Introduction

In March of 2006, MCC signed a five-year, $65.69 million compact with the Government of Vanuatu (GoV) to reduce poverty and stimulate economic growth by targeting the country's poor transportation infrastructure through the completion of 11 different infrastructure sub-projects on 8 islands. The projected economic rate of return (ERR) for this group of activities, calculated in April 2006, was 24.2%

In early 2008, after the bids received for the design and build of all sub-projects came in at approximately three times the project amount, MCC, the GoV, and MCA-Vanuatu recognized that rising construction costs, changes in currency exchange rates, and delays in mobilizing implementing entities and contractors limited MCA-Vanuatu's ability to implement the Transport Infrastructure Project within its allocated budget and timeline. Consequently, MCC, the GoV, and MCA-Vanuatu drafted an action memorandum (Restructuring Memo) containing several options for the restructuring of the Transport Infrastructure Project, dated January 28, 2008. Based on the Restructuring Memo, the GoV and MCA-Vanuatu proposed to modify the Transport Infrastructure Project by focusing on the construction and sealing of the high priority national roads, the Efate Ring Road and portions of the Santo East Coast Road.

In preparation for Compact closeout, MCC contracted the Transport Research Laboratory (TRL) to conduct an ERR analysis on the modified scope of the Compact. To calculate the ERR, TRL utilized the Highway Design and Maintenance Standards Model (HDM-4), the state-of-the-art software program for technical and economic appraisal of road investment projects, standards, and strategies. The following report details TRL's methodology and findings, which include a 10.3% overall ERR for the combined portfolio of Vanuatu roads projects. Note that the report uses the term "Internal Rate of Return" ("IRR") in place of ERR. The project benefits considered by this analysis are largely related to reductions in vehicle operating costs as a result of improved road surfaces. All MCC Compact investments are included as costs in the model.

While the MCC typically presents economic analysis outputs in Microsoft Excel format, this report captures the Vanuatu ERR analysis in a clear and accurate manner. The data used for this analysis is available upon request.

HDM-4 Analysis of the Efate Ring Road and the Santo East Coast Road

by

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TRL

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1 Background

The Millennium Challenge Corporation (MCC) provided funds for the upgrade of two roads in Vanuatu. These were the Efate ring road and the Santo East Coast Road. Both these roads were unpaved (coral) roads and were sealed with a double surface dressing in 2009/10. The length of road sealed in Efate was 92.5 km and 57.2 km in Santo.

An HDM-4 analysis was conducted to examine:

i) The economic viability of upgrading the two roads
ii) The future performance of the roads

This report documents the results of this analysis.

2 HDM-4 Data

Prior to undertaking the HDM-4 analysis, it was necessary to collate information relating to the level of traffic on the roads, description of the vehicle fleet operating on the roads, the type and costs of road works activities and condition of the road network.

2.1 Traffic

Traffic surveys were carried out on the two roads both prior to sealing (May/Aug 2008) and after sealing (Dec 2010). In Efate the traffic surveys were conducted at 5 locations and in Santo at 4 locations. The 2008 and 2010 traffic counts are summarised in Table 1 and Table 2 respectively.

Table 1
2008 Traffic Counts

Location	Cars	4WD / UTE	Mini-bus / Van	Small Truck (2-axle)	Empty Truck (3-axle)	Loaded Truck (3-axle)	Truck Trailer (4-axle)	Total
Efate – May 2008								
Klehm's Hill	113	143	124	121	4	3	0	508
Tanoliu	18	35	28	25	0	0	1	107
Takara	9	16	15	11	0	0	0	51
Pang Pang	8	14	17	4	2	2	0	47
Rentabao	17	30	25	11	1	1	0	85
Santo – Aug 2008								
Rubbish Dump	111	229	35	20	12	7	1	415
Matevulu	50	256	49	17	12	0	3	387
Kole	6	72	14	7	4	4	1	108
Hog Harbour	8	113	24	11	0	0	0	156

Table 2
2010 Traffic Counts

Location	Cars	4WD / UTE	Mini-bus / Van	Small Truck (2-axle)	Empty Truck (3-axle)	Loaded Truck (3-axle)	Truck Trailer (4-axle)	Total
Efate – Dec 2010								
Klehm's Hill	122	154	133	130	4	4	0	547
Tanoliu	54	109	84	75	0	0	2	324
Takara	26	53	44	32	0	0	0	155
Pang Pang	25	43	54	13	5	6	0	146
Rentabao	72	133	106	46	4	2	0	363
Santo – Dec 2010								
Rubbish Dump	245	502	77	44	26	15	3	912
Matevulu	53	268	51	17	13	0	3	405
Kole	11	134	26	13	7	7	3	201
Hog Harbour	11	141	30	14	1	0	0	197

These traffic counts indicate there were significant increases in traffic volumes following the sealing of the roads, ranging from 5% to over 300%. These increases are summarised in Table 3.

Table 3
Percentage Increase in Traffic Volumes

Island	Location	Percentage Increase
Efate	Klehm's Hill	8%
	Tanoliu	203%
	Takara	203%
	Pang Pang	211%
	Rentabao	328%
Santo	Rubbish Dump	120%
	Matevulu	5%
	Kole	85%
	Hog Harbour	26%

The traffic levels were assigned to sections of the roads as detailed in Table 4. Each of these sections was treated as a homogeneous road section in the HDM-4 analysis.

Table 4
Road Sections

Island	Location	From (km)	To (km)	Length (km)
Efate	Klehm's Hill	0	15.0	15.0
	Tanoliu	15.0	35.0	20.0
	Takara	35.0	50.0	15.0
	Pang Pang	50.0	75.0	25.0
	Rentabao	75.0	92.5	17.5
Santo	Rubbish Dump	0	15.0	15.0
	Matevulu	15.0	25.0	10.0
	Kole	25.0	40.0	15.0
	Hog Harbour	40.0	57.2	17.2

2.2 Vehicles

2.2.1 Characteristics

In HDM-4 it is necessary to describe the characteristics of the vehicle fleet operating on the roads under investigation. The characteristics of the 7 vehicle types identified in the traffic surveys were estimated following discussions with the PWD and are summarised in Table 5.

Table 5
Vehicle Fleet Characteristics

Parameter	Cars	4WD / UTE	Mini-bus / Van	Small Truck (2-axle)	Empty Truck (3-axle)	Loaded Truck (3-axle)	Truck Trailer (4-axle)
No. of wheels	4	4	4	6	10	10	14
No. of axles	2	2	2	2	3	3	4
Annual km	10000	20000	40000	20000	20000	20000	20000
Working hours	550	1000	2000	1500	1750	1750	1750
Average life (yr)	15	15	15	15	15	15	15
Passengers	1	1	10	0	0	0	0
ESALF	0	0.02	0.1	0.1	0.2	3.0	4.5
Operating weight (tonnes)	1.2	1.8	2.0	2.0	3.0	20.0	30.0

2.2.2 Vehicle Unit Costs

In HDM-4 the unit costs of vehicle related items need to be specified as economic unit costs; i.e. costs before import duty, excise duty, VAT, etc is added. It was estimated that the taxes on most of these items total approximately 35% with the exception of lubricating oil whose tax was half this amount.

The economic unit costs of vehicle related items used in the analysis are given in Table 6.

Table 6
Vehicle Economic Unit Costs (Vatu)

Parameter	Cars	4WD / UTE	Mini-bus / Van	Small Truck (2-axle)	Empty Truck (3-axle)	Loaded Truck (3-axle)	Truck Trailer (4-axle)
New vehicle (million)	2.35	3.3	3.2	3.0	6.7	6.7	11.0
Replacement tyre	17000	22000	22000	30000	33000	33000	33000
Fuel / litre	110	110	110	110	110	110	110
Lubricating oil / litre	1225	1225	1225	1225	1225	1225	1225
Maintenance labour / hr	1500	1500	1500	1500	1500	1500	1500
Annual overhead	235000	330000	320000	300000	670000	670000	1100000
Annual interest (%)	10%	10%	10%	10%	10%	10%	10%

2.3 Road Works

The unit costs of road works activities need to be specified in HDM-4 both in economic and financial terms. Following discussions with the PWD, the unit costs of road works activities were estimated as detailed in Table 7.

Table 7
Works Activities Unit Costs (Vatu)

Works activity	Unit	Economic Cost	Financial Cost
Single Surface Dressing	m^2	4000	4500
Patching Potholes / Ravelled areas	m^2	3000	3375
Edge Repair	km	3000	3375
Drainage Clearance (both sides)	km	140,000	157,500
Grass Cutting (both sides)	km	16,000	18,000
Spot Regravelling	m^3	3500	3940

2.4 Road Condition

No measurements of road condition were available for the two roads that reflected the condition of the roads prior to sealing and the condition after sealing. Anecdotal evidence suggested that the condition of the unpaved roads prior to sealing was very poor with estimated roughness levels in excess of 15 IRI. The roughness of the roads after being sealed was estimated to be 3 IRI.

The strength of the pavement after sealing was estimated as having an adjusted structural number of 3. This was based on a base thickness of 300mm with a material strength coefficient of 0.15 and a subgrade of 8 CBR.

3 HDM-4 Analysis

3.1 Adaptation of HDM-4

Prior to undertaking HDM-4 analysis, it is necessary to configure HDM-4 to local conditions and to calibrate the predictive relationships to reflect the performance of the local roads.

3.1.1 Configuration

Configuration of HDM-4 includes specifying the climate, currency, speed/flow characteristics, etc. Items such as accidents were not considered in this analysis.

For climate, rainfall was set at 180 mm/month (i.e. approx 2 metres of rainfall per annum), a dry season of 4 months and the mean temperature at 27 deg C.

The traffic flows on these roads are low (AADT < 1000) and hence congestion effects are likely to be minimal over an analysis period of 20 years. The HDM-4 default speed/flow parameters for a standard 2-lane road were selected for the analysis.

The currency used in the analysis was Vatu.

3.1.2 Calibration

The majority of the road network in Vanuatu comprises unsealed roads. No measurements of condition on the small kilometrage of paved roads were available. Hence it was not possible to compare a range of observed paved road condition with that predicted by HDM-4 to establish calibration factors for the paved road distresses modelled in HDM-4.

The other main paved road in Efate of similar structure was the 'Japanese' road which was approximately 10 years old. An examination of this sealed road showed that the pavement was still in a relatively good/fair condition with the main form of deterioration being a small amount of ravelling (< 5% of the carriageway area). Although no roughness measuring devices were available, it was estimated that the roughness of the road was between 4 – 5 IRI. No cracking, rutting or edge break were evident.

Using these observations, the following preliminary calibration factors were derived:

i) Ravelling initiation (Kvi) – 0.65

ii) Ravelling progression (Kvp) – 1.0

iii) Roughness environmental component (Kgm) – 1.5

The default value of 1.0 was used for the calibration factors of the other distresses.

3.2 Sealing of the Roads

An HDM-4 analysis was conducted to examine the economic viability of sealing the two roads.

As stated earlier the roughness of the unsealed road prior to sealing was set at 15 IRI. For the base case scenario it was assumed that spot regravelling of the unpaved road would take place with up to 10% of the material lost being replaced each year of the analysis period of 20 years. In addition grass cutting and drainage clearance would also be undertaken.

The sealing option was to seal the road with a double surface dressing followed by annual routine maintenance comprising the works activities as described in Table 8. For example, the routine maintenance activity of patching ravelled areas was set to trigger when > 5% of the carriageway area was ravelled and that 25% of this area would be patched (i.e. only the more severely ravelled areas).

Table 8
Routine Maintenance

Routine Maintenance	Intervention Criteria	Quantity
Patch Potholes	> 15 m^2/km	50%
Patching Ravelled areas	> 5% of c/way area	25%
Edge Repair	> 50 m^2/km	50%
Drainage Clearance	1/3rd every year	
Grass Cutting	twice a year	

The cost (construction & supervision) of resealing the 149.7 km of road (92.5 km in Efate & 57.2 km in Santo) was US$67.7 million. This equates to approximately Vatu 42 million / km which was used as the cost of the reseal. The costs of the routine works activities used in the analysis were as listed in Table 7.

The initial traffic levels for the unsealed roads were those recorded in 2008 (see Table 1). For the sealing option it was assumed that the traffic levels after completion of the seal increased to those recorded in 2010 (see Table 2), this increase being treated as generated traffic resulting from the improvement to the roads.

For both options, an annual traffic growth rate of 3% was then used for the analysis period of 20 years.

A discount rate of 10% was used in the analysis. However, in the current economic climate, lower discount rates may be considered appropriate.

The economic viability of each of the 9 road sections (see Table 4) was examined separately and also as packages of the sections grouped by island and both islands together. The internal rates of return (IRR) from this analysis are summarised in Table 9.

Table 9
Internal Rates of Return

<table>
<tr><th>Road Section</th><th>IRR</th><th>Island</th><th>IRR</th><th>Total</th><th>IRR</th></tr>
<tr><td>Klehm’s Hill</td><td>20.7</td><td rowspan="5">Efate</td><td rowspan="5">7.4</td><td rowspan="9">Both Roads</td><td rowspan="9">10.3</td></tr>
<tr><td>Tanoliu</td><td>7.6</td></tr>
<tr><td>Takara</td><td>-0.2</td></tr>
<tr><td>Pang Pang</td><td>0.0</td></tr>
<tr><td>Rentabao</td><td>7.8</td></tr>
<tr><td>Rubbish Dump</td><td>27.1</td><td rowspan="4">Santo</td><td rowspan="4">14.4</td></tr>
<tr><td>Matevulu</td><td>17.3</td></tr>
<tr><td>Kole</td><td>5.7</td></tr>
<tr><td>Hog Harbour</td><td>5.9</td></tr>
</table>

The IRR values show that:

i) as a package sealing both roads was economically justified (IRR = 10.3)

ii) sealing all the roads in Santo was justified with an IRR of 14.4, whereas sealing all the roads in Efate was not justifiable with an IRR of 7.4 (i.e. < discount rate)

iii) it is economically highly viable (IRR > 15) to seal the individual road sections with AADT > 400 (Klehm's Hill, Rubbish Dump, Matevulu)

iv) the individual road sections with AADT between 300 & 400 (Tanoliu & Rentabao) produced IRR values between 7 & 8 which may be considered marginally justifiable if lower discount rates were deemed appropriate

v) sealing road sections with AADT < 300 is not economically viable, particularly with the very low proportion of heavy vehicles

It should be noted that this economic analysis was based on benefits derived from reduced vehicle operating costs. There are other benefits that can, and probably should be taken into account covering issues such as travel time, possible lower public transport service costs, increased tourism, agricultural output, industrial output, land value, etc.

3.3 Performance of the Sealed Roads

An HDM-4 analysis was carried out to investigate the likely future performance of the sealed roads with regards as to whether it was economically viable to reseal the roads over the next 20 years. The analysis was conducted using a discount rate of 10%, initial traffic levels as recorded in Dec 2010 (see Table 2) and a traffic growth rate of 3% per annum over the 20-year analysis period.

The preliminary calibration factors derived in Section 3.1.2 were used to model the deterioration of the 9 roads sections as a package.

The scenarios investigated were:

i) Base Case – Routine maintenance only (drainage clearance, grass cutting, patching potholes & ravelled areas, repair edge break – see Table 8)

ii) Alternatives - Single surface dressing every 7, 8, 9, 10, 12, 15 years with the above routine maintenance

The costs of these work activities used in the analysis were as detailed in Table 7.

This analysis clearly showed that resealing the roads during the next 20 years is not economically viable with negative IRR values ranging between -30 and -80 for the reseal alternatives.

In the next stage of the analysis, each of the 9 road sections was analysed separately using the same base case and 6 surface dressing alternatives. The IRR value for each road section was negative (i.e. economically not viable) for each surface dressing alternative.

3.4 Deterioration of the Sealed Roads

The deterioration of the sealed roads predicted by HDM-4 over the analysis period indicated that:

i) Ravelling is initiated after approximately 7-8 years

ii) Cracking is initiated after 13-14 years on the higher trafficked roads and by 16 years on the lower trafficked roads

iii) Potholes are initiated after approximately 17-18 years

iv) Roughness increases rapidly once potholes have been initiated – i.e. after 18 years

It should be noted that these rates of deterioration were predicted by HDM-4 with only a preliminary calibration of the deterioration models.

Potholes have obviously a large influence on the rate of roughness progression. Potholes initiate from areas of cracking or ravelling. To maintain the integrity of the road, maintenance of areas of cracking and ravelling should be undertaken prior to their extent and severity increasing to a level that causes potholes to appear.

As discussed in Section 3.3, resealing the roads over the next 20 years is not economically viable on these two roads, primarily because of the low levels of traffic. A sensitivity analysis was carried out on traffic growth rates to examine at which traffic levels it would be viable to reseal the roads.

Using a traffic growth rate of 7.5% resulted in surface dressing the ‘Rubbish Dump’ road section after 12 or 15 years becoming economically viable – the other reseal options for this section and all reseal options for all the other road sections were not economically viable. This road section had the highest traffic level (>900 in 2010), which at a growth rate of 7.5% results in traffic levels of almost 4000 vehicles per day after 20 years. It was only at these levels of traffic that resealing appears to be a viable option.

3.5 Vehicle Operating Costs

The HDM-4 economic analysis computes the cost of operating vehicles for the various alternatives being examined in order to derive the benefits of reduced vehicle operating costs (VOC). The VOCs derived from the analysis for each of the 7 vehicle types running on the deteriorated unsealed road and on the newly sealed road are summarised in Table 10.

Table 10
Vehicle Operating Costs

Vehicle	Vatu / veh-km	
	Unsealed Road	Sealed Road
Cars	53.32	68.18
4WD / UTE	34.32	35.01
Mini-bus / Van	59.67	34.75
Small Truck (2-axle)	79.22	46.04
Empty Truck (3-axle)	131.43	74.96
Loaded Truck (3-axle)	188.25	106.92
Truck Trailer (4-axle)	275.54	149.26
Total	**855.63**	**481.25**