Appendix I

Economic Analysis of Pavement Design Options

Peka Peka to Otaki Expressway
Scheme Assessment Report Addendum
Economic Analysis of Pavement Design Options

Quality Assurance Statement

Project Manager: Andrew Quinn (NZTA)	
Prepared by: Sheryn Reilly	
Reviewed by: Tony Coulman	………………………………
Approved for issue by: Tony Coulman	………………………………

Revision Schedule

Rev. No	Date	Description	Prepared by	Reviewed by	Approved by
1	6/6/11	First Issue	S. Reilly	T. Coulman	T. Coulman
2	16/2/12	Second Issue	S. Reilly	A. Murashev	T. Coulman

NZ Transport Agency

Contents

Executive Statement 1

1. Introduction 2
2. Pavement Options 2
3. Construction Costs 4
4. Maintenance Costs 4
5. Economic Analysis 5
6. Subgrade Strength 7
7. Summary of Results 8
8. Conclusions and Recommendations 9

Executive Statement

An alternative route to the existing State Highway One between Peka Peka and Otaki is being proposed as part of the Roads of National Significance scheme. This expressway provides a new expressway corridor parallel to the existing State Highway One between Peka Peka in the south and Otaki in the north. To determine the most appropriate pavement type, both technical requirements as well as the whole of life costs have been considered. To evaluate the whole of life costs the base design option has been compared against alternative options in accordance with the New Zealand Transport Agency Economic Evaluation Manual (EEM) methodology. This report outlines the whole of life cost analysis, analysis assumptions, and the preferred pavement design options. This report presents the results of the analysis and has been peer reviewed by acknowledged pavement experts within NZTA and Wellington Civil.

1. Introduction

The Peka Peka to Otaki expressway provides a new expressway corridor parallel to the existing State Highway 1 between Peka Peka in the south and Otaki in the north. It is predominantly a greenfield project with some widening of the existing State Highway at the tie-ins at the extents of the project. There is also a portion of new local arterial road between Marycrest and Peka Peka (the current SH1), together with new portions of local roads to maintain connectivity across the corridor. The focus of this report is a comparative analysis of pavement types and their costs for the expressway portion of this project.

The base case pavement option for the project allows for an unbound granular pavement throughout the project length. This design is based on the latest Austroads pavement design guide (2004) and the 2007 New Zealand Supplement to Austroads.

The alternative design options are a cement modified basecourse pavement (MAB), a cement stabilised subbase and cement modified basecourse pavement (MABSS), a structural asphalt pavement (SA), and a foam stabilised bitumen pavement (FSB). These designs are based on the latest Austroads pavement design guide (2004) and the 2007 New Zealand Supplement to Austroads.

The purpose of this paper is to explore the whole of life costs of each option and potential risks of these options to confirm an appropriate pavement selection for the Peka Peka to Otaki expressway.

NZTA has instructed Opus to carry out a risk-based economic analysis for a number of different pavement design configurations which have been discussed and agreed with NZTA. This report comments on the risk of failure and whole of life costs for the base flexible pavement option against a range of alternative pavement options.

2. Pavement Options

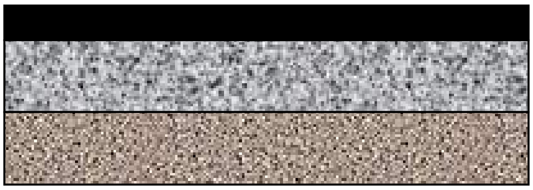
The pavement options considered for Peka Peka to Otaki expressway are shown on Figure 1.

The base option is the unbound granular pavement option. This option would require a minimum 3 month delay prior to placing the OGPA seal to allow for compaction related rutting.

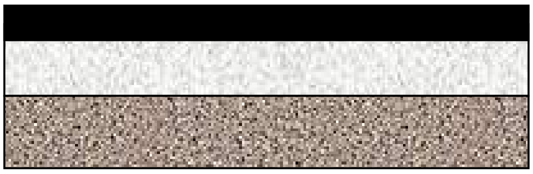
The base option of an unbound granular pavement has been compared against four alternative options. The alternatives are a modified basecourse option, a modified basecourse on stabilised subbase option, a structural asphalt option, and a foam bitumen stabilised basecourse option.

The surfacing requirements for the expressway will be determined by noise restrictions. Where noise restrictions are applied the surfacing choice will be Open Graded Porous Asphalt (OGPA). Where noise restrictions are not applied a two coat chipseal (either 2/4 or 3/5) will be applied. For the purpose of this analysis all surfacing was assumed to be OGPA. As the whole of life cost analysis is a comparative analysis, the choice of what surfacing option is chosen does not affect the outcome.

Base Option – Unbound Granular (UB)

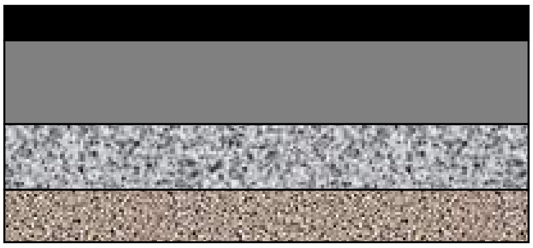


Option 1 – Modified Basecourse Pavement (MAB)



Option 2 – Modified Basecourse Cement Stabilised Subbase (MABSS)

Option 3 – Structural Asphalt (SA)



Option 4 – Foam Stabilised Bitumen (FSB)

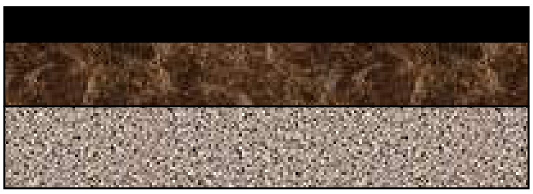


Figure 1 – Schematic of Pavement Options

3. Construction Costs

The construction costs used are based on rates used on a widening project in the Wellington Region. The rates used are as follows:

Item	Units	Rate
Sub-base (AP 65)	m3	$ 90.00
Basecourse (TNZ M4)	m3	$ 65.00
Stabilise	m2	$ 17.80
Cement	Tonne	$ 350.00
Lime	Tonne	$ 400.00
Foam Stabilised Basecourse	m3	$130.00
2 Coat Chip Seal Grade 3/5	m2	$ 9.00
Structural Asphalt Mix 20	Tonne	$250.00
50mm OGPA (including tack or membrane)	Tonne	$ 260.00

Table 1: Construction Rates

4. Maintenance Costs

It has been assumed that periodic maintenance (area wide treatment and resurfacing) can be carried out during the night. For all options it has also been assumed that any area wide treatment applied will be a structural asphaltic concrete option so that it can be carried out in sections at night and have the road fully open to the traffic the following day. It is possible that a granular overlay is a more appropriate option but there may be some time delays with this option and issues with changing the finished road height. For the purposes of this comparative whole of life cost analysis the structural asphalt pavement option was the adopted treatment option.

The cost of periodic maintenance has been based on the estimated rates shown in Table 1. The percentage of repair changes for each risk scenario, as discussed in Section 5 of this report.

The cycle time for an OGPA surface treatment has been assumed to be 8 to 10 years.

The annual maintenance costs used are the average cost for the Hawkes Bay, Gisbourne and Whanganui networks which is 29 cents/ m2/ year for a thin AC surface over a granular base and 8 cents/ m2/ year for a structural AC pavement. Rates from Hawkes Bay, Gisbourne and Whanganui networks have been used because the Wellington region has been under a hybrid contract for a number of years and rates/m2 are no longer available.

5. Economic Analysis

Risk based Approach

A risk based economic analysis was carried out to evaluate the relative economic merits and whole of life outcomes of the pavement design options for the Peka Peka to Otaki Expressway.

Transit NZ's "Calculation of Whole of Life Costs", (from the NZ Supplement to the 2007 AustRoads Pavement Design Manual), was used for the economic analysis of the pavement options. The discount factor adopted is 8%.

Five generic risk scenarios ranging from early failure through to long life failure have been used in the analysis with an estimated probability for each scenario. The failure probabilities were agreed between NZTA and Opus. The risk based approach is based on recent experience which shows that unbound granular pavement construction is considered to be less reliable in terms of its early performance than pavements constructed using structural asphaltic concrete.

The probabilities are shown in the Table 2 below:

Scenario	Base Case	Option 1 (MAB)	Option 2 (MABSS)	Option 3 (SA)	Option 4 (FSB)
1. Early Failure (Within 20% of design life)	0.15	0.10	0.10	0.01	0.05
2. Premature Failure (20% -70% of design life)	0.40	0.15	0.10	0.05	0.10
3. Predicted Failure (70-130% of design life)	0.40	0.50	0.55	0.20	0.50
4. Late Failure (130%-150% of design life)	0.04	0.20	0.15	0.44	0.25
5. Long Life Failure (beyond 150% of design life)	0.01	0.05	0.10	0.30	0.10
Sum	1.00	1.00	1.00	1.00	1.00

Table 2: Probabilities of failure for each Risk Scenario

The base case has the highest risk of premature failure at 15% and is based on performance of unbound granular pavements on highly trafficked roads. This is a considerable risk and may be unacceptable to NZTA irrespective of the economic analysis. Risk scenarios for other options are based on experience of performance of these pavements and familiarity of local contractors with construction of the pavement type.

Traffic Delays from Construction and Maintenance Operations (Travel Time Savings)

As this site is predominantly a Greenfield site it allows the majority of the construction work to be done without working in the existing lanes, therefore there is little difference between the options in regard to traffic delays from initial construction.

Pavement maintenance is assumed to be mill and inlay with structural AC for all options. Because these operations can be carried out at night, it has been assumed that traffic delays associated with maintenance will be minor and similar for all options.

Vehicle Operating Costs

The vehicle operating costs for each option are based on the different road surface conditions for each option. The costs accrue from pavement deflection, roughness and texture which influence rolling resistance and therefore fuel and tyre consumption.

The deflections used for each option were calculated from a CIRCLY analysis of each pavement using a standard Benkelman Beam load. The analysis allows a prediction of deflection deterioration in the analysis of the vehicle operating costs. The deflections used are shown in Table 3. The traffic distribution is assumed to be Rural Strategic and a cost of 0.15 cents /veh-km/mm has been applied.

Pavement Type	Typical Deflection
Base Option - Unbound Granular	0.60 mm
Option 1 - Cement Modified Base	0.59 mm
Option 2 - Cement Stabilised Subbase	0.48 mm (cracked)*
Option 3 - Structural Asphaltic Concrete	0.34 mm
Option 4 – Foam Stabilised Basecourse	0.54 mm

*cracked phase shown as cemented layer will be cracked for the majority of the pavement life

Table 3: Typical Pavement Deflections

The road roughness for Options 1 and 2 is based on the Central Laboratories Report 91-29301, Prediction of Road Roughness Progression with deterioration based on time after construction. For the structural asphalt pavement a road roughness of 60 NAASRA is assumed.

Road user costs associated with texture, noise and safety have been considered constant for all scenarios because the OGPA surfacing is applied throughout the entire length for the purpose of this comparison.

6. Subgrade Strength

In reality many areas of this project will be located on engineered fill with at least CBR 10 or alluvium material or sand with CBR values 10 or better.

Also there is a considerable risk that up to 30% of the in situ subgrade or subgrade fill may be below the design CBR 10. This could mean that additional undercut or a thicker pavement will be required.

The subgrade CBR varies throughout the project length, for the purpose of this analysis a subgrade CBR of 10 (E=100MPa) has been chosen based on the Geotech information we have available to date. In reality many areas of this project will be located on engineered fill with at least CBR 10 or alluvium material or sand with CBR values greater than 10. However some areas may have lower CBRs than the design CBR. Some of these areas are sand and alluvium material and may be lower strength than test results are indicating at this phase of investigation. Also some weaker materials may be proposed for subgrade fill material. Some areas, approximately 1.8km length of new road, are over peat subgrade. As the in situ strength of peat is very low and peat is prone to large long term creep deformation, it is proposed to undercut and remove the peat in these areas. Where depth of peat makes this option unfeasible preloading may be employed to reduce post-construction total and differential settlements. We would expect that a specific pavement design will be required in these areas to allow for some additional movement of the fill embankments and lower in situ CBR values. The in situ peat is proposed to be undercut and replaced with preloading proposed where some additional peat remains due to the depth making it unfeasible to remove all of it. An understanding of the where these areas of lower strength CBR should be determined before final design is confirmed. An estimate of where we might expect these areas is shown in Table 4 below.

Note: where areas of more extensive undercut are indicated in Table 4 (e.g. Station 1450m to 1750m) these relate to areas of inter-dunal deposits, or weaker subgrades that are expected to occur within these chainages, albeit not over the entire chainage or footprint of works. Refer to the PP2O geotechnical interpretive report (2011) for further details of areas of undercut.

Station	Depth of Undercut	Station	Depth of Undercut
0 to 750	0.3 m	5500 to 8200	0.3 m
750 to 800	2.0 m	8200 to 8500	0.3 m
850 to 900	2.0 m	8500 to 9250	0.3 m
900 to 1000	0.3 m	9400 to 9450	0.3 m
1000 to 1450	1.5 m	9450 to 9850	1.5 m
1450 to 1700	3.0 m	9850 to 10100	3.0 m

Station	Depth of Undercut	Station	Depth of Undercut
1700 to 1800	1.0 m	10100 to 10550	0.3 m
1800 to 2000	1.0 m	10550 to 10700	3.0 m
2000 to 2650	0.3 m	10700 to 10850	1.5 m
2650 to 2750	2.0 m	10850 to 11000	3.0 m
2750 to 3450	0.3 m	11000 to 11200	1.5 m
3450 to 3500	2.0 m	11200 to 11500	3.0 m
3800 to 3880	2.0 m	11500 to 12200	1.0 m
3880 to 5500	0.3 m		

Table 4: Locations Where Subgrade Strength Might Be Lower Than Design CBR

Depths of undercut shown are given from current design levels.

Our best estimate is that there is a considerable risk that up to 30% of the in situ subgrade or subgrade fill may be below the design CBR 10. This could mean that additional undercut is required or a thicker pavement will be required where subgrade CBR is low.

7. Summary of Results

A summary of the risk based economic analysis results for the two sections of expressway are shown below. The capital cost indicated is for the main line of the expressway and does not include ramps and side roads. The capital costs are for comparison only and will not be the same as the costs used in the scheme design due to varying CBR and the addition of side roads and ramps. The Net Present Value (NPV) is expressed as “no risk”, i.e. assumes each option meets it design life, and “with risk” which is based on risk scenarios and associated probabilities ranging from early failure through to long life failure.

Option	Description	Capital Cost ($M)	NPV (no risk, $M)	NPV (with risk, $M)
Base Option	Unbound Granular	13.01	34.53	45.62
Option 1	Cement Modified Basecourse	13.77	36.23	41.36
Option 2	Cement Modified Basecourse with Stabilised Sub-base	15.09	35.69	39.73

Option 3	Structural Asphaltic Concrete	34.24	50.71	49.67
Option 4	Foam Stabilised Basecourse	15.26	36.56	38.87

Table 5: Summary of Economic Analysis

Option 4 is the most favoured option with the lowest net present value (NPV) after the consideration of risk but is very similar to Options 1 and 2 in terms of NPV (risk adjusted) outcomes. This is depicted in Figure 2 below. As illustrated in Table 5, Option 1 is likely to be the chosen option as the capital cost is lower than all other options and there is little economic benefit in the other options. Although Option 4, the foam stabilised bitumen is the favoured option, there is limited experience in the construction of this pavement type in Wellington, and limited data on the performance of foam bitumen stabilised pavements long term. Based on the limited performance data and construction experience, we do not feel that foam bitumen stabilised pavement is suitable for this site.

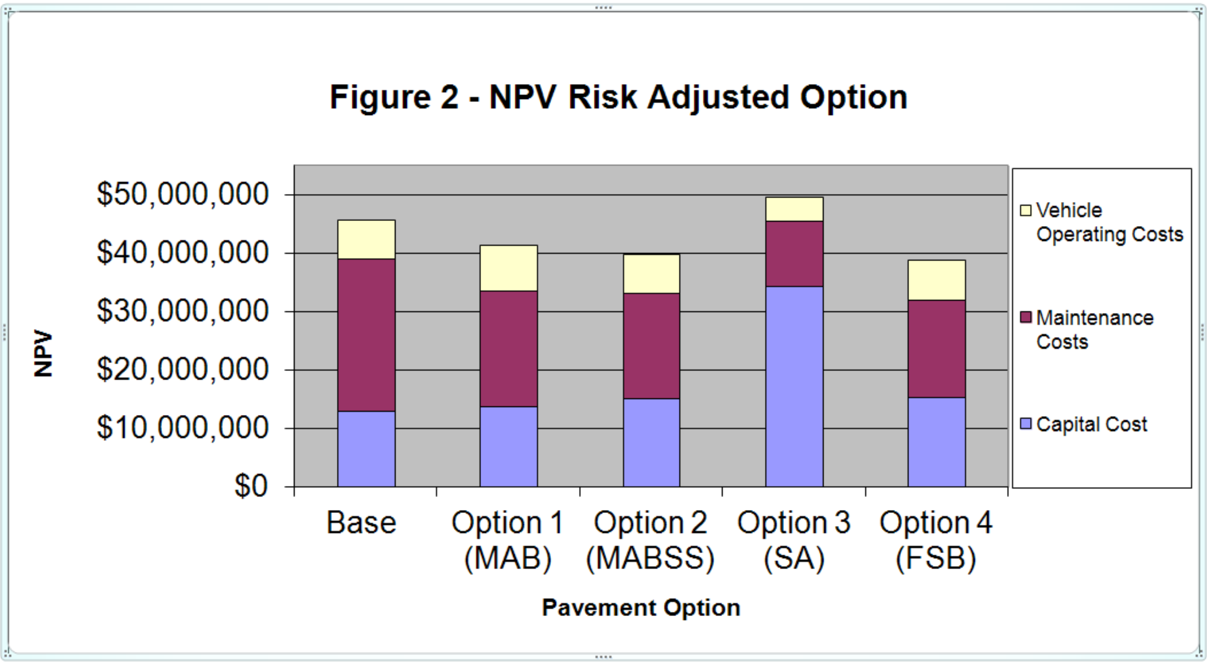


Figure 2 – NPV Risk Adjusted Option

8. Conclusions and Recommendations

The designs used in this analysis were based on a subgrade CBR of 10%. There is a considerable risk that up to 30% of the in situ subgrade or subgrade fill may be below the design CBR 10. This could mean that additional undercut is required or a thicker pavement will be required where subgrade CBR is low. This additional undercut and/or thicker layers of granular pavement could have a significant effect on the overall cost of this project and an assessment of this will be captured within the scheme estimate. Further analysis of the design CBR should be undertaken at further investigation or design phases to ensure these potential costs are allowed for.

The economically favoured option is the foam bitumen stabilised basecourse, however this is only very slightly more cost effective than the cement modified basecourse with cement stabilised subbase, and the cement modified basecourse options. We believe that due to the lower capital costs, and contractor experience, the cement modified basecourse option is a more appropriate option.

The risk based economic analysis indicates that the foam stabilised basecourse pavement, the modified basecourse with stabilised subbase pavement, and the cement modified basecourse pavement are all very similar in terms of whole of life costs and capital costs. The structural asphalt pavement is the least favoured as the capital costs are more than double the other options and the reduced maintenance costs and vehicle operating costs still make it a largely unfavourable option. The unbound granular pavement (the base option) is the second least favourable due to the likelihood of early failure. This option would also require a minimum of three months trafficking prior to placing the OGPA surfacing which further reduces the preference for this pavement option. It is our opinion that the cement modified basecourse pavement would be the most preferred option. This pavement option has the second lowest capital cost and second lowest whole of life cost. It is a common pavement type in the Wellington Region, and therefore we are confident in the performance of this pavement and confident in local contractors ability to construct this pavement type. The foam bitumen option has not been considered favourable due to the limited construction and performance information available in Wellington. NZTA may still wish to consider trialling this pavement option in some sections of this project to begin gaining some experience of the performance of this pavement type in Wellington