# A method for the appraisal of low volume roads in Tanzania[1]

**M. BENMAAMAR**
**TRL, Crowthorne, UK**
**mbenmaamar@trl.co.uk**

## Abstract

The objective of this paper is to present a ranking method for low volume road improvement as an alternative appraisal method to the consumer surplus approach used by HDM. The consumer surplus method is generally considered to be reliable when applied to high volume roads (AADT >200). However, its application to low-volume roads (AADT < 50) encounters problems related to the small magnitude of user benefits and the stronger influence of the environment rather than traffic on road deterioration. Considering the low volume of traffic and its composition on most of the unpaved road network in Tanzania, it is recommended that a cost-effectiveness approach that takes account of the social and economic importance of rural infrastructure interventions be applied to prioritise investments. Establishing the priorities for rural road interventions in Tanzania requires a selection process consisting of a combination of screening and ranking procedures. The screening process reduces the number of investment alternatives. This can be done through targeting disadvantaged communities based on poverty indices using the Human Development Index by region. After screening methods have been applied to a given set of investment choices, resources are still unlikely to be sufficient to finance the balance of the remaining desirable interventions, and hence a ranking or prioritisation method based on Cost Effectiveness Analysis (CEA) was developed.

**KEY WORDS:** LOW VOLUME ROADS / PARTICIPATORY APPROACH / PRIORITISATION METHOD / COST-EFFECTIVNESS / HDM / POVERTY / POPULATION / NMTs

## Background

This method was developed as part of the Tanzanian Road Mentor Management System study (Jones, C R, 2002). The objective of the project was to produce a road management system for the newly formed Tanzanian National Roads Agency, TANROADS. TANROADS currently have responsibility for the maintenance, to specific standards, of both the trunk and regional road networks in Tanzania, totalling 28,000kms.

HDM-4 was used as part of a Road Maintenance Management System (RMMS) to develop maintenance strategies for the 4,000km of paved roads. However, the project team quickly realised that for various reasons the use of HDM-4 model on low volume roads was unsatisfactory. There was subsequently a need to develop an alternative method to prioritise investments on low volume roads that could be integrated with the RMMS.

[1] Paper for the XXII PIARC World Road Congress, Durban October 2003

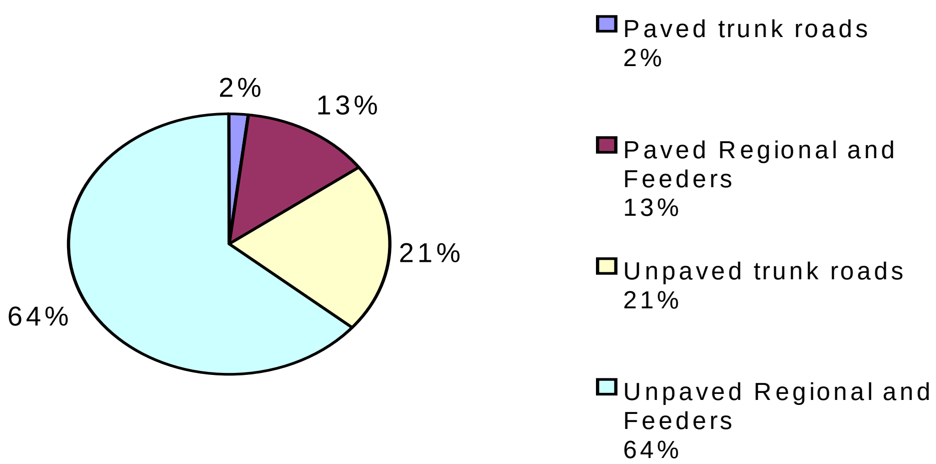
The method needed to take into account the characteristics of low volume roads, be relatively easy to implement and be part of the future development of the Road Mentor Data-Base. The road mentor system was first implemented within the central zone. It is expected that the experience gained in this exercise will be used across the rest of Tanzania.

**Network characteristics**

The total size of the Tanzanian road network is estimated at around 85,000 km of which more than two thirds are district and feeder roads that are under the Ministry of local government (Road User Charges and Road Financing Study, 2001).

TANROADS is responsible for 28,000 km of main road network of which 24,000 km (85%) are unpaved (Tanzania RSDP, 2000). The paved road network comprises some 4,000 km, most of which are classified as trunk roads. Around 6,000 km of the unpaved road network are classified as trunk roads and 18,000 km as regional roads. The distribution of the main road network by type and classification is shown in Figure 1.

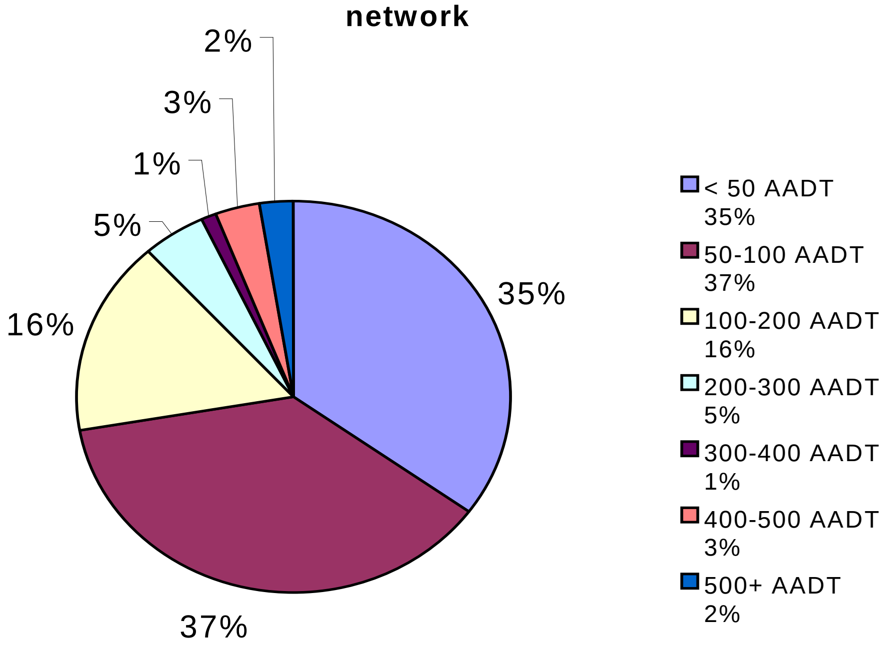
**Figure 1: Network by type and classification**




**Traffic levels on the unpaved road network**

Around three-quarters of the unpaved roads carry, on average, an Annual Average Daily Traffic (AADT) of less than 100 vehicles and more than one third (8,400km) carry an AADT of less than 50 vehicles. Most of these roads are regional and feeder roads. The distribution of traffic on the unpaved road network is shown in Figure 2.

**Figure 2: Traffic distribution on the unpaved road network**




## Traffic characteristics

Traffic and road condition surveys carried out on 20 roads in the Kilimanjaro and Iringa regions during dry and wet seasons (Ellis S. D. and Hine J. L. 1997), show that roads in poor condition suffered from reduced traffic levels in the wet season. In the wet season, traffic volume is reduced, on average, to only 35% of the dry season traffic. The main reasons for road closure were poor drainage, broken or missing structures, slippery surfaces and emergency situations such as landslides.

An analysis of the traffic data highlighted that the majority of traffic using the roads was Non-Motorised Means of Transport and pedestrians (NMT's). The survey roads had an average daily traffic, including NMT's, of 5 to 170. For the entire survey sample the proportion of NMT's to the total averaged 84%. In addition, it was found that the total burden carried by NMT's, in terms of tonnes-kilometres, was also high with an average of 33%.

## Social and economic role of low volume roads

In general, low volume roads are built to lower standard than high volume roads, carry a small fraction of the total traffic, but serve the majority of the predominantly rural population. Therefore, low volume rural roads play a very important economic and social role. They enable rural communities to grow and market their agricultural produce more efficiently, and they ease access to alternative income sources. On the social side, rural roads increase access to schools, health facilities, friends and relatives, and other social activities that promote the well being of the community. Therefore most expected benefits from Rural Transport Interventions are related to the provision of basic access which, in turn, increases socio-economic opportunities, but are difficult to quantify in monetary terms.

Another characteristic of rural road investment programmes is the coverage of large areas where needs include both the improvement of existing all-weather passable roads for the purpose of network efficiency and the provision of basic access for poverty alleviation. Moreover, rural road projects are often screened from a vast road network. For the purposes of equity among villages, the spatial balance of the programme must be considered as well as economic criteria in selecting individual roads for investment.

A conventional road project appraisal methodology is unsuitable to address these characteristics. Other tools are thus necessary to supplement the conventional methodology and they are based on a cost effectiveness approach.

**The Cost effectiveness approach**

Establishing the priorities of rural road intervention requires a selection process consisting of a combination of screening and ranking procedures.

The screening process reduces the number of investment alternatives. This is done through targeting of disadvantaged communities based on poverty indexes, or by eliminating low-priority links from the list according to agreed-criteria.

After screening methods have been applied to a given set of investment choices, resources are still unlikely to be sufficient to finance the balance of the remaining desirable interventions, and hence a ranking or prioritisation exercise is required (Schelling D. and Lebo J. 2001).

The methodology for project ranking is based on Cost Effectiveness Analysis (CEA) for the majority of rural roads where traffic volumes are relatively low. After dividing the selected roads into homogenous links, a priority index is defined for each road link based on a cost-effectiveness indicator equal to the ratio of the total life-cycle cost of ensuring basic access divided by the population served. With this approach, a threshold cost effectiveness value should be determined below which a link should not be considered for investment**.**

Unlike Cost-Benefit Analysis (CBA), where projects normally are deemed “uneconomic” when their Economic Rate of Return (ERR) falls below 10-12%, there are no well established criteria for determining “opportunity cost” thresholds when ranking on the basis of cost-effectiveness. Such a determination is left to policy makers. For example, if access can be provided to two, otherwise similar, communities at $US100 per person served and $US50 per person served, respectively, cost-effectiveness criteria would clearly “rank” the latter community higher. However, the question that remains is whether $US50 per capita is a sufficient "return" to justify intervention (could that $US50 per person be spent with more impact in another sector, or would it yield an ERR of 10-12% considering the opportunity cost of capital in the country?).

**Determination of the threshold CE-value**

The method for determining a threshold CE-value is a cost-benefit analysis on a sample of selected links applying enhanced benefit measurement approaches for establishing a threshold CE-value. The proposed enhancements of traditional Cost Benefit Analysis (CBA) techniques are aimed at finding broader measures of economic benefits and costs applicable to rural road projects. In addition to benefits associated with Vehicle Operating Costs (VOC) savings, possible enhancements of CBA includes better assessment of the costs of interrupted access, cost and time saving of non-motorised traffic, improved valuation of time savings, and valuation of social benefits from improved access to schools and health centres.

With this approach, a threshold Cost Effectiveness value is determined below which a link should not be considered for investment. This is estimated by carrying out a sensitivity analysis on the selected links to determine the cost that would make the project economically viable (ERR= 12%). The project cost divided by the population served by the link should then be used as the cost-effectiveness value.

Finally, once the very high unit cost road links are dropped, available financial resources should be taken into consideration in deciding the number of candidate road links that will pass the ranking stage and be eligible to be considered in the maintenance programme.

**Possible application of the cost-effectiveness approach to Tanzania**

A two-stage screening procedure can be applied to select rural road links amongst the 4,000km candidate roads (AADT < 100) within the Central zone in Tanzania to be included in a rural road investment programme.

The first stage of screening identifies the "priority regions" that will be most in need of improved road transport as an element in alleviating their poverty. In the case of Tanzania, the screening process could be applied by using the Human Development Index, HDI (Human Development Report, 1998) which was calculated for each region for the purpose of the 10-year Road Sector Development Program project. The HDI is composed of three parameters, namely:

1- Longevity, expressed in terms of life expectancy at birth

2 -Educational attainment, expressed as weighted average of adult literacy (2/3) and the combined Gross Enrolment Ratio (GER) (1/3)

3 - Standard of living, expressed in terms of the purchasing power parity GDP per capita in USD.

The results are presented in Table 1 below.

**Table 1: Human Development Index per region, Tanzania**

| Region | Unpaved Roads, AADT<100 (km) | Life expectancy 1988 (year) | Literacy rate, 1998 (%) | GER* 1995 (%) | GDP/ capita 1997 $US | HDI | Rank |
|---|---|---|---|---|---|---|---|
| **Dodoma*** | **765** | **46** | **55.5** | **67** | **181** | **0.319** | **1** |
| Kagera | 1114 | 45 | 59.5 | 66 | 156 | 0.320 | 2 |
| Coast | 602 | 47 | 51.1 | 74 | 203 | 0.324 | 3 |
| Rukwa | 1345 | 45 | 58.6 | 65 | 315 | 0.325 | 4 |
| Kigoma | 608 | 48 | 55.1 | 66 | 162 | 0.327 | 5 |
| Mitwara | 615 | 46 | 53.1 | 78 | 207 | 0.327 | 6 |
| Lindi | 738 | 47 | 53.8 | 74 | 207 | 0.330 | 7 |
| Shinyanga | 826 | 50 | 48.3 | 73 | 242 | 0.335 | 8 |
| Tabora | 1082 | 53 | 50.5 | 63 | 214 | 0.344 | 9 |
| Mwanza | 972 | 48 | 57.3 | 75 | 219 | 0.345 | 10 |
| Morogoro | 842 | 46 | 62.8 | 79 | 205 | 0.350 | 11 |
| Mbeya | 1356 | 47 | 61.9 | 80 | 211 | 0.355 | 12 |
| Iringa | 826 | 45 | 68.3 | 87 | 258 | 0.368 | 13 |
| **Tanga*** | **684** | **49** | - | **77** | **284** | **0.370** | **14** |
| Mara | 665 | 47 | 63.9 | 92 | 194 | 0.372 | 15 |
| **Singida*** | **1233** | **55** | **51.4** | **75** | **218** | **0.384** | **16** |
| Ruvuma | 1186 | 49 | 70.5 | 80 | 258 | 0.388 | 17 |
| **Arusha** | **1014** | **57** | **58.1** | **73** | **264** | **0.397** | **18** |
| D-E-S | 269 | 50 | 80.7 | 93 | 607 | 0.449 | 19 |
| Zanzibar | 169 | 55 | - | 100 | - | 0.471 | 20 |
| **Kilimanjaro** | **369** | **59** | **81.8** | **100** | **166** | **1.485** | **21** |

***** Selected regions

- Gross Enrolment Ratio
- Source: 1- Human Development Report, 1998
  2 - United Nations Development Report, 1998
  3 - Poverty and Welfare Monitoring Indicators, Vice president's Office, 1999

For example, application of the first stage of the screening process to prioritise investment alternatives for low volume roads within the Central zone (Dodoma, Tanga, Singida, Arusha and Kilimanjaro) using the HDI would result in selecting 3 less developed regions out of 5 (Dodoma, Tanga and Singida). This could reduce the road network that was considered for interventions from the initial 4,000km to 2,700km.

In the second stage of the screening process, to establish a functional road network system from these three priority regions, rural roads for improvement in these regions should be grouped into sub-networks systems based on three criteria:

- continuity of the system;
- maximisation of the population served; and

- connection with as many settlements as possible.

Once the most functional road system is selected, to maintain a degree of equity among villages, a redundancy criteria could then be used to eliminate low priority links from consideration for investments. For example, it could be decided that for each village only one link, usually the shortest, would be upgraded to basic access standard. This could reduce further the size of the road network that will be considered for interventions from 2,700km to 2,000km.

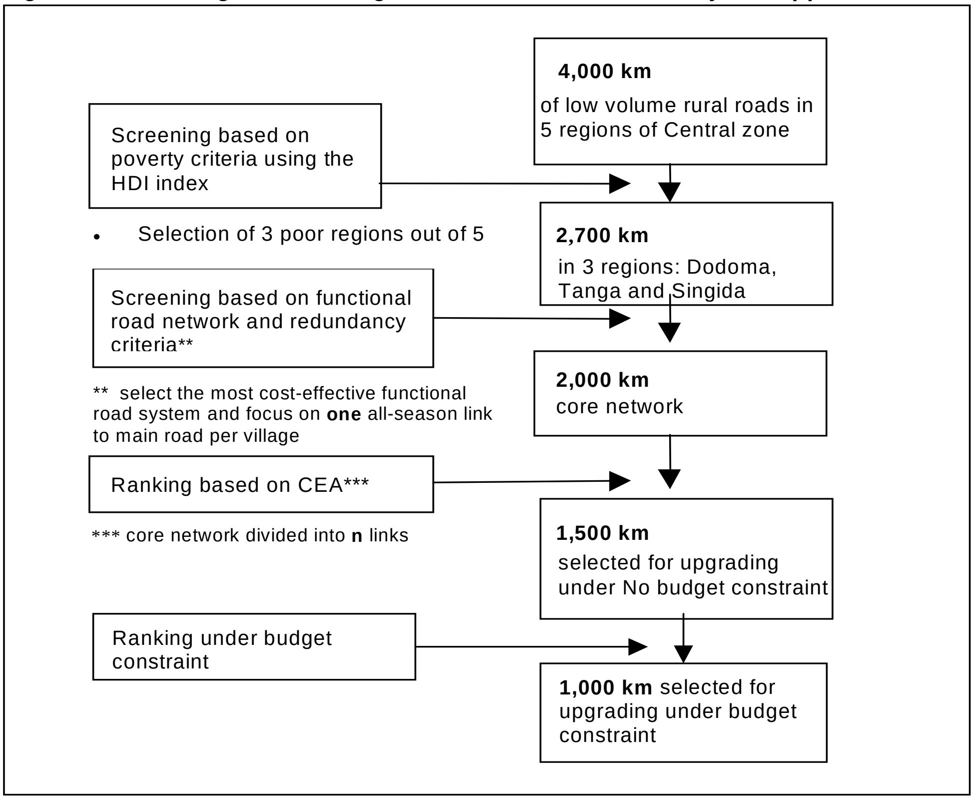
### Ranking

After dividing the selected roads into homogenous links, the CEA could then be applied to rank individual links of a "core network" selected on the basis of screening criteria (2,000km). The cost-effectiveness indicator is defined as the cost of improving a particular link to "basic access standard" divided by the number of people served by the link. Thus, the population within the catchment area of each road link is essential and will be used as a proxy variable to estimate benefits.

$$\textbf{Cost-effectiveness indicator of link}_{(i)} = \frac{\textbf{Cost of upgrading of link}_{(i)}\textbf{ to basic access standard}}{\textbf{Population served by link}_{(i)}}$$

On this basis, up to **n** individual links could be ranked. In view of the available financing, it could be decided that the maximum amount of investment allowed per link would be $X per person served, which will be used as a threshold CE-value below which a link should not be considered for investment**.** This process could reduce the core network of 2,000km to 1,500km of economically viable project links to be upgraded under no budget constraints. Finally, an additional ranking, under budget constraint, could reduce further the size of the selected links for upgrading to 1,000km. The main stages of the screening and ranking procedure are shown in Figure 3 below.

**Figure 3. Screening and Ranking Method for Rural Road Projects Appraisal.**




## A participatory approach

The implementation of the screening and ranking process described in Figure 3 above requires the maximum participatory involvement from all stakeholders. Stakeholders come from a wide range of interest groups covering direct users of basic social services, occupational groups (e.g. transport operators, traders and small scale farmers) and community based groups (e.g. village leaders, health care and education providers).

As far as possible, representatives of all these groups need to be canvassed in the process and all should be encouraged to submit their views in nominating the candidate roads of a functional road network. The participation should, however, not replace the economic selection process. This might be the case if investments are entirely locally financed, but even then the "wish list" will typically be more sizeable than available resources and a rational process (using economic criteria) should be used to help prioritise alternative investments.

## Data requirements

A key tool to implement the cost-effectiveness approach is a local government or community transport plan. Consultants and Local engineers, in consultation with communities, also need to conduct a low-cost inventory and condition survey of the local transport network in each study area, including roads, tracks, paths and bridges, with a focus on existing obstacles (impassability). On the basis of the information generated, and additional economic, social and demographic information, an "as is" map should be produced. Based on such information, stakeholders could co-operatively decide upon desired improvements in the rural road network, taking into account objectives and available resources.

Along with extensive traffic surveys (Motorised and Non Motorised traffic) on a representative link for the determination of the Cost-effectiveness threshold value, the application of the cost-effectiveness method requires two main inputs:

1- The cost of the maintenance intervention for each link; and
2- The population served by each link

**The Cost of the maintenance intervention of each link**

During the road condition surveys, planners and engineers conducting the survey should assess the expenditure and type of works necessary to bring each link to basic access standard.

**Population served by each link**

Population data for each link is another important component of the prioritisation Index. The current rural population needs to be allocated to each road link under investigation. For any given area the population should be allocated to the nearest road or track (by walking distance). In the allocation process natural barriers such as rivers and lakes should be observed if there is not a convenient crossing point available.

The prioritisation process demands that account be taken of the complete catchment area of the road covering the whole population that would normally use the road (to visit markets, hospitals, schools, district administration etc) and thus directly benefit from its improvement. This may involve collecting and assigning population data relating to roads and tracks that are not under direct consideration for improvement. This "other population" component is treated a little differently from the population that is adjacent to the road link.

To undertake the population allocation, maps and census data are required. If possible 1 to 50,000 maps should be used. It is recognised that the census data in Tanzania is out of date and a new population census will be taking place soon. A range of central and local government offices (e.g. covering health, education, water, elections, District Common Fund etc.) use population data to allocate resources and it would make sense to examine what data sources and procedures are used. It would also be useful to check with each District Administration as to where the major anomalies might occur and what up-to-date population data they might have for different communities in their District.

## Conclusion

Unlike the conventional Cost-Benefit Analysis methods the Cost-Effectiveness Approach is easier to implement and requires no traffic data for each road link. The population within the catchment area of each road link will be used as a proxy variable to estimate project benefits and it is therefore important that the collection of these data be part of the future development of the Road Mentor Data-Base.

With this approach, a threshold CE-value needs to be determined below which a link should not be considered for investment. The recommended method for determining a threshold CE-value is to do a sample cost-benefit analysis on a few selected links applying enhanced benefit measurement approaches for establishing a threshold CE-value.

For roads where higher than basic access standards seem justified (e.g. those that provide an alternative access to the same location, or experience traffic levels above 50 AADT (but below 200 AADT)), the use of standard cost-benefit analysis is recommended. For roads that carry above 200 AADT, the utilisation of HDM-4 is recommended.

## References

Ellis S. D. and Hine J.L. Rapid Appraisal Techniques For Identifying Maintenance Priorities On Low Volume Rural Roads, TRL Unpublished Report PR/OSC/122/97, 1997

Human Development Report, 1998

Jones C. R. Tanzanian Road Maintenance Management System: Development of Road Mentor, Phase 2, Final Report. TRL unpublished report PR/INT/710/02, November 2002

Schelling D. and Lebo J. Design and Appraisal of Rural Transport Infrastructure: Ensuring Basic Access for Rural Communities. World Bank Technical Paper No 496, 2001

Study to review road user charges and rates for sustainable road financing, The United Republic of Tanzania, 2001

Tanzania 10 Year Road Sector Development Program- Phase I, Final Report, September 2000

## Acknowledgements

The study from which these results were derived were part of a DFID-financed project 'Tanzanian Road Maintenance Management System: Development of Road Mentor'. I am grateful for comments on various drafts to John Howe. However, responsibility for any inaccuracies or opinions is those of the author alone.