WHOLE LIFE COSTS

A Tool for Low Volume Rural Road Managers

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1. Introduction

The South East Asia Community Access Programme (SEACAP)[1] is researching alternative options to the indiscriminate use of gravel for the surfacing of Low Volume Rural Roads (LVRR). The objective is to generate information on the use of appropriate surfacing/paving options. This information will assist LVRR managers/owners/investors to select the most appropriate pavement and surfacing options according to a range of factors and circumstances.

The preservation and development of a road network represents a very large capital investment. Inevitably there are insufficient funds to undertake all the necessary road works. This problem is especially acute for LVRR. Decision makers need to prioritise the investments within often severely constrained budgets. A universally accepted method for prioritising road works uses the concept of 'Whole Life Costing' which considers costs such as construction, maintenance and vehicle operation over the 'life' of the road.

Operating vehicles on poorly maintained roads such as rough unpaved roads costs a great deal more than on, say, smooth bituminous surfaced roads. These costs include the costs of fuel, tyres, spare parts, vehicle maintenance, time, reduced utilisation and much more. For any country, especially developing countries, thus there is an important and very direct economic trade-off between investing in better roads and reducing the costs of using those roads as illustrated in Figure 1.

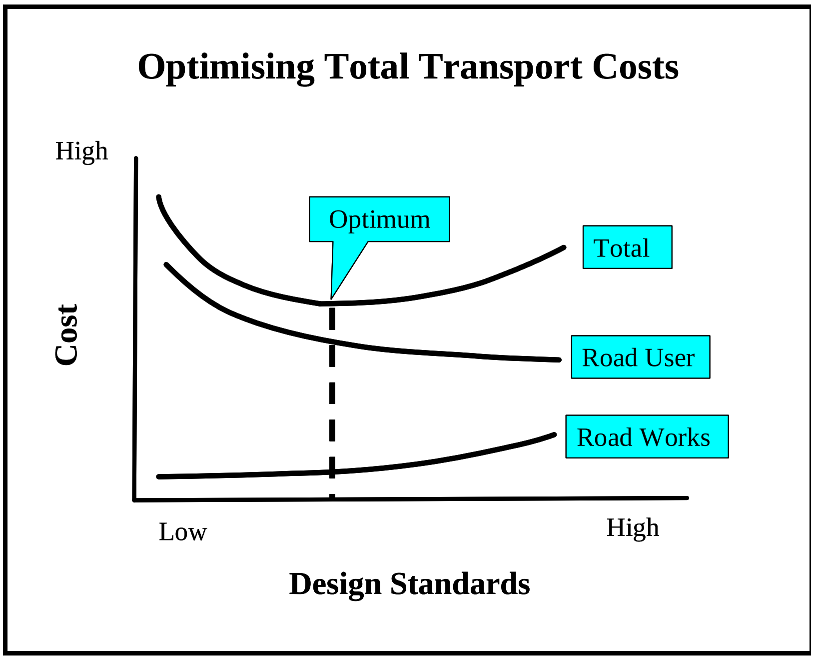

Figure 1: Optimising Road Standards

Such a trade-off includes investing in new roads and also in improving the maintenance and rehabilitation of the existing network. To identify the optimum standards and actions it is necessary to predict how roads of different designs perform (or deteriorate), to predict the effects of different types of rehabilitation and maintenance on the rates of deterioration and to calculate how the deterioration influences the costs borne by the road users. In this way optimum

[1] SEACAP www.seacap-info.org

engineering solutions can be selected, based on economic principles, for the wide ranges of conditions encountered throughout the world.

2. LVRR Surfacing and Paving Deterioration

Unlike high volume roads, the local environment tends to be the dominant factor influencing the deterioration of LVRR. Environmental factors include the influence of climate, hydrology, terrain, sub-grade conditions, etc. Traffic does contribute to deterioration but as the effect of tire pressure and vehicle loading more than the volume of equivalent standards axles. This relationship is represented in the chart below.

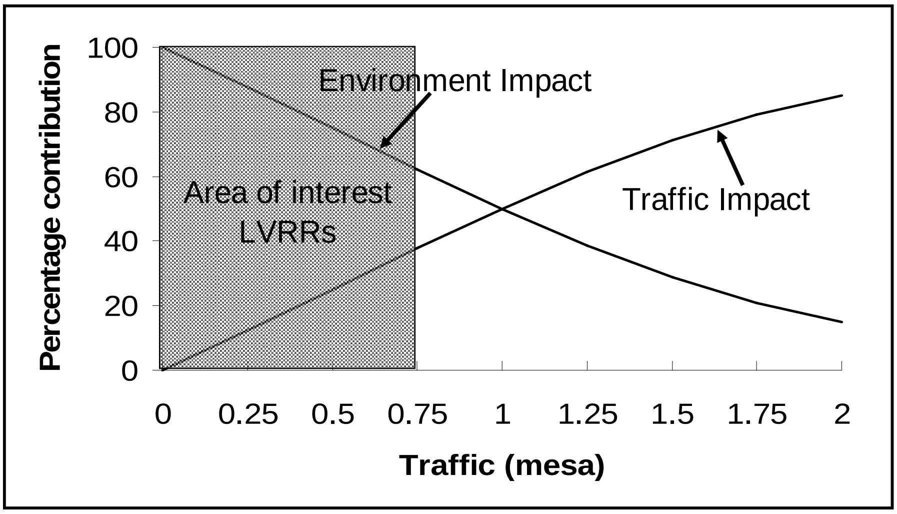

Figure 2: Impact of traffic and environmental factor on LVRRs. (Source: SEACAP3 Project)

To accurately predict the deterioration of LVRR empirical data is usually needed.

3. Unsealed road sustainability

In South East Asia, engineers have traditionally relied on the use of unsealed natural gravel/laterite as a LVRR surface, due to its initial low costs and simplicity of construction. However recent SEACAP research confirms the serious problems relating to maintenance and sustainability of such surfaces in many road environments common in South East Asia. Further, there are health and environmental concerns associated with the widespread use of gravel as a LVRR surface.

Gravel is a ‘wasting’ surface and as such material is lost from the surface of the road due to the erosive actions of traffic, flooding and rainfall. Gravel can be lost from the road surface at more than 30mm per year, leading to the need to re-gravel at very frequent intervals. The funding, resources and capacities are usually not available to achieve this and the surface will invariably deteriorate and revert to an earth surface.

Since there are problems associated with gravel surfaced LVRR, SEACAP is researching alternative technologies that may improve sustainability. In order to assess the relative merits of these technologies life cycle cost comparisons are needed.

4 Whole Life Road Asset Costs

4.1 Introduction

There are a number of accepted and documented techniques to assess various aspects of the costs and effectiveness of road investments. Some methods require substantial amounts of data that may not be readily available, would be costly to collect, would be difficult to analyze with confidence, and may not justify the levels of investment funding available, especially for smaller projects.

An approach that looks at the costs associated with the whole life cycle of the asset is preferable to simply considering only the initial design and construction costs of a range of surfacing or paving options for a complete route or a route section. The consideration of all present and expected future costs involved with an investment in LVRR infrastructure should be an integral part of the planning and design process.

There are two basic approaches to the assessment of whole life costs for LVRR which can each reflect discrete objectives, and may result in different conclusions depending on the local circumstances. These can be characterized as:

- Whole Life Costs of the Road Asset; and
- Whole Life Transport Costs.

The aim of Whole Life Road Asset Costs assessment is to minimise the costs of construction and maintenance of a particular road and pavement over a selected assessment period. This assessment would be of interest to an asset manager such road authority, particularly in a severely constrained resource environment.

A Whole Life Transport Cost assessment brings in the component of user benefits, and may include saving of Vehicle Operating Costs (VOCs) and other economic or socio-economic factors (e.g. user time savings, socio-economic or environmental impact). This assessment is of more interest to, for example, national policy makers, planners and development agencies.

Any assessment will only be as good as the data and knowledge used in the relationships incorporated in the evaluation. It is very likely that the confidence in the cost data may be good for construction components. However, the knowledge and confidence may be less robust for both maintenance cost components of various road surface options and for user VOCs and other socio-economic, environmental costs. The latter aspects are particularly uncertain regarding the effects of different road conditions in South-East Asia.

The paragraphs that follow outline a simple approach to Whole Life Costing for supporting decision making of rural road investment. This is initially based on Whole Life Road Asset Costs but, as reliable data becomes available, then Whole Life Transport Costs may be introduced.

4.2 General Approach to WLC of Road Asset

Whole Life Asset Costing is a process of assessing all costs associated with an investment over its intended (initial) or design lifetime. The aim is to minimize the sum of these values to obtain the minimum overall expenditure on the asset, yet achieving an acceptable level of service of the asset. The principal cost components are the initial investment or construction cost and the future costs of maintaining (or rehabilitating) the asset over the assessment period selected (for example, 12 years from construction).

Any rehabilitation costs will need to be included (for example, if maintenance is deficient and the road will need to be reconstructed during or at the end of the assessment period). Usually an assessment of the residual value of the asset at the end of the assessment period is included to incorporate the possible different consequences of construction and maintenance strategies for the pavement and surface options investigated.

From an economic evaluation viewpoint, an important decision is the reduction in value that is assigned to future costs. A discount rate is usually used to reflect future costs and benefits. In this way a dollar spent after one year is only valued at 90 cents at a discount rate of 10%. Similarly, a dollar expected to be spent after two years is valued at only 81 cents in current terms. The decision on discount rate selection is usually based on a combination of policy and economic considerations. In some industrialized countries the discount rate for public investments is 7%. Several international funding agencies use a rate of 12%. In the absence of specifications by the responsible authority, figures of around 10% are often used.

Future costs are discounted to present values using the formulas:

$$PCV = \frac{c_i}{(1 + r/100)^i}$$

Future costs are discounted to present values using the formulas where:

PCV = present value of cost in year i;

c_i = sum of all costs (including construction and maintenance) in year i

i = year of analysis where, for the base year, i = 0;

r = discount rate expressed as a percentage.

WLC of Road Asset is simply the different between discounted costs over the analysis period and discounted residual value of road asset at the end of the analysis period.

$$WLC = \left[\sum_{i=o}^{n} \frac{c_i}{\left(1 + (\frac{r}{100})\right)^i}\right] - \left[\frac{R_n}{\left(1 + (\frac{r}{100})\right)^n}\right]$$

where:

n = project analysis period in years

R_n= Discounted residual value of road asset at the end of analysis period (n)

4.3 Construction Costs

Construction costs are available from previous contracts throughout the country. For Whole Life Costing purposes it would be very useful to regularly compile these costs on a regional basis, and broken down for each surface and paving option. In view of the high variability of energy/transport and materials costs the data should also be compiled by year so that any inflation cost adjustments can be made. Refinements could later be incorporated for such factors as size of contract, remoteness from main administrative centres, etc., as these aspects usually influence the overall cost of works.

4.4 Maintenance Costs

The maintenance required on a LVRR is a function of the rate and the nature of road deterioration, and is best predicted based upon empirical knowledge. Once the deterioration properties are known accurate costing of the required maintenance regime can be determined. The experiences in South East Asia indicate that the capacity and delivery of LVRR maintenance is generally far from adequate.

Appropriate maintenance is fundamental to the sustainability of any road provision. Some LVRR technologies are more demanding of maintenance and more sensitive to the timing of its provision than others. Therefore before coming to a final decision on the selection of a pavement or surface type, **it is advisable to assess the future maintenance requirements** of the options being considered and to decide whether or not there is a likelihood of this level of maintenance being resourced (financially and physically) and being arranged in a timely manner.

In general earth and gravel surfaced LVRRs tend low investment costs and have relatively high maintenance characteristics. On the other hand while their construction costs tend to be higher, bitumen seal pavements generally have more modest maintenance requirements and concrete pavements usually require the least maintenance.

It is the analysis of the trade off between initial and recurrent costs that is crucial. Both of which must fit within the resource and capacity envelopes of the road authority.

Maintenance for LVRRs can be categorised principally as Routine and Periodic.

Routine maintenance comprises a range of small scale and simple activities. Associated activities are dispersed regularly over the time. Typical activities include roadside verge clearing and cutting back encroaching vegetation, cleaning of silted ditches and culverts, repairing minor erosion, patching and pothole repair, and light grading/reshaping of unsealed surfaces. This maintenance may be able to use unskilled as well as skilled labour, or labour-based methods supported by light equipment. Conventional or community contracting may be appropriate. These regular operations are a good opportunity to identify periodic maintenance needs.

Periodic maintenance occurs less frequently – usually after a number of years. Works can include regravelling, resurfacing, resealing and repairs to structures. These works can be expected and planned. They are normally large scale and may require standard or specialist equipment and some skilled resources.

Spot Improvement, pavement strengthening overlays or pavement reconstruction are normally not considered to be ‘maintenance’ and are often funded separately under ‘development’ or ‘capital’ budgets. Rehabilitation is also not considered to be maintenance.

Occasionally urgent, unplanned, maintenance works may also be required – sometimes known as Emergency Maintenance - for example because of particularly severe weather conditions, floods, unexpected deterioration, landslips or exceptional damage caused by over-size/weight vehicles.

A pragmatic assessment of the costs of the maintenance operations and the expected maintenance resources and capacity are needed to achieve a realistic WLC assessment.

4.5 Residual Value

WLC assessment requires valuation of assets in monetary terms. Each road investment still has an economic value to the transport network beyond the analysis period. Realistic estimation of residual value of the asset is essential for the evaluation of WLC. Over-estimation this residual value will lead to lower WCL and may result in selecting less effective option.

5. Whole Life Transport Cost

In addition to the information required for a Whole Life Asset Cost as described above, Whole Life Transport Costs includes an assessment of vehicle costs savings for road interventions or maintenance strategies. The aim is to minimize the sum of construction, maintenance and VOC over the selected assessment period. Various economic models have been developed to help decision makers including HDM4 and the World Bank’s RED model. These models require more capacity to gather, manage and analyze data than is usually available at the LVRR management level.

6. Conclusion

The use of Whole Life Asset Cost comparisons for the selection of alternative LVRR technologies is a practical, simple and transparent tool for LVRR managers to make better decisions.

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Appendix: Typical Worked Example of WLC Comparison

The following example illustrates a typical comparison of Whole Life Asset Costing between a sealed and an unsealed option in a mountainous, high gravel loss environment, Table C1. Some of the key points are as follows.

- The road options are designed and construction quantities of each material are calculated from the unit cost of each material.
- The maintenance needs (routine and periodic) of the road are then estimated and the maintenance costs are calculated.
- The residual value of the road at the end of the analysis period is calculated. Residual values were assumed to be the discounted value of the construction cost of the lower layers of the pavement and half the construction cost of the surfacing. This assumption is based upon the pavement layers being still in good condition but the surfacing layer having lost half its initial value.
- The analysis period is 12 years.
- Because these above costs occur in the future, it is necessary to discount them at an agreed discount rate to give their Net Present Value (NPV). A discount rate of 10% was used.

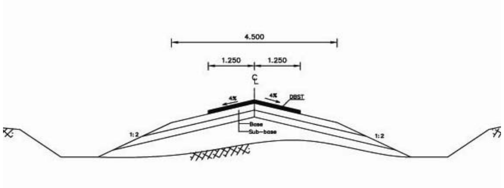
The costs for construction and maintenance were taken from locally available sources, however, it is worth noting that the applied routine maintenance costs for gravel are lower than regional experience indicates. Nevertheless the advantage of using this approach is well illustrated by clearly indicating the WLC advantage of sealed option over and unsealed option despite the apparent initial attractiveness of the latter’s construction costs.

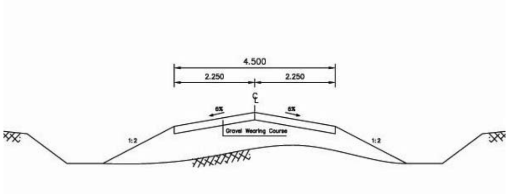
Table 1: WLC Work Sheet

EXAMPLE OF WHOLE LIFE ASSET COST CALCULATION AND COMPARISON

Pavement option	Pavement design			
	Capping	Sub-base	Base	Surface
1. Gravel Wearing Course	25cm	-	-	20cm
2. Double seal on gravel	10cm	10cm	10cm	DBST

Region: North
Terrain: Mountainous
Gravel loss : 50 mm/year
Subgrade CBR : 4%
Traffic :10,000 ESA





Work Description	Pavement Option (Cost per km)									
	Seal on gravel					Gravel surface				
	Unit	Qty	Rate (USD)	Amount (USD)	NPV (USD)	Unit	Qty	Rate (USD)	Amount (USD)	NPV (USD)
1. Construction										
1.1 Capping Layer	m3	510	4.00	2,040.00		m3	1275	4.00	5,100.00	
1.2 Sub-base	m3	480	6.50	3,120.00		m3	0	6.50	0.00	
1.3 Base	m3	470	22.00	10,340.00		m3	0	6.50	0.00	
1.4 Surfacing	m3	50	59.75	2,987.50		m3	900	6.50	5,850.00	
Sub -Total:				18,487.50	18,487.50				10,950.00	10,950.00
2. Routine Maintenance										
2.1 Year 1				889.34	808.49				664.99	604.54
2.1.1 Grass cutting	m2	400	0.16	64.00		m2	400	0.16	64.00	
2.1.2 Bush cutting	m2	200	0.02	4.00		m2	200	0.02	4.00	
2.1.3 Clearing of ditches	m	800	0.39	312.00		m	800	0.39	312.00	
2.1.4 Grading of shoulders	m2	450	0.39	175.50		m2	450	0.39	175.50	
2.1.5 Filling pothole of Amoured	m3	3	22	66.00		m3	0	22	0.00	
2.1.6 Filling pothole of Natural grave	m3	0	4.37	0.00		m3	5	4.37	21.85	
2.1.7 Patching of pothole	m2	20	4.37	87.40		m2		4.37	0.00	
2.1.8 Filling along edges with grave	m3	8	3.38	27.04		m3	8	3.38	27.04	
2.1.9 Edge repairs, patching	m2	10	3.46	34.60		m2	10	3.46	34.60	
2.1.10 Crack sealing, minor arears	m2	60	1.98	118.80		m2		1.98	0.00	
2.1.11 Grading of gravel surface	m2		0.26	0.00		m2	100	0.26	26.00	
2.2 Year 2				889.34	734.99				664.99	549.58
2.3 Year 3				889.34	668.17				664.99	499.62
2.4 Year 4				889.34	607.43				664.99	454.20
2.5 Year 5				889.34	552.21				664.99	412.91
2.6 Year 6				889.34	502.01				664.99	375.37
2.7 Year 7				889.34	456.37				664.99	341.25
2.8 Year 8				889.34	414.88				664.99	310.22
2.9 Year 9				889.34	377.17				664.99	282.02
2.10 Year 10				889.34	342.88				664.99	256.38
2.11 Year 11				889.34	311.71				664.99	233.07
2.12 Year 12				889.34	283.37				664.99	211.89
Sub -Total:					6,059.69					4,531.04
3. Periodic Maintenance										
3.1 Year 1										
3.2 Year 2										
3.3 Year 3										
3.4 Year 4									6,339.50	4,329.96
3.4.1 Regravelling						m3	675	7.54	5,089.50	
3.4.2 Scarifying of existing road						m2	2,500	0.5	1,250.00	
3.5 Year 5										
3.6 Year 6										
3.7 Year 7									6,339.50	3,253.17
3.7.1 Regravelling						m3	675	7.54	5,089.50	
3.7.2 Scarifying of existing road						m2	2,500	0.5	1,250.00	
3.8 Year 8				4,400.00	2,052.63					
3.8.1 Resealling	m2	2500	1.76	4,400.00						
3.9 Year 9										
3.10 Year 10									6,339.50	2,444.15
3.10.1 Regravelling						m3	675	7.54	5,089.50	
3.10.2 Scarifying of existing road						m2	2,500	0.5	1,250.00	
3.11 Year 11										
3.12 Year 12										
Sub -Total:					2,052.63					10,027.28
Residual Value (= cost of the pavement + half of the surfacing cost)				16,994.00	5,414.81				8,025.00	2,557.01
NPV net cost @10%					**21,185.01**					**22,951.31**