JUSTIFICATION OF INVESTMENTS FOR LOW-TRAFFICKED ROADS BASED ON THE FIRST YEAR RATE OF RETURN INDICATOR AND USING VEHICLE OPERATING COST SAVINGS

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ABSTRACT

It is nowadays normal practice to carry out economic analyses in order to facilitate the decision-making process concerning road improvement investments. Such analyses are usually undertaken during the feasibility study stage and involve the comparison of various improvement options. In developing and emerging economy countries, road improvement needs are great but resources are scarce and many roads carry low traffic volumes. In such cases, the levels of acceptable investment costs are likely to be fairly low, if such investments were to be justified solely on the basis of vehicle operating costs (VOC) savings, yielding an acceptable economic rate of return of at least 12% per annum.

This paper discussed the merits of a simplified economic evaluation method based on the calculation of the First Year Rate of Return (FYRR) as a preliminary economic analysis indicator, prior to embarking on a more comprehensive economic analysis, likely to be more complicated and time consuming (e.g. using HDM4).

The methodology outlined in this paper could particularly assist engineers and transport economists to quickly evaluate the economic worth of the upgrading of low-trafficked roads in developing countries.

1. TYPICAL VEHICLE OPERATING COSTS (VOC) VALUES

A series of typical average VOC values were computed by the author on the basis of road evaluation projects conducted over the period 1997–2005 in nine regions/ countries [1] (Central America, Chad, Haiti, Ivory Coast, Kenya, Madagascar, Niger, Rwanda, Swaziland) using either of the World Bank developed software programmes [2] (HDM-VOC, HDM-MAN, HDM4, RED 3.2). VOC values were calculated for a number of vehicle categories, for IRI (International Roughness Index) ranging between 2 and 15 and for average terrain conditions (150 deg/km and rise & fall of about 4 m/km), given in the table below.

Table 1 - Average VOC values for various vehicle categories and IRI between 2 and 15 (US$/veh-km)

IRI	Car	LDV	Mini-bus	Bus	Med. Truck	Heavy Truck	Articul. Truck
2	0,246	0,276	0,342	0,737	0,607	0,940	1,339
3	0,251	0,284	0,347	0,750	0,635	0,970	1,383
4	0,260	0,297	0,358	0,770	0,676	1,017	1,445
5	0,272	0,310	0,371	0,791	0,715	1,064	1,509
6	0,284	0,324	0,384	0,813	0,754	1,111	1,575
7	0,297	0,340	0,398	0,836	0,794	1,155	1,642
8	0,312	0,359	0,412	0,861	0,834	1,207	1,713
9	0,333	0,382	0,430	0,891	0,878	1,258	1,792
10	0,352	0,405	0,449	0,920	0,917	1,301	1,863
11	0,374	0,432	0,471	0,957	0,964	1,357	1,955
12	0,396	0,458	0,492	0,996	1,011	1,419	2,043
13	0,418	0,484	0,533	1,038	1,065	1,496	2,123
14	0,440	0,511	0,558	1,078	1,112	1,554	2,210
15	0,464	0,539	0,582	1,121	1,161	1,616	2,298

The average VOC for a medium car and very good surface conditions (IRI of 2) was calculated to be approximately 0.25 US$/veh-km.

The results above were summarised in terms of VOC coefficients, in relation to the VOC of a passenger car and an IRI of 2, which was given a value of 1.0 (see table 2).

Table 2 - Average VOC coefficients for various vehicle categories and IRI ranging between 2 and 15

IRI	Car	LDV	Mini-bus	Bus	Med. Truck	Heavy Truck	Articul. Truck
2	1,000	1,125	1,393	3,001	2,473	3,829	5,453
3	1,023	1,158	1,414	3,054	2,588	3,950	5,633
4	1,061	1,208	1,459	3,136	2,755	4,143	5,888
5	1,107	1,261	1,513	3,222	2,911	4,333	6,147
6	1,156	1,320	1,564	3,313	3,072	4,525	6,416
7	1,209	1,384	1,622	3,407	3,234	4,707	6,689
8	1,271	1,462	1,680	3,507	3,396	4,916	6,976
9	1,355	1,555	1,753	3,628	3,575	5,124	7,298
10	1,432	1,648	1,831	3,748	3,735	5,298	7,590
11	1,524	1,760	1,917	3,899	3,927	5,527	7,963
12	1,613	1,865	2,004	4,058	4,117	5,780	8,323
13	1,702	1,973	2,172	4,229	4,336	6,092	8,648
14	1,793	2,083	2,271	4,391	4,531	6,330	9,000
15	1,889	2,196	2,373	4,566	4,730	6,581	9,362

For example, the VOC of an articulated truck at the worst road surface conditions given (IRI of 15), would be about 9.4 time as high as that of a car driving on a very good paved road.

The main advantage of the presented VOC coefficients is that the calculation of a single VOC value (most likely that for a passenger car and an IRI of 2), may suffice to estimate a whole range of VOC values involving the most commonly used vehicle categories, for a range of IRI figures.

2. TYPICAL ROAD CONDITIONS

Existing road conditions were defined for six typical cases. Each of them was associated with an average IRI value to describe the riding conditions as shown below:

Table 3 - Road conditions and IRI values

Existing road conditions	Paved Fair	Paved Poor	Paved Very Poor	Unpaved Fair	Unpaved Poor	Unpaved Very Poor
Assumed IRI values	5	8	12	8	12	15

It is assumed that an IRI of 12 defines the worst riding quality of a paved road, i.e. destroyed pavement.

3. THE FIRST YEAR RATE OF RETURN (FYRR) AS AN ECONOMIC ANALYSIS INDICATOR

The economic worth of a road project can be assessed by means of calculating various economic indicators, such as, net present value (NPV), internal rate of return (IRR), first year rate of return (FYRR), NPV/Cost ratio.

Although indicators such as NPV and IRR take into account the cash-flow of various works related costs and benefits over the analysis period of, say, 15 to 25 years, the FYRR was chosen in the current analysis as economic analysis indicator, primarily because it is easier to apply. The FYRR is simply the sum of the benefits in the first year of trafficking after the project completion, divided by the present value of the capital cost (expressed as a percentage). A discount rate should be used to bring the capital investment costs to the same base year as the benefits:

$$\text{FYRR (\%)} = \frac{\text{Discounted benefits in the first operating year}}{\text{Discounted capital investment cost}}$$

If a calculated FYRR is greater than the planning discount rate (in this case 12%) than the project is timely and should go ahead. If the FYRR is less than the discount rate, the start of the project should be deferred and additional calculations should be undertaken to define the optimum starting date.

Among the advantages of the FYRR are that it is easily calculated, it avoids going into the traffic growth rate issue over the analysis period and it is an indicator that assists best in determining the optimum time of implementation.

The above formula takes into account the case where investment costs are spread over a number of years, whereas for simplification purposes, in the current calculations the capital investment were assumed to occur in one year only (the year prior to the first year of opening of the improved road facility to traffic).

4. CALCULATION OF FIRST YEAR BENEFITS

VOC costs depend on the traffic composition, in particular the percentage of heavy vehicles. In the current analysis the following traffic composition was assumed for the two main categories (light/passenger and heavy/ goods vehicles):

Table 4 - Assumed traffic composition for the two main categories

Light & passenger vehicles assumed composition

Car	LDV	Mini-bus	Bus	Total
30%	30%	25%	15%	100%

Heavy Goods vehicles assumed composition

Med. Truck	Heavy Truck	Articul. Truck	Total
50%	30%	20%	100%

Keeping the above composition by main category constant, calculations were carried out for a range of heavy vehicle percentages, as follows:

Table 5 - Range of heavy vehicle component of traffic

Composition type	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	Type 8	Type 9
Light & passenger vehicles	90%	80%	70%	60%	50%	40%	30%	20%	10%
Heavy & Goods vehicles	10%	20%	30%	40%	50%	60%	70%	80%	90%

First year VOC benefits (for one km) were calculated by subtracting the yearly VOC costs for a good paved road from that of a road in existing conditions (as given above in Section 2.), for various average daily traffic (ADT) volumes and the above 9 types of traffic composition.

5. CALCULATION OF FYRR

FYRR were computed for each type of upgrading to good paved road conditions, assuming investment costs in the range of 50 000 – 500 000 US$/km and for the various heavy vehicle percentages (types 1 to 9 given above). However, according to the riding quality given above for the different road conditions, in terms of IRI, there are four distinct categories of upgrading to be considered:

- Paved fair	
- Paved poor or Unpaved fair	upgrading to good paved road
- Paved very poor or Unpaved poor	all 4 road categories
- Unpaved very poor	

For every upgrading road category above, the FYRR was calculated as mentioned above. Then, unitary investment costs were extracted for all cases where the computed FYRR was equal or above 12% threshold. An example for the upgrading from "paved fair" road to "paved good" road is given in the table below:

Table 6 - Upgrading from Paved Fair road - maximum investment costs in '000 US$/km for FYRR $\geq$12%

	% Heavy								
ADT	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**
50	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
100	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
150	n/a	n/a	n/a	n/a	n/a	n/a	n/a	50	50
200	n/a	n/a	n/a	n/a	50	50	60	60	70
250	n/a	n/a	n/a	50	60	70	70	80	90
300	n/a	n/a	50	60	70	80	90	100	110
350	n/a	50	60	70	80	90	100	110	120
400	50	60	70	80	100	110	120	130	140
450	60	70	80	100	110	120	130	150	160
500	60	80	90	110	120	140	150	160	180

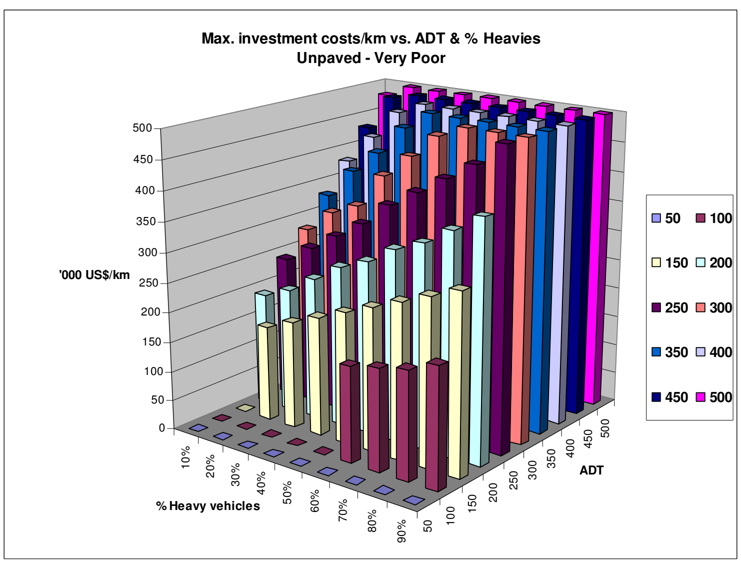
The figures in this table show that even when the ADT is relatively high and the percentage of heavy vehicles substantial, only moderate investment costs would yield economic returns of 12% or greater. Below a certain ADT, the results are not applicable, i.e. no matter how low is the investment cost and what is the heavy vehicle percentage, the FYRR would be below the 12% threshold level. For instance, for an ADT of 300 and 30% heavy vehicle, a maximum investment of 50 000 US$/km only is likely to yield a 12% rate of return.

The following table and associated figure illustrate the results obtained for the most extreme case analysed, i.e. upgrading of a very poor unpaved road to paved good conditions.

Table 7 - Upgrading from Unpaved Very Poor road – max. investment costs in '000 US$/km for FYRR ≥12%

	% Heavy								
ADT	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**
50	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
100	n/a	n/a	n/a	n/a	n/a	160	170	180	200
150	n/a	160	180	200	220	240	260	280	300
200	190	210	240	270	290	320	340	370	400
250	240	270	300	330	370	400	430	460	500
300	280	320	340	400	440	480	500	500	500
350	330	380	420	470	500	500	500	500	500
400	380	430	480	500	500	500	500	500	500
450	430	490	500	500	500	500	500	500	500
500	480	500	500	500	500	500	500	500	500

Figure 1 - Upgrading from Unpaved Very Poor road – max. investment costs in '000 US$/km for FYRR ≥12%



6. DISCUSSION AND CONCLUSIONS

Every so often, there is a tendency to upgrade poor roads to good paved roads, with an emphasis on unpaved road carrying low to moderate traffic volumes. In most case there is a requirement to use HDM or an associated model developed by the World Bank to conduct the economic analysis. Even when using a traditional basic spreadsheet type calculation, it is expected that benefits would primarily be derived from road user costs, mostly VOC, savings.

The results of the analysis presented in this paper show that unless a road carries a significant amount of traffic, and if possible a high percentage of heavy vehicles, the economic return on investment is likely to be below an acceptable rate of 12%, if VOC savings alone are considered. In most cases, the heavy vehicle component is unlikely to exceed 30% - 40%. Upgrading from unpaved to paved standards is expensive and may often cost over 300 000 US$/km. It can therefore be argued that based on VOC savings, a road should carry at least 200 – 300 vehicle per day to justify economically the investment of upgrading from unpaved to paved standards. For instance, based on the current analysis, the upgrading from a very poor unpaved road would justify an investment of 300 000 US$/km, if the ADT≥250 with a 30% heavy vehicles component. For the same type of upgrading, an investment of 500 000 US$/km or more would be justified if the ADT ≥ 500.

The IRI values assumed for various unpaved road conditions may be somewhat conservative (i.e. on the low side) and if the roughness values were to be higher, for instance an IRI=20 for the riding quality of a very poor unpaved road, then the benefits would be higher, thus justifying a somewhat higher investment cost. However, it is obvious that VOC savings for roads trafficked at the completion of works by 200 or less vehicles per day, are unlikely to justify upgrading from unpaved to paved road conditions. In such cases two possibilities exist to justify investments from an economic view point:

- To look for lower road standards, such as engineered gravel road with adequate drainage facilities.
- Calculate additional benefits, other than VOC related, e.g. increase in agricultural production, on the basis of which the investment could be justified. One could associate to that little or non-quantifiable benefits, such as, national/ regional development, environmental benefits, social benefits, etc.

In conclusion, the FYRR could be used as indicator to estimate fairly quickly the economic worth of a road project, based on VOC savings, prior to embarking on more complicated calculations involving a full economic analysis. Based upon the results obtained, one could decide whether it is worthwhile to proceed with a full economic analysis or to adopt another method of evaluation.

The process involving the calculation of the FYRR as a preliminary economic indicator using the results of the research included in this paper, are as follows:

- estimate the ADT and vehicle composition of the project road for the envisaged first year of operation
- compute the VOC for a “passenger car” (cost/veh-km)
- use the VOC coefficients given in Table 2 to expand the calculation to all vehicle types (to obtain a table similar to that of Table 1, but applicable to your case study)
- estimate the road conditions “before” and “after” in terms of riding quality expressed in IRI values
- calculate yearly VOC savings for the appropriate ADT, traffic composition and the road length applicable
- estimate the construction/investment costs, required for the upgrading from “before” to “after” conditions (for the same year as that of the benefits)

- compute the FYRR by dividing the yearly VOC savings (benefits) by the investment cost.

If the result obtained equals or exceeds the planned discount rate (in this case 12%), the project is most likely to be economically viable and one may proceed with a full economic analysis, if need be. Obviously, one may decide to carry out a full economic analysis if the FYRR is somewhat below the planned discount rate (say, 9% to 11%, if the threshold is 12%). However, if the calculated FYRR result is much lower, either a lower-cost upgrading should be considered or additional benefits, other than VOC related, should be contemplated to justify the investment from an economic view point.

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