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Multi-criteria Evaluation for Ranking Rural Road Projects: Case study of Nepal

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Abstract**:** *This study describes the evaluation criteria involving three aspects of sustainability and finding their importance for ranking rural road projects. The evaluation criteria were derived from a thorough literature review and individual importance was determined via a Google survey among different experts, who have worked on rural roads in Nepal and other 22countries. This survey used Analytic Hierarchy Process.Thirteen sub criteria and three criteria were considered in the question on the survey and almost all of the respondents responded that these criteria and sub criteria were necessary in the criteria for the ranking of rural road projects fromthe point of sustainability. The result of the case study in Dang District of Nepal is also presented in thisarticle.*

Keywords**:***Analytic Hierarchy Process, Evaluation Criteria, Nepal, Rural Roads, and Sustainability.*

I. INTRODUCTION

About half of the world population still lives in rural areas. In the least developed countries this figure is more than 71%[1]. About one billion or 31% of the rural population still live isolated from markets and services[2]. However the roads are highly capital-intensive projects, they are the most vital infrastructures for the development of these rural areas. In order to properly utilize the scarce financial resources to develop the rural areas of the developing countries, evaluation for ranking of rural road projects is anutmost stage of the planning process.

Evaluation of rural road projects is a systematic method for collecting, analysing and using information to answer the questions about their effectiveness and efficiency. On the basis of this evaluation, project alternatives are categorized for their prioritization, acceptance or rejection for implementation. Stakeholders from public as well as in private sectors want to know whether the programs they are funding, implementing, voting for, receiving or objecting to are actually having the intended effect, and answering this question is the job of an evaluator. Evaluation must be based on some well-defined and tested criteria. These criteria shall give distinct between alternatives, be simple for evaluation and shall cover the sustainability aspects.

The study of rural areas by transport researchers appears very much in a minority interest as compared to other transportation fields [3]. Rural Roads have just recently received attention in several development researches[2]. Different project evaluation methodology has been adopted for the evaluation of road projects since a long time ago. In the early 1960 Cost-Benefit Analysis (CBA) methods were developed and spread across the transportation sectorsin France[4]. CBA methods are widely used in different countries such as the France [4], UK[5], Japan[6], USA[7]and other developing countries[8]. A recent study shows that cost-benefit analysis has the potential to be challenging for a number of reasons, including the inherent difficulty in obtaining accurate cost information and estimating cost of externalities and accounting for impacts outside of the geographical projects[9]. The United Nations 2005, World Summit defined the interdependent & mutually reinforcing pillar of sustainable development as economic development, social development and environmental protection[10]. Over the decade, many researchers are practicing to incorporate these three pillars in different development fields including roads. When projects are selected based only on cost minimization, the selection process is likely to overlook some other important aspects. So, the project selection problem is a multi criteria problem [11].For the sustainability of the infrastructure, its planning and design must be context sensitive to ensure a balance among economic, social and environmental objectives[10].Multicriteria methods are more suitable methods for evaluation of the sustainability of rural roads. Various practitioners /researchers had worked in the field of multi-criteria methods on transportation projects. Some of them are mentioned below.

Novak et al developed a network based, spatial performance measurement called Network robustness (NTR) approachto ranking transportation roadway projects[9]. The NTR approach includes aspects of network topology and connectivity, the interests of all in traffic flow on individual road links due to dynamic rerouting. He used a multiple criteria approach that directly incorporates user equilibrium dynamic traffic optimization into the routing choices of the individual travelers on the road network for ranking roadway projects in terms of the highest travel time benefit.Jing Shi and Nian Zhou have done evaluation of 12 highway projects in China[12]using different social aspects such as equity and efficiency. The authors found that the model with social aspects, which evaluates different highway investments in different regions based on the result of BCA, gives comprehensive and reasonable judgments. They proved the model with equity and equality aspects is practicable and applicable. Devkota et al, University of Waterloo, Canada discussed about the use of GIS systems in planning non-motorized travel in rural Nepal [13].They used two criteria: access to schools and health services in ranking trail bridges in rural areas. The cost of trail bridges as compared to rural roads is very low and the criteria used in trail bridges are not sufficient for evaluation of rural roads. Klaas De Brucker, Cathy Machairs, main Verbeke demonstrated that Multi -Criteria Analysis (MCA) can be usefully applied within the context of stakeholder driven or institutional approach to transport project evaluation[14]. In their research it was concluded that an evolutionary perspective, the level of conflict may be lower in a second application of the MCA and it may become much easier to construct and implement solutions acceptable to the community of stakeholders, thereby creating value added to society as a whole.

Dr. J.S. Shang, Mrs. Y. Tjader and Professor Dr. Y. Ding had explored the potential of applying the analytic network process (ANP) to evaluate transportation projects in Ningbo, China[15]. They have identified 27 criteria that are important to transport selection. These criteria are further analyzed and grouped into BOCR (benefits, opportunities, costs and risks) subnets according to the framework of Saaty. They provided a new approach to transportation project selection. Although the approach has several contributions, the model is large, time –consuming and suitable for mega projects. Mongkat Piantakulchai and Nattapan Saengkhao applied Analytic Hierarchy Process (AHP) to transport decision making[16]. Related social interest groups were modeled in the decision process to reflect a social preference. The relative importance of each attribute in AHP was modeled by combining engineering model with decision model. A case study of alternate motorway alignment was conducted using this technique in Thailand. The impact was estimated by the aid of Geographical Information System and AHP model was developed. Finally, the best alignment was proposed by generating at least path, which is most socially preferable.Mr. Sudhakar Yedla and Ram M. Shrestha from Asian Institute of Technology used a multi-criteria approach for the selection of alternative options for environmentally sustainable transport system in Delhi[17]. They had been selected three options (replacing 2 stroke 2 wheelers by 4 stroke 2 wheelers, converting conventional fuel cars into CNG cars and Converting conventional fuel buses into CNG buses) with the view of different actors. An interesting observation this study is that the priority ranking would be almost reversed with the inclusion of qualitative criteria in the decision making process which might explain the reasons for the failure of many potential alternative urban transport options.Ludmil Mikhaillov and Madan G. Singh, fellow, IEEE proposed a fuzzy extension of the analytic network process (ANP) that uses uncertain human preferences as input information in the decision making process[18]. They developed a new fuzzy preference programming method, which obtains crisp priorities from inconsistencies interval and fuzzy judgments applied. A prototype decision support system realizing the proposed method is developed.Evil Avineri, Joseph Prashkar and Avishai Cedar developed an efficient technique for the selection of transportation projects using fuzzy set theory[19]. In their research paper they described four major commonly used approaches (Profile and checklist methods, Scoring methods, Cost- Benefit analysis method and Mathematical programming models) and concluded that due to the complexity and comprehensiveness of the transportation projects, fuzzy set theory is a convenient tool for dealing with linguistic description. They used the technique in a case study of interurban road projects in Israel. The technique was successfully used in a case study of interurban road projects in Israel.

Different criteria are used for evaluation of rural roads in the world. In Nepal two types of criteria: population per unit cost, cultivated land per km, population multiplied by walking hours, the total population of poor and indigenous groups are used for new construction and cost per traffic unit, cost per km and centrality index related to market centres are used for rehabilitation[20]in the rural road sector. Similarly, achievement of goals, cost, economic viability, financial viability, technical viability, operational viability, operational cost, multimodal transfer, sustainability, environmental impact, resettlement impact and social impact are used North South fast track, an important project to link the Kathmandu to southern part studied by Asian Development Bank[21]. Dr. Chandra Shrestha proposed in his research, Cost- benefit criteria in developed areas and agricultural potential, interaction, accessibility and environmental impact in theunderdeveloped areaand tested these criteria in one district of Nepal[22].

In Lao PDR, agricultural potential, non agricultural potential, existing health services used by population, primary school attendance, secondary school attendance, access to district centre, access to markets, water supply in the area, road condition before rehabilitation/construction, road condition as a community problem, road condition as a community priority, population served are used in rural roads planning[23].

Mongkut Piantanakulchai, a faculty member of Thammasat University, Thailand proposed economic, engineering and construction, traffic and transportation, environment, land use and social criteria, 34 sub criteria and general public, local community, trade and industry road users and government officers as a stakeholder[24]for study highway corridor planning. In the developed country, like USA the rural road selection/ranking criteria are preservation of the secondary road system, reduction of safety hazards, enhance geometric configuration of the roadway alignment, reduce maintenance costs, favor projects from counties going into this positive funding balances, projects with leveraged funds, project with completed preliminary engineering, projects that will complete a roadway corridor, and threat of closure for emergency response[25]. Likewise eleven criteria: construction costs, benefits to goods traffics, disruption from construction, safety, system operating cost and maintenance, noise, passenger travel time savings, air pollution, local and regional, user charges and revenues, climate change and vehicle operating costs are proposed for rural roads selection in European Countries[26].

Thus appropriate methods and evaluation parameters are still lacking in the evaluation of rural road projects in developing countries like Nepal.

The objective of this study is to identify the criteria for the evaluation of rural road projects and to recommend the ranking methodology by using the Analytical Hierarchy Process (AHP). In the broader aspect, the study is intended to answer the following questions.

- What are the criteria for the evaluation of rural transportation projects?
- What is the importance of different criteria and sub criteria for the evaluation of rural transportation projects?
- How the multicriteria methods can be applied to the rural transportation infrastructure projects in the context of developing countries?

II. METHODOLOGY

The research was conducted in two stages. At the first stage, a set of criteria was formulated and tested among the experts by interviewing with the structured questionnaire. At the second stage, the online interview was prepared to accommodate the experts from various geographical locations. The responses of the first stage of the interview were considered for the second. The questionnaire was designed for pairwise comparison to assign the weightage according to Analytical Hierarchy Process (AHP). The questionnaire form was sent to the experts using emails and linkages of Google drives. Consideringthe accessible population and random cluster sampling120experts and practitioners in rural roads were selected. Eighty respondents were from Nepal and forty were from other countries such as Afghanistan, Australia, Austria, Bulgaria, Bangladesh, Canada, China, Czech Republic, France, Iceland, India, Germany, Israel, Italy, Kenya, Liberia, Pakistan, Philippines, Slovenia, Serbia, Switzerland, Tanzania, UK and USA. The respondents were engineers involved in rural road andhighwayplanning, government employees, consultants and professors.

AHP is a decision making tool used to organize various criteria into a relative hierarchy that allows for comparisons among these criteria relevant to their common goal[27]. The goal of this study is an evaluation of rural road projects based on different criteria of sustainability. In the evaluation of rural roads, the first step of the hierarchy is to determine the relative importance of the three general sustainability criteria. The second step of the hierarchy is to find the relative importance of specific sustainability of sub-criteria. In the third step,the local system provider shall conduct a pairwise comparison to indicate the relative importance of each candidate project with respect to sub criteria. The third step is beyond the study of this research. The scope of this research is to find criteria and their weightage only. The weightage of the three criteria of sustainability and sub criteria is found in the normalized matrix of geometric mean of the responses in AHP different experts mentioned above. Geometric mean considers the best methods for synthesizing group judgments' [27]. The consistency index of each response of AHPis calculatedwith the excel sheet software developed by K.D. Goepel version 08.05.2013 (http//bpmsg.com) and acceptedif their consistency index (CI) is less than or equal to 10%[28]. If the CI is over than 10 %, Saaty andTran proposed: find the most inconsistent judgment, determine the range of values to which is that judgments can be changed corresponding to the consistency to which CI will be improved and ask the judge to reconsider the plausible value to change in the range. As the respondents are scattered different geographic location of the world and the limitation of time for study, the inconsistent judgments were simply removed from the calculation. The derived criteria are used in the selection of rural roads in Dang district of Nepal as a case study.

III. THEORY AND CALCULATION

The evaluation and selection of roadprojects depend on the Government policies, local conditions and allocated funds. Under the allocatedbudget (say X million $ per year), it is necessary to pick one or more projects that will maximize the benefits without disturbingenvironment.The score as well as weightage of a criterion is needed for evaluation of the road project. Analytic Hierarchy Process is taken, as an appropriate tool for finding the weightage after pairwise comparison.Sustainability criteria are widely practiced in most of the development activities. Therefore, sustainability criteria were taken as the fundamental criteria for the evaluation of rural road projects. As the broad-spectrum of this study economic, social and environmental aspects were taken as the fundamental criteria. Further, these three sustainability pillars were fragmented into thirteen indicators. These indicators are: construction cost, maintenance cost, vehicle operation cost, pollution cost, travel time cost, accident cost, population served per km, access to educational services, access to other services (market, health services, administrative services), road as a community priority, impacts on natural resources, encroachment on social and historical aspects and land sliding /erosion or flooding.

3.1 MEASUREMENT OF CRITERIA FOR RURAL ROAD PROJECTS EVALUATION

From the literature review and collection of experts' opinion three groups of criteria (economic costs, social aspects and environmental aspects) are determined for ranking sustainable rural roadprojects. An absolute and the relative measurement are used for the determination of the score ofthe criteria. In an absolute measurement, the score of each criterion is derived in 100-point scale. Local institutions shall define the methodology of the determination of score of the different alternative of rural transportation projects, which depends upon local conditions influence. If the authentic body does not define such methodology the final decision score in 100-score will be converted as follows[29].

Firstly, the performance indicator is measured in different appropriate unit. The probability distribution of all data is assumed approximately normal. The measurement is normalized with the calculation of Z-score using the formula

$$Z_{nj} = \frac{X_{nj} - \bar{X}_j}{\sigma_j}$$

Where j performance measures of the indicators, no alternative index (n = 1,2… N), X_{nj} the average value of performance measure j of alternative n, $\bar{X}_j$ Overall mean of all alternatives on performance measure j, σ_j Standard deviation of all alternatives on performance measure j, Z_{nj} Z score of performance measure j on alternative n. The Z score is converted into percentile score using conventional statistical formula or Z table

In relative measurement, the pairwise comparison matrix is developed for each alternative in the scale of 1 to 9. The relative score of each criterion is determined by eigenvector found with normalized matrix using AHP. Parameters of the various evaluation criteria are described below.

3.1.1 ECONOMIC CRITERIA

Economic criteria have been defined by the two groups of sub-criteria as financial costs and social costs. Financial costs can be described by the three sub-criteria: construction and maintenance cost of the road project and vehicle operation cost.

Social costs are external costs, which are generally not borne by the transport user. The social costs depend upon location (urban or suburban), road geometry (gradients, width, horizontal and vertical curves etc.). The costs can be measured based on a bottom up approach considering specific traffic conditions, and referring to case studies [30]. The bottom up approach is expensive. So, in planning phase the social costs are measured from a top-down approach. Three types of social costs: travel time cost, accident cost and pollution cost are considered in evaluation of rural road projects

CONSTRUCTION COST

The construction cost of road projects mainly includes the cost of surveying and design, site clearance, earthwork, different structures, side drains, pavement, establishment of road furniture and land acquisition. The construction cost depends upon the topography and geology of the road alignment, availability of construction materials, laborsand equipment along the construction site. The approximate construction cost in different planning documents depending upon terrain and location. There are various methods of cost calculation during planning stage such as cost of similar projects in the pasts, use of cost per kilometer of some itemsor developing rough estimates of quantities and multiplyingthe recent bid price and adding inflation and contingency factors.

MAINTENANCE COST

The maintenance cost of a road depends upon the topography of road alignment, precipitation characteristics, road surface, existing structure and drainage system, type of vehicle and loading etc. Maintenance cost includes routine, recurrent and periodic maintenance cost. These costs are generally determined by the past studies of the similar projects at the planning stage.

VEHICLE OPERATION COST

Vehicle operation cost depends upon the characteristics of vehicles and roads. World Bank has developed computer models HDM-VOC model and Road Economic Decision Model from controlled experiments and extensive user surveys in Kenya, Brazil, India and the Caribbean. The vehicle operation cost can be calculated using this model calibrating as per the condition of the country.Reduction in vehicle operating costs (VOCs) represents a major component of the benefits from road investment. Savings in VOCs principally arise from road investment in the following ways: through a reduction in trip distance, through a reduction in trip time and through reduced road roughness. There may also be some changes VOCs through a better road alignment (in terms of reduced gradient or less road curvature).

The components of vehicle operating costs are: capital costs, including depreciation and interest, fuel consumption, tire consumption, maintenance costs, including parts and labor charges, driver and conductors' labor costs, passenger and freight values of time, oil and lubricants and overhead costs including garaging and insurance.

TRAVEL TIME COST

The value of travel time is another important factor in the selection of rural transportation projects. Good transportation system helps to save the passenger travel time. The value of travel time depends upon the income of the passenger and mode of travel. For instance, the author's study shows that value of travel time inNepalis 5.61NRs. per-hour for motorcycle with one passenger,24.96 NRs./hour for car medium with 4 passengers and 62.40 NRs. /hour bus medium. In other hand,developed European countries have the value of travel time 21 € per person in business hour and 4 € per hour per person in leisure period[30]. Thus travel time cost in a road can be calculated with the multiplication of totalpassenger numbers, travel time and passengers time cost.

ACCIDENT COST

The road accident cost depends upon the nature of the site (topography, visibility, road geometry etc.) and level of exposure. A way of road accident cost estimation for a roadway is the use of predictive models which relate the accident occurrence to traffic volume and a range of attribute such as road design features, traffic control features and site geometry[31]. The cost includes all direct and indirect costs of an accident, such as material costs, medical costs, production losses, suffer and grief's caused by fatalities. Like other social costs, this indicator is measured either bottom up approach or top down approach. In the bottom up approach, it is measured as a resource costs for health improvements using willingness to pay (WTP) for the estimation of value of statistical life based on stated preference (SP) for the reduction of traffic risk. Ontop down approach, the national data on accident are used for the evaluation of accident costs. This indicator is the function of average and maximum gradient of the road, numbers of hairpin bends, visibility, cross slope of the topography etc. The marginal accident costs can be calculated by the formula below [30].

$$\mathrm{Accidentcost} = \mathrm{trafficvolumeXRiskelasticityXUnitcostperaccidentXexpernalpart}$$

The risk elasticity is taken from case study report or literature review or planning models and external cost is calculated based on the insurance policy.

POLLUTION COST

Air pollution is the major pollution type caused by any transportation system. Two types of air pollution are considered in transportation projects: tailpipe emissions, and lifecycle emissions. Lifecycle emission includes both tailpipe emissions from fuel extraction and construction of facilities. In Europe the cost is calculated by the impact pathway approach using resource cost and willingness to pay (WTP) for human life base or willingness to accept (WTA). The pollution cost is calculated by the following formula.

$$\mathrm{POLLUTIONCOST} = \mathrm{SPECIFICEMISSION} \quad \mathrm{XCOSTFACTORPERPOLLUTAN} \quad \mathrm{T}$$

3.1.2 SOCIAL ASPECTS

Social factor generally refers to the social benefits from the transport projects. It has been described by the four sub-criteria in this study viz. population served per km, access to educational services, access to health, administrative and market services and road as a community priority.

POPULATION SERVED PER KM

This sub-criterion is specified by the population of the area within the road corridor of five kilometer (two hours walking distance), which is considered as the influenced area of the project[32]. The population is taken from the latest census and projected to the required year of calculation.

ACCESS TO EDUCATIONAL SERVICES

This criterion is measured can be measured as the numbers of students in the influence area of the roadproject (within 5 km) using the road services. The data are collected during the feasibility study of the road.

ACCESS TO OTHER SERVICES (HEALTH SERVICES, ADMINISTRATIVE SERVICES AND MARKETS)

It is described by the use of road facility for access to the health services (health posts or hospitals), administrative services (village or district headquarters) and market centers. This criterion is measured by the judgments of the planner during social studies with nos. of type service facilities within the influence area.

ROAD AS A COMMUNITY PRIORITY

This criterion is measured same as access to other services by the judgments of the planner during social studies. The presence of local people in the public meeting, their commitment for participation in road construction and donation of land shall be considered as the elements to measure this criterion.

3.1.3ENVIRONMENTAL ASPECTS

The environmental aspect is an important factor for sustainability of the road projects. Environmental aspects are further sub classified into the three sub-class viz. encroachment on historical/cultural and precious ecology, possibility of landslide or flooding, and impacts on natural system such as forest, hydrology and others.

ENCROACHMENT ON HISTORICAL/ CULTURAL AREAS AND PRECIOUS ECOLOGY

The indicatormeasures thenumber and area of encroachment of historical/ cultural areas and precious ecology (e.g. sensitive or protected areas). This is measured by the judgment of the planner. This indicator is measured subjectively in the scale of five.

POSSIBILITY OF LANDSLIDE OR FLOODING

This indicator can be measured in length of the road, which passes through landslide/erosion in the mountain or a flooding prone zone in plain area.

IMPACTS ON NATURAL SYSTEM

Number of trees to be cut down, the area of forest that should be encroached by the road, alteration of surface water hydrology of waterways crossed by roads resulting in increased sediment in streams affected by increased soil erosion at construction site are considered while evaluating this criterion.

3.2 WEIGHTAGE OF CRITERIA

Above mentioned criteria are synthesized in two levels using AHP. In the first level three major criteria viz. economic, social and environmental aspects are taken in to consideration. In the second level analysis, all thirteen sub-criteria representing the first level criteria are taken into consideration. The criteria and sub-criteria of each level are compared pairwise with respect each other in order to determine the relative weights ofall criteria. Then the pairwise comparison matrix was developed as suggested by T.L. Saaty. Saatysuggested an arbitrary rating scale of 1 to 9 based on psychological experiments. The definition of each scale is as follows.

1: two criteria are equally important.
3: moderate importance of criterion X over criterion Y.
5: strongly importance of criterion X over criterion Y.
7: very importance of criterion X over criterion Y.
9: extreme importance of criterion X over Y.
2, 4, 6& 8: intermediate value between two criteria.

With this rating value as an element of matrixa_{ij} ofcriteria i and j (a_{ij}-geometric mean value of respondents), a pairwise comparison matrix A has developed as follows:

$$A=\begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ 1/a_{12} & 1 & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ 1/a_{1n} & 1/a_{2n} & \dots & 1 \end{bmatrix}$$

The judgment matrix is said to be consistent if it satisfies transitivity of allpairwisecomparison. The AHP allows inconsistency ten percent. The random Index (RI) measures the consistency ratio (CR) dividing the Consistency Index (CI). Saaty gives RI for a matrix order n. CI is calculated by the formula:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

Where, $\lambda max$is the largest Eigenvalue and nis the number of matrix order.

In this research, questions with a pairwise comparison of each criterion were askedto the experts and consistency of each value was calculated. Ageometric mean value of the data with consistency ratio (CR) less or equal 10% istaken for the development of the final pairwise comparison matrix. The sample weightage calculation of each criterion is given below in the tables.

Table 1: Matrix For Weightage Calculation

Criteria	Economic Criteria (a_{i1})	Social Aspects (a_{i2})	Environmental Aspects(**a_{i3}**)
Economic Criteria(a_{1n})	1.00	1.12	1.38
Social Aspects (a_{2n})	0.90	1.00	1.22
Environmental Aspects (a_{3n})	0.73	0.82	1.00
Sum ($s_n^1 = \sum_{i=1}^{3} a_{in}$)	2.62	2.94	3.60

Table 2: Normalized Matrix For Weightage

Criteria	Economic Criteria $m_{i1}=a_{i1}/ s_1^1$	Social Aspects$m_{i2}=a_{i2}/ s_2^1$	Environmental Aspects $m_{i3}=a_{i3}/ s_3^1$	Sum ($s_i= \sum_{n=1}^{3} m_{in}$)	Priority ($p_i= s_i/ \sum_{i=1}^{3} s_i$ *100)
Economic Criteria	0.38	0.38	0.38	1.145	38.16%
Social Aspects	0.34	0.34	0.34	1.021	34.04%
Environmental Aspects	0.28	0.28	0.28	0.834	27.79%
Sum($s_n^2 = \sum_{i=1}^{3} m_{in}$)	1	1	1	3	100%

Table 3: Consistency Ratio

LAMBDA MAX, $\Lambda_{MAX}= s_1^1 *P_{1+} s_2^1 *P_{2+} s_3^1 *P_3$	3.00
Number of Variables, (n)	3
Consistency Index, (CI=: (λ_{max}-n) /(n-1))	0%
Consistency Ratio (CR=CI/RI)	0%

Table 4: Random Consistency Index (RI)

Nos. Of Variables, N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

The table 1 shows the matrix of responses. In the matrix the diagonal value is 1, the geometric mean of the comparison between the indicator of row 1 and column 1,2, and 3 are above the diagonal. The reciprocal values of the matrix above the diagonal are below the diagonal. The table 2 shows the calculation of weightage. From this table, it is known that the priority of economic, social and environmental criteria is 38.16%, 34.04% and 27.79% respectively. The consistency is checked in table 3, which gives the value 0 (below 10%) and the responses are acceptable. Table 4 gives the random consistency index for different numbers of variables as per T.L. Saaty.

IV. RESULTS

In this study amulticriteria method,Analytical Hierarchy Process (AHP) is used to determine the weightages of evaluation criteria for ranking rural road projects. Among the 120 respondents, 89 only responded AHP questionnaire. Several data were not useful due to the lack of required consistency 10%. The summary of derivedweightage of each criterionis given in the table 5 and 6.

Table 5: Weightage of Criteria and Sub criteria

Criteria	Sub Criteria		Weightage (AHP), %
Economic	1.	Construction Cost	6.70
	2.	Maintenance Cost	9.41
	3.	Vehicle Operation Cost	5.04
	4.	Travel Time Cost	4.79
	5.	Accident Cost	8.29
	6.	Pollution Cost	3.96
Social Aspects	7.	Population Served	10.96
	8.	Access to Education Services	6.53
	9.	Access to other services	8.87
	10.	Road as a community Priority	7.69
Environmental Aspects	11.	Impacts on Natural System	8.46
	12.	Encroachments of Historical and Cultural Areas	7.79
	13.	Possibility of Landslide / Erosion	11.54

Table 6: Overall weightage of first level criteria

I.	Economic Criteria	38.16
II.	Social Aspects	34.04
III.	Environmental Aspects	27.79

It can be noticed from the calculated values by using AHP the highest weightage shall be given to the economic aspect of the projects (i.e. 38.16%) whereas the lowest importance shall be given to the environmental aspects (27.79%). The intermediate value shall be assigned to the social aspects (34.04%).

Final ranking score

The final score of each alternative is determined by summing the weighted single dimensional weighted scores on each sub criteria as follows:

Ranking score of each alternative n (S_{on}) $$s_n = \sum_{j=1}^{n} \pm w_j * z_{jn}$$

WhereasW_e= estimated weightageof sub criteriaj, n= alternative index (n=1,2…. n), Z_{jn} a Normalized score of performance measure for alternative n under the sub criteria j (+ for the criteria maximization and **-** for the criteria minimization).

V. CASE STUDY: APPLICATION OF MULTI-CRITERIA EVALUATION FOR THE SELECTION OF RURAL ROADS

A case study with the application of the multi-criteria for the selection of rural road projects was done in Dang District. The required data for the evaluation were collected from the prepared project documents for the district level planning. The data such as construction cost, traffic, purpose of visit, topography, purposed designed standards, social and environmental aspects were collected with the field visit. The following four roads were taken for case study.

Road A: Kalakate-Gadawa-Rajpur Road, 15.168 km
Road B: Bhaisahi- Simaltara –Shantipur Road, 16.2 km
Road C: Bijauri-Manpur -Duruwa Road, 9.32 km
Road D: Pawannagar- Purandhara Road, 9.93 km

The brief about study area and study is as follows.

5.1 RURAL ROAD SITUATION ON DANG DISTRICT

Dang District is an Inner Terai district, some 280 km west of Kathmandu in Rapti Zone of Nepal's Midwestern Region. Dang covers an area of 2,955 square kilometres with a population of 552,583 (population census 2011). Ghorahi is the district's administrative center, which is located within 82^o 2' east to 82^o 54' east longitude and 27^o 36' north to 28^o 29' north latitude. The district population growth rate is 1.95%. There are 807.11km length of A and B Classes of roads in the district, which are to be constructed /upgraded to all weather road standards. Out of which Class A roads have a length of 550.21km and Class B roads have a length of 256.90 km.Map of the Dang district is given below in figure 1.

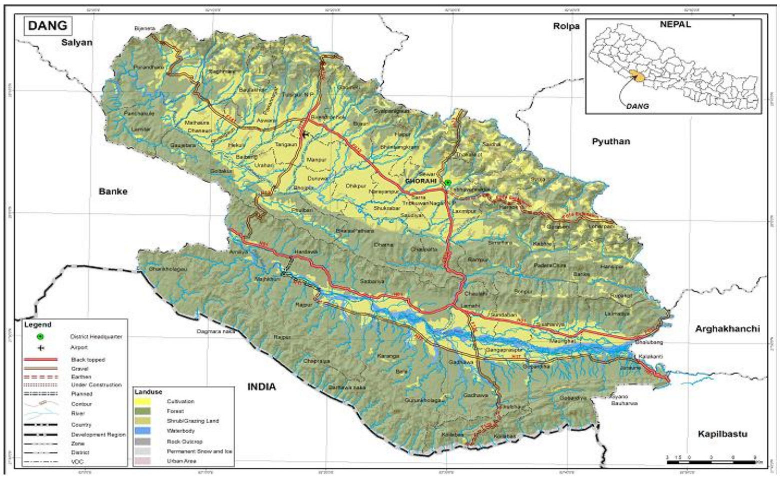

Figure 1: The Study Area (Dang District of Nepal)

Dang district has 24 district roads of class A and 16 district roads of class B. Most of the district roads built with gravel surface. Four roads of class A were taken in this study. The main objective of the case study was to rank the road projects by using the AHP multi-criteria evaluation method.

5.2 Summary of Different Multicriteria Parmetres

Economic Parameters

The construction cost of the road was taken from a detailed survey of the road. The maintenance cost was derived with similar type of road. Vehicle operation cost savings and Travel time cost savings were calculated with and without projects. Accident cost was calculated using the data of Nepal traffic police for the given traffic data. Pollution costs were calculated using the Nepal Emission Standards, 2069 Guidelines and average unit cost of pollution in European Countries. The summary of the economic parameters of the selected roads is given in the Table 7.

Table 7: Economic Parametrs of the Roads

Parameters	Road A	Road B	Road C	Road D
Construction Cost, 000 NRs.	136776	127156	78149	77084
Maintenance Cost, 000 NRs/year	11376	12150	6990	7448
Vehicle Operation Cost Saving, 000 NRs/year	2880	6598	2400	12824
Travel time Saving Cost, NRs.	353483	909901	438893	2030180
Accident Cost, NRs.	3316991	6795786	5137292	9667815
Pollution Cost, 000 NRs.	26970	86188	22704	76031

NRs: Nepali Rupees (1 US dollar= 97 NRs., 2014)

Social And Environmental Aspects

Four parameters, namely: Population Served per km, Access to Educational Services, Access to Other Services and Road as a Community Priority were identified under the Social criteria. Three Parameters namely: Encroachments on Historical or Sensitive Areas, Possibility of Land Slides or Erosion and Impact on Natural Resources were determined under "Environmental Aspects". These data were directly collected from field observations. The data are given below in the table 7 and 8 respectively.

Table 8: Social Aspects Parameters

Parameters	Road A	Road B	Road C	Road D
Population Served Per km	1350	988	571	1440
Access to Educational Services	2517	4400	1975	475

(student Nos.)				
Access to Other Services, Nos.	3	3	1	1
Road as a community priority (5-point Scale)	5	5	5	5

Table 9: Environmental Aspects Parametres

Parameters	Road A	Road B	Road C	Road D
Encroachment on historical areas	none	none	none	none
Possibility of Landslide or flooding	none	none	none	none
Impacts on Natural Systems	140 trees to be felled	25 trees to be felled	none	100 trees to be felled

5.3 RANKING OF THE SELECTED ROADS

For ranking of the selected rural road projects, the performance indicators have been collected above. The probability distribution of theses data is assumed approximately normal. The measurement is normalized with the calculation of Z-score using the formula

$$Z_{nj} = \frac{X_{nj} - \mu_j}{\sigma_j}$$

Where j= performance measures of the indicators, no alternative index (n = 1, 2, N), Xnj= the average value of performance measure j of alternative n, μ_j=Overall mean of all alternatives on performance measure j, σ_j=Standard deviation of all alternatives on performance measure j,Z_{nj} =Z score of performance measure j on alternative n. The Z score is converted into percentile score using conventional statistical formula or Z table. The detail calculation for ranking and ranks of the projects are given below on tables10,11,12,13,14and 15 respectively.

Table 10: Mean Value and Standard Deviation

S. No.	Parameters	Max. Value	Min. Value (Sigma)	Mean Value (Sigma)	Standard Deviation
1	Construction Cost, 000 N's	136,776	77,084	104,791	31626.51
2	Maintenance Cost, 000 NRs/year	12,150	6,990	9,491	2,649
3	Vehicle Operation Cost Saving, 000 NRs/year	12,824	2,400	6,176	4,813
4	Travel time Saving Cost, NRs.	2,030,180	353,483	933,114	771,215
5	Accident Cost, NRs.	9,667,815	3,316,991	6,229,471	2,696,808
6	Pollution Cost, 000 NRs.	86,188	22,704	52,973	32,799
7	Population Served Per km	1,440	571	1,087	395.74
8	Access to Educational Services (student Nos.)	4,400	475	2,342	1621.35
9	Access to Other Services, Nos.	3	1	2	1.15
10	Road as a community priority (5-point Scale)	5	5	5	0
11	Encroachment on historical areas	0	0	0	0
12	Possibility of Landslide or flooding	0	0	0	0
13	Impacts on Natural Systems (nos. of trees to be felled down)	140	0	66	65

Table 11: Multi-Criteria Value of Road A

Indicator	Value	Z SCORE, Z_NJ=(X_NJ-μ)/Σ_J	Priority Coefficient, C	Total Value(C*Z SCORE)	Remarks
1. Construction Cost	136,776	1.0	-6.7	-6.78	
2. Maintenance Cost	11,376	0.7	-9.41	-6.70	
3. Vehicle Operation Cost Saving	2,880	-0.7	5.04	-3.45	
4. Reduced Travel Time Cost	353,483	-0.8	4.79	-3.60	
5.Accident Cost	3,316,991	-1.1	-8.29	8.95	
6. Pollution Cost	26,970	-0.8	-3.96	3.14	
7. Population Served Per km	1,350	0.7	10.36	6.88	
8. Access to Educational Facilities	2,517	0.1	6.53	0.71	
9.Access to Other Facilities	3	0.9	8.87	7.68	
10. Community Priority as a road	5	0.0	7.69	0.00	
11. Encroachment in historical/Cultural Areas	0	0.0	-8.46	0.00	
12.Possibilty of landslide/erosion or flooding	0	0.0	-7.79	0.00	
13.Impacts on Natural System	140	1.1	-11.54	-13.10	
			Sum	-6.26	

Table 12: Multicriteria Value of Road B

Indicator	Value	Z Score, Z_NJ=(X_NJ-μ)/Σ_J	Priority Coefficient, C	Total Value(C*ZSCORE)	Remarks
1. Construction Cost	127,156	0.7	-6.7	-4.74	
2. Maintenance Cost	12,150	1.0	-9.41	-9.45	
3. Vehicle Operation Cost Saving	6,598	0.1	5.04	0.44	
4. Reduced Travel Time Cost	909,901	0.0	4.79	-0.14	
5.Accident Cost	6,795,786	0.2	-8.29	-1.74	
6. Pollution Cost	86,188	1.0	-3.96	-4.01	
7. Population Served Per km	988	-0.3	10.36	-2.60	
8. Access to Educational Facilities	4400	1.3	6.53	8.29	
9.Access to Other Facilities	3	0.9	8.87	7.68	
10. Community Priority as a road	5	0.0	7.69	0.00	
11. Encroachment in historical/Cultural Areas	0	0.0	-8.46	0.00	
12.Possibilty of landslide/erosion or flooding	0	0.0	-7.79	0.00	
13.Impacts on Natural System	25	-0.6	-11.54	7.33	
			Sum	1.06	

Table 13: Multicriteria Value of Road C

Indicator	Value	Z SCORE, Z_NJ=(X_NJ-μ)/Σ_J	Priority Coefficient, C	Total Value(C*ZSCORE)	Remarks
1. Construction Cost	78,149	-0.8	-6.7	5.64	
2. Maintenance Cost	6,990	-0.9	-9.41	8.88	
3. Vehicle Operation Cost Saving	2,400	-0.8	5.04	-3.95	
4. Reduced Travel Time Cost	438,893	-0.6	4.79	-3.07	
5.Accident Cost	5,137,292	-0.4	-8.29	3.36	
6. Pollution Cost	22,704	-0.9	-3.96	3.65	
7. Population Served Per km	571	-1.3	10.36	-13.51	
8. Access to Educational Facilities	1975	-0.2	6.53	-1.48	
9.Access to Other Facilities	1	-0.9	8.87	-7.68	
10. Community Priority as a road	5	0.0	7.69	0.00	
11.Encroachment in historical/Cultural Areas	0	0.0	-8.46	0.00	
12.Possibilty of landslide/erosion or flooding	0	0.0	-7.79	0.00	
13.Impacts on Natural System	0	-1.0	-11.54	11.76	
			Sum	3.61	

Table 14: Multicriteria Value of Road D

Indicators	Value	Z SCORE, Z_NJ=(X_NJ-μ)/Σ_J	Priority Coefficient, C	Total Value(C*ZSCORE)	Remarks
1. Construction Cost	77,084	-0.9	-6.7	5.87	
2. Maintenance Cost	7,448	-0.8	-9.41	7.26	
3. Vehicle Operation Cost Saving	12,824	1.4	5.04	6.96	
4. Reduced Travel Time Cost	2,030,180	1.4	4.79	6.81	
5.Accident Cost	9,667,815	1.3	-8.29	-10.57	
6. Pollution Cost	76,031	0.7	-3.96	-2.78	
7. Population Served Per km	1440	0.9	10.36	9.23	
8. Access to Educational Facilities	475	-1.2	6.53	-7.52	
9.Access to Other Facilities	1	-0.9	8.87	-7.68	
10. Community Priority as a road	5	0.0	7.69	0.00	
11. Encroachment in historical/Cultural Areas	0	0.0	-8.46	0.00	
12.Possibilty of landslide/erosion or flooding	0	0.0	-7.79	0.00	
13.Impacts on Natural System	100	0.5	-11.54	-5.99	
		Sum		1.59	

Table 15: Summary of Ranking

S/N	Name of the Road	MCE Score	Ranks	Remarks
1	Road A	-6.26	4th	
2	Road B	1.06	3rd	
3	Road C	3.61	1st	
4	Road D	1.59	2nd	

VI. Conclusions And Recommendation

The study shows that AHP is a useful and robust tool in evaluating and ranking rural road projects. It is useful in developing weightage of criteria also. AHPis morecomplicated to new participants. So, it needs orientation to participants. The method can be used as in deriving weightage.

The case study shows that there should be certain screening with respect to construction cost, available budget and environmental aspects of the road before evaluation under multiple criteria evaluation. It shows that the developed thirteen criteria forthe selectionof rural roads are most suitable for the developing countries like Nepal.

Developing countries are facing resource scarcity for maintenance, whichshould be important sub criteria in ranking the rural road projects. Evaluation with these different criteria of sustainability with participatory approach will help to sensitize the participants about the importance and preparedness for positive and negative impacts of the projects.

This is a general study for evaluation criteria for ranking rural road projects in the developing countries. Based on this framework, local evaluation criteria shall be derived such as new construction and upgrading separately.Some additional criteria such as traffic volume, access to tourism, hydropower project area, agricultural and livestock pocket area, access to adjacent linkages, future settlement developments, spatial distribution etc. shall also be added in the local evaluation criteria.

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