Adoption of Road Asset valuation that takes into account economic, environmental, political and social factors as a means of prioritising development and preservation of rural road assets

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Abstract

This paper proposes a new rural road valuation methodology encompassing economic, environmental, political and social factors as a means of prioritising development and preservation of rural road assets. A combination of models have been adopted to monetise and rank the road assets for prioritization. The models include; Modified Transport demand model (MTDM) for valuation of social-economic benefits, Multi-criteria analysis (MCA) method for valuing and ranking the social – economic benefits to be considered for monetization calculation and a value model (VM) that combines all the other models to calculate the actual value of the road asset.

The road asset is divided in three components for valuation purposes; physical road based on physical components such as road pavement, drainage, ancillary works and services running under or above the road surface, economic components and social components. This paper is on the valuation of social-economic components and mentions physical components for completeness.

The MCA model provides road network social benefit score for each social sector (trading, transport, agriculture, education and health and other high-level objective) which is a measure of its value associated with the roads serving the selected communities in the road network. The villages / trading centres or user communities identified act as generators of social benefits, enabling the value of individual roads linking the selected benefiting communities to be compared. The score is calculated using MCA protocol through a series of calculations.

Transport demand (TD) model that combines both the tangible and the intangible parameters is adopted as a link model with a bit of fine tuning to match the selected benefits derived from MCA model. Example of this is the changes in the transport cost in relation to changes in enrolled school pupils.

This paper also introduces a value model which is used to aggregate all the monetised social benefits in relation to the cost of improving the quality of the road network. (Raiding quality). The true value of the road is a combination of the physical value of the road calculated based on replacement cost method and the monetised social benefit. The value model proposed is the core of the research and more work will be conducted to have an accurate system.

A case study based on social-economic data collected from AfCAP-GEM project currently ongoing in the three participating countries (Kamuli district in Uganda, Tonkolile in Sierra Leone and Chongwe in Zambia) was adopted for testing the proposed models and sensitivity analysis of results.

It may be stated that, the proposed measure of the value of the road is expected to be a very useful tool to be used in prioritising roads for improvements such as routine and periodic maintenance, upgrading and reconstruction. It may also be used by policy makers, financiers, funding organisations and administrators in resource allocation for road asset improvement.

Keywords - rural road valuation, socio-economic benefits, multi-criteria analysis, value model, measure of the value.

I. INTRODUCTION

A comprehensive literature review conducted using systematic review process indicate that Sub-Saharan Africa has approximately 700,000 kilometres of rural roads, with half of them in poor condition (African Development Bank, 2010).

Literature review also indicates that rural roads contribute significantly to the economic and social development of the areas they traverse (World Bank, 2005). It's also noted that although a lot of research has been put into the rural road sector, no attempt has been made to monetise social economic benefits based on rural road asset.

Available literature reveals that the current available methods of rural road valuations are shy of using the contribution of social benefits to calculate the true value of the rural roads. The available literature indicates use of physical infrastructure based on cost benefit analysis (CBA) and other related economic based methodologies. To assess the true value of the road, monetised value of social-economic benefits of rural roads to the communities they serve is required in combination to the economic value and physical value. A rural road based social –economic benefit model, based on social monetisation principles has been developed and is the subject of this paper.

The true value of the road asset requires a combination of the physical value, Economic value and the social value. A combined model is required to combine all the parameters. For comprehensive valuing of the assets on the road, the main components which need to be considered, should include: Physical road and its structures, Services running along or under the road, the economic benefits or costs, the social benefits or costs, political benefits, cultural benefits among others. This paper concentrates on the social-economic monitisation.

The objective of social-economic impact analysis is to assess the magnitude and distribution of both direct and indirect effects. Past efforts in assessing the impact of infrastructure projects have been limited due to the lack of available baseline and control data. This has made it difficult to disentangle the effects of the infrastructure project from those of other interventions and the overall development of the economy. Road condition (in the form of road roughness IR) used to determine the cost and benefits of roads may be useful for roads with a reasonable amount of traffic, however MCA among others models provide comparisons between projects and this may be useful for prioritization of road assets through ranking.

Several approaches for the cost-benefit analysis of rural roads have been put forward in the past: consumer surplus; producer surplus; compound ranking methods; and multi-criteria analysis (Dr. Richard Robinson (1999)). However, there are a variety of tools which can capture the economic benefit of rural roads these include, HDM-4. CBA, and RED among others

Monetizing social benefits remain a key issue for research. Most literature on this aspect relate to other sectors other than rural roads. The current practice of road valuation ignores the value accrued from the social benefits underscoring the true value of the rural roads.

The main objective of this valuation methodology therefore is to bring on board the consideration of the social benefits in the calculation of the true value of the road. The true road value is expected to be a very useful tool in prioritising roads for improvements such as routine and periodic maintenance, rehabilitation, upgrading and or construction of roads by policy makers, financiers, funding organisations and fund managers

I) Transport demand

Transport demand is related to the number of people and amount of goods that move around the road network and the derived costs and benefits accrued from such decisions SACTRA (1996). Transport demand can be measured in several ways commonly by number of trips, number of passengers, vehicle-miles, passenger miles and freight tonnes among others. It's noted that the consumption of transport is the result of several individual decisions about whether, when and how to travel or transport goods. Transport demand is directly related to the needs of the people and therefore to social economic changes in the community.

Transport demand analysis is one of the common ways of calculating the benefits accrued from maintenance, upgrading and or construction of roads by comparing the reduction in user costs, increase in traffic and increased social benefits or costs among others.SACTRA (1996). Figure 1; below shows the relationship between increased consumer surplus and improved travel conditions derived from SACTRA (1996). If the travel conditions between any two points i and j improve so that generalised costs fall from C_0 to C_1 and the volume of trips increases from T_0 to T_1 then the user benefit, is the darker shaded area C0XYC1. For minimal changes in generalized cost, the demand curve is taken treated as linear and the user benefit is given by the half formula rule as; $0.5(C_0 - C_1) (T_0 + T_1)$.
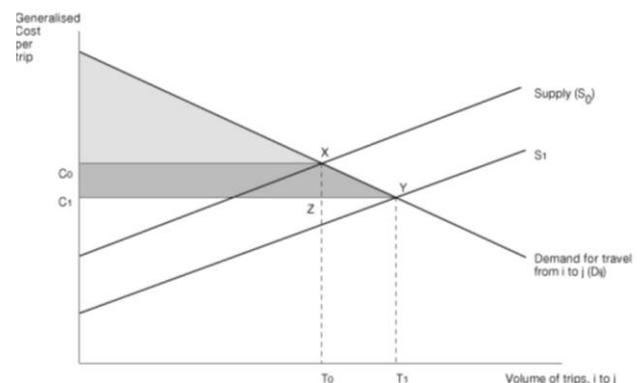

Figure 1: Increased consumer surplus with improved travel conditions (SACTRA, 1996)

This method is limited to accurate calculation of the reduction in user costs due to road maintenance and increase in traffic volume. However, this method in combination with MCA can be used to determine the value of the rural road. A sensitivity analysis is required to adjust the accuracy of

II) Impacts of rural road improvements to user community

Reductions in road maintenance works activity emanating from budget reductions can have accrued costs to society in terms of economic, environmental and social impacts. According to Zebra et al, (1994), the impacts of road maintenance investment can be costs (negative) or benefits (positive). Economic impacts are easy to value whereas social impacts which are intangible may not easily be monetised. This paper discusses the later.

III) Benefits due to road improvements

Social impacts fall into three categories; Direct benefits, indirect benefits and Induced impacts. Direct benefits refer to those benefits that have direct positive impact on the road user and are aimed at lowering the cost of transport and production through; Cost savings in vehicle operation cost (VOCs), Travel time costs, Reduction in road accident costs and possible savings in road maintenance costs.

Indirect benefits refer to those benefits that do not directly impact to the road user and have wider impacts. These are sometimes referred to as Wider Economic Benefits (WEBs) as they relate to the notion of potential transport impacts on agglomeration. These include; contribution to GDP, lower costs of production, widening labour catchment areas, increased competition, stimulated inward investment, re-organization of land use and opening inaccessible sites for development. According to SACTRA (2002), there is a direct relationship between the increase in traffic and the GDP.

Induced impacts refer to those impacts that can be attributed to local economic development resulting from road maintenance investment. These are sometimes referred to as Economic Activity and Location Impacts (EALIs), they indicate the impact of an option expressed in terms of the net effects of the option on the local and/or national economy. This section is outside the scope of this paper and maybe case for further research.

IV) The rural road valuation methodology (Road Value Model – Rvm)

Depending on the benefits of the trading centre of the affected community, the value accrued from social benefits together with the replacement value of the road derived through economic procedures are jointly used to calculate the true value of the road. Analysis of this methodology is based on replacement cost method and a combination of TM and MCA process that gives a comprehensive and rational framework for: structuring a decision problem, representing and quantifying its elements, relating the elements to overall goals, and evaluating alternative solutions. Accordingly, in this work pair-wise comparisons of the high-level objectives is carried out to analyse the priorities. The high-level objectives considered in this paper include; *Economic, Safety, Environment, Wider benefits, and rural Accessibility*. The value of replacement cost has not been included in this paper. It will be mentioned for completeness of the paper.

V) Monetisation of benefits

Available literature indicates, monetisation of social benefits has been carried out in some sectors such as health, however limited information is available for data in the rural road sector. There are several approaches used to calculate Social economic benefits of the rural road maintenance or upgrading. The common ones currently available are; Cost effectiveness analysis (CEA), Cost benefit analysis (CBA), Life cycle models such as HDM4 and Multi Criteria Analysis (MCA). Most of the mentioned methods require input values however, MCA method is commonly used for ranking options due to its appropriateness to handle both monetised and non-monetised impacts and its consideration of all stake holders' requirements. The stake holders include politicians, policy makers, technical and none technical users among others.

VI) Multi-criteria analysis (MCA) Method

According to Belton and Stewart (2002), MCA methods utilize a decision matrix to provide a systematic analytical approach for integrating uncertainty, risk levels and valuation, which enables evaluation, scoring and ranking of many alternatives. Bridges et al. 2005 acknowledges that MCA method overcomes the limitations of less structured methods such as comparative risk assessment (CRA), which suffers from the unclear way in which it combines performance on criteria. However Elementary MCA methods can be used to reduce complex problems to a singular basis for selection of a preferred alternative. MCA approaches require the exercise of judgment although they differ in the way they combine data.

MCA techniques usually make use of explicit relative weighting system for the different criteria. Its foundation is majorly hinged on the decision makers' own choices of objectives, criteria, weights and assessments of achieving the objectives. MCA, however, does bring a degree of structure, analysis and openness to classes of decision that are beyond the practical reach of CBA (DfC&LG, 2009). MCA methodology is commonly used for analysis of wider social - economic benefits including those that are not monetized. It's on this basis that MCA is suited for analysis of social benefits accruing from road improvements.

MCA is used by combining qualitative costs and benefits and monetized and non-monetized benefits into a single analytical framework related to the road maintenance (Odoki et al 2012). Figure 2; below, shows an example of multi-criteria analysis showing section alternatives X, Y, Z and two levels of objectives.
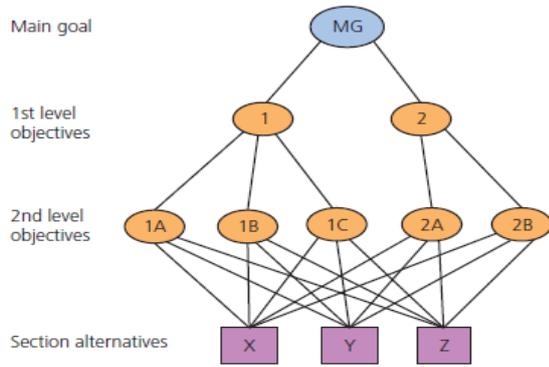
Figure 2: Multi-criteria (MCA) tree (Source Odoki et al, 2012)

According to Odoki et al, 2012, Issues considered under wider economic benefits may follow MCA procedures for economic benefit for maintaining local roads. According to Saty, 1980, process preference indices are assigned with values ranging from 1 to 9 for importance assessment from equally preferred to extremely preferred respectively, as shown in the table below;

Although MCA is a very robust method of comparing alternatives, weaknesses may occur where; maximization of utility may not be important to decision makers, criteria weights are obtained through less rigorous stakeholder surveys thus not accurately reflecting stakeholders' true preferences and where rigorous stakeholder preference elicitations are expensive to obtain.

a. Objectives for Road related social benefits

Objectives are measures of policy goals. They represent the quantifiable attribute of an investment policy goal. MCA synonymous with multiple conflicting objectives and trade-offs to be made. However, in applying MCA it is important to identify high level objectives and sub-objectives if there is any. The use of a value tree hierarchy is always handy. To establish objectives, it is good practice to refer to underlying policy statements and to identify both who the decision-makers and those who may be affected by the decision. For road maintenance in the wake of dwindling funding, the main goal of this paper is to assess the social-economic benefits associated with the maintenance of local roads to form a case for funding using value as a driver. The high-level objectives considered in this paper are; *Economic, Safety, Environment, Wider benefits, and Accessibility.*

Each of these high-level objectives is broken down into lower-level objectives or attributes sometimes referred to as performance criteria. The objectives considered do not cover all aspects of road sector but are considered representative of the sector mainly in line with road improvements.

Table 1: high-level objectives

Category / Objective	Attributes
Economic	to contribute to an efficient economy, and to support sustainable economic growth in appropriate locations
Safety	to improve safety for all travellers
Environment	to protect and enhance the built and natural environment, improve air quality
Accessibility	to promote accessibility to everyday facilities for all, especially those without a car, and those with a car
Wider Impacts	Maximise wider benefits (employment, reduction in production cost, housing investment, rents and GDP)

b. Scoring and weighting for each option to derive an overall value.

Scoring is the process of allocating preference values associated with the consequences of each option against the selected criterion. The scoring procedure follows three major steps; describe the consequences of the elements, Score the elements in pairwise matrices and Check the consistency of the scores on each element.

It is noted that all the components of different objectives, criteria and alternatives as derived from the value tree are measured using different scales. To place these components on a common scale, independent scales representing preferences are constructed for the consequences and weighted for their relative importance from which the weighted averages across the preference scales are calculated. Relative scales are simple scales denoted with the least and most preferred option on a criterion.

The approach used for scoring in this paper is dependent on "pairwise" comparisons (Saaty, T, 1980). The consistencies of the scores on each criterion are checked by ensuring the consistence ratio (CR) is equal or less than 10% (CR ≤10%). CR is derived from consistence index (CI) that is in turn calculated using the principal Eigen value (λmax). Principal Eigen value (λmax) is obtained from the summation of the product between the sum of columns of the reciprocal matrix and the individual element of Eigen vector. Consistence index and consistence ratio are calculated using formulas 4.0 and 4.1 below;

$$CI = (\lambda max - n) / (n - 1)$$

Where: n = number of elements considered

$$CR = CI / RI$$

Where: RI = Random consistence index derived from Saaty, 1980 article

Weighting is the process of assigning weighted scores for each of the criterion to reflect their relative importance to the decision

that will provide the best fit to the 'observations' recorded in the pairwise comparison matrix. There are several ways of calculating weights. This paper follows the most straight forward method provided DfC&LG, (2009), indicated here below

  i.   calculate the geometric mean of each row in the matrix

  ii.   total the geometric means, and

  iii. normalise each of the geometric means by dividing by the total of the geometric means

The overall score weighting for options is calculated using linear additive evaluation models. This process assumes that the criteria are preferentially independent of each other. The calculation is done by multiplying the value score on each criterion by its weight, and then summing up all the weighted scores together as per the linear additive model used for MCA according to Keeney, L. and Raiffa, H. (1993), below:

$$S_i = \sum_{i=1}^{n} w_i \, s_{ij} = w_1 \, s_{i1} + w_2 s_{i2} + \cdots.. + w_n \, s_{in} \qquad (1)$$

Where: Si = weighted score

W = weight

S = Score

Performance matrix

Multi-criteria analysis is based on a performance matrix sometimes called the consequence table, in which each row describes an option and each column describes the performance of the options against each criterion. The individual performance assessments are often numerical but may also be expressed in other styles such as "bullet point' scores, or colour coding. The performance assessments are usually allocated by experienced people whereas weighted scores per criteria are calculated through normalization. In this research numerical factors are used. The indices used in the performance matrices are collected from a wide scope of people who understand road maintenance impacts through questionnaires. A key factor of MCA method is the emphasis on the judgement by decision makers. The median of the returned results of the preference indices are used to calculate the weightings and final score. Details of the preference scores, weighting and normalization factors are shown in following tables below.

High level objectives:

The high-level objectives for the maintenance of local roads include *economy, environment, accessibility and wider economic benefits*. Scores, weights, normalisation and consistency checks for the high-level objectives are calculated in the same way as the scores for the lower level objectives as described above. The table below summarises the calculations involved in scoring, weighting and normalisation of the high-level objectives.

Table 2: High level objectives performance matrix

	Economy	Environment	Accessibility	Wider economic benefit	Geometric mean	Weights
Economy	1.00	2.00	3.00	2.00	1.86	0.43
Environment	0.50	1.00	2.00	1.00	1.00	0.23
Accessibility	0.33	0.50	1.00	2.00	0.76	0.18
Wider economic benefit	0.50	1.00	0.50	1.00	0.71	0.16
Sum	**2.33**	**4.50**	**6.50**	**6.00**	**4.33**	**1.00**

λ =4.165, CI = 0.0548, CR = 0.0489 which is 4.89% < 10%, OK

The consistencies of the scores on each criterion (economy, environment, accessibility and wider economic benefits) were checked by calculating for (CR). The value of CR was found to 4.89% which was less than 10% (CR ≤10%) as required. The values consistence index (CI) and Principal Eigen value (λmax) were calculated as 0.0548 and 4.165 respectively using the formulas indicated above.

Wider Social - economic benefit

This comprises the bulk of the benefits most of which cannot be easily monetised. Such benefits considered in this paper include: Agriculture, Education, property rents, housing investments and GDP. The benefits of this nature are indirect and can be analysed through surveys and trend analysis or MCA. The MCA was designed and adopted for this research.

Table 2; below shows a pairwise matrix that provides linkages between the scoring, weighting, and normalisation of the factors that comprise the wider economic benefit component and summarises the calculations involved.

Table 3: Preference scores for the wider social-economic benefit

	Production cost	Employment	Rents	Housing investment	Geometric mean	Weight
Agriculture	1.00	1.00	2.00	3.00	1.64	0.31
Education	1.00	1.00	2.00	2.00	1.32	0.25
Property Rents	0.50	0.50	1.00	2.00	1.00	0.19
Health	0.33	0.50	0.50	1.00	0.76	0.14
Trading	0.50	1.00	0.50	0.33	0.61	0.11
Sum	**3.33**	**4.00**	**6.00**	**8.33**	**5.33**	**1.00**

λ = 5.3566, CI =0.0891, CR = 0.0796009 which is 7.96% < 10%

The consistencies of the scores on each criterion were checked by calculating for (CR). The value of CR was found to 7.96% well below the required 10% (CR ≤10%) discussed in section 3.4.2.3. The values consistence index (CI) and Principal Eigen value (λmax) were calculated as 0.0891and 5.3566 respectively.

VII) Results of the findings - Socio-economic benefits of rural roads

Social-economic benefit of rural roads weighted and calculated using MCA, rank Economy as the highest contributing factor, followed by Environmental impacts while wider economic benefits are the least contributing factor at 0.16. Wider economic benefit is attributed to the bulk of social benefits such as; Agriculture, Education, Property Rents, Health and Trading. An analysis of wider social-economic impacts places agricultural benefits on top of the pack followed by education, property rents, health and trading at the bottom of the pack.

This provides the delicate nature of the changes in the road condition to the economy of the communities, impacts on environment and accessibility.

VIII) Monetisation of socio-economic benefits of rural roads

Based on the transport demand relationship between increased consumer surplus and improved travel conditions derived from SACTRA (1996) discussed above, the travel conditions between any two points i and j improve so that generalised costs fall from C_0 to C_1 and the volume of trips increases from T_0 to T_1 hence the user benefit can be calculated using the half formula rule as; $0.5(C_0 - C_1) (T_0 + T_1)$. An application of this method is indicated in the Kamuli District case study.

c. Value Model of the road asset

The combination of the physical cost of the road asset that comprises of; the pavement, drains, service lines, ancillary structures and the land cost occupied by the road infrastructure, and the monetised value of the social – economic benefits derived through half formula rule as; $0.5(C_0 - C_1) (T_0 + T_1)$. This combination constitutes the total or true value of the road. *The value mode proposed = Social Benefit value (SBV) + Replacement cost (Investment cost).*

This model is still under research and its accuracy is yet to be confirmed. More research will be undertaken in due course.

d. Prioritisation of road asset improvements using the Value Model.

The value model is expected to be a very useful tool in prioritising roads for improvements such as routine and periodic maintenance, rehabilitation, upgrading and or construction of new roads by policy makers, financiers, funding organisations and administrators in resource allocation for maintenance. The current trends in most of Sub Saharan Africa indicate that prioritisation of roads for improvement are based on either local politics or World Bank Economic Models based on traffic levels.

IX) Case study – AFCAP – GEM -Kamuli District roads in Uganda Kampala

The Africa Community Access Partnership (AFCAP) is providing technical assistance to achieve improvements in asset management performance on selected rural roads networks through an initiative project; Economic Growth through Effective Road Asset Management (GEM) project. The participating countries are Sierra Leone, Uganda and Zambia, with the Western Cape of South Africa providing an example of good practice in rural road asset management

Data collected using questionnaires from Kamuli District in Uganda under AfCAP - GEM project provides the requisite case study of the analysis of the relationship between changes in travel costs and increase in volume of the trips of the selected mode (Motorcycles – locally known as Boda boda) occasioned by improvement of the selected road section through routine maintenance. The changes in cost and trip numbers is monitored through routine questionnaires empirically. The area under the plot of the cost against the trips is the value of the benefit accrued from improvement of the road section under review.

The figure below indicates the extract of the Kamuli data that is being monitored for better results. One transport mode has been used for analysis in this paper, however other modes will be analysed for comparison purposes. Also, this process should be repeated for other socials activities such as; education (increase in enrolment), health (increase in outpatient visitation), and agriculture (increase in farm gate outputs).

Figure 3: Transport demand calculation

Benefit value (BV) $= 0.5(C_0 - C_1) (T_0 + T_1)$

$= 0.5 X (1660 - 1510) X (210 + 267)$

$= 35,775$

The outcome benefit value (BV), is the value attributed to one component - transport. The relevant components are identified and ranked through MCA process. The value of the social benefits is calculated as the half area formula rule for each ranked benefit factor. The important output of this valuation method is the impact of rural road improvements to social benefit. A plot of social benefit provide an indication of how the benefits behaves under varied investments.

X)   Expected benefits

The main objective of this valuation methodology was to bring on board the consideration of the social benefits in the calculation of the true value of the road. The true road value provides a useful tool in prioritising roads for improvements such as routine and periodic maintenance, rehabilitation, upgrading and or construction of roads. It is expected that valuation will be used by policy makers, financiers, funding organisations and fund managers to allocate funds. The high the value of the road asset the higher the ranking. Its common understanding that asset with higher value should be maintained or improved in relation to the one with a lower value.

This method will also help the mangers document the actual values of the road assets they own.

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