difference between the ‘do treatment’ option and the ‘do nothing’ option. The future benefits stream is discounted back to Net Present Value (NPV) so that comparisons can be made. Each treatment
option is then deferred by one year and the modelling rerun to determine if deferral of the treatment will produce greater or lesser long term benefits. The benefits that are calculated include:

- Improvement in network PCI;
- Savings in road user costs;
- Savings in routine maintenance costs;
- Savings in total costs;
- Increase in asset value.

After the life cycle analysis for each road section has been completed for each possible treatment option, the benefits and costs are passed over to an optimisation program.

The optimisation process can be run in either of two ways:

- Select the optimum works program that can be achieved within an annual budget constraint; or
- Find the optimum works program and budget required to achieve a target network PCI.

For multi-year works programs, the system performs the optimisation on a year by year basis. The effect on the road condition of applying each year’s treatments is modelled into the database before proceeding to the next year of the analysis.

VI. CASE STUDY ANALYSIS

The main purpose of this study was to attempt to quantify the benefits that can be achieved by moving from works programs that are based on a ‘worst roads first’ strategy to works programs that have been developed through the use of a PMS that has modelling and optimisation capability.

The ‘worst roads first’ strategy was simulated by ranking all of the road sections by PCI and then only allowing the PMS to select treatment options from the worst 200 sections in the network.

The current average network PCI for Wyong Shire was measured at 5.47. Based on benchmark comparisons with other Councils, this is considered to be a relatively poor network. For the first stage of analysis it was decided to develop a 10 year optimised works program that would maintain the current average network condition level at a PCI of 5.47.

The modelling for this analysis was saved to the database as Scenario 1. The annual funding requirement to achieve this goal was calculated as the sum of the cost of each of the selected treatments. A graph showing the annual network PCI and the funding required to achieve the target PCI can be seen in Figure 2.

![Projected Changes To Average Network PCI (By Scenario And Year)](image)

Figure 2. Funding required to achieve target PCI of 5.47 using an optimised works program
Having determined the funding required to maintain the road network at its current condition level using an optimised works program, the next step was to determine what would happen to the condition of the network if the same funding was used but a ‘worst roads first’ strategy was adopted. This was modelled as Scenario 2. The annual funding determined from Scenario 1 was used as an annual budget constraint.

The results of this analysis can be seen in Figure 3.

![Figure 3](image)

**Figure 3.** Effect on network condition if ‘worst roads first’ strategy adopted

The graph shown in Figure 3 indicates that, under the ‘worst roads first’ strategy, the average network PCI would decrease from 5.47 to 3.5 by the year 2022.

The next stage of the analysis was to determine how much funding would be required to maintain the current network condition if a ‘worst roads first’ strategy was adopted to develop the works program.

This was modelled as Scenario 4. A target network PCI of 5.47 was set. To simulate the ‘worst roads first’ strategy only the worst 200 road sections were considered each year for a treatment.

The results of this analysis can be seen in Figure 4. The funding requirements for the optimised strategy (Scenario 1) have also been shown on the graph for comparison purposes.

![Figure 4](image)

**Figure 4.** Funding comparison between ‘worst roads first’ strategy and ‘optimised’ strategy
The analysis shows that adopting an optimised works program for maintaining the road network (as opposed to developing a works program using the ‘worst roads first’ strategy) has the potential to save the Wyong Shire Council just over $20 million over a ten year period.

As well as reporting the average PCI for the network it is often informative to examine the spread of road condition states that are used to calculate the average value.

Figure 5 shows the distribution of the network condition by PCI in 2011 at the start of the analysis period as well as the predicted network condition in 2022 if no treatments were done for 10 years. This can be compared to Figure 6 which shows the distribution of condition in 2022 at the end of the analysis period after applying 10 years of maintenance treatments. The effects of both the optimised works program and the ‘worst roads first’ works program are displayed.
When examining the 2022 network condition graphs shown in Figure 6 the following points can be noted:

- Although the ‘worst roads first strategy produces a greater length of road in excellent condition (PCI = 10) the optimised strategy has 167 km more road with a PCI > 5. Conversely the ‘worst roads first’ strategy has 167 km more roads in a poor condition.
- After applying the optimised strategy for 10 years, there were still a number of roads in very poor condition. This could be addressed by setting the minimum acceptable PCI threshold within the PMS that would trigger a treatment when that threshold was reached.

VII. FUTURE DEVELOPMENTS

SMEC is looking to expand the techniques developed for the optimisation of maintenance programs road assets and to apply similar techniques for all other classes of assets that may be owned by an organisation. Some of the challenges involved in this process include:

- Developing deterioration models for different assets;
- Establishing the works effects of different maintenance treatment options;
- Quantifying the benefits resulting from applying treatments;
- Establishing a range of optimisation parameters (e.g. minimise risk, maximise asset value, minimise depreciation, etc.) that can be used to express an organisation’s goals.

VIII. CONCLUSION

This case study has shown that, for the Wyong road network, use of advanced asset management techniques such as life cycle modelling and optimisation of works programs can lead to significant savings over more traditional techniques based on inspections to find and treat the worst roads first. The ‘worst roads first’ strategy required a total of $93 million over 10 years to maintain the network at its current condition. If an optimised works program was adopted, then only $73 million would be required. This represents a savings of $20 million or 22% of the capital works maintenance budget.

A computerised PMS can perform the hundreds of thousands of calculations that are required to do the modelling and optimisation. This is well beyond the analysis that any human could do manually. Despite the power of a PMS, it is still a tool and any works programs produced need to be verified by an experienced road maintenance Engineer. The challenge for the Engineer is to embrace the capabilities of the tool and not be lulled back into the strategy of searching for the worst roads and always treating them first.

REFERENCES


BIOGRAPHY

Roy Bartlett is the Manager of SMEC’s Asset Management Group. He first joined SMEC Australia in 1978. Since then he has worked in many different countries including Nepal, Bhutan, Indonesia, Burma, Yemen and Hong Kong. He has a background in computer programming, highway and drainage design and asset management. Roy is the architect for the SMEC Pavement Management System which is currently being used by over fifty Local Government authorities within Australia to manage their road networks. The system has also been implemented in a number of overseas countries.