Project Report

Program 3

Productivity through Innovation

Project 3.48

Sustainable Asset Management – Selecting optimal maintenance strategies based on multi-criteria decision making

Subtopic: Integrating road user cost into the decision making process of road maintenance

Project Number	3.48
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Status	Case study report
Date	21/02/2017
Version Number	V2

Executive summary

Current maintenance decisions are based on direct cost and improvement to the overall road network health. This case study focuses on analysing 20-years of life cycle cost (LCC) on Albany Highway in Western Australia by integrating road user cost, which can be considered as the social impact of road maintenance works.

The four maintenance scenarios are:

- Option 1: Routine Only MMIS Defects (3.33 $\$/\mathrm{m}^2$)
- Option 2: Granular Overlay (Rehab 50 $\$/\mathrm{m}^2$)
- Option 3: Granular Overlay (Rehab 60 $\$/\mathrm{m}^2$) m^2
- Option 4: Pre + Resealing (8 years life)

Through a road user cost calculation, 20-years life cycle cost analysis of each maintenance strategy is analysed. Under current condition, the value of time is 2,316.62 $/day and vehicle operating cost is 4,300.26 $/day. For four each option, reduction on user cost for rehab treatments are:

- Option 1 & 4: No influence and change
- Option 2 & 3: Total $ 1,570,000 for 20-years

20-year whole of life cycle cost for Options 1, 2, 3 and 4 is $610.06k, $443.52k, $516.83k and $405.79k respectively. The result shows that rehab treatment changes the roughness of road and have 371.29 $/day cost saving to the whole community. Over 20-year life cycle, the total saving is $1,570,000, which is significant compared to routine defects repair and re-sealing.

Keywords: Road Maintenance; Life Cycle Cost; Road User Cost; Vehicle Operating Cost

Contents

1. Introduction

1.1 Purpose

The purpose of this report is to analyse the 20 year whole of life cycle cost on roads undertaken on different options. This analysis is to help in the decision making to select the road maintenance strategy with different options including social impacts such as road user cost.

1.2 Case project background

This case study is an analysis of regional number 8, Albany Highway in Western Australia. The total lengths of 1.81 km which start chainage of the site from 64.76 km to end chainage of the site 66.57 km. Specific details are as below:

Table 1. Case Project Information

Road No.	H001	**Region No.**	8
SLK Start	64.76 km	**Area**	14480 m^2
SLK End	66.57 km	**Width**	8 m
Length	1.81 km	**Roughness**	4.08
AADT (2015)	3823	**Speed Limit**	110 km/h
Link Category	AW+ (high standard single carriage way)		

1.3 Method

The methodology used in this report was part of the ATAP (Australian Transport Assessment and Planning) guidelines. The guideline deals with the updated parameter (unit) values for use by economic evaluation practitioners in Australia jurisdictions as at June 2013, as well as models to estimate vehicle operating cost and, in turn, the calculation of road user cost.

1.4 Assumption and limitations

Assumption and limitations include:

- Vehicle operating cost unit prices are provided for fuel, oil, tyres, repairs and maintenance, depreciation. Value of time is provided for vehicle occupants and value of travel time for freight.
- Vehicle operating cost models are provided for a variety of different user types in an uninterrupted flow, Gradient (Rise & Fall) and Curvature (Terrain type) were assumed for road stereotypes in Australia.
- Vehicle classifications appropriate to Australia have been reviewed and the Austroad 12 vehicle classification has been selected for road user cost calculation.

- Mass limit of typical heavy vehicles was calculated with MRWA data however, passengers in the bus were not considered to calculate the value of time.

2. Findings

2.1 LCC model description

An LCC analysis was undertaken on four different options. Options are only routine works with MMIS (Maintenance Management Information System) defects, rehab treatment of Granular Overlay in two different unit price, and Pre + Resealing in 8 years life. Net Present Value in 20-year whole lifecycle cost analysis has been represented with 7.0% discount rate. Detail information for four options are:

- Option 1: Routine Only MMIS Defects (3.33 $/㎡)
- Option 2: Granular Overlay (Rehab 50 $/㎡)
- Option 3: Granular Overlay (Rehab 60 $/㎡)
- Option 4: Pre + Resealing (8 years life)

2.2 Road user cost

The total vehicle operation cost model structure and coefficients are adapted from ATAP guidelines, PV2 Road Parameter Values – Transport and Infrastructure Council (2016). This study adapted uninterrupted flow VOC model which was developed by several different previous models, such as Australianised HDM-4 VOC, ARRB aggregate model and alternative aggregate model. The total vehicle operation cost, including fuel consumption, is as follows:

$$VOC = BaseVOC * (k_1 + k_2/V + k_3*V^2 + k_4*IRI + k_5*IRI^2 + k_6*GVM)$$

Where:

VOC =	vehicle operating costs in cents/km
BaseVOC =	lowest VOC point in curve from raw HDM-4 output
V =	Vehicle speed in km/h
IRI =	International Roughness Index in m/km
GVM =	gross vehicle mass in tonnes
k_1 to k_6 =	model coefficients.

Coefficients for uninterrupted free flow speed VOC model (cents per km) was calculated with rise and fall (RF) as 0% and curvature as 20 ˚/km. 20 vehicle types data from ARRB Group has been modified and transfer to 12 vehicle types. Coefficient values for a sample of the relationships shown in table 2:

Table 2. Coefficients for VOC

Vehicle Type	BaseVOC	k1	k2	k3	k4	k5	k6
1. Short	31.0232	0.6925	9.0531	0.0000	0.0309	0.0015	0.0264
2. Short – towing	31.0232	0.6925	9.0531	0.0000	0.0309	0.0015	0.0264
3. Two Axle Truck or Bus	48.2074	0.6685	6.9406	0.0000	0.0400	0.0018	0.0120
4. Three Axle Truck or Bus	82.2650	0.5257	9.7212	0.0000	0.0740	0.0006	0.0055
5. Four Axle Truck	82.2650	0.5257	9.7212	0.0000	0.0740	0.0006	0.0055
6. Three Axle Articulated	86.4629	0.4437	9.1691	0.0000	0.0875	0.0003	0.0065
7. Four Axle Articulated	86.4629	0.4437	9.1691	0.0000	0.0875	0.0003	0.0065
8. Five Axle Articulate	95.6524	0.4868	8.8512	0.0000	0.0839	0.0004	0.0044
9. Six Axle Articulated	103.6022	0.4919	8.5864	0.0000	0.0852	0.0004	0.0041
10. B Double	117.1770	0.4973	7.6288	0.0000	0.0860	0.0001	0.0037
11. Double Road Train	161.2433	0.4806	7.4702	0.0000	0.0974	0.0001	0.0027
12. Triple Road Train	188.2864	0.4800	6.7317	0.0000	0.0991	-0.0001	0.0024

Vehicle speed limit is 110 km/h and current IRI was provided from MRWA as 4.08 m/km. The mass limits were calculated through MRWA heavy vehicle operations data. GVM was calculated with single steer as mass limit 6 tonnes, twin steer 11 tonnes, single 9 tonnes, tandem 16.5 tonnes, and triaxle as 20 tonnes.

Road user cost was calculated on $/day value, due to provided data of average traffic in each 12 classes. Detail percentage of average annual daily traffic (AADT) for each 12 class was used to calculate accurate road user cost.

This study calculated the daily value of time in original speed and new speed due to maintenance activities. For the vehicle operating cost, speed and roughness were the parameters and variables to calculate. In that way, cost changes due to speed and roughness changes were calculated.

Consequently, results from this case study are as below:

Table 3. Value of Time Result

VOT ($/hour)	VOT ($) - daily		
	Original speed	New speed (40 km/h)	cost due to speed change
141098.95	2321.72	6384.73	4063.01

Table 4. Vehicle Operation Cost Result

Treatment	VOC ($) - daily					Delay cost ($/day)
	Original speed & rough	Speed change	Rough change	Cost due to speed change	Cost due to rough change	
RipSeal	4300.26	4100.63	3970.79	-199.63	-329.47	3863.37
Gravel OL	4300.26	4100.63	3928.34	-199.63	-371.92	3863.37

Under current condition value of time was 2,316.62 $/day and vehicle operating cost was 4,300.26 $/day. With Ripseal treatment value of time has no change as 2,316 $/day, however, vehicle operation cost changed to 3,970.79 $/day which means 329.47 $/day cost saving. With GrOL treatment, vehicle operation cost changed to 3,928.34 $/day with 371.29 $/day cost savings.

When the speed limit is set to 40 km/h during road works, delay cost happens with VOC change and VOT change. In this case, delay cost for VOC was 4,100.63 $/day and delay cost for VOT was 6,384.73 $/day, total delay cost of 3,863.38 $/day (-199.63 + 4,063.01).

2.3 LCC model analysis

An LCC analysis was undertaken on five options with 20 years. Discounted life cycle costs for each option are:

Table 5. Discount Life Cycle Cost

Components	Option 1	Option 2	Option 3	Option 4
Maintenance Works	$1,104,212.88	$789,050.95	$927,156.61	$643,665.23

Detail of analysis results are as follow:

Table 6. Detail Input Data

Year	Routine Only MMIS Defects = $3.33/m2		Rehab $50/m2		Rehab $60/m2		Pre+Resealing (8 yrs life)	
	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	Activity	Cost	Activity	Cost	Activity	Cost	Activity	Cost
0	RM only	$48,267	Rip & Seal	$724,000	Granular Overlay	$868,800	Pre+Resealing	$203,734
1	RM only	$50,680	RM only (fix rate)	$1,000	RM only (fix rate)	$1,000	RM only	$10,000
2	RM only	$53,214	RM only (fix rate)	$3,000	RM only (fix rate)	$3,000	RM only	$10,500
3	RM only	$55,875	Final Seal + RM	$58,934	Final Seal + RM	$58,934	RM only	$11,025
4	RM only	$58,668	RM only (fix rate)	$1,000	RM only (fix rate)	$500	RM only	$11,576
5	RM only	$61,602	RM only (fix rate)	$1,000	RM only (fix rate)	$500	RM only	$12,155
6	RM only	$67,762	RM only (fix rate)	$1,000	RM only (fix rate)	$500	RM only	$13,371
7	RM only	$74,538	RM only (fix rate)	$1,000	RM only (fix rate)	$500	RM only	$14,708
8	RM only	$81,992	RM only (fix rate)	$1,000	RM only (fix rate)	$500	Pre+Resealing	$276,134
9	RM only	$90,191	RM only (fix rate)	$1,000	RM only (fix rate)	$500	RM only	$10,000
10	RM only	$99,210	RM only (fix rate)	$1,000	RM only (fix rate)	$500	RM only	$10,500
11	RM only	$109,131	RM only (fix rate)	$2,000	RM only (fix rate)	$1,000	RM only	$11,025
12	RM only	$120,045	RM only (fix rate)	$2,000	RM only (fix rate)	$1,000	RM only	$11,576
13	RM only	$132,049	RM only (fix rate)	$2,000	RM only (fix rate)	$1,000	RM only	$12,155
14	RM only	$145,254	RM only (fix rate)	$2,000	RM only (fix rate)	$1,000	RM only	$13,371
15	RM only	$159,779	RM only (fix rate)	$3,000	RM only (fix rate)	$1,500	RM only	$14,708
16	RM only	$175,757	RM only (fix rate)	$3,000	RM only (fix rate)	$1,500	Pre+Resealing	$493,334
17	RM only	$193,333	RM only (fix rate)	$3,000	RM only (fix rate)	$1,500	RM only	$10,000
18	RM only	$212,666	RM only (fix rate)	$3,000	RM only (fix rate)	$1,500	RM only	$10,500
19	RM only	$233,933	RM only (fix rate)	$3,000	RM only (fix rate)	$1,500	RM only	$11,025
20	RM only	$257,326	RM only (fix rate)	$3,000	RM only (fix rate)	$1,500	RM only	$11,576

After analysing the 20-year life cycle cost of Albany Highway, Net Present Value ($k) is as follow:

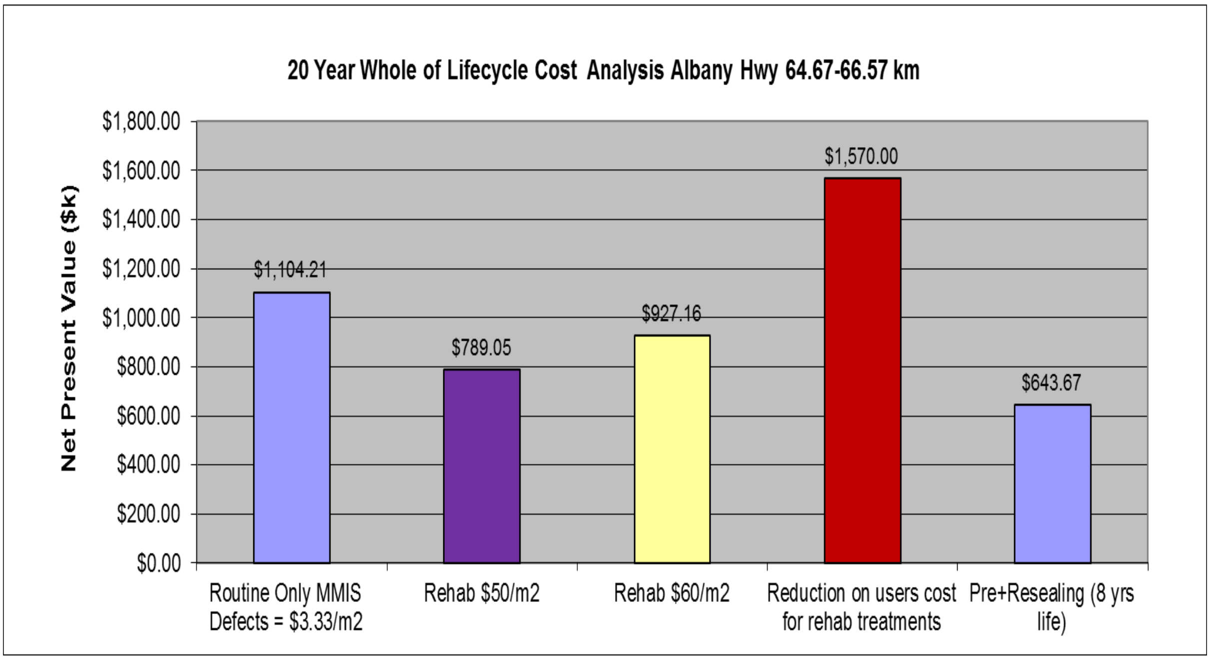

Figure 1. NPV for Options

3. Conclusions

This case study provides road maintenance strategy analysis, considering road user cost which is an integral part of the life cycle cost of the road. The case study result shows that $371.92 can be saved per day to road users by improving roughness at selected area. Maintenance work influences the roughness and speed of the road, which can also affect the road user cost. However, road agencies usually do not consider the road user cost in making maintenance decision even though road user cost is considered as a key factor for decision making and infrastructure asset management. The findings from this case study show that road user cost should be integrated into the decision making model because it has a high impact on economic, environmental, and social sides of road infrastructures.

References

Transport and Infrastructure Council. (2016). Australian Transport Assessment and Planning Guidelines. PV2 Road Parameter Values.