Opus International Consultants Ltd
Hamilton Office
Opus House, Princes Street
Private Bag 3057, Waikato Mail Centre, Hamilton 3240
New Zealand

t: +64 7 838 9344
f: +64 7 838 9324
w: www.opus.co.nz

TO	Gerhard van Blerk
COPY	FILE
FROM	[redacted]
DATE	02 July 2014
FILE	
SUBJECT	Huntly Section: Pavement Economics

1.0 Introduction

The Transport Agency have requested that a Whole of Life Economic Analysis be undertaken to evaluate the economic merits of two possible pavements configurations being considered for use on the Huntly Section of the Waikato Expressway.

The Economic Analysis has been undertaken along similar lines to previous economic evaluations of pavement alternatives and is based on the principles outlined in the latest version of The Agencies pavement design supplement to Austroads.

The Economic Analysis allows a risk based approach to account for the fact that that certain pavement types may be more or less reliable than others and also accounts for differing pavement performance between options.

2.0 Traffic Volumes

Traffic volumes for use in the analysis has been provided through the Waikato Regional Traffic Model (WTRM) for years 2021 and 2046.

Traffic Volumes are as follows;

- 2021: 18,000 AADT with 23.3% HCV
- 2046: 24,000 AADT with 24.6% HCV

Using a 25 year design life, a 2.7% HCV growth rate, and the NZTA Traffic Load Distribution the **Design ESA has been calculated at 36.66 x 10^6**

3.0 Pavement Configurations

Two pavement configurations have been considered for this economic analysis both of which are tabled below.

Table 1: Pavement Configuration - Base Option

Layer Type and Thickness	Units Rates
30mm PMB OPGA on Tack Coat	$25/sq.m
First Coat Grade 3/5 seal on prime coat	$6.5/sq.m
190mm NZTA M4 + 2% cement	$19.00/sq.m at $100/cu.m
430mm WHAP 65 + 2% cement	$32.25.00/sq.m at $75/cu.m
Total Thicknesses is **650mm** over an assumed **CBR of 3.5%**	Total Cost is **$82.75/sq.m**

Table 2: Pavement Configuration - Alternative Option

Layer Type and Thickness	Units Rates
30mm PMB OPGA on Tack Coat	$25/sq.m
First Coat Grade 3/5 seal on prime coat	$6.5/sq.m
200mm HiLab 40(3% cement)	$22.00/sq.m at $110/cu.m
200mm HiLab 65(3% cement)	$21.00/sq.m at $105/cu.m
220mm WHAP 65 + 2% cement	$16.50/sq.m at $75/cu.m
Total Thicknesses is **660mm** over an assumed **CBR of 3.5%**	Total Cost is **$91.00/sq.m**

The rates used are based on current assessed market rates exclusive of P&G. It is noted that the rates for HiLab materials are based on projects where small quantities of HiLab where used, so the rates are considered to be slightly high.

4.0 Key Principles of the Economic Analysis

Some key assumptions and parameters used in the economic analysis are summarised below;

- A 40 year analysis period has been used
- A discount rate of 6% has been used
- Only mainline pavements only have been considered - The area of the mainline pavement has been determined at 325,500 sq.m (15.5 km x 21 m of pavement width)
- Texture - The economic analysis assumes that both pavement types will be surfaced with the same surfacing type (in this case OGPA). The economic analysis therefore ignores the effects of texture on the basis that the effects are the same for both options and they will cancel each other out.
- Economic Analysis assumes that the OGPA will be delayed by 1 year for both options.
- Annual Maintenance Costs – There is no basis to determine if the annual maintenance costs for the Alternative (HiLab) Option will be any different to the Base Option. The economic analysis therefore ignores routine maintenance on the assumption that annual maintenance cost are the same for both options and they will cancel each other out.

- Noise, Safety, and Travel Time - The economic analysis ignores these effects on the analysis on the basis that the effects are the same for both options and they will cancel each other out.
- Vehicle Operating Costs – The economic analysis considers the costs associated with Roughness, Pavement Deflection (or Rigidity) and carbon dioxide emissions. Roughness and Pavement Deflections are discussed later in Section 4.1 and 4.2 respectively.
- The Economic Analysis uses a rate of $1.232 per veh per km (2009 dollars) to determine VOC due to pavement deflection/rigidity effects. This rates accounts for the high HCV content of the project (24% HCV) and includes update factors.

4.1 Pavement Roughness

The following summarises the assumptions around roughness used for the Base Option;

- Initial roughness after construction is 60 NAASRA
- Roughness at rehabilitation is 120 NAASRA
- Initial Roughness after rehabilitation is 60 NAASRA
- OGPA resurfacing (between construction and rehabilitation) does not improve roughness
- After rehabilitation it is assumed that roughness increases by 2 NAASRA counts per year
- After the first rehabilitation it is assumed that the NAASRA counts reduce by 20 NAASRA counts (to a minimum of 60 NAASRA) with each SMA resurfacing

The following summarises the assumptions around roughness used for the Alternative Option;

- Initial roughness after construction is 60 NAASRA
- Roughness at rehabilitation is 110 NAASRA (minimum)
- Initial Roughness after rehabilitation is 60 NAASRA
- OGPA resurfacing (between construction and rehabilitation) does not improve roughness
- After rehabilitation it is assumed that roughness increases by 1.5 NAASRA counts per year
- After the first rehabilitation it is assumed that the NAASRA counts reduce by 20 NAASRA counts (to a minimum of 60 NAASRA) with each SMA resurfacing

4.2 Pavement Stiffness/Deflection

The structural number for the two options has been calculated as follows;

- Base Option = 3.7
- Alterative Option = 5.7

The higher structural number determined for the Alternative Option is associated with the stiffer nature of the HiLab materials used in the top of the pavement. A higher Structural Number is also associated with a slower roughness progression.

Benkelman Beam deflections for the two options has been calculated using Circly as follows;

- Base Option = 0.7 mm
- Alterative Option = 0.3 mm

For the economic analysis the following assumptions around deflection progression has been used for the Base Option;

- Initial Deflections after construction are 0.9mm (no OGPA) and 0.7mm (OGPA)
- Deflection at rehabilitation is 2 x times that of the initial deflection (i.e. 1.4 mm)
- Initial Deflection after the rehabilitation treatment is 1.0mm

For the economic analysis the following assumptions around deflection progression has been used for the Alternative Option;

- Initial Deflection after construction is 0.5 mm (no OGPA) and 0.3 mm (with OGPA)
- Deflection at rehabilitation is 1.4 mm
- Initial Deflection after the first rehabilitation is 1.0 mm

5.0 Periodic Maintenance

The Period maintenance used in the Economic Analysis consists of the following

1) Prior to Rehabilitation (Both Options);
   - Mill and re-surfacing with as PMB OGPA on an 8 year cycle at $30/sq.m (the exception being Scenario 5 where the last resurfacing prior to rehabilitation is with SMA in order to improve roughness)
2) Rehabilitation

The rehabilitation treatments considered for this economic analysis is summarised in the following tables;

Table 3: Rehabilitation Treatment - Base Option

Layer Type and Thickness	Units Rates
Foam bitumen stabilise top 200mm of pavement	$27.50/sq.m
First Coat Grade 3/5 seal on prime coat	$6.5/sq.m
60mm PMB SMA 14 layer	$36.00/sq.m at $600/cu.m
	Total Cost is **$70.00/sq.m**

Table 4: Rehabilitation Treatment - Alternative Option

Layer Type and Thickness	Units Rates
Cement stabilise top 200mm of pavement	$10/sq.m
First Coat Grade 3/5 seal on prime coat	$6.5/sq.m
60mm PMB SMA 14 layer	$36.00/sq.m at $600/cu.m
	Total Cost is **$52.50/sq.m**

6.0 Risk Scenarios

The approach taken in the Economic Analysis follows the prescribed approach in NZTA pavement design supplement to Austroads in which 5 scenarios are considered each with its own risk probability. The probabilities adopted for the economic analysis are presented in Table 5 below are subjective and have been based on judgment.

Table 5: Risk Probability Scenarios

Scenario	Risk Probabilities		Comment
	Base Option	Alternative Option	
1	0.10	0.05	**Early Failure** - within 20% of design life (road fails in **year 6**, replacement lasts normal design life)
2	0.20	0.10	**Premature Failure** - 20-70% of design life (road fails in **year 11**, replacement lasts normal design life)
3	0.50	0.5	**Predicted Failure** - 70-130% of design life (road fails in year 28, replacement lasts beyond analysis period)
4	0.15	0.25	Late Failure - 130-150% of design life (road fails in year 35, replacement lasts beyond analysis period)
5	0.05	0.10	Long Life Failure – beyond 150% of design life (road fails in year 38, replacement lasts beyond analysis period)
Sum	1	1	

7.0 Results of the Economic Analysis

The results of the Economic Analysis is summarised in Table 6 and 7 below.

Table 6: Overall Summary of the Results of the Economic Analysis

Cost	Base Option	Alternative option
Capital Cost (Construction Yr 0 and Yr 1 costs only)	**$ 26,935,125**	$29,620,500
NPV Whole o Life Cost (No Risk)	$ 75,863,512	**$63,809,327**
NPV Whole of Life Cost (Risk)	$77,489,748	**$ 65,653,038**

Table 7: Summary (by Scenario) of the Results of the Economic Analysis

Option	Base Option				
Scenario	**1**	**2**	**3**	**4**	**5**
NPV Capital Cost	$50,389,686	$44,345,321	$41,067,837	$40,029,472	$40,572,874
NPV Annual Maintenance Costs	Ignored in the analysis				
NPV VOC (2008)	$32,974,846	$34,834,121	$33,138,738	$31,323,466	$36,303,321
NPV VOC Update factor (2008 to 2013)	1.05	1.05	1.05	1.05	1.05
NPV VOC (2013)	$34,623,589	$36,575,827	$34,795,675	$32,889,640	$38,118,487
NPV Noise, Safety, Travel Time	Ignored in the analysis				
NPV Total	$85,013,275	$80,921,149	$75,863,512	$72,919,112	$78,691,360
Probability	0.1	0.2	0.5	0.15	0.05
Prob NPV	**$8,501,327**	**$16,184,230**	**$37,931,756**	**$10,937,867**	**$3,934,568**
Expected NPV	**$77,489,748**				

Option	Alternative Option				
Scenario	**1**	**2**	**3**	**4**	**5**
NPV Capital Cost	$49,520,043	$44,490,596	$43,099,467	$42,434,348	$39,554,032
NPV Annual Maintenance Costs	Ignored in the analysis				
NPV VOC (2008)	$27,874,607	$25,551,658	$19,723,676	$21,753,154	$22,883,603
NPV VOC Update factor (2008 to 2013)	1.05	1.05	1.05	1.05	1.05
NPV VOC (2013)	$29,268,337	$26,829,241	$20,709,860	$22,840,812	$24,027,783
NPV Noise, Safety, Travel Time	Ignored in the analysis				
NPV Total	**$78,788,380**	**$71,319,837**	**$63,809,327**	**$65,275,160**	**$63,581,815**
Probability	0.05	0.1	0.5	0.25	0.1
Prob NPV	**$ 3,939,419**	**$ 7,131,984**	**$ 31,904,664**	**$ 16,318,790**	**$ 6,358,181**
Expected NPV	**$65,653,038**				

8.0 Discussion of the Economic Analysis

The economic Analysis shows the following;

- The alternative option will initially cost an additional $2.7 M extra compared with the base option.
- Compared to the based Option Alternative Option has a lower Whole of Life Cost (WOLC) over the 40 year analysis of approximately $12 M (No risk i.e. scenario 3 only) or $11.8 M when Risk adjusted over a 40 year period at a 6% discount rate.
- The main driver of the lower WOLC of the alternative option is the lower Vehicle Operating Costs (VOC) associated with the lower pavement deflection (rigidity effects) and lower roughness costs of the alternative. Table 8 below outlines the effects that Deflection and Roughness make to the NPV of the VOC.

Table 8: Summary of VOC

	Base Option		Alternative Option		VOC Difference between Options
	No Risk	Risk Adjusted	No Risk	Risk Adjusted	
NPV VOC (2013)	$ 34,795,675	$35,014,732	$20,709,860	$22,614,252	$14,085,815 (No Risk) $12,400,480 (Risk adjusted)
NPV VOC (2013) but excluding Roughness effects	$20,636,151	$21,498,708	$15,751,426	$16,357,127	$4,884,725 (No Risk) $5,141,581 (Risk Adjusted)
NPV VOC (2013) but excluding Deflection effects	$14,159,523	$13,516,023	$4,958,434	$6,257,125	$9,201,089 (No Risk) $7,258,898 (Risk Adjusted)

- Table 8 above indicates that rigidity effects is contributing between $7.2 M to $9.2 M to the total difference in VOC between the options and roughness effects is contributing between $4.8 M to $5.1 M.
- If the effects of either roughness or rigidly are excluded from the Economic Analysis, the Alternative Option still has a lower NPV than the Base option.
- Sensitivity Analysis shows that the Alternative Option retains a lower Whole of Life Cost (WOLC) over the 40 year period with a 10% discount factor.
- Sensitivity Analysis shows that the Alternative Option retains a lower Whole of Life Cost (WOLC) over the 40 year period (with a 6% discount rate) even if the costs of the Alternative increases to $100/sq.m (i.e and extra $5.6 M in initial capital cost)

9.0 Conclusions and Recommendations

From the economic analysis it can be concluded that the Alterative Option provides a clear economic benefit over the Base Option due mainly to the effects of rigidity and roughness.

Due to the high traffic loading it is recommended that a Structural Asphaltic Concrete (SAC) pavement also be considered for evaluation.

It is recommended that NZTA review the economic analysis, endorse the approach taken and the conclusions made and reach consensus on whether or not to mandate the use of the Alternative Pavement on the Huntly Section of the Waikato Expressway.