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Prioritization of Road Upgrading Projects for District Road Core Network: A Case study of Lamjung District

by

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled "**Prioritization of Road Upgrading Projects for District Road Core Network: A Case study of Lamjung District**" submitted by Sudip Bikram Bhatta in partial fulfillment of the requirements for the degree of Master of Science in Transportation Engineering.

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ABSTRACT

One of the essential needs of a citizen in the twenty-first century is the ease of access to transportation whose construction normally requires a huge capital investment. Government of Nepal has been carrying out road network expansion, up-gradation, and maintenance through Department of Roads (DoR) and Department of Local Infrastructure and Agricultural Roads (DoLIDAR). DoLIDAR prepares a list and executes the development of road network interconnecting all local bodies in a district termed as District Road Core Network (DRCN). Ranking criteria for road construction and up-gradation have been focused on the beneficiary population rather than access which has been ineffective for the balanced development.

This study is focused on the development of a composite index with technical criteria for the prioritization of district roads to be upgraded with an emphasis on the rural road network. This index is based on novel set of factors namely link performance, link accessibility, link connectivity and link associated cost.

A case study was carried out in the Lamjung district of Gandaki Province, Nepal. Primary data were collected from Field Survey and Questionnaire Survey while Secondary data were collected from respective Government authorities. Analysis of the collected data was done by assigning the obtained weight of prioritization factors through probabilistic approach. Each of the factors was provided a certain weight using Analytical Hierarchy Process (AHP). The actual condition rating of these factors is multiplied with weighting factors and hence a composite index was obtained to rank each road.

Keywords: Prioritization, District Road Core Network (DRCN), Composite Index (CI), Analytical Hierarchical Process (AHP)

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LIST OF SYMBOLS

μ	Overall mean of all alternatives.
λ	Lambda
σ_{φ}	Standard deviation of all alternative on performance measure.
A	A comparison Matrix
CS_i, CS_j	Centrality index score of the settlement i and j
d_{ij}	Spatial separation distance between settlement i and j
F_{ij}	Force of interaction between settlements i and j
i	Growth Rate
N	Order of Matrix
P_i,P_j	Population of settlements i and j respectively
Wi,wj	Vector of weights
Xnj	The average Value of performance measure.
Z	Normalized score of performance measure

LIST OF ACRONYMS AND ABBREVIATIONS

AADT	Annual Average Daily Traffic
ADB	Asian Development Bank
ADT	Average Daily Traffic
AHP	Analytical Hierarchy Process
APP	Agricultural Perspective Plan
CBS	Central Bureau of Statistics
C.I	Consistency Index
C.R	Consistency Ratio
DCO	District Co-ordination Office
DDC	District Development Committee
DIM	District Inventory Map
DoLI	Department of Local Infrastructure
DoLIDAR	Department of Local Infrastructure Development and Agricultural Roads
DoR	Department of Roads
DRCN	District Road Core Network
DTMP	District Transport Master Plan
FR	Feeder Road
GIS	Geographical Information System
GM	Geometric Mean
HQs	Head Quarters
IDMP	Indicative Development Potential Map
ILO	International Labor Organization
IOE	Institute of Engineering
Km	Kilometer
LRN	Local Road Network
MCA	Multi Criteria Analysis
MoPPW	Ministry of Physical Planning and Works
NH	National Highway
NPC	National Planning Commission
NRRS	Nepal Rural Road Standard

NTR	Network robustness
PCU	Passenger Car Unit
RI	Random Index
RM	Rural Municipality
RoW	Right of Way
RRUI	Rural Road Upgrading Index
RU	Road Utilization
Sq.km	Square Kilometer
SRN	Strategic Road Network
TU	Tribhuvan University
U.S.	United States
UR	Urban Road
VDC	Village Development Committee
VoC	Vehicle Operating Cost
VPD	Vehicle Per Day
VR	Village Road
VRCN	Village Road Core Network
ZoI	Zone of Influence

CHAPTER ONE: INTRODUCTION

1.1 Background

Major portion of population of Nepal are living in rural area. Attentions and efforts have been made in Nepal for the development and deployment of different types of road construction in various geographic regions of the country, under the number of policies and programs launched from those government and non-government sides. Though such effort have brought some noticeable changes in the acted region, still appreciable number of populations are using less efficient transportation system and are waiting for the improved and the efficient ones. It is far distance for them to have access for other facilities (driven by modern transportation) as their main demand, concerned with livelihood, has not been fulfilled in proper manner.

National road network in Nepal is classified as: Strategic Road Network (SRN) and Local Road Network (LRN). According to Department of Roads (DoR), 2010 SRN is considered as backbone of the national economy. DOR is solely responsible for SRN while LRN is responsibility of Department of Local Infrastructure Development and Agricultural Road (DoLIDAR). The main objective of local road network is to reduce poverty. District Road Core Network (DRCN) is the minimum network of rural roads that provide access to all Village Development Committee (VDCs), Head Quarters (HQs) or to a SRN (NRRS, 2055). SRN for mobility, whereas LRN for accessibility. Though DRCN road is quite less standard than SRN, attempts have been made for its utilization through different efficient ways which can bring significant positive impact on the rural area people and economic spheres of life.

Mobility is the efficient movement of people and goods that is seen as beneficial and is considered key aim of policy. This is much wiser than traffic focus because at least it helps move the attention to more efficient ways of moving people and goods. This would put a high priority on collective modes of transport (eg, buses, rail). Accessibility is the ability to reach opportunities that is beneficial, not movement itself. In remote rural contexts gaining access to services, goods and contacts will often require a lot of mobility. However, in many urban contexts accessibility might involve very short trips. In suburban or rural areas, policy to enhance accessibility

might actually require that we reduce traffic or even reduce the need to travel (or reduce mobility).

The proper planning of LRN is important for reaching the target set by National Transport Policy. In order to have unbiased means of prioritization we need to formulate a methodology without subjective means i.e. focusing on objective means (qualitative analysis, incorporating technical factors). This study will demonstrate the Multi Criteria Prioritization model based on novel set of factors like Link Performance, Link Accessibility, Link Connectivity and the link associated cost in order to rank roads to be selected for upgrading. Using Analytical Hierarchy Process (AHP) the weight of each factor in Composite Index calculation will be formulated. This prioritization model shall be used for prioritizing District Road Core Network in Lamjung district of Nepal. The influence of each of the factors or the weightage of each index in the total Composite Index (CI) calculation is derived by survey among experts using AHP. The AHP results have been used to develop a prioritization methodology. Redefining of priority process will keep the essence of current practice and incorporate technical factors to develop new priority process.

1.2 Statements of the Problem

Planning approaches have been changing over a short time period. There are no long-term plan and consistent approach for local road network. Hence, districts are adopting random basis of development without considering the quality, sustainability and economic development methodology.

Most of the DRCN roads do not have minimum accessibility and serviceability standards and are functioning during winter season only. This has caused hindrance in the economic and social development in the served areas. People are missing out an opportunity cost due to elongated time of travel. It, sometimes, has also caused loss of lives due to delay in accessing the health centres and facilities in rural areas.

Nepal faces a problem of allocating scarce resources among competing users in a way that maximizes social welfare. The DRCN construction and up-gradation projects in any district also face a similar scenario. It is indispensable to prioritize among the number of road construction and up-gradation projects within a district through established and improved linkages for year round transportation.

Ranking criteria for road construction and up-gradation have been focused on the beneficiary population rather than access. For an effective ranking, it is essential to incorporate technical approach into the road construction and up-gradation prioritizing process.

In response to this problem, this study focuses on prioritizing the rural road to set up an upgrading hierarchy to ensure that the scarce resources are utilized and spent judiciously. More advanced technology has been adopted to be able to mitigate some or all of the above-mentioned problems for increase in social and economic aspects and overall increase in travel time saving cost. This, in turn, can increase the opportunity for the overall development of the society.

1.3 Research Questions

The case study answers the following questions:

1. What are the local roads prioritizing factors?
2. What is the weightage of each factor that are considered for prioritization using AHP?

1.4 Objectives of Research

1. The main objective of the study is to develop prioritization factors and their respective weights.

Specific objectives are as follows:

1. To identify the criteria and sub-criteria to be considered in prioritizing the DRCN.
2. To develop prioritize list of upgrading for selected DRCN roads using composite index score.

1.5 Significance of the study

The main significance of this case study is to propose new parameters over the existing prioritization that would be beneficial to different stakeholders such as Department of Local Infrastructure (DoLI), District Co-ordination Office (DCO), Municipalities, Rural Municipalities (RM) as well as donor agencies to prioritize the robust development of LRN.

The main finding of this case study is to develop an AHP based framework for the prioritization of the development of district roads. This study can also contribute in reinforcing and modifying the prioritization of other roads which are not included in District Road Core Network (DRCN).

1.6 Scope of Study

The study mainly focuses on the development of Rural Road Upgrading Index (RRUI), also called as composite index, for the prioritization of development of district roads based on novel set of factors like link performance, accessibility connectivity and associated cost and their individual sub-criteria. These sub-criteria are very useful for ranking of development of DRCN roads.

1.7 Assumptions and Limitations of Study

- AADT of the road link was calculated based on seven days traffic count.
- This case study did not consider the other sub-criteria related to vehicle operating cost (VoC), maintenance cost and negative externality cost.
- GIS based buffer analysis was done excluding physical barrier for direct access to the road head.
- Major settlements and market centre of the district were considered as same node for the analysis.

CHAPTER TWO: LITERATURE REVIEW

2.1 History of Road Network System in Nepal

The Department of Road (DOR) is a government agency whose main purpose is to translate government policies for the road sub-sector into the provision of a service to the general public of Nepal, (DOR, 1995). Keeping this purpose in organization goals, DOR was established in 2027 BS. DOR is fully responsible for the construction and maintenance of SRN. The SRN is the backbone of the national road network which are the main national arteries providing inter-regional connections and links to regional and district headquarters, international borders, key economic centres, touristic centres and the major urban roads. The SRN consists of 21 national highway and 208 feeder road totaling 14488.30 km as of year 2015/16 (DOR, 2016). Depending upon the importance, the roads are further classified as National Highway (NH), Feeder Road (FR), District Road (DR), and Urban Road (UR). According to Nepal Road Standard (NRS), second revision 2013, functional classification has been added as class I, II, III and IV. The national highways belong to class I, II and III whereas feeder road belong to class II, III and IV.

Similarly, rural roads are the integral part of society. Roads those are not part of central road system and where project formulation, construction, maintenance and repair have to be done by local institution shall be classified as local road system (MoPPW, 2001). DoLIDAR under Ministry of Federal Affairs and Local Development (MoFALD) has been facilitated for the overall planning, technical cooperation with centre level and to local authority. Before the establishment of DoLIDAR, all roads were constructed by DOR and some other donor agencies. DoLIDAR was established under the ministry of Local development in 2055 B.S. DTO was constructed in all 75 district as a wing of DDC to support for the planning and construction and maintenance of rural roads. Afterwards all rural infrastructures were constructed by DDC under technical support of DTO. At present, DoLIDAR is fully responsible for improving accessibility of local people residing in rural areas and facilitating in providing access to opportunities, services and resources (DoLIDAR, 2012).

2.2 Road Network in Nepal

Every district has network of roads (SRN & LRN). District Development Committee, is a autonomous body formed on the basis of Local Self Governance Act (2055) is overall responsible for the infrastructure development of the district. The planning, implementation, operation and maintenance of district road network are done by DDC's in respective district based upon the standard developed by DOLIDAR. Nepal Rural Road Standard (NRRS) 2055 was revised in 2012 during the preparation of 'new DTMP Guidelines 2012' which categorize the district road network into only two types such as DRCN and Village Road Core Network (VRCN) (World Bank, 2012). Total number and total length of DRCN is 1890 and 25728.18 km respectively till 2016 (DoLIDAR 2016).The percentage of DRCN in Mountainous region, Hills Region and Terai Region gives share of 10.53%, 62.07% and 27.39% respectively. Total length of DRCN in province wise is presented here under.

Table 2.1:District Road Core Network of Nepal in province Wise

Road Class	**Total length; Km**	**Percentage of road length in province wise**	**Black Top**	**Gravel**	**Earthen**
Province 1	5,715.40	22.21	261.95	817.41	4,636.05
Province 2	2,519.28	9.79	67.14	1,603.44	848.70
Province 3	5,230.42	20.33	287.06	851.89	4,091.46
Province 4	4,082.38	15.87	180.51	594.25	3,307.62
Province 5	4,080.67	15.86	432.95	1,214.22	2,433.50
Province 6	1,671.25	6.50	9.99	136.83	1,524.43
Province 7	2,428.79	9.44	71.14	651.25	1,706.40
Total of DRCN Roads	**25,728.18**	**100.00**	**1,310.74**	**5,869.29**	**18,548.16**

(DoLIDAR, 2016)

Table 2.2 :DRCN Standards in Hill District

Road Class	Carriageway Width (m)	Design Speed (km/Hr)	Design Capacity	Surface type	ROW
DRCN	5.5 (if traffic > 400 VPD)	Rulling – 25 Min – 20	400 PCU in Both Direction	Blacktop (if Traffic >50 PCU)	10 m on either side
	3.75 (if traffic > 100 VPD)				
	3.0 (If traffic <100 VPD)				

(DoLIDAR, 2012)

Village Road (VR) is smaller road not falling under District Road Core Network category, including other agricultural road (DoLIDAR, 2012). Total number and total length of VRCN is 5789 and 28270.16 km respectively till 2016 (DoLIDAR, 2016). The percentage of VRCN in Mountanious region (17 districts), Hils Region (40 districts) and Terai Region (20 districts) gives share of 9.0%, 57.10% and 33.90% respectively. Total length of VRCN is presented here under.

Table 2.3: Village Road Core Network of Nepal in Province Wise

Road Class	**Total length; Km**	**Percentage of road length in province wise**	**Black Top**	**Gravel**	**Earthen**
Province 1	6,121.64	19.19	142.27	1,616.54	4,362.83
Province 2	3,175.93	9.95	15.31	1,176.20	1,984.42
Province 3	9,248.60	28.99	289.29	1,722.77	7,236.53
Province 4	6,831.32	21.41	128.53	696.87	6,005.91
Province 5	4,470.53	14.01	97.88	1,467.63	2,905.02
Province 6	857.25	2.69	9.36	23.07	824.82
Province 7	1,198.60	3.76	10.81	250.63	937.16
Total of Village Road	**31,903.86**	**100.00**	**693.45**	**6,953.72**	**24,256.69**

(DoLIDAR, 2016)

2.3 Review of Planning Methodology of Rural Roads

In developed areas, the planning approach primarily depends upon the interaction among different settlements whereas in underdeveloped areas, the focus is to provide accessibility to almost all the settlements to the area (Shrestha & Shrestha, 2011). In

case of Nepal most of the rural roads projects are being implemented based on new DTMP Guidelines 2012. The guidelines related to rural road planning in Nepal since 1999 are presented shortly here under.

2.3.1 Approach Manual 1999

The rural road development standardized approach in Nepal had started since 1999. Before 1999, the respective approaches were varying from programme to programme despite the fact that they were implemented through the same DDC (DoLIDAR, 1999). In government funded projects, the situation was even worse. In spite of having some kind of guidelines provided by the MLD, it was apparent that most of the work was being carried out on ad-hoc basis. Furthermore, the implementing agencies as well as the beneficiaries were in a state of confusion with the varied approaches of different rural road projects. Therefore, DoLIDAR has promulgated the 'Approach for the Development of Agricultural and Rural Roads' with the funding support from Asian Development Bank (ADB) and Technical Support from International Labor Organization (ILO) in 1999. The first guideline for the preparation of DTMP and its implementation has covered the process of planning, implementation and operation and maintenance in comprehensive way.

The approach starts with process of planning. Under this, the preparation of the Indicative Development Potential Map (IDMP) which clearly indicates the existing growth centres and the areas having various development potentials (high value crops, agro-based industry, tourism, micro hydro power) is vital. The growth centres were then ranked on the basis of seven criteria namely; existing infrastructure network, centre location, potential for the commercial agriculture and non-agriculture growth, market development potential, physical setting of the location and partnership attitude of the local people. The ranking of growth centre based on scoring system should be basis for the overall network planning.

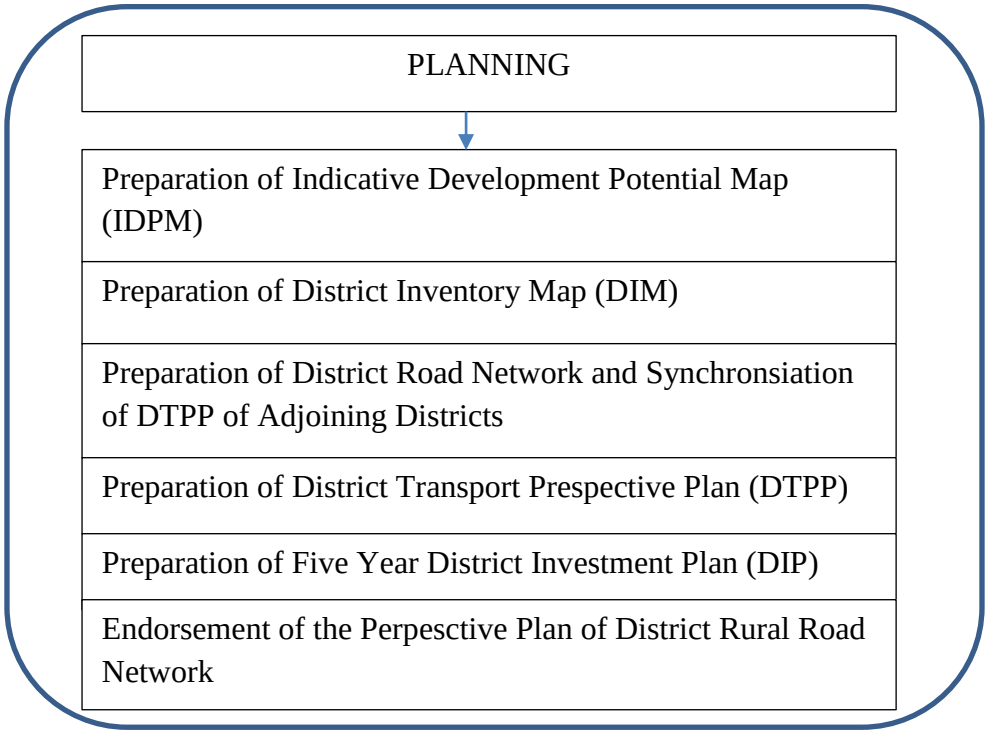
The overall existing roads and proposed new links were presented by preparing District Inventory Map (DIM). Social as well as technical information of each link are necessary while preparing DIM. In this way, the prepared DIM is plotted on IDPM which gives the clear picture of accessible and inaccessible areas in district. Social data related to each link are settlements/population served, economic activity/production, export import goods, food sufficiency, land holding pattern,

transport facility/traffic volume, service centres and other infrastructure facilities, natural resource base, land use pattern, migration pattern, development potential and people's willingness to contribute for growth centres. Screening and grading works based on eight criteria having weightage score of 41 to 60 are used to identify the transport links whether it is road or trail. Perspective plan is finalized which is the also used to prepare a DTMP. The five year rural road master plan is a prioritized abstract of the perspective plan. Every five years, the DDC gets on opportunity to revise the perspective plan. Five year rural road master plan is referred as 'District Transport Master Plan (DTMP)'. In order to allocate fund in the road links, each road link is prioritized according to the respective criterion. These criteria are related for new construction, rehabilitation and upgrading of road. For new construction, the criteria are weighted score of link, investment per Km, social and environmental issues. Likewise, the criteria are serviceability of road, investment per Km and traffic volume for rehabilitation and upgrading. Last approach of this manual is implementation and maintenance phase. In this phase, the approach manual recommends the implementation modality, work division and funding arrangement.

2.3.2 Guideline for the Preparation of District Transport Master Plan 2010

The approach manual has considered the village roads, trails and ropeways which had made the DTMP more complex. So, the DoLIDAR has changed the approach manual in many aspects. Firstly, the major inclusion of interim guideline for DTMP 2010 was the government transport policy to provide access within 2 hours walking distance in Terai and 4 hours in Hills and Mountain (MoPPW, 2001). Secondly, interim guideline excludes the planning of Village roads as it was complicated task in district level. Thirdly, this guideline included the trail bridge. Similarly, this guideline also included the grading of market centre based on Centrality Index (CI) and simplified prioritization process. Lastly, the guideline 2010 excluded the implementation, operation and maintenance process which were in approach manual 1999. Rural roads are classified only in two categories A and B. the criteria for the new construction are population per unit cost in zone of influence, cultivated land per Km, population walking hour per km in ZOI and disadvantaged population per km in ZOI. Similarly for the rehabilitation, the criteria are cost per traffic unit, rehabilitation cost per km, size of market. Likewise, future traffic is accounted in case of upgrading of roads. The

overall process of planning adopted in interim DTMP Guideline is presented in figure 2.1.



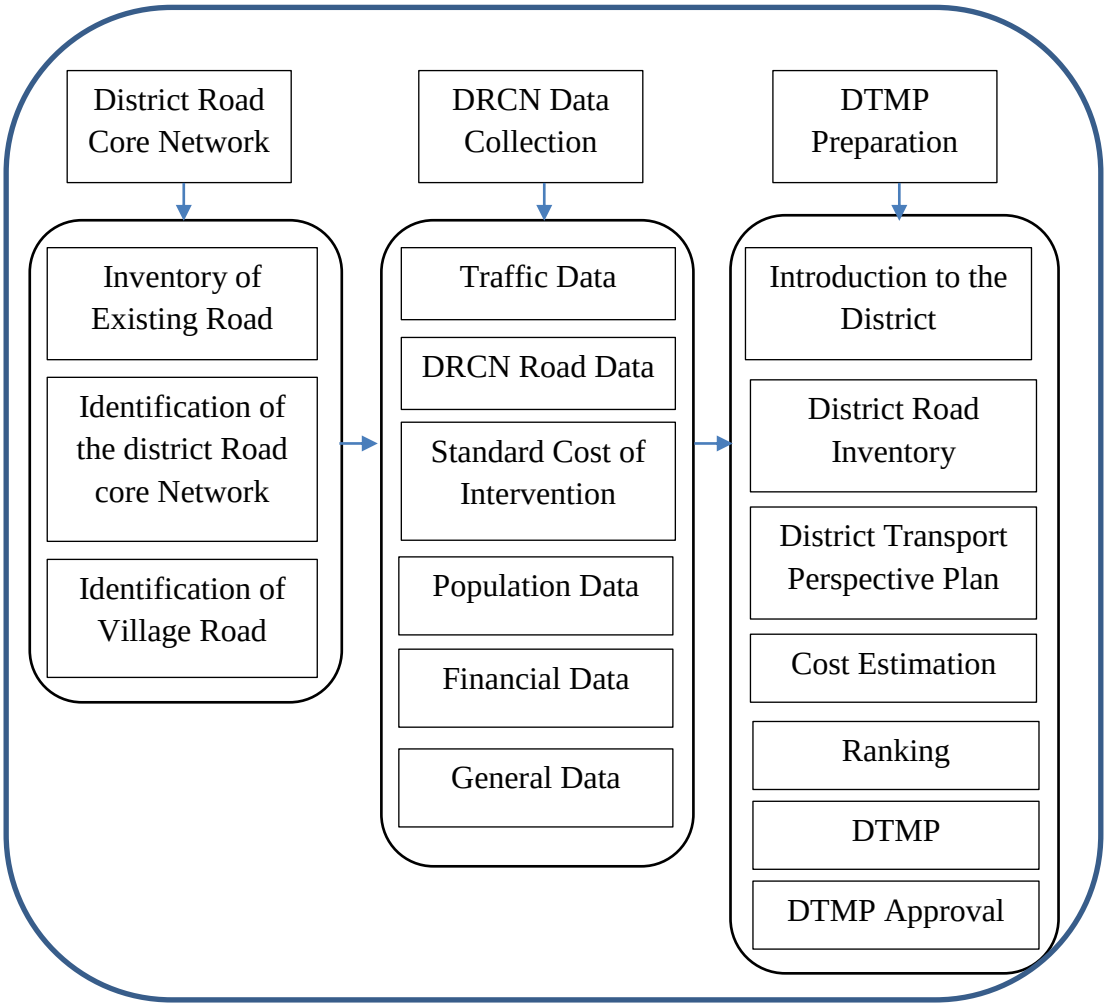
(DoLIDAR, 2010)

Figure 2.1: Planning Process of DTMP Preparation 2010

2.3.3 Guideline for the Preparation of District Transport Master Plan 2012

The huge quantity of rural roads has been constructed since 1999, the interim guideline was revised in 2012 with the concept of maintenance as first approach. NRRS, 2011 also recommends to improve the interim DTMP Guidelines 2010 with simplified approach of road classification. Similarly, road classification is simplified to district road core network and village road only. The major changes in new DTMP guidelines were described here under.

The scoring system only requires information about population and traffic volume for ranking of road links whereas interim guidelines 2010 requires other information about market centres, socio-economic status, cultural and heritage place, environmental issues and existing public infrastructure. While reviewing about type of road intervention, this guideline classifies the road intervention into three categories which are conservation, improvement and new construction. The overall process of preparing DTMP drastically reduces into three processes as shown in figure 2.2.



(DoLIDAR, 2012)

Figure 2.2: DTMP Planning Process 2012.

At first, inventory of existing roads in district are carried out with the help of Global Positioning System (GPS). Various parameters related to the inventory are good/fair condition of road, permanently/temporarily imposable. Based upon the inventory of road, DRCN is selected. The identification of the DRCN roads involves the selection of one road linking each VDC headquarters to the SRN, to the district headquarters or to another VDC headquarters (which in turn is linked to the SRN or VDC headquarters). Wherever VDC headquarters are already linked directly to the SRN, no other roads need to be selected to form part of the DRCN, as the required access already exists. In many cases, however, there will be different alternative roads linking the VDC headquarters, and the most suitable link should be selected. In this selection, the following criteria should be taken into account (DoLIDAR, 2012).

Road surface

Priority should be given in the order blacktop-gravel-earthen, as higher standard roads will require fewer interventions to bring them to a maintainable.

All-weather status

Missing water crossings-priority should be given to roads that are not lacking important water crossings that prohibit access in the rainy season, as the construction of such water crossings will be very costly.

Condition

Priority should be given to roads in better condition, as these will require fewer investments to bring them to maintainable standard.

Length

Priority should be given to roads that provide the shortest connection compared to the rest of the DRCN, as this will reduce the costs involved in the upgrading and maintenance of the DRCN.

Traffic

Priority should be given to roads with higher traffic volumes. In the absence of traffic data, the knowledge of the DTO engineers and other local authorities should be used. (DoLIDAR, 2012). Other data necessary for planning and prioritization purpose related to DTMP preparation are traffic data, details of road structures, population data for the VDC's in the District, financial data for the road sector and other general data such as geography, demography, climate, economy and administration division.

2.4 Comparison of evaluation criteria in DTMP Guidelines

In prioritization criterion, the new DTMP guideline 2012 is much simple than the rest of the two previous guidelines. The nodal point is taken at VDC centre so there is no need to identify and categories market centre. Likewise the economy based criteria such as agricultural production and trade volume are not considered in the new DTMP guidelines 2012. From the social perspective also, the new guideline do not consider poors, Dalit, Janajatis and marginalized people including place of geographic importance.

Looking into all the planning process and prioritization criteria, the major differences in the evaluation approach of the DTMP guidelines are: the first two guidelines tried to look into equity based development aspects covering the remote areas and disadvantaged people along with the production and economic centres. Whereas, the latest guideline of 2012 is solely economic efficiency based. The later only focuses on the least cost for investment and great population served. Another difference is in the first two guidelines market centre was considered as the most potential nodal point in the network whereas, in the latest guideline of 2012, VDC centre is considered as the nodal point which primarily serves the administrative purposes. Another significant difference is that the DTMP guideline 2012 allocates funds with principle of maintenance approach. It means the fund available in the districts first allocated to conservation than in improvement and at the last in new construction. If there is no money left after fulfilling the cost of conservation work then improvement and new construction cannot be done. In the first two guidelines, fund was said to be allocated in all types of works including upgrading, rehabilitation and new construction. The share of allocation in different types of road intervention was at the discretion of DDC Engineers and DDC council.

2.5 Road Prioritization

Prioritization of road network is based on Analytical hierarchy process (AHP).

2.5.1 Analytical Hierarchy Process (AHP) used in Prioritization

AHP is one of the most effective techniques in multi criteria decision making (MCDM) .This techniques is based on pair wise comparison enables decision make to investigate several different criteria to find the relative importance to alternative strutting the decision problems as a hierarchy as fundamental to the process of the AHP. Hierarchy indicates a relationship between elements of one level with those of the level immediately below. This relationship percolates down to the lowest level of the hierarchy and in this manner every element is connected to every other one, at least in an indirect manner.

Analytical hierarchy process could be one of the options and is used in the decision for the planning and implementation of bridge and roads (Zavadskas, et al., 2008). Because of the simplest and most useful processes of AHP, this method is globally applied to solve wide range of problems related to diversity of field. Keeping the

benefits of AHP method, Farhan & Fwa (2009) explored the use of an AHP for the prioritization of pavement maintenance activities. The main aim was to identify an approach that can reflect the engineering judgment of highway agencies and engineers more closely. Mozazmi et. al., (2011) applied AHP for determining maintenance priority indices for 131 road sections by means of three modeling parameters, PCI value, traffic volume and the road type. In that study, relative weights of criteria, sub-criteria and inconsistency rate in each pair wise comparison matrix were calculated with the help of MATLAB software, coded M-Files as well as useful in other variety of field. Development of composite index based on AHP with novel set of factors like growth centres, road utilization, connectivity, accessibility, road class are developed to prioritize district road corridors in Kerala state of India (Linaraj, et al., 2013). Relative weights of criteria and sub-criteria were calculated manually.

Dahal et al., (2010) developed AHP model considering several socio-economic criteria relevant to a road and the region through which it passes and finally reach to the solution of ranked-order lists of 178 rural roads in two districts of Orissa, a relatively backward state of India. Investments from government and other sources in rural road projects are inadequate, leading often to political, rather than socio-economic, considerations in allocating funds to specific projects. Realizing this, many donor organizations demand an unbiased study for prioritizing rural roads for funds allocation. This requires prioritizing rural roads on a rational basis. Hence this study successfully has drawn the satisfactory result in case of rural roads. In a similar way, a case study was done in Kerala state of India to prioritize the district roads by using AHP. Shang et al., (2004) also applied the AHP to evaluate the transport projects in Ningbo, China. His model incorporated the factors namely benefits, opportunity costs and risk. He established BOCR model under four factors with 27 sub factors according to the framework of Saaty (1980).

Prioritization of works such as maintenance and upgrading of roads, bridges and other engineering infrastructure in the form of scoring system are based on some empirical mathematical expression. Though it is convenient to use empirical mathematical indices, do not have a clear physical meaning and cannot accurately and effectively convey the priority assessment or intention of highway agencies and engineers (Prakasan, et al., 2015). The AHP methods fulfill all those limitations of empirical mathematical indices by giving group decision behavior in diversified field. Some

research has also been done using AHP methodology in Nepal. Bhandari & Shrestha, (2014) integrated the multi-criteria decision model with AHP to rank the rural roads of Dang district where three main criteria were established and 13 sub-criteria were produced according to Saaty (1980) criteria of AHP. Ultimately roads were ranked based upon the expert information and weighted of criteria. Similarly, Khanal (2015) applied the AHP to identify the importance of accident factors in road safety in case of Mungling-Narayangarh highway. The Linear additive model integration with AHP consists of calculating the overall value score of a proposed road scheme by adding its weighted score on a set of criteria. Kaysi et al (2010) suggested the approached used with AHP to prioritize national road projects as presented below.

$$S_i = \sum_{j=1}^{n} W_j S_{ij} = + W_2 S_{i2} + W_3 S_{i3} + \ldots\ldots\ldots\ldots\ldots W_n S_{in}$$

Where,

S_i = Total value score of scheme i,

W_i = relative weight of the criteria j,

S_{ij} = Value score of scheme I on criteria j

n = Total number of criteria of the function (number of establishments or shops at the j^{th} market centre)

2.5.2 Parameters used in Prioritization

Prioritization based on simple parameters may enough and practical for the rural roads. These methods can be any of the population covered by a road link, per person-km, population per unit construction cost, and use of gravity flow model. The network links can also be prioritized based on all the parameters and be superimposed to compare the results (Shrestha, 2016). Due to the limitation of fund available for rural road construction/upgrading in developing countries, the available resources should be effectively used while selecting the most potential links. Most of the prioritization methods for road links are usually based on economic returns from the road linkages so that feasibility indicators such as Net present Value (NPV), discounted benefit cost (B/C) ratio, internal rate of return (IRR) are used where economic return can fairly estimate. Conversely, that methodology did not appropriate for rural roads which make up over 80% of the road network length, but given lower priority in the

allocation of funding because they carry much lower volume of motorized traffic (Schelbert, 2073). Most of the rural roads are purposed to cover the accessibility of goods for providing basis rural facilities and service to a minimum level. Shrestha (2016) suggests four methods which are applicable to prioritize the rural road networks. First and foremost factor is population served by link which is key social factor in the rural areas. The link which serves the more population can be considered as potential link in the rural areas hence population served by link can be considered as an important indicator for the rural road links prioritization. Secondly, the construction/improvement cost for the link is considered justifiable in terms of benefits. The population served with unit investment for prioritization of rural roads is simple parameter (Kumar & Kumar, 1999). The priority for a rural road link can be calculated with population served by the link divided by construction cost of the link. The link lengths can be taken as good proxy for construction cost (Kumar & Tilloston, 1985). The construction costs can be taken as proportional to the lengths of links hence the priority for a road link can be considered as population served per unit length of a link in km (Population served/km). Similar kind of parameter (population per unit cost) is adopted in DoLIDAR (2012). Thirdly, the factor Person-km (multiplication of population and the distance travelled) can be used to take the effect of travel cost in the evaluation of rural road linkage. Travel costs are assumed to be proportional to product of population connected by the link and the distance between the village and the destination through the link ("person-kilometers") (Makarachi & Tillotson, 1991). DoLIDAR (2012) has also taken the parameters (population-distance) in a different form (Population – hour) based on walking time to a road corridor. Last but not the least, the simple gravity flow formulation suggested by Mac & Hudgson (1969) and followed by Shrestha (2016) was as follows;

$$F_{ij} = K \frac{P_i P_j}{D_{ij}^{b}}$$

Where, i and j are nodal points, F_{ij} is traffic flow through link ij. P_i and P_j are the population at node i and node j. D_{ij} is the distance between node i and node j. Population data can be obtained from census data and distance between population centres can be obtained from map measurement.

PR methods ('Sufficiency Rating') were used in the early 1950's for planning maintenance and improvement of U.S. highways (Highway Research Board, 1952). This method is one of the maintenance of highways. However, the concept has been proposed for adaptation for rural road projects (Carnemark et al., 1976). PR is a weighted rating technique. An overall rating score S_i is determined for each proposed project by:

$$S_i = \sum_{j=1}^{m} W_j X_{ij}$$

Where, W_i is the weight of the j^{th} considered factor or characteristic; X_{ij} is the score of the i^{th} project for the j^{th} actor; m is the number of factors. The higher the S_i value , the more urgent is the project.

Centrality Index

The majority of the trips in rural areas area originated from one population centre and ended in another population centre. The centrality index can be used to assess the relative importance of settlements identified as transport nodes (Shrestha & Routray, 2001). Each settlement has different function (service centres). The functions can be Education, Health, Business & Commerce, industry institutions, and offices (Bank, Agriculture Service centre, Veterinary office, post office, Telephone office, Electricity office, cooperatives office). These functions attract the trips from other settlements hence these are included in the centrality index (DoLIDAR, 2010). The centrality index of each settlement is calculated by:

$$C_i = \sum_{i=1}^{n} W_j Z_{ij}$$

where,

C_j= centrality index of the j^{th} market centre,

w_i= weight of the j^{th} marketing functions,

X_{ij} = value of the function (number of establishments or shops at the j^{th} market centre)

A settlement which has centres for marketing, clinics, schools and other commercial, social and welfare activities is called market centres. The weight of a function can be

obtained on the median threshold population technique. According to the technique, the weight can be calculated as:

Wi = (Population Median i^{th} Function)/(lowest median population of the market centres where a function exists)

This index was also used in the determination of hierarchy of nodal points as a network model for the district road network planning and prioritization.

Intensity of Interaction

Maximization of settlement interaction and minimizing network length to provide accessibility to all settlement nodes is the major goal of rural road network planning (Kumar & Tilloston, 1985). If the interaction between the market centre/settlement can be calculated, we can find the importance of link between them or link connecting the market/settlement (Shrestha, 2013). Any one settlement in a region may not have all types of utility and amenity for fulfilling the social functions. Thus, the settlements will have different levels of functional importance depending on the concentration of available facilities. A gravity model can be used to find the interaction between two nodal points as suggested by (Kumar & Tilloston, 1985).

$Fij= PiPj[|CSi-CSij|/d_{ij}^2$

Where;

F_{ij} is the force of interaction between settlement i and j

d_{ij} is the spatial separation in the form of straight line distance between settlement i and j

CS_i and CS_{ij} are the centrality index score of the settlement i and j

P_i and p_j are the population of settlement i and j respectively

Link Efficiency

The efficiency of road link is expressed as the amount of interaction served per unit length. the efficiency of individual link is nothing but the force of interaction served per unit length, therefore for any link between two settlements, the efficiency can be expressed as in the following equation (Mahendra, et al., 1985).

$LE_{ij} = F_{ij}/L_{ij}$

Where,

Lij is the link length joining the settlements i and j which is a direct and shortest length of that link

Fij is the force of interaction between settlement i and j.

similarly, (Mahendra et al.,1983) also suggested the route efficiency and network efficiency to generate, analysis and evaluated alternate rural road linkage pattern.

Traffic Volume

Traffic volume is the number of vehicles crossing a section of road per unit time at any selected period. Traffic volume is used as a quantity measure of flow; the commonly used units are vehicle per day and vehicle per hour.

VDOT., 1990 recommended the nine variables to prioritize nine projects under three criteria service, safety and other consideration. Among them, one variable, the existing volume of traffic on a given road segment divided by the service volume (v/SV) and forecasted traffic on a given road segment divided by the service volume (FV/SV) for that road segment under service criteria has given 30 points and 20 points while rating the infrastructure projects. But, the parameter was slightly changed while prioritizing the rural infrastructure needs in 25 districts of Texas. Texas Department of Transportation (TxDOT) suggested the four variables namely average daily traffic, vehicle-mile travelled, average daily truck traffic and trucks miles travelled. The weights of four categories in terms of scoring was only 15. However, traffic volume is the major criteria while prioritizing the rural roads in districts. In context of Nepal, traffic volume is the major factor for defining the surface rehabilitation and upgrading purpose. Traffic Volume (PCU) parameter was used in all three DTMP guidelines since 1999 to present (DoLIDAR, 1999; DoLIDAR, 2010; DoLIDAR, 2012). Similarly, Linaraj et al.,2013 suggested the parameter road utilization as volume to capacity ratio (V/C ratio) along with other parameters such as connectivity, accessibility to prioritize the some important infrastructure projects in the state of Kerala, India.

Road Utilization = Volume of traffic in that link / Design Volume

According to rural road standard 2055, 2nd revision 2071 the design capacity of DRCN is proposed as 400 PCU per day in both direction.

Rate of Accidents

Although there is shortage of reliable data for all aspects of rural transport, this is particularly acute for safety and security. It is well known that under reporting is a major issue for road safety in Nepal. However there are good grounds to believe that better data exist and consequently much more is known on the incidence and causes of road crashes in urban areas and along inter urban routes than for rural areas. Similarly, there are very few specific studies of rural transport safety and security in Nepal.

Most rural roads have no separate provision for pedestrians who tend to use the road along with the mix of vehicle types, unsafe vehicles, poor traffic awareness and safety knowledge will also be issues alongside lack of enforcement. However, an enforcement regime that interprets the regulations too strictly would involve a significant decrease in services or an increase in prices. A balanced approach is therefore recommended. Strakey (2007) identified the following safety issues in rural areas: inadequate infrastructure, including potholes, lack of safety barriers & signs, unsafe vehicles, unsafe loads and mixed passengers & fright & unsafe behaviors of drivers.

Link Accessibility

Accessibility may include the percent of the population within X minutes of Y percent of employment sites, whether special population, such as the elderly are able to use transportation whether transportation services provide access for undeserved population to employment sites and whether services are ADA compliant. It also refers to the people's ability to reach goods, services and activities. Many factors affect accessibility such as mobility and connectivity and land use pattern. In case of rural road simple approach of accessibility is reliable to measure the accessibility of links in terms of services. An adequate access to social services such as medical and health services, proper nutritional care for the young and education facilities would determine to a large extent the improvement of social and economic welfare of the rural population (Haward & Richard, 1984). Construction of rural roads is one of the major infrastructure development projects in Nepal in order to improve accessibility in rural areas. Accessibility in the rural areas is the easiness of getting facilities and services that the rural residents needs for everyday life at minimum time, effort and cost (Dennis, 1998). National transport policy 2001 also recommends to achieve 2

hours walking distance and 4 hours walking distance to the nearest road head in rural roads in case of accessibility for Terai and Hills respectively. So those accessibility indicators for rural roads are measured by accessibility with various services such as education, tourism/industry/others, Hospitals/Health post and Market centre/administrative centre (DoLIDAR, 1999; Linaraj, et al., 2013; DoLIDAR, 2010; Bhandari & Shrestha, 2014).

Link Connectivity

Rural Road connectivity is a key component of rural development that promotes access to economic and social services, thereby generating increased agricultural productivity, non-agriculture employment as well as non-agricultural productivity, which in turn expands rural growth opportunities and real income through which poverty can be reduced (Mohapatra & Chadrasekhar, 2007). In the context of rural roads, a higher degree of care is required at the planning stage to integrate connectivity needs of DTMP since 1999. The connectivity concept in new DTMP guideline was not mentioned. Some developing countries like India, Bhutan are giving prime importance for the connectivity while developing their District Road Master Plan. Approach manual 1999 suggested to incorporate the direct linkage of links with another network namely National Highway, Feeder Road, District Road, Village road, airport and trails with highest score of 100 for connectivity with NH and lowest score of 50 to 60 for the trails. Similarly, Linaraj et. al., (2013) used the concept of connectivity using the parameter inter district, NH/SH connectivity, connection with airport, seaport and railway stations while prioritizing some important roads in the state of Kerala, India. Prozzi & Harrison (2004) also included the parameters namely links between towns and cities, link for travel across the state and alternative road available from the links to prioritize the rural infrastructure needs with scoring system for the connectivity of rural roads.

Travel Time Cost

Another factor to be considered in the evaluation is travel cost by the population of the rural areas. However, this travel cost is difficult to quantify being a time consuming and costly work. A huge amount of travel data is needed to model the travel behavior of the rural settlements, which is not practical. However, we need to include the effect of travel cost in the evaluation of rural road linkages. The travel cost can be more relevant than the construction cost of rural road link (Shrestha, 2013).

Travel time is one of the largest costs of transportation and travel time savings are often the primary justification for transportation infrastructure improvements. The value of travel time refers to the cost of time spent on transport including waiting as well as actual travel (VTPI, 2013). It includes costs to consumers of personal (unpaid) time spent on travel, and costs to business of paid employee time spent in travel. The value of travel time unit cost depends upon various factors such as type of trip, travel condition and traveler preferences (small, et al., 2005). Travel time saving cost suggested by Bhandari & Shrestha (2014) for ranking rural roads was presented as below.

Travel time saving cost = Total number of passenger * Travel time * Time value of travelers

In case of Nepal, time value of travelers are Nrs. 5.61 per hour for motorcycle with one passenger, Nrs. 24.96 per hour for car medium with 4 passenger and Nrs. 62.40 per hour for bus medium as suggested by Bhandari & Shrestha (2014).

Upgrading Cost

To achieve priority, it was recommended that improvement of rural roads could be ranked using the following simple cost per head of population served factor. Such improvements were generally the minimum requirements for opening the road. Schemes giving the lowest cost per head were ranked highest (Airey & Taylor, 2002).

$$\text{Cost per head} = \frac{\text{Estimated cost of minimum improvement works}}{\text{Population served by or living in the zone of influence of the improvement}}$$

The construction cost of road projects mainly includes the cost of surveying and design, site clearance, earthwork, different structures, side drains, pavements establishment or road furniture and land acquisition. The construction cost depends upon the topography and geology of the road alignment, availability of construction materials, labors and equipment along the construction site. The approximate construction cost in different planning documents depending upon terrain and cost of similar projects in the pasts, use of cost per kilometer of some items or developing rough estimates of quantities and multiplying the recent bid price and adding inflation and contingency factors (Bhandari & Shrestha, 2014). Similarly, interim DTMP Guidelines 2010 also suggested incorporating the construction cost for new linkage, rehabilitation and upgrading of rural roads prioritization.

2.5.3 Analytical Hierarchical Process (AHP)

AHP is a mathematical technique used for multi-criteria decision-making. In a way it is better than other multi-criteria techniques, as it is designed to incorporate tangible as well as non-tangible factors especially where the subjective judgments of different individuals constitute an important part of decision making (Saaty, 1980). Saaty & Vargas (2000) elaborated detail procedure of AHP method for decision making. AHP uses a five-step process to solve decision problems. They are:

- Create a decision hierarchy by breaking down the problem into a hierarchy of decision elements.
- Collect input by a pair wise comparison of decision elements.
- Determine whether the input data satisfies a consistency test. If it does not, go back to step 2 and redo the pair wise comparisons.
- Calculate the relative weights of the decision elements.
- Aggregate the relative weights to obtain scores and hence rankings for the decision alternatives.

Step 1

Let {A1, A2, …An} denote the alternatives (n is the number of compared alternatives) then a (n x n) decision matrix of pair wise comparisons is formulated which represents the intensities of the expert's preference between individual pairs of alternative (ai versus aj, for all i, j = 1, 2, …, n).

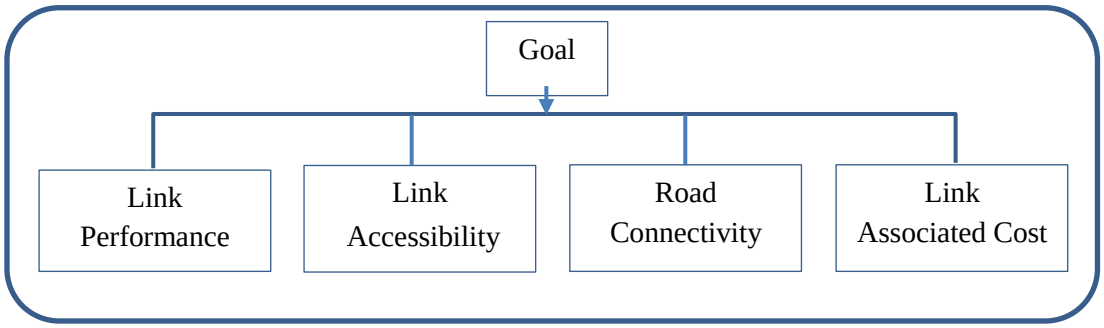


Figure 2.3: Hiearchy of Objectives

Step 2

Decision matrix is formulated based on the criteria as shown in figure 2.3 and sent to planning experts for pair wise comparisons. Measurement scale has rating from 1 to 9 as adopted by Saaty (1980).

Table 2.4: Scale used for comparison

Preference on Pair wise Comparison	Preference number
Equally Important	1
Moderately more important	3
Strongly more important	5
Very strong more important	7
Extreme importance	9
Intermediate Values	2,4,6,8

(Saaty, 1980)

Step 3

Calculating of matrix eigenvector, Aij and Consistency Index (CI) test for the criterion. For matrix eigenvector, Aij multiply then elements in each row, take the n^{th} values. Then divide each number by the sum of resulting values of the new column constructing the pair-wise comparisons of alternatives with respect to factors (criteria) in a matrix.

Step 4

Computing the relative weight and ranking the alternatives

$W_i = \Sigma A_i K_{ij}$

Where,

W_i = overall relative rating factors i

A_i = Average normalized weights for factor i

K_{ij} =Average normalized ratings for alternatives j with respect to factor i

Step 5

Ranks the alternatives based on weightage

2.5.4 Random Index (RI)

Random Index (R.I) was developed at Oak Ridge National Laboratory by researchers that generated R.I for matrices of order 1-15. The sample size was 100 and Saaty with his colleagues repeated the calculation at Wharton School with a sample size of 500.

In the table 2.7 below, R.I from 1-11, come from the results obtained at Wharton, and from 12-15, from results at Oak Ridge (Saaty, 1980).

Table 2.5: Random Index (RI) for different dimensions of Matrix

N	1 & 2	3	4	5	6	7	8	9
RI	0	0.58	0.9	1.12	1.24	1.32	1.4	1.46

(Saaty & Vargas, 2000)

2.6 Fuzzy method used in validation

Many challenges are ahead for conceptual models same as the models related to creativity and ideation. Conceptually, creativity seems to be related to vague and uncertain issues. Uncertainty may be high in models and processes associated with creativity.

By employing fuzzy method, we combine creativity process with a fuzzy map that can understand uncertainty and make people understand the creativity process. Fuzzy method improves conventional true/false logic with the notion of partial truth that is adopted for qualitative judgments.

In terms of applicability, fuzzy theory can be considered as a functional tool, which eases making decision in multi-criteria condition, considering uncertainty in the clarification of alternatives. In addition, it can be applied in a decision-making process when there is a high range of equivocation and conflicting criteria. In linguistic terms (for instance to differentiate between ‘high’, ‘medium’ and ‘low’) rather than using real numbers. Consequently, fuzzy numbers are presented instead of a single value in traditional deterministic methods, and thus fuzzy method seems to be the most proper method. In terms of validity, fuzzy systems are validated in the same way as traditional system.

Regarding the mentioned facts, the reasons for employing fuzzy method in this study are as follows:

- Creativity is related to vague and uncertain issues.
- Models and processes associated with creativity are related to high uncertainty.
- This research needs qualitative judgments.
- Similar researches have used this approach.

Considering these points, the method that is study uses to categorize parameters subset of integrated management of creative ideation criteria is fuzzy method.

Applying fuzzy sets is more consistent with vague explanation and human linguistic, and using fuzzy numbers seems to be a proper way to make decisions. Noorderhaben indicated that using the fuzzy method for group decision could resolve the fuzziness of frequent understanding of specialist opinions. Therefore, this method is an

appropriate way to evaluate the importance of the parameters affecting a phenomenon or a concept on a more flexible.

2.7 Study Area Profile

2.7.1 Demographic Data

According to the National Population Census 2011 (CBS), the total population of the district is 167724 with comprises 75913 male and 91811 female. There are 42079 households in the district with an average household size of 4.0. The population density per sq. km. is estimated at 99.13 with an average growth in population recorded at -0.53 annum. The table 2.6 below shows the population census of 2011 in Lamjung district.

Table 2.6: Demographic Situation of the Study Area

SN	Description	Remarks
1	Total Population	167724
2	Male	75913
3	Female	91811
4	No of household	42079
5	Population Density	99.13

(CBS, 2011)

2.7.2 Settlement/Market centre in district

There are altogether forty one numbers of market centres in Lamjung district. Market centres are categorized as type: existing growth centre and potential key growth centre. Existing Key Growth Centre are Twenty three (23) in number where as Potential Key Growth centres are Eighteen (18) in number respectively. (DTMP, 2070).

2.7.3 Educational Services

There are altogether 432 educational institutions including 297 primary schools, 40 lower secondary schools, 59 secondary schools and 26 higher secondary, 10 campuses in Lamjung district (DEO, 2070).

2.7.4 Historical Place/Industry/Health Centres

Lamjung district has historical, cultural and religious places located in different parts of the district. It has famous historical and touristic place of Rinaskot and Ghalegaun. The historical, religious and tourist places are more than forty (40) but few of the important places are given below:

Table 2.7 : List of historical places in Lamjung

SN	Historical/Tourism/Religious Place	Located VDC
1	Ghalegaun/GhanPokhara	Ghanpokhara
2	Honey Hunting place	Ghopte
3	Bhujung	Bhujung
4	Rinaskot	Rinaskot
5	KaudaChudka and sorathiNirthya	Rinaskot
6	Beshisahar	Beshisahar Municipality
7	BahraPokhari	Gotihawa
8	IlamPokhari	IlamPokhari
9	LamjungDarbar	Beshisahar Municipality

(District profile of Lamjung District, 2070)

The district has total 161 registered industries but total renewed industries are 37. The existing small cottage and agro-based industries in district are as given below.

Table 2.8: List of Industry in Lamjung District

S.N.	Industries	Registered	Percentage coverage
1	Productive Type	40	24.8
2	Tourism	64	39.8
3	Forest animal based	28	17.4
4	Services type	29	18.0

(District profile of Lamjung District,2070)

The district has 5 Hospital(1 Government and 4 Private),2 Primary health centre,13 Health post,45 sub-health post,8 Ayurvedic hospital,171 gaunghar clinic,197 khop clinic and 75 private medical hall etc.

2.7.5 District Road Core Network(DRCN) in Lamjung District.

The detail about the SRN, UR, DRCN and VRCN Road of Lamjung District is as follows:

Table 2. 9: List of Roads in Lamjung District

Road Class	**Total length; km**	**Black Top; km**	**Gravel; km**	**Earthen; km**
Strategic Road network	**72.04**	25.17	5.92	40.95
Urban Roads	**5.13**	3.05	1.07	1.01
District Road core network	**534.25**	4.47	84.12	445.67
Village Roads	**453.60**	-	19.01	434.59
Total	**1,065.02**	**32.69**	**110.12**	**922.21**

(DoLIDAR,2016)

Table 2. 10: List of DRCN Roads in Lamjung District

Road Code	**Name of Road**	**Total length; km**	**Black Top; km**	**Gravel; km**	**Earthen; km**
37DR001	Taghring (Rambazar)-Chhapadanda VDC Road	**1.00**			1.00
37DR002	Thakanbesi-Shitaldanda-Bahundanda-Ghermuphant Road	**8.55**		1.44	7.11
37DR003	Khudi-Bhache-Ghimarang-Ghanpokhara VDC	**8.23**			8.23
37DR004	Khudi (Chhaharekhola)-Bhulbhule VDC Road	**74.10**			74.10
37DR005	Khudi-Segle (Simpani) VDC Road	**5.79**			5.79
37DR006	Besishahar-Chandisthan VDC Road	**5.48**			5.48
37DR007	Besishahar-Baglungpani-Kapurgaun-Bhujung	**32.46**		19.24	13.22
37DR008	Kadelung-Bagum (Uttarkanya) VDC Road	**1.27**			1.27
37DR009	Kapurgaun-Maling-Salmebhanjyang Road	**14.77**			14.77
37DR010	Besishahar-Banjhakhet-Bhachokbesi VDC Road	**3.06**	0.32		2.74
37DR011	Banjhakhet-Hile-Karkidanda-ChitiTilahar	**10.12**			10.12
37DR012	Karkidanda-Majhgaun (Hiletaksar) VDC Road	**3.45**			3.45
37DR013	Karaputar-Daduwa-Gilung-Salmebhanjyang-Pasagaun-Singdi "	**33.00**			33.**00**

Road Code	Name of Road	Total length; km	Black Top; km	Gravel; km	Earthen; km
37DR014	Salmebhanjyang-Bhojegaun VDC Road	**0.98**			0.98
37DR015	Ranikuwa-Gaunshahar-Nalma-Rambazar (Karaputar) Road	**34.51**		8.53	25.98
37DR016	Rambazar-Bhantbesi-Kalyan-Majuwa-Rudi Dovan MHP Road	**4.72**			4.72
37DR017	Bakhrejagat-Purankot-Chihanpata-Satrasaya	**14.93**		7.09	7.84
37DR018	Chihandanda-Sindure VDC Road	**1.20**			1.20
37DR019	Neta (Jyamirebhanjyang)-Thansingkot-Bangre VDC Road	**3.08**			3.08
37DR020	Bimirebhanjyang-Jyamirebhanjyang-Neta VDC	**1.53**		1.11	0.42
37DR021	Koiralaphant-Dhuseni VDC Road	**2.86**			2.86
37DR022	Siundibar-Sundarbazar-Khatrithanti-Satrasaya-Bimirebhanjyang-Bhorletar Road	**26.69**	3.45	18.79	4.45
37DR023	Rithebagar-Tiwaridanda-Tinpiple-Tilahar-Hilebesi-Faleni Road	**21.27**			21.27
37DR024	Udipur-Ramchokbesi-Nauthar Sera-Kirtipur	**16.43**		7.10	9.33
37DR025	Sera-Shikhra-Kabakue (Nauthar) VDC Road	**3.50**			3.50
37DR026	Belghari-Archalbot-Lamabagar-Serabazar-Jitaure-Pachok Road	**10.98**			10.98
37DR027	Lamabagar-Shreemanjyang VDC Road	**15.51**			15.51
37DR028	Thanti-Archalbot VDC Road	**2.99**			2.99
37DR029	Bhoteodar-Belghari-Bharte-Gaunda Road	**17.28**	0.06	0.95	16.27
37DR030	Kaphalbot-Bharte VDC Road	**0.20**			0.20
37DR031	Duipiple-Samibhanjyang VDC Road	**5.42**			5.42
37DR032	Sundaradihi-Suryapal VDC Road	**4.16**			4.16
37DR033	Sotipasal-Taksar VDC Road	**2.84**			2.84
37DR034	Jitatar-Shaptadhara VDC Road	**4.91**			4.91
37DR035	Khatrithati-KunchhaBhanjyang-Sotipasal-Sundaradihi-Duipiple	**23.08**	0.64	18.15	4.29
37DR036	Paundidhik-Harrabot-Kuwapani (Mohoriyakot)-Pyarjung-Gaunda-Ilampokhari-Bichaur-Dudhpokhari-Kunaghat Road	**52.70**			52.70

Road Code	Name of Road	Total length; km	Black Top; km	Gravel; km	Earthen; km
37DR037	Kokegaun-Lamagaun (Pyarjung) VDC Road	**6.92**			6.92
37DR038	Bansarabesi-Kolki VDC Road	**4.21**			4.21
37DR039	Samghaderi-Taji (Ilampokhari) VDC Road	**3.00**			3.00
37DR040	Thanti-Kallabari (Dudhpokhari VDC)-Phiripaincho MHP Road	**7.11**			7.11
37DR041	Harrabot-Bhaisekhola Road	**2.38**			2.38
37DR042	Tarkughat-Dhamilikuwa-Chakratirtha-Sahilitar-Borangkhola-Bansarabesi Road	**27.03**		1.72	25.31
37DR043	Sahilitar-Balayakharka VDC Road	**10.56**			10.56
43	**Total**	**534.25**	**4.47**	**84.12**	**445.67**

(DoLIDAR,2016)

Road upgrading prioritization for blacktopped requiring in district are tabulated below:

Table 2. 11: List of DRCN Road Requiring Blacktopping

Code	Description	Total Length(Km)	Traffic (PCU)	Remarks
37DR007	Besishahar-Baglungpani-Kapurgaun-Bhujung	**32.46**	**51**	Beshisahar - Khlosothar R.M
37DR022	Siundibar-Sundarbazar-Khatrithanti-Satrasaya-Bimirebhanjyang-Bhorletar Road	**26.69**	**56**	Sundarbazar-Madhyanepal R.M
37DR023	Rithebagar-Tiwaridanda-Tinpiple-Tilahar-Hilebesi-Faleni Road	**21.27**	**52**	Beshisahar-Dordi R.M
37DR024	Udipur-Ramchokbesi-Nauthar Sera-Kirtipur	**16.43**	**55**	Beshisahar-Dordi R.M
37DR035	KhatrithatiKunchhaBhanjyang-Sotipasal-Sundaradihi-Duipiple	**23.08**	**78**	Sundarbazar-Madhyanepal R.M
37DR042	Tarkughat-Dhamilikuwa-Chakratirtha-Sahilitar-Borangkhola-Bansarabesi Road	**27.03**	**67**	

(DoLIDAR, DTMP of Lamjung District, 2016)

DOR has already started the construction of road 37DR042. So, only 5 roads has been taken for the detailed study with redefined named as 37DR007 is DR001,37DR022 is DR002 and so on for the research purpose only.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Research Design

The methodology to prioritize the road upgrading based on Multi-Criteria Analysis has been evolved from literature review of Moazami et al., (2011) and similar studies. The methodology considers the role of the selected stretch in the socio-economic growth of the region and traffic demand on the corridor. The screening is conducted with the objective of identifying specific stretches of roads which are likely to lead to the overall economic development, by connecting settlements and backward area. The methodology followed is explained in this section.

The roads which are to be prioritized are first identified and the following secondary data are collected.

- Census classification of the towns, village along with their population.
- Educational Centre, Tourist spot, SEZ, heritage centre in the region.
- Industries, Market centre, Administrative area and possible settlements.

The primary data are collected includes classified volume and visual road inventory.

Proper planning for the research work is necessary to make the work effective and efficient. The process as a whole shall follow the standard method of research. From the formulation of research problem to the final preparation of research report, many activities need to be performed. This case study is carried out based on composite index using the Analytical Hierarchy process (AHP) tool. In the meantime, primary data were collected from questionnaire survey with the highly experienced road professionals from 30 experts including consultant, who have knowledge on rural road planning. Various steps have been followed in research work and can be expressed through flow diagram as follows:

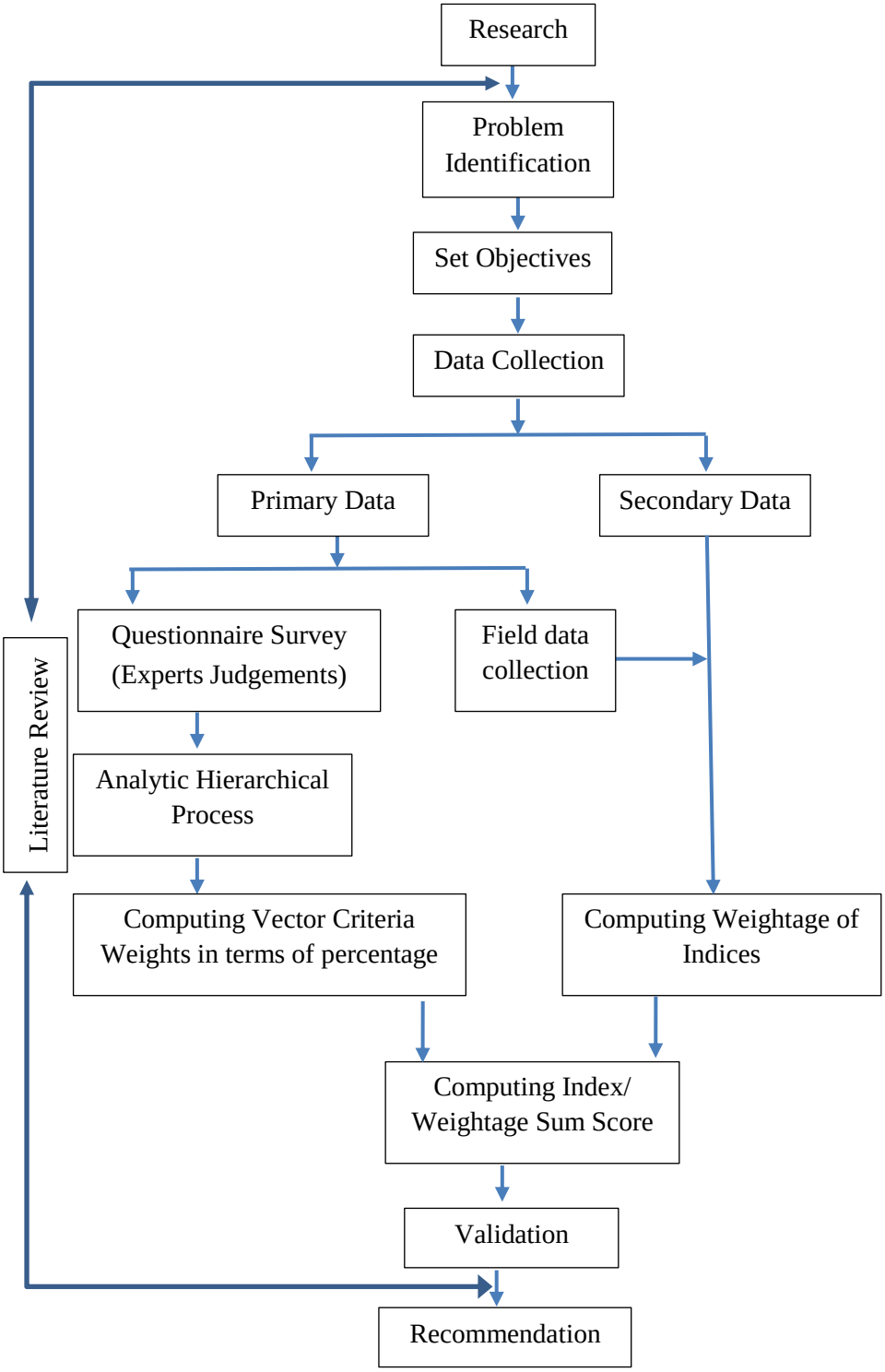


Figure 3.1: Flow diagram for Research Methodology

In order to achieve the objectives of this research, the work have been divided into five main stages as seen in figure 3.1.

First stage: Literature Review has been done in this stage. Ranking process, DTMP guidelines 2012, literature related to AHP, District Development Plan, and policy of Nepal Government etc. have been reviewed in this stage. The concentration will be on

the development of criteria on the ranking of DRCN roads. Parameters will be developed based on the data required for DTMP preparation based on DTMP guidelines 2012. Expert survey questionnaire form for DRCN ranking process has been developed based on the criteria/parameters. Development of parameters and expert Questionnaire form for the ranking of DRCN Roads are the main output of this stage.

Second stage: This stage involved the collection of secondary data of DTMP of Lamjung District. After the identification of DRCN Roads data such as cost of roads, roads importance, traffic volume, number of local bodies, HQs connection has been collected. Expert survey Questionnaire form for ranking of DRCN roads has been distributed to experts and collected in this stage. Collections of primary and secondary data are the main output of this stage.

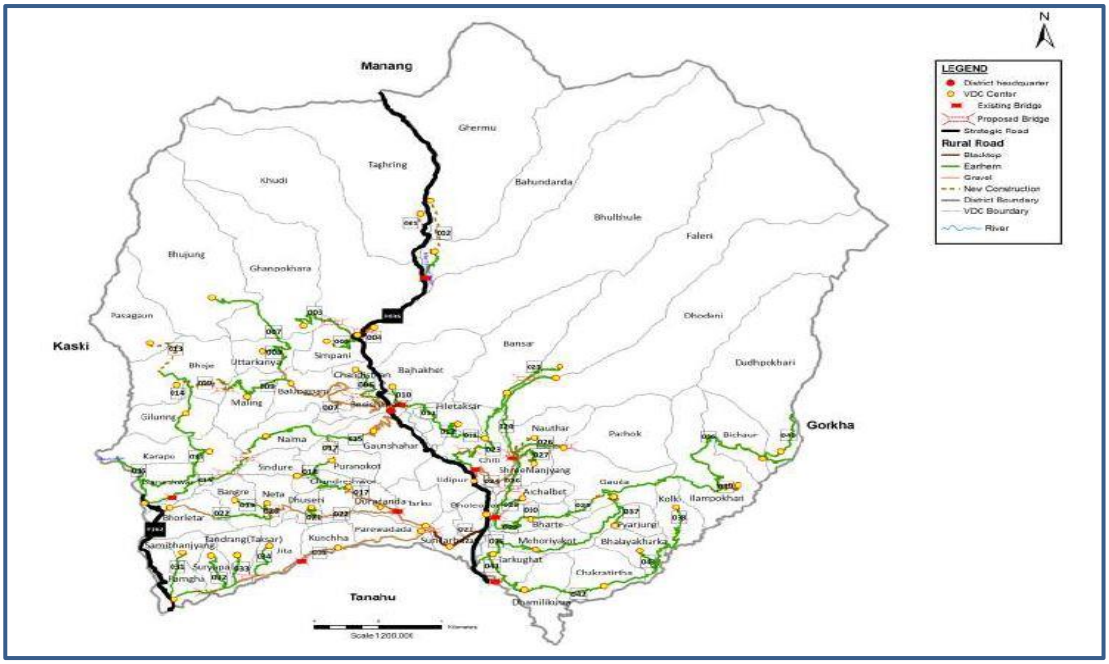
Third stage: DRCN Roads along with their respective data were collected. Data related to alternative roads were categorized for simplification. Likewise categorizations have been done for all other criteria; listing of all alternative roads and categorizing of their respective criteria are the main output of this stage.

Fourth stage: A simple and user friendly tool developed by Saaty (1985), used for pair wise comparison via questionnaire survey to develop the weightage of selected indicators is used in the ranking procedures. The Consistency Index (CI) of matrix organized from questionnaire survey was checked. The field data for selected parameters was collected from selected DRCN. Composite index was prepared for selected roads incorporating AHP weightage and field data base to rank the upgrading works of selected roads.

Fifth Stage: Conclusion and recommendation regarding the ranking of DRCN roads have done in this stage.

3.2 Study Area

Lamjung district is situated in Gandaki zone of western development region in Hill district. This district comprises 4 Municipalities and 4 Rural Municipalities for administrative purpose. Total area of district is 1692 sq.km.



(DTMP, 2016, Lamjung District)

Figure 3.2: DRCN Map of Lamjung District

The district is bordered with Manang and Gorkha in the North, Gorkha in the East, Tanahun in the south and Kaski in the West. Total number of DRCN and VRCN are 43 and 112 within district respectively. The table 3.1 below shows salient features of selected DRCN roads in study area.

Table 3.1: Salient features of Selected DRCN in Lamjung district

Road Code	Name of Road	Total Length(Km)	Right of way	Remarks
37DR007	Besishahar-Baglungpani-Kapurgaun-Bhujung	**32.46**	10 m either side	
37DR022	Siundibar-Sundarbazar-Khatrithanti-Satrasaya-Bimirebhanjyang-Bhorletar Road	**26.69**	10 m either side	
37DR023	Rithebagar-Tiwaridanda-Tinpiple-Tilahar-Hilebesi-Faleni Road	**21.27**	10 m either side	
37DR024	Udipur-Ramchokbesi-Nauthar Sera-Kirtipur	**16.43**	10 m either side	
37DR035	Khatrithati-KunchhaBhanjyang-Sotipasal-Sundaradihi-Duipiple	**23.08**	10 m either side	

3.3 Research Approach

The criteria and sub-criteria of prioritization were determined from the literature review as described in Chapter Two: 2.5.2 and these factors used in road planning were weighted from expert's ratings. The research includes both quantitative and qualitative approach. This case study is based on:

A. Link Performance

i. Population served

ii. Efficiency of Link

iii. Road utilization

iv. Rate of accidents

B. Link Accessibility

v. Accessible to educational services

vi. Accessible to Market Centre/Administrative Centre

vii. Accessible to Hospitals/Health posts

viii. Accessible to Tourism/Industry/Others

C. Link Connectivity

ix. Connectivity with NH

x. Connectivity with FR

xi. Connectivity with LRN

D. Link Associated Cost

xii. Upgrading Cost

xiii. Travel time Cost

A simple graphical figure representing the AHP procedure is presented in figure 3.3.

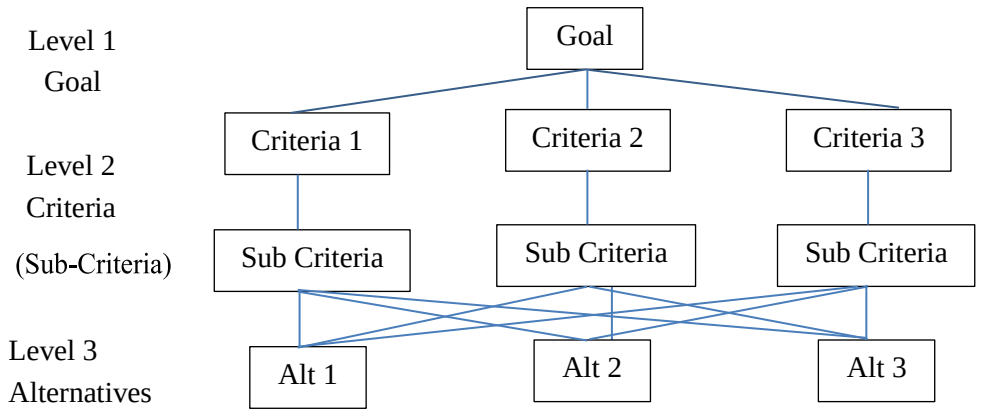


Figure 3.3: Analytical Hierarchical Process (Saaty and Vargas,2012)

The figure 3.4 below shows the simple graphical figure representing the overall research approach for the study.

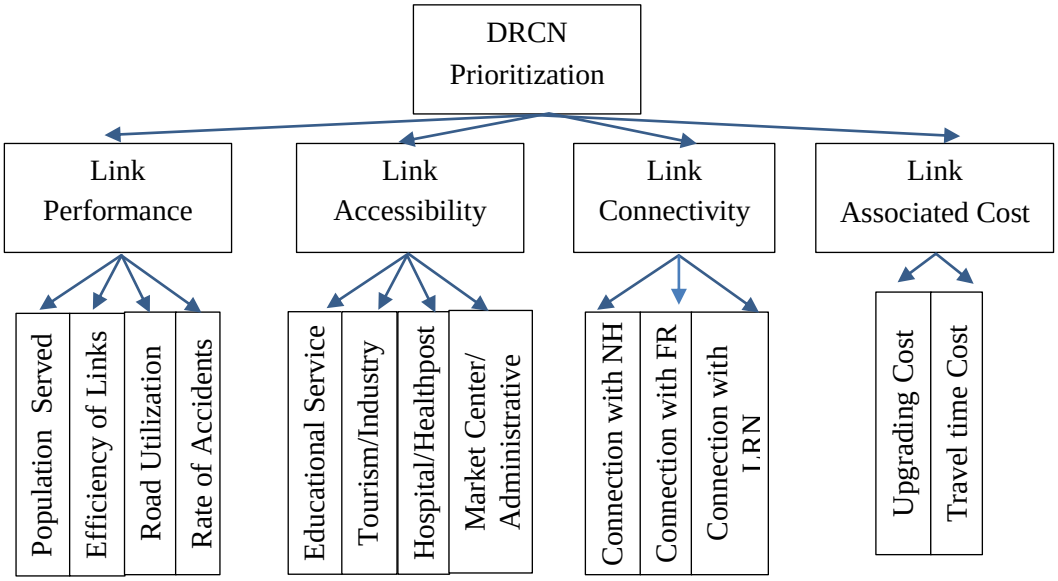


Figure 3.4: Research Approach

3.4 Sample collection and Sample Size

The samples were selected by purposive sampling. As the planning indicators were dependent upon the views of the experts, the required information were collected from them who were involved in the rural road planning and implementation. There was no general rule for sample size used in AHP. Some researchers run the survey within very small group (n=3) while some other have huge groups using AHP questions. The sample size of the questionnaires required to be collected for the analysis should be at least 4 to 5 times the number of independent variables or parameters considered (Prakashan et al.,2015). The sample size for this case study was taken thirty experts based upon the existing literature.

3.5 Methods of Data Collection

Two kinds of data were collected in this case study.

1. Primary Data
2. Secondary Data

The primary data were collected in two parts. Firstly, questionnaires were distributed to the expert involved in rural road planning to decide the weightage of various parameters as mentioned in research approach. Experts were categorized into client engineers and consultant engineers who were involved in rural road planning and

implementation. The second part of data was related to the selected DRCN of study area. Following data were collected on field.

1. Traffic Volume
2. Road inventory
3. Inventory of Growth Centre
4. Market Centre/Settlement.
5. Inventory of educational/Tourist/Health centres.

The secondary data were collected in the following form from different Government and non-Government Organizations.

1. Population of market centre
2. Unit price for road upgrading
3. Number of offices (Banks, Agricultural service Centres, Post office, Telephone office, Electricity office, Cooperatives, Non-Governmental Office (NGO)
4. Number of industries
5. Number of business and commerce (Hotel, Restaurants, Stationary, Hardware shop, Grocery Shops)
6. Number of students in education centres
7. Number of patients visited annually in Health Centres/Hospitals
8. Total land area and land use pattern (Cultivated Land, Residential Area)

3.6 Research Matrix

Table 3.2: Research Matrix

Specific Objective	**Data Needed**	**Source of Data**	**Analysis**
To identify the criteria and sub-criteria to be considered in prioritizing the DRCN		From the literature review to identify the criteria and sub-criteria that affect the upgrading prioritization of DRCN.	
To determine the weightage of factors those are considered for	Multi-criteria factors were used as decision support. **Linked Performance** • Population served, • Efficiency of links, • Road utilization	• **Primary Data:** Traffic volume of road, Number of market centre, Linkage with	Centrality index, Intensity of Interaction, Travel Time

prioritization using Analytical Hierarchical Process (AHP).	• Rate of Accidents **Link Accessibility** • Educational services • Tourism/Industry/ Others • Hospital/Health Post • Market/Administrative centre **Link Connectivity** • Connection with NH • Connection with FR • Connection with LRN **Link Associated cost** • Upgrading cost • Travel Time cost	NH, FR and LRN, Road inventory and Traffic Accidents • **Secondary Data:** Unit Upgrading Cost, Number of Population Number of Students, Number of Patients, Road Network Database, Road Network Map,	Value of Travelers' AHP to find out the weightage of indicators
To evaluate the characteristics of selected DRCN roads for prioritization.	• CI of each opinion of expert • CR of each opinion of expert • Calculation of W factor for each indicator • Calculation of Z score of each indicator based on Field Survey data.	• **Primary Data** Expert Opinion weightage (w) • **Primary and Secondary Data** Mean of each values of indicator for five roads Standard Deviation (Z) Score of each indicator	Calculation of Geometric Mean of all experts' opinion and check for CI and CR. Composite Index Score is calculated by multiplying W and Z of each indicator and summed them.
To develop prioritize list of upgrading for selected DRCN roads using composite index score.	• AHP weightage and composite index score on the sub-criteria	• Field measurement data	Description of road based on the score of sub-criteria

3.7 Rural Road Upgrading Index (RRUI)/Composite Index (CI)

Prioritization of road is done on the basis of above multiple criteria. This requires the assessment of various criteria and the evaluation of alternatives on the basis of each

criteria and the aggregation of each evaluation to achieve a composite index and then give a relative ranking of the roads.

The method used for finding the Rural Road Upgrading Index is the Weighted Sum Method. In this method all the indices are given a specific weight. After which for each of the project alternative a score is given for all indices based on the sub-criteria . The weightage of each of the above indices in the Rural Road Upgrading Index calculation is tabulated by survey among experts using Analytical Hierarchy Process (AHP). The scores set for each criterion are multiplied with the corresponding weightages and then added up to get Rural Road Upgrading Index for each road. The roads are ranked based on the final total score.

3.8 Data Analysis

The data collected as primary and secondary are quantitatively analyzed and a composite index was established using mathematical modeling (AHP). The Excel software was used to analyze the Eigenvector in the matrix form for find out the composite index.

3.8.1 Data analysis for AHP

The analysis of the data is done by AHP tool. AHP is mathematical tool which is very efficient and instrumental in pair wise comparison with very high degree of precision. Let {A1, A2 …… An} denote the alternatives (n is the number of compared alternatives) then a n x n decision matrix of pair wise comparisons is formulated which represents the intensities of the expert's preference between individual pairs of alternatives (ai versus aj, for all i, j =1, 2, ….n).

Table 3.3: Matrix Table of AHP

A =	A_{11}	…….	a_{1n}
	……	……..	…….
	a_{n1}	…….	a_{nn}

(Saaty & Vargas, 2000)

A comparison matrix A is obtained where the element a_{ij} shows the preference weight of a_i obtained by comparison with a_j. Each entry in the matrix A is positive (a>0) and reciprocal as;

$$a_{ji} = \frac{1}{a_{ij}}$$

Compute a vector of weights {w1, w2 ….. w_{nj}} associated with matrix A. Calculate the sum each column of the reciprocal matrix. Then, divide each element of the matrix with the sum of its column, we have normalized relative weight. The sum of each column is 1. The normalized Principal Eigenvector can be obtained by averaging across the rows as shown below.

aij = wi/wj …… (1)

As a result, the problem becomes that of finding an eigenvector w in order to satisfy equation (2):

Aw = λw …….. (2)

Where, λ is the average Eigenvalue of the matrix A. Now check the consistency of the matrix has to be calculated by using the formula.

$$CI = \frac{\lambda_{max} - n}{n-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where n is the order of matrix.

This consistency index is compared against a reference average Random Index (RI) which is given in Table 2.7 (Saaty and Vargas, 2000). The ratio of consistency index, CI, to the average random consistency index, RI, is called Consistency Ratio which is calculated by equation (4).

CR = CI/RI …….. (4)

If the value of CR is smaller or equal to 10% the inconsistency is acceptable. If the CR is greater than 10%, we need to revise the subjective judgment.

3.8.2 Data analysis for Field data

Field based data for each indicator were tabulated in their respective unit. It is assumed that probability distributions of all data are approximately normal and then measurement is normalized with the calculation of Z-score using the formula as per Baskota, 2009.

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

Where,

Z_{nj} = Z score of performance measure j on alternative n.

X_{nj} = the average Value of performance measure.

σ_j = Standard deviation of all alternative on performance measure.

μ = Overall mean of all alternatives.

The Z score is converted into percentile Score using Z table.

The individual score for each sub-criteria were tabulated for selected DRCN roads. These score were multiplied by tabulated weights calculated by AHP tool and were added up to give composite score. This score was then used to prioritize the district corridors. Composite score is calculated as per Linaraj, et al., 2013.

$$R_i = \sum_{j=1}^{n} W_j * Z_{jn}$$

Where,

$W_1, W_2 \ldots W_n$ are the weightage of sub-criteria j,

Z_{jn} is normalized score of performance measure for alternative n under the sub-criteria j.

Positive sign for criteria maximization and negative sign for criteria minimization is used in the calculation.

3.9 Measurement of Sub-Criteria

3.9.1 Link Performance

Link performance is determined based on four sub-criteria namely population served per kilometer, efficiency of links, road utilization and rate of accidents.

Population Served

Each link of road network served the population of the area within the road corridor. Total number of population within four hours walking distance from centreline of road was considered as population served by link. For this purpose, GIS based analysis (Buffer Analysis) at land use map of Lamjung district has been done to find out the influencing population. Total population served by the road corridor was calculated by using the formula:

Total Population = Built up area * Population Density (Population/Sq. Km).

Population density was taken from National census data. Settlement data of year 2011 has been used in this analysis so that total served Population of road corridor was calculated by using formula.

Future Population = Present Population * $(1+i)^{\wedge n}$

Where,

i = Growth Rate

n = Number of period

Link Efficiency

The efficiency of links was calculated by assigning the intensity of settlement linked by each road links. Efficiency of links has increased if the links is connected by settlement with higher value of intensity. The force of interaction between Market centres (Settlement) i and j were obtained by gravitational law as per Mahendra, et al., 1985.

$$F_{ij} = \frac{P_i P_J [|CS_i - CS_j|]}{d_{ij}^2} \quad \text{.....(5)}$$

Where,

F_{ij} is the Force of interaction between settlements i and j

d_{ij} is the spatial separation in the form of straight line distance between settlement i and j

CS_i and CS_j are the centrality index score of the settlement i and j

P_i and P_j are the population of settlements i and j respectively.

Centrality index was calculated using the following formula.

$$C_i = \sum_{i=1}^{n} W_j X_{ij}$$

Where,

C_i = Centrality index of the j^{th} market centre,

W_i = Weight of the j^{th} marketing functions,

X_{ij} = Value of the function (number of establishments/shops at the j^{th} market centre)

A settlement which has centres for marketing, clinics, schools and other commercial, social and welfare activities is called market centres. The weightage of a function was obtained on the median threshold population technique. According to the technique, the weightage is calculated as:

$$W_i = \frac{\text{Population Median } i^{th} \text{ Function}}{\text{Lowest Median population of the market centers where a function exists}}$$

The distance matrix was prepared among the market centre (Settlement) and presented in table as shown.

Table 3.4: Distance Matrix of Settlement

Market Centre	A	B	c	D
A	0	……	……	……
B	…….	0	…..	…….
C	…….	……..	0	…….
D	……..	…….	……..	0
Σd_{ij}				

Force of interaction among the settlement was calculated by using the equation (5). Values were summed along rows and column which should be equal. Overall matrix is presented as follows:

Table 3.5: Force of Interaction between Settlements

Market Centre	Centrality Index	Population	A	B	C	D	Σ
A			0	Fab	Fac	Fad	…….
B			Fba	0	Fbc	Fbd	…….
C			Fca	Fcb	0	Fcd	…….
D			Fda	Fdb	Fdc	0	…….
ΣF_{ij}			……	……	…….	……..	

Then, the intensity of settlements was calculated by dividing the ΣFij by Σdij and results were presented in graph according to the size of settlement data.

Road Utilization

Road utilization is the indicator of road uses. Road utilization is defined as the ratio of traffic volume in Passenger Car Units (PCU) to Design Capacity (C). As the DRCN Road has been standardized to meet the Level of Service B, the design service volume shall be around 0.5 times the maximum capacity of that link.

Road Utilization = V/C

Where,

V = Volume of traffic

C = Design Capacity

Rate of Accidents

Rate of Accidents could be the major sub factor under the link performance. If the rate of accident is higher within the link, performance would be lower of that link and vice versa. Rate of Accidents data will be collected from the District Police Office (Traffic Unit) of Lamjung District.

3.9.2 Link Accessibility

Accessibility of road was measured in terms of access to educational services, Tourism/industry/Others, Health Centres, and Market/Administrative Centres within four hours walking distance from the selected DRCN.

Table 3.6: Format of Link accessibility

S.N.	Number of Students influencing by links	Number of Tourism/industry/Others influenced	Number of health Centres	Number of Market Centres/Administrative centres
Road A				
Road B				
……				
Road N				

3.9.3 Link Connectivity

Connectivity of road was measured with direct linkage of roads with other existing roads in network. Total number of linkage was counted on field from walk through survey and presented in table format as shown in table 3.7.

Table 3.7: Format for Linkage of Road

S.N.	Direct Linkage with		
	NH	FR	LRN
Road A			
Road B			
……..			
Road N			

3.9.4 Link Associated Cost

Travel Time Saving Cost

Travel time study assesses the performance of the roadway system. Passengers travel time is based on type of transportation system and surface condition of road. Value of travel time is based on income of passenger and mode of travel. Travel time cost in road was calculated with the multiplication of total passenger numbers, travel time and passenger's time cost. Travel time cost by mode is presented as shown in table 3.8.

Table 3.8: Travel time Cost by Mode

S.N.	Mode of Travel	Cost of Travel	Remarks
1	Motorcycle	NRs 5.61/Hour	
2	Car	NRs 24.96/Hour	
3	Bus	NRs. 62.40/Hour	
Road N			

(Bhandari and Shrestha, 2014)

Travel Time Saving Cost = Total Number of passenger *Travel Time*

Time value of Travelers (Maibach, et al., 2008)

Table 3.9: Format for travel time cost calculation

Link Name	1	2	3	4	5
AADT					
Bus	…..( )				
Car					
Motorcycle					
Travel Time Cost					
Bus+Car+Motorcycle					

Capacity of Bus = 25 Passenger, Capacity of Car = 5 and Capacity of Motorcycle = 1.5. The given figures of AADT is multiplied with the capacity provides total number of passenger (Shrestha, 2002). Values in Bracket represent the travel time for respective mode.

Upgrading Cost

The upgrading cost of road was calculated based upon the existing condition of road and its required intervention to upgrade to all weather DRCN standards according to the Nepal rural road standard second Revision.

The detail road inventory was taken from field and required intervention cost was calculated in detail rather than unitary method of calculation and presented as shown in table 3.10.

Table 3.10: Format of road inventory

		Surface Condition (Km)			Required Structures				
Road Name	Total Length	Black Top	Gravel	Earthen	Retaining Wall (Nos)	Hump Pipe Culvert	Slab Culvert (Rm)	Bridge (Rm)	Drainage
Road A									
Road B									
……..									
Road N									

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Determination of Criteria and Sub-criteria

The criteria and sub-criteria of prioritization were determined from the literature review as described in Chapter Two: 2.5.2 and these factors used in road planning were weighted from expert's ratings. Following results has been obtained from the study:

A. Link Performance

i. Population served

Total population influenced by the link was taken as the population that passes the alignment in all DTMP guidelines as it is reliable and practical. For that, this case study adopted GIS buffer analysis to find out the influencing population within 4 hours of walking distance from road head. Shrestha (2016) has also suggested the population served within road corridor (Zone of Influence) as first and foremost factor while planning rural road network.

ii. Efficiency of Link

Only the concept of centrality index was used to find the importance of settlement while the impacts of settlement interactions were not analyzed in DTMP guidelines. Due to these limitations, the new concept of settlement interaction was adopted in this case study using the gravity model as suggested by (Kumar and Tillostons, 1985; Shrestha, 2002; Shrestha, 2013). Efficiency of link depends upon the interaction between settlements. The details measurement and analysis is attached in Annex-VII, Annex-VIII and table 4.8.

iii. Road Utilizations

Maximum weighted value has been taken in traffic volume of local road planning in three DTMP guidelines. Traffic volume was the major indicator of local road planning in three DTMP guidelines. Traffic volume was the basis for selection of surface condition. Approach manual 1999 and interim DTMP guideline 2010 proposed the measure of average traffic flow over a 24 hours period and then conversion of the hourly traffic namely Motorcycle, Car-Jeep-Minibus, Tractor, Truck, Bus. This new guideline has focused on carrying out at least two interviews for every 10 km of road and has taken an average for the estimation of number of vehicle

in each category in each interview. This case study adopted seven days traffic count and conversion of Average Daily Traffic (ADT) to Annual Average Daily Traffic (AADT) based on PCU factors and vehicle composition to represent more accurate traffic data. The concept of road utilization was used to identify the current status of road uses.

iv. Rate of Accidents

In previous DTMP guidelines, Rate of Accidents were not considered within the link for road upgrading prioritization. Since Rate of Accidents is the huge loss in real socio economic parameter while analyzing the rural roads, it could be the major sub factor under the link performance. If the rate of accident is higher within the link, performance would be lower of that link and vice versa. Rate of Accidents data has been collected from the District Police Office (Traffic Unit) of Lamjung District within the study area. Only number of accident has been taken for analysis.

B. Link Accessibility

The main theme of the rural roads was conceptualized to provide accessibility. Haward and Richard (1984) had applied the concept of link accessibility to social services. National transport policy 2001 also recommends to achieve 4 hours walking distance to the nearest road head in case of Hill districts. So, it is justifiable to consider the accessibility indicators for various services namely:

v. Accessible to educational services

vi. Accessible to Market Centre/Administrative Centre

vii. Accessible to Hospitals/Health posts

viii. Accessible to Tourism/Industry/Others

C. Link Connectivity

Connectivity is prime factor for the accessibility. High connectivity represents the high accessibility and low isolation whereas low connectivity represents the low accessibility with high isolation of settlements. Connectivity is not only the measure of relative isolation but also measure of centrality. So that it is justifiable to incorporate the connectivity of roads with other roads. In this case study three kinds of connectivity namely:

ix. Connectivity with NH

x. Connectivity with FR

xi. Connectivity with LRN

D. Link Associated Cost

Link associated cost is found out based on two sub-criteria namely travel time saving cost and upgrading cost of that link of DRCN.

xii. Upgrading Cost

Total upgrading cost of roads was taken in different way. There was various method of cost calculation during planning stage. Previous DTMP guideline used the basis of unit cost of intervention method while estimating were used as the basis of innervations. This case study has calculated the total cost required to upgrade the roads into DRCN standards using reference of Detail Project Report.

xiii. Travel time cost

Previous DTMP guidelines did not consider the travel time cost in link. Travel time is the largest cost of transportation in real socio economic parameter while analyzing the rural roads. Shrestha (2002) and Bhandari & Shrestha (2014) have applied their case study in Nawalparasi and Dang district respectively. They have recommended using including the travel time cost parameter for further research while planning the local road networks. In this case study, travel time costs of road user were measured by considering the time value of travelers and travel of respective modes.

4.2 Weightage of Prioritization Criteria and Sub-criteria

The expert questionnaire survey form was prepared and interviewed from thirty experts working on rural roads planning and implementation in Nepal. The matrix table was prepared for each expert and weightage of prioritization factors were obtained by calculating the eigenvector of the matrix. The eigenvector gives the weights of each item based on the experts' viewpoint.

4.3 Development of comparison matrix

The geometric mean of ratings taken from key informant was calculated after checking the consistency ratio of view of each expert. Then it was put in matrix table

as shown in table 4.1. The geometric mean value of expert rating for A to B is 0.93. Furthermore, the value of B to A was taken the reverse value of A to B and the other values were computed and filled in the similar way. The value of A to A, B to B, C to C, D to D was kept 1 as per rule of AHP. Similar procedure was followed for the sub-criteria also. The table 4.1 below shows the comparison matrix for criteria.

Table 4.1: Comparison Matrix for Criteria

	A	B	C	D
A	1.00	0.93	1.07	1.90
B	1.08	1.00	0.48	0.73
C	0.93	2.10	1.00	0.99
D	0.53	1.37	1.01	1.00
Sum	3.53	5.40	3.56	4.62

Where,

A= Link Performance

B= Link Accessibility

C= Link Connectivity

D= Link Associated Cost

4.4 Calculation of Eigenvector Matrix

The summation value of column from A to D is computed and each respective row was divided by the respective summation value. The table 4.2 below shows the eigenvector of matrix.

Table 4.2: Calculation of Eigenvector of matrix

	A	B	C	D
A	0.28	0.17	0.30	0.41
B	0.30	0.19	0.13	0.16
C	0.26	0.39	0.28	0.21
D	0.15	0.25	0.28	0.22

After dividing each row from its respective summation, the summation of row was calculated then each sum is divided by 4 since we have taken 4 factors which give the relative weight and Eigen vector. The table 4.3 below shows the relative weight of A (Link performance) is 0.2919 equivalents to 29.19%.

Table 4.3: Eigenvector Calculation

	A	B	C	D	Total	Weightage(W)
A	0.28	0.17	0.30	0.41	1.17	0.2919
B	0.30	0.19	0.13	0.16	0.78	0.1953
C	0.26	0.39	0.28	0.21	1.15	0.2870
D	0.15	0.25	0.28	0.22	0.90	0.2257
	1.00	1.00	1.00	1.00		

Hence, the priority vector (W) weightage of each prioritization factors for consistency ratio calculation. The table 4.3 gives the weightage of factors from A to D which showed the relative weight matrix of factor A which links performance was highest similarly links Accessibility factors 'B' was the lowest.

Table 4.4: Relative weight Matrix

	A	B	C	D	Total	Average(W)
A	1.00	0.93	1.07	1.90	1.17	0.2919
B	1.08	1.00	0.48	0.73	0.78	0.1953
C	0.93	2.10	1.00	0.99	1.15	0.2870
D	0.53	1.37	1.01	1.00	0.90	0.2257

For Eigenvalue Lambda (λ) calculation, the matrix multiplication of first matrix table 4.1 as a result of expert survey was multiplied with relative weight matrix table 4.4 which gives the value 'Ws'. The Eigen value was obtained after multiplying Ws with 1/W. The average of Eigen value is performed which gives rise to the required Eigen value. Lambda (λ) is taken as the mean value of the computed different 4 lambda which is 4.15. The table 4.5 below shows the necessary calculation procedure for Lambda value.

Now, Ws* (1/W)

Ws= Weight after matrix multiplication

W= Relative weighted matrix

Table 4.5: Eigen Value Calculation

Ws	Average(W)	Ws*1/W
1.21	0.2919	4.15
0.81	0.1953	4.15
1.19	0.2870	4.16
0.94	0.2257	4.15
	Sum	16.60
	Lambda	4.15

4.5 Consistency Valuation

We Know that, Consistency Ratio = CI/RI

CI = (λ-n)/ (n-1)

λ= 4.15

n=4

CI= 0.0501

Since n= 4 from table 2.7 of Random Index, RI=0.9

CR= CI/RI

CR = 0.0557< 0.1 hence, it fulfills the consistency criteria.

4.6 Weightage on First Level Criteria

From the analysis of questionnaire survey using AHP, it was found that 29.19 percent of experts have focused on the link performance while prioritizing the rural roads. Similarly, links performance was followed by link connectivity, link associated cost, link accessibility respectively as shown in figure 4.1.

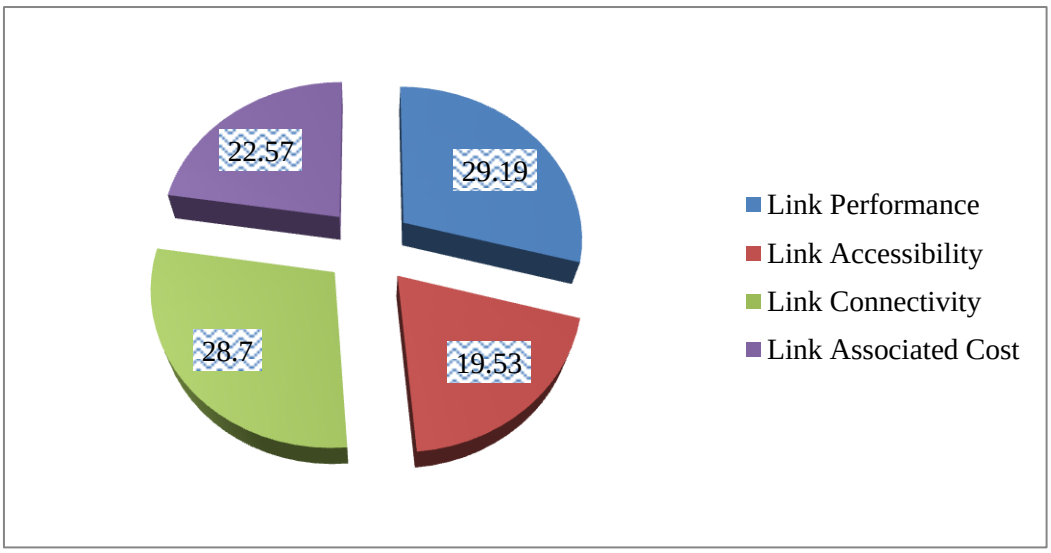


Figure 4.1: Experts Weightage on First Level Criteria

4.7 Weightage on Second Level Criteria

4.7.1 Link Performance

After analysis of different parameters of link performance, it was found that road prioritization based on rate of accident of vehicles by 9.0% which was followed by road utilization by 8.4% population served by 6.7% and efficiency of links by 5.1% respectively as shown in figure 4.2.

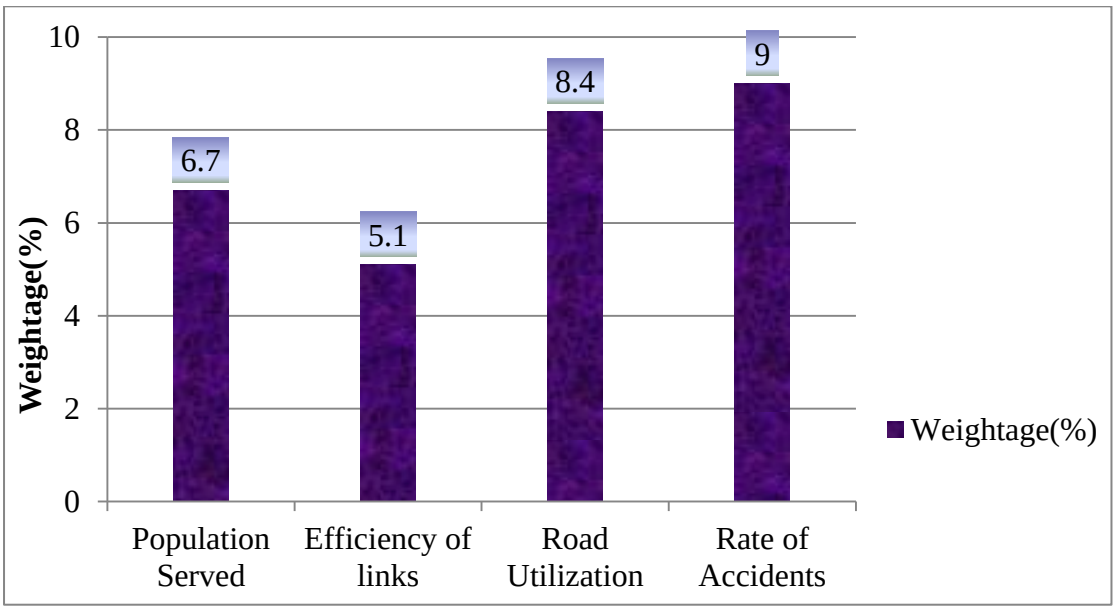


Figure 4.2: Link Performance

4.7.2 Link accessibility

With regards to the link accessibility of roads, roads under case study are accessible for different kinds of services. Based on expert's views, it has been clearly seen that accessibility of hospitals as a first priority (6.4%), Likewise, roads prioritization is based on educational services by 5.1% whereas Tourism centre by 4.5% and market centre by 3.5% as shown in figure 4.3.

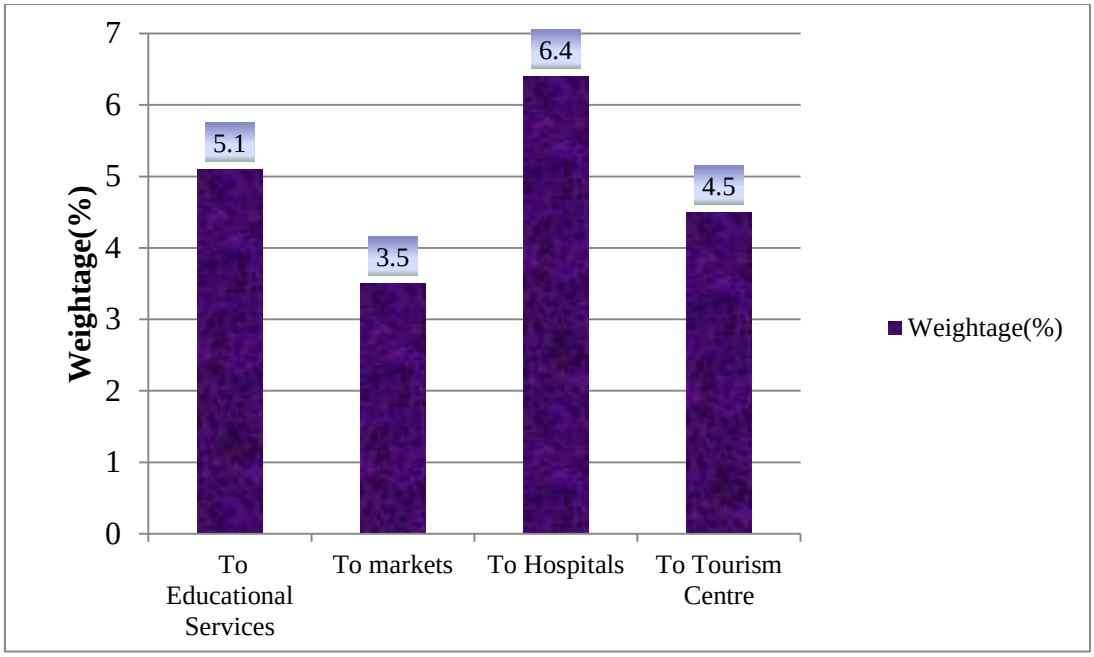


Figure 4.3: Link Accessibility

4.7.3 Link Connectivity

With regards to the link connectivity of roads, roads under case study connect three kinds of roads (NH, FR and LRN) which were taken as one dimension of prioritization. It has been clearly seen that connection with Local Road Network had taken as first priority (10.77%). Similarly, Feeder road connectivity had taken as second priority (9.25) whereas connectivity of NH equivalent to 8.68% as shown in figure 4.4.

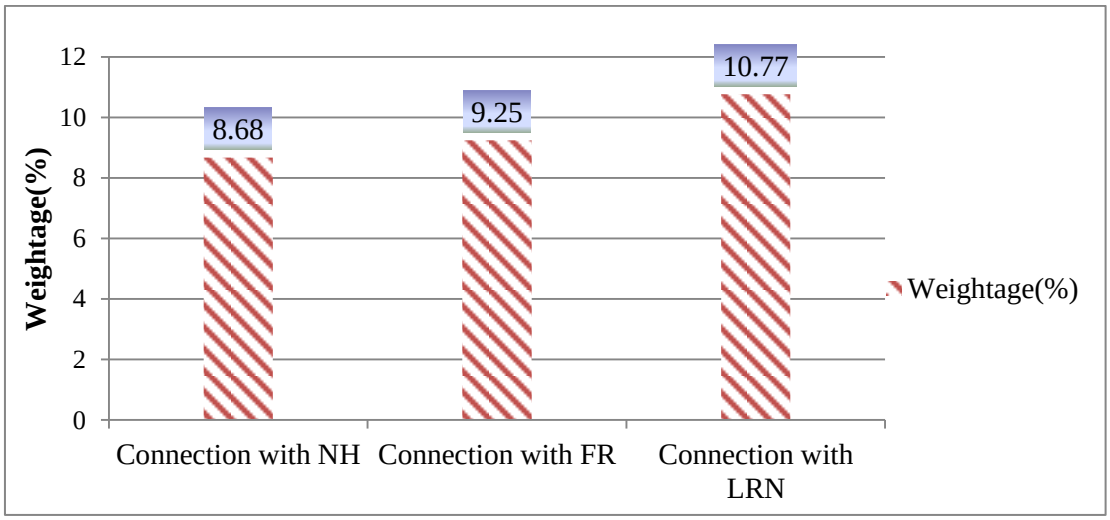


Figure 4.4: Link Connectivity

4.7.4 Link Associated Cost

After analysis of different parameters for link associated cost, it was found that road prioritization had based on travel time cost of road users by 14.2% which was followed by upgrading cost 8.37% as shown in figure 4.5.

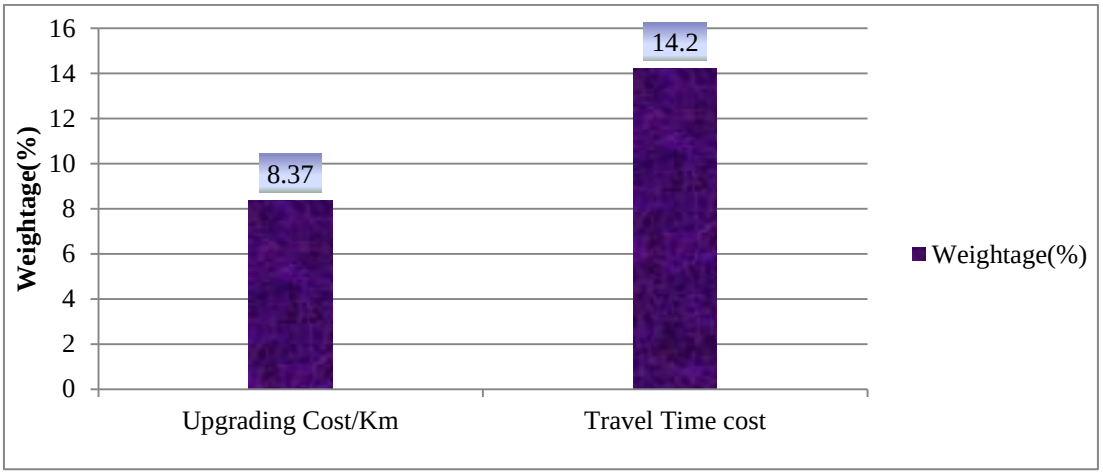


Figure 4.5: Link Associated Cost

4.8 Field Measurement and Analysis for determining road characteristics

4.8.1 Link Performance

Population Served

The table 4.6 below shows the total population served by five roads based upon GIS buffer analysis for 4 hours walking distance from road centreline. It is noticed that the road DR003 has influenced highest population of 33333 whereas the road DR002 has influenced lowest population of 17752. Similarly the road DR001 has second highest influencing population of 29729 and followed by DR005, DR004. Buffer analysis map is attached in Annex-V.

Table 4. 6: Affected Population by each Road Link

Road Code	DR001	DR002	DR003	DR004	DR005
Length (Km)	32.46	26.69	21.27	16.43	23.08
Infuencing Area (Km^2) (from GIS analysis)	311.26	185.86	349	290	278.79
Population Density/ Km^2	99.13				
Growth Rate	-0.53				
Number of year	7 Years (from Settlement Base data)				
Population Served at Present (Nos)	29729	17752	33333	27698	26627

Link Efficiency

Market centres of Lamjung district is presented geographically based upon the field data from study area. Distance matrix between the settlements and force of interaction were calculated and attached in Annex-VII and Annex-VIII respectively. Centrality index and intensity of settlements were calculated and attached in Annex-IX. Now the individual link efficiency was calculated by adding the intensity of settlement passing by alignment of road within the influencing zone (4 hours walking distance). The table 4.7 below shows the efficiency of each link. It is noticed that the road DR002 has highest link efficiency of 2240.47 because it passes large numbers of settlement as compared to other roads. The link efficiency of DR002 is followed by DR005 DR001, DR003 and DR004 respectively. The Table 4.7 below shows the link efficiency of individual link.

Table 4. 7: Link Efficiency of each link

Parameter	**DR001**	**DR002**	**DR003**	**DR004**	**DR005**	**Remarks**
Settlement Passing	1,2	4,5,6	8,7	8,9	5,10,11,12	
Link Efficiency	9.19	2240.47	1.27	0.71	1080.09	

Table 4. 8: Intensity of Market Centre/Settlement

S.N	**Name of Market Centrre/Settlements**	**Centrality Index**	**Population**	**∑Fij**	**∑dij**	**Intensity of Market Centre/Settlement (∑Fij / ∑dij)**
1	Besishahar	564.65	34642	2206.37	292.52	7.54
2	Kapurgaun	81.29	6230	804.68	487.78	1.65
3	Siundibar	121.10	40842	39176.80	192.93	203.06
4	Sundarbazar	334.04	40842	224742.16	192.93	1164.89
5	Khatrithanti	103.89	40842	214335.96	199.51	1074.31
6	Bhorletar	194.49	22367	535.86	422.8	1.27
7	Hilebesi	62.25	5708	200.93	329.43	0.61
8	Udipur	96.17	5708	133.11	202.93	0.66
9	Nauthar Sera	101.76	5708	20.79	372.93	0.06
10	Kunchha Bhanjyang	86.66	22367	302.65	245.51	1.23
11	Sotipasal	82.83	22367	582.62	295.85	1.97
12	Duipiple	165.16	22367	992.72	384.98	2.58

Road Utilization

The figure 4.6 below shows the road utilization value of each link. It has been clearly noticed that road DR001 has accommodated highest traffic flow among five DRCN. The calculation sheets are attached in Annex-III and Annex-IV. It is Concluded that traffic are less than design capacity because utilization values are less than 1.Whereas other three roads DR002,DR003 and DR004 have almost equal road utilization values.

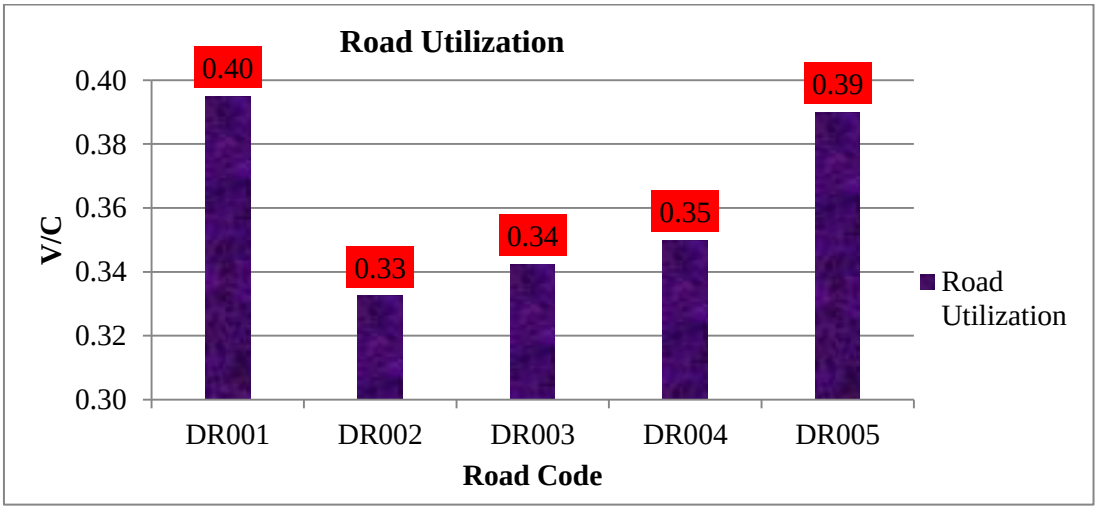


Figure 4. 6: Road Utilization

Rate of Accidents

The figure 4.7 below shows the rate of Accidents of each link. It has been clearly noticed that road DR001 has accommodated highest rate of accident among five DRCN. It is Concluded that DR001 has only one casualties due to surface condition of road .Whereas other four roads DR002, DR003, DR004 and DR005 have not taken the casualties due to the surface condition of links.

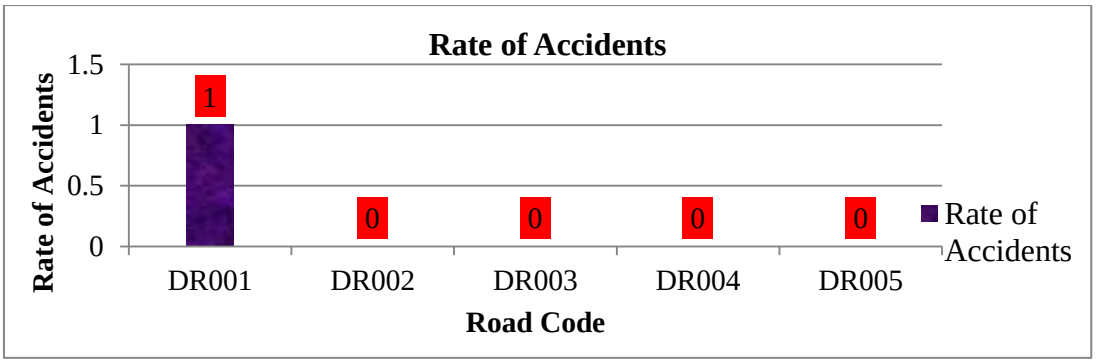


Figure 4. 7: Rate of Accidents

4.8.2 Link Accessibility

Educational Service

The table 4.9 below shows total influencing number of educational services and their respective student's number within 4 hours of walking distance (zone of influence). Total number of educational service were found using the buffer analysis in GIS. It has been clearly noticed that road DR002 has influenced highest number of students 4620 with highest number of educational service among five DRCN. The road DR001 has almost fifty percent accessibility to educational services as compared to DR002. The lowest accessibility for educational services is provide by DR004 among five DRCN selected for the study.

Table 4. 9: Number of influencing students

Parameters	**DR001**	**DR002**	**DR003**	**DR004**	**DR005**	**Remarks**
Educational Services(No.)	17	36	16	13	27	
Students Numbers	2182	4620	2053	1668	3465	

Tourism Industry

The figure 4.8 shows the total accessible number of tourism spot and industry by the road corridor within 4 hours walking distance. It is clearly noticed that the highest accessibility to both industry and tourism is provided by road DR005 among five roads. It is following by road DR002, DR001, DR003 and DR004.

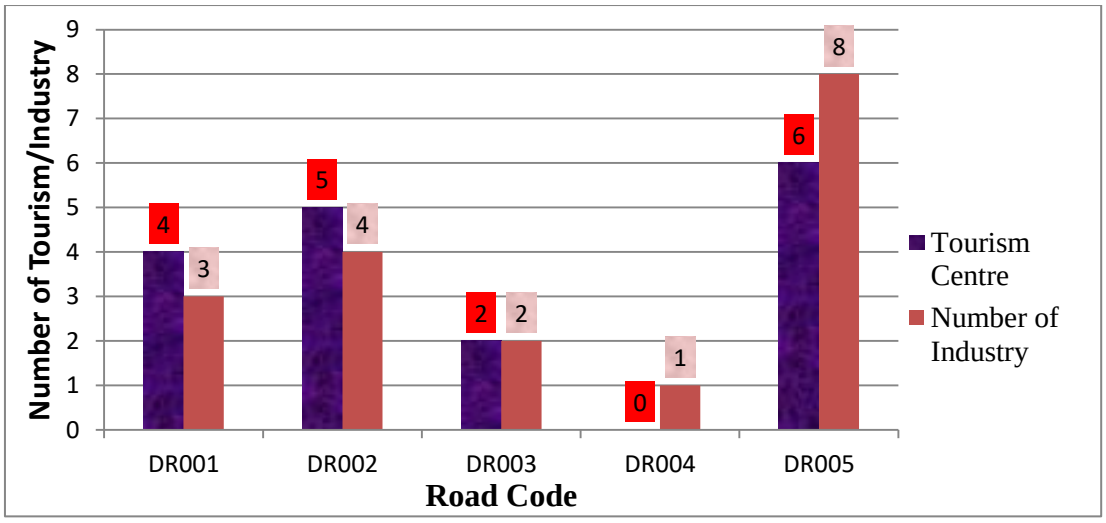


Figure 4. 8: Tourism Spot and Industry covered by each link

Health Centre

The figure 4.9 below shows the total number of health centre influenced by road corridor within 4 hours walking distance. Total influencing health centre within study area was found using GIS map and secondary data from DHO, Lamjung. It is clearly noticed that the road DR002 have provided highest access to 13 health centres where other two roads DR001 and DR005 have provided nearly equal accessibility to 10 health centres and remaining two roads DR003 and DR004 have provided nearly equal accessibility to 7 health centres by respective links.

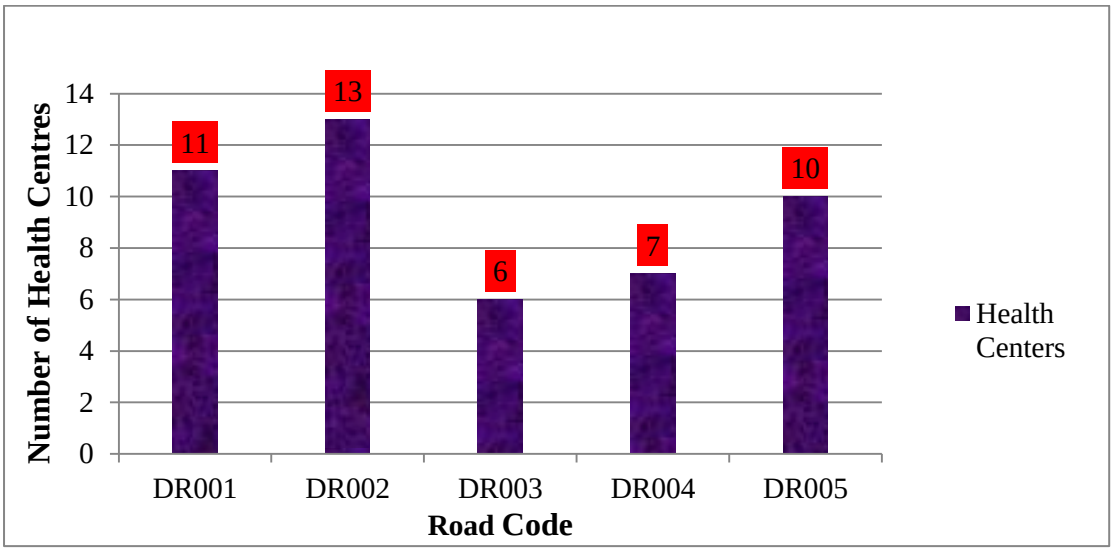


Figure 4. 9: Number of Health Centre of each link

Market Centre/ Administrative Centre

The figure 4.10 below shows the accessibility to market centre and administrative centre by five DRCN selected for periodization within study area. Total influencing number of administrative centre and market centre where identified from GIS map and secondary sources. It is observed that DR002 has highest accessibility to market centre whereas DR001 has highest administrative centre followed by road DR005 while others three roads have nearly equal level of accessibility to administrative centre and accessibility to market centre is gradually declined from four to one number.

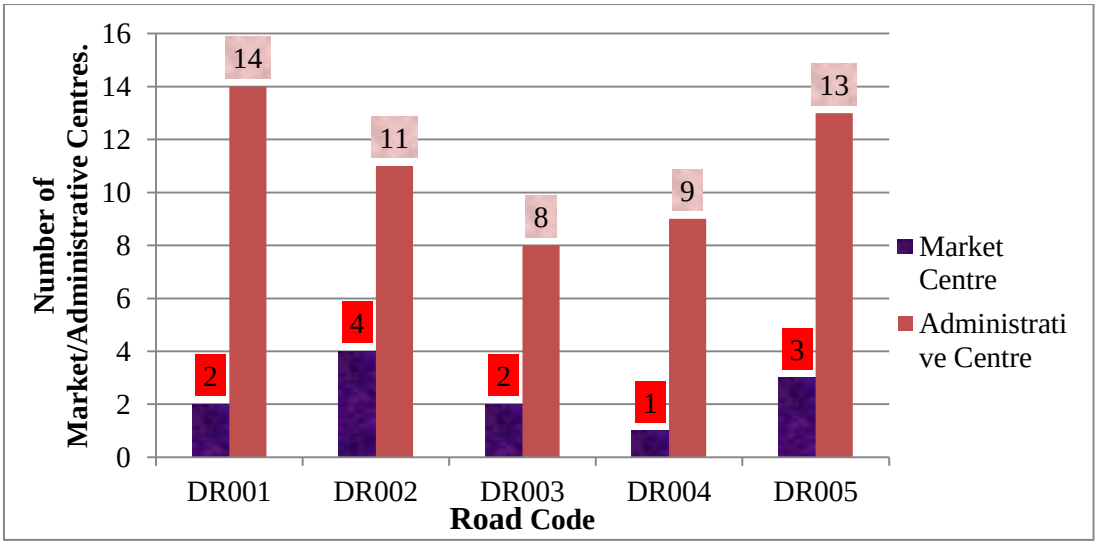


Figure 4. 10: Market Centre/ Administrative Centre of each road

4.8.3 Link Connectivity

In this case study; three kinds of connectivity were counted based on walkthrough survey in study area. The figure 4.11 below shows the three kinds of connection for five roads. It is noticed that all roads have higher connectivity with local road network as compared to FR and NH connectivity. The road DR002 has highest connectivity with LRN and followed by other roads DR005, DR003, DR001 and DR004 respectively. In addition to that, one road DR003 have no connectivity with FR. There was no any Connectivity of all selected local road to NH.

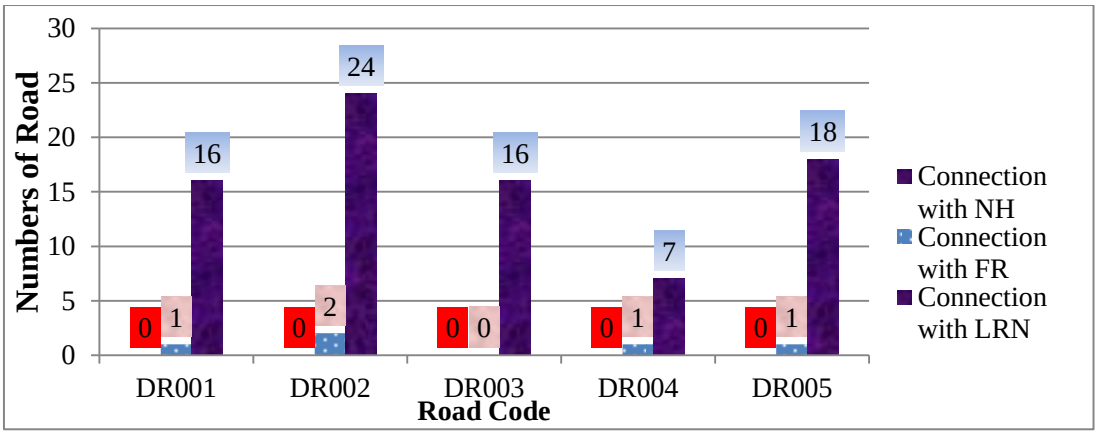


Figure 4. 11: Connectivity of road networks

4.8.4 Link Associated Cost

Upgrading Cost

From the inventory of road links and cost of intervention, total cost of intervention was calculated. It has been clearly noticed that the road DR001 has 16.24 km length

of gravel surface and 13.22 km length of earthen surface with requirement of minor and major structures. Similarly, other four road also have the different types of surface and require the minor and major structures. Major cross drainage structures (bridge and causeway) are also required along the selected DRCN within study area. The table 4.10 below shows the inventory of roads describing the surface condition and required structures.

Table 4. 10: Road Inventory

S.N	Length (Km)	Surface Condition			Required structures						
		Blacktop surface	Gravel	Earthen	Retaining wall (Cu.m)	Gabion wall (Cu.m)	Bridge (Rm)	Slab Culvert (no.)	Hume Pipe Culvert (Nos)	Causeway (Rm)	Drainage (Rm)
1	32.46	3.00	16.24	13.22	7081.98	22314	0	6	82	2	14000
2	26.69	3.45	18.79	4.45	13959.86	21098.45	0	7	66	4	5000
3	21.27	0.00	0.00	21.27	12762	20956.3	0	9	69	7	21270
4	16.43	0.50	7.10	8.83	9837.79	2862	0	2	44	20	16490
5	23.08	0.64	18.15	4.29	11525.57	10272	1	5	29	3	9029

While comparing the cost per kilometer (km), necessary intervention cost for road (DR005) is 17753.63 ('000) because it has longest gravel surface. Similarly, the lowest cost was required for the road (DR002) because it has least earthen surface. Other three roads DR001, DR003 and DR004 have requires nearly equal amount.The intervention cost of road was computed according to Nepal roads standard 2012, first revision with district rate. The table 4.11 below shows the total upgrading cost and per kilometer cost required for the intervention.

Table 4. 11: Intervention Cost of Road

Parameter	**DR001**	**DR002**	**DR003**	**DR004**	**DR005**	**Remarks**
Length	32.46	26.69	21.27	16.43	23.08	
Total Upgrading Cost	499085.55	359,762	348,414	270,731	409,754	
Upgrading Cost/Km in Thousand	15375.40	13479.28	16,380.53	16,477.85	17,753.63	

Travel Time Cost

Total travel time cost was calculated using the travel time, total number of traveler's in year with capacity of Bus, Car and Motorcycle only. Values in the bracket represent the respective travel time saving by mode of travel. Total travel time saving cost in individual road links are presented in table 4.12

Table 4. 12: Travel time saving cost

Parameter	DR001	DR002	DR003	DR004	DR005	Remarks
Bus	2(90)	3(70)	3(56)	3(40)	6(61)	
Car/Jeep	56 (52)	17(40)	28 (26)	43 (21)	6 (31)	
Motorcycle	86(42)	49 (36)	50 (19)	45 (20)	59 (15)	
Travel Time Cost Nrs. in Thousand (Bus+Car+Motorcycle)	4103.89	2599.46	2195.65	1907.29	3659.86	

4.9 Ranking of selected Roads

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

$$Znj = \frac{Xnj-\mu}{\sigma j}$$

Where,

Z_{nj} = Z score of performance measure j on alternative n.

X_{nj} = the average value of performance measure.

σ_j = Standard deviation of all alternative on performance measure.

μ = Overall mean of all alternatives

The Z score is converted into percentile Score using Z table.

The table 4.13 below shows the mean and standard deviation of thirteen sub-criteria.

Table 4. 13: Mean and Standard Deviation

S.N	Parameters	Max. Value	Min. Value	Mean Value (μ)	Standard Deviation (σ_j)
1	Population Service	29729.00	26627.00	27027.80	5171.12
2	Link efficiency	9.19	0.71	666.35	890.65
3	Road Utilization	0.34	0.40	0.36	0.03
4	Rate of Accidents	0.00	0.00	0.20	0.40
5	Educational Service	2182.00	1668.00	2797.60	1093.25
6	Tourism/Industry/ Others	5.00	6.00	7.00	4.43
7	Health Centres	11.00	10.00	9.40	2.58
8	Market/Administrative centre	2.00	3.00	13.40	2.80
9	Connection with NH	0.00	0.00	0.00	0.00
10	Connection with FR	2.00	1.00	1.00	0.63
11	Connection with LRN	24.00	7.00	16.20	5.46
12	Upgrading Cost	17753.63	13479.28	15893.34	1423.77
13	Travel Time saving Cost	4103.89	1907.29	2893.23	848.34

4.9.1 Besishahar-Kapurgaun-Bhujung Road (DR001)

The Rural Road Upgrading Index score (based on index values of thirteen sub-criteria) of Besishahar-Kapurgaun-Bhujung road (DR001) is 0.528 calculated by multiplying Z value and AHP coefficient. The value of Z is calculated using the standard normal table available for the normal curve having $\mu = 0$ and $\sigma = 1$. Technically, this link provides good connectivity to other road network especially LRN. The parameter connection with LRN contributes the third highest index score of 0.053 in evaluation of road. Furthermore, this road starts from heart of Lamjung district (i.e headquarter of the district, Beshisahar) and passes through Khwolosothar Rural Municipality and ends at Bhujung (one of the tourist destination). This road is second highest among the five DRCN with score of 0.047 in terms of total population served within 4 hours of walking distance from nearest settlement to the road head. In social aspects, this road influences Beshisahar Municipality and Khwolosothar Rural Municipality. From the accessibility perspective, it is found that the link provides good accessibility to health centres as compared to other three services namely education, market/administration and tourism/industry. It has been clearly seen that the index value for travel time saving cost parameter has highest score of 0.131

because experts provided the highest weightage for travel time saving cost and the highest travel time saving cost was achieved in this link. Also, the index value for road utilization parameter has highest score of 0.076. At last, the index value for upgrading cost was taken negative because it is inversely proportional to the performance of road. The table 4.14 below shows the composite score of Besishahar-Kapurgaun-Bhujung road (DR001).

Table 4. 14: Composite Score of Besishahar-Kapurgaun-Bhujung Road

S.No	Parameters	Obtained Value	Z Normalized Value	Z Percentile Value	AHP Coefficient	Composite Score
1	Population Served	29729.00	0.52	0.6985	6.70	0.047
2	Link Efficiency	9.19	-0.74	0.0367	5.10	0.002
3	Road Utilization	0.40	1.29	0.9015	8.40	0.076
4	Rate of Accidents	1.00	2.00	0.9772	9.00	0.088
5	Educational Service	2182.00	-0.56	0.2877	5.10	0.015
6	Tourism/industry	4.00	0.00	0.5000	3.50	0.018
7	Health Centres	11.00	0.62	0.7291	6.40	0.047
8	Market/administration Centres	2.00	0.93	0.8238	4.50	0.037
9	Connection with NH	0.00	0.00	0.0000	8.68	0.000
10	Connection with FR	1.00	0.00	0.5000	9.25	0.046
11	Connection with LRN	16.00	-0.04	0.4880	10.77	0.053
12	Upgrading Cost ('000)	15375.40	-0.36	0.3594	-8.37	-0.030
13	Travel Time saving Cost ('000)	4103.89	1.43	0.9236	14.20	0.131
					Composite Index (CI)	**0.528**

4.9.2 Siundibar-Sundarbazar-Khatrithanti-Bhorletar Road (DR002)

The composite index score (based on index values of thirteen sub-criteria) of Siundibar-Sundarbazar-Khatrithanti-Bhorletar road (DR002) is 0.487 calculated by multiplying Z value and AHP coefficient. Technically, this link provides good connectivity to other road network especially to LRN. Hence, the connection with LRN parameter contributes the highest score of 0.099 in evaluation of road. It is concluded that this factor highlights the importance of road in economic development of district. Furthermore, this road starts from FR (Dumre-Beshisahar-Chame road) and passes through different Municipalities and Rural Municipalities. From the

accessibility perspective, it is seen that the link provides better accessibility to health centres as compared to other three services namely education, market/administration centres and tourism/ Industry. That the index value for connection with feeder road parameter has second highest score of 0.087. At last, the index value for upgrading cost was taken negative because it is inversely proportional to the performance of road. The table 4.15 below shows the composite score of Siundibar-Sundarbazar-Khatrithanti-Bhorletar road (DR002).

Table 4. 15: Composite Score of Siundibar-Sundarbazar-Khatrithanti-Bhorletar Road

S.No	Parameters	Obtained Value	Z Normalized Value	Z Percentile Value	AHP Coefficient	Composite Score
1	Population Served	17752.00	-1.79	0.0367	6.70	0.002
2	Link Efficiency	2240.47	1.77	0.9616	5.10	0.049
3	Road Utilization	0.33	-1.15	0.1251	8.40	0.011
4	Rate of Accidents	0.00	-0.50	0.3085	9.00	0.028
5	Educational Service	4620.00	1.67	0.9525	5.10	0.049
6	Tourism/industry	5.00	0.45	0.6736	3.50	0.024
7	Health Centres	13.00	1.40	0.9192	6.40	0.059
8	Market/administration Centres	4.00	0.57	0.7157	4.50	0.032
9	Connection with NH	0.00	0.00	0.0000	8.68	0.000
10	Connection with FR	2.00	1.58	0.9429	9.25	0.087
11	Connection with LRN	24.00	1.43	0.9236	10.77	0.099
12	Upgrading Cost ('000)	13479.28	-1.70	0.0446	-8.37	-0.004
13	Travel Time saving Cost ('000)	2599.457365	-0.35	0.3632	14.20	0.052
					Composite Index (CI)	**0.487**

4.9.3 Rithebagar-Tiwaridanda-Hilebesi-Faleni Road (DR003)

The composite index score (based on index values of thirteen sub-criteria) of Rithebagar-Tiwaridanda-Hilebesi-Faleni road (DR003) is 0.184 calculated by multiplying Z and AHP coefficient. Technically, this link provides good connectivity to other road network especially to LRN. Hence, the connection with LRN parameter contributes the second highest score of 0.053 which highlights the importance of this road. In social aspects, this road influences Dordi Rural Municipality. Total population served within 4 hours of walking distance from the road centreline is

highest among the five DRCN with the respective index score is 0.059. From the accessibility perspective, it is found that the link provides good accessibility to educational services as compared to other three services namely market/administration centres, Health centres and tourism/industry. At last, the index value for upgrading cost was taken negative because it is inversely proportional to the performance of road. The table 4.16 below shows the composite score of Rithebagar-Tiwaridanda-Hilebesi-Faleni road (DR003) .

Table 4. 16: Composite Score of Rithebagar-Tiwaridanda-Hilebesi-Faleni Road

S.No	Parameters	Obtained Value	Z Normalized Value	Z Percentile Value	AHP Coefficient	Composite Score
1	Population Served	33333.00	1.22	0.8869	6.70	0.059
2	Link Efficiency	1.27	-0.75	0.2266	5.10	0.012
3	Road Utilization	0.34	-0.76	0.2236	8.40	0.019
4	Rate of Accidents	0.00	-0.50	0.3085	9.00	0.028
5	Educational Service	2053.00	-0.68	0.2483	5.10	0.013
6	Tourism/industry	4.00	-0.68	0.2483	3.50	0.009
7	Health Centres	6.00	-1.32	0.0934	6.40	0.006
8	Market/administration Centres	10.00	-1.21	0.1151	4.50	0.005
9	Connection with NH	0.00	0.00	0.0000	8.68	0.000
10	Connection with FR	0.00	-1.58	0.0571	9.25	0.005
11	Connection with LRN	16.00	-0.04	0.4880	10.77	0.053
12	Upgrading Cost ('000)	16380.53	0.34	0.6331	-8.37	-0.053
13	Travel Time saving Cost ('000)	2195.65	-0.82	0.2061	14.20	0.029
					Composite Index (CI)	**0.184**

4.9.4 Udipur-Nauthar Sera-Kirtipur Road (DR004)

The composite index score (based on index values of thirteen sub-criteria) of Udipur--Nauthar Sera-Kirtipur road (DR004) is 0.144 calculated by multiplying Z and AHP coefficient. Technically, this link provides good connectivity to other road network especially to FR. Hence, the connection with FR parameter contributes the highest score of 0.046 highlighting the importance of road in economic development. Furthermore, this road starts from FR (Dumre-beshisahar-Chame road) and passes through different Municipalities and Rural Municipalities. In social aspects, this road

influences the Dordi Rural Municipality. Total population served within 4 hours of walking distance from nearest settlement to the road head is third lowest among the five DRCN with the respective index score of 0.037. From the accessibility perspective, it is seen that link provides highest accessibility of 0.011 to health centres. At last, the index value for upgrading cost was taken negative because it is inversely proportional to the performance of road. The table 4.17 below shows the composite score of Udipur-Nauthar Sera-Kirtipur road (DR004).

Table 4. 17: Composite Score of Udipur-Nauthar Sera-Kirtipur Road

S.No	Parameters	Obtained Value	Z Normalized Value	Z Percentile Value	AHP Coefficient	Composite Score
1	Population Served	27698.00	0.13	0.5478	6.70	0.037
2	Link Efficiency	0.71	-0.75	0.2266	5.10	0.012
3	Road Utilization	0.35	-0.47	0.3192	8.40	0.027
4	Rate of Accidents	0.00	-0.50	0.3085	9.00	0.028
5	Educational Service	1668.00	-1.03	0.1515	5.10	0.008
6	Tourism/industry	1.00	-1.36	0.0869	3.50	0.003
7	Health Centres	7.00	-0.93	0.1762	6.40	0.011
8	Market/administration Centres	10.00	-1.21	0.1151	4.50	0.005
9	Connection with NH	0.00	0.00	0.0000	8.68	0.000
10	Connection with FR	1.00	0.00	0.5000	9.25	0.046
11	Connection with LRN	7.00	-1.69	0.0455	10.77	0.005
12	Upgrading Cost ('000)	16477.85	0.41	0.6591	-8.37	-0.055
13	Travel Time saving Cost ('000)	1907.29	-1.16	0.1251	14.20	0.018
					Composite Index (CI)	**0.144**

4.9.5 Khatrithati-Kunchha Bhanjyang-Duipiple Road (DR005)

The composite index score (based on index values of thirteen sub-criteria) of Khatrithati-Kunchha Bhanjyang-Duipiple road (DR005) is 0.466 calculated by multiplying of Z and AHP coefficient. Technically, this link provides good connectivity to other road network especially to LRN and hence, the parameter connection with LRN contributes the third highest score of 0.068 in evaluation of road among thirteen criteria. Furthermore, this road starts from Sundarbazar Municipality and passes through Madhya Nepal Municipality, which is the border between Lamjung and Kaski. In social aspects, this road influences Sundarbazar and Madhya

Nepal Municipality. Total population served within 4 hours of walking distance from the road head is second lowest among the five DRCN with the respective index score is 0.032. From the accessibility perspective, it is found that the link provides almost equal accessibility of 0.035 to market/administrative centres, education, health centres and tourism/ industry. It has been clearly seen that the index value for travel time saving cost parameter has highest score of 0.116 among thirteen sub-criteria .The table 4.18 below shows the composite score of Khatrithati-Kunchha Bhanjyang-Duipiple road (DR005).

Table 4. 18: Composite Score of Khatrithati-Kunchha Bhanjyang-Duipiple Road

S.No	**Parameters**	**Obtained Value**	**Z Normalized Value**	**Z Percentile Value**	**AHP Coefficient**	**Composite Score**
1	Population Served	26627.00	-0.08	0.4721	6.70	0.032
2	Link Efficiency	1080.09	0.46	0.6772	5.10	0.035
3	Road Utilization	0.39	1.10	0.8643	8.40	0.073
4	Rate of Accidents	0.00	-0.50	0.3085	9.00	0.028
5	Educational Service	3465.00	0.61	0.7291	5.10	0.037
6	Tourism/industry	14.00	1.58	0.9429	3.50	0.033
7	Health Centres	10.00	0.23	0.5910	6.40	0.038
8	Market/administration Centres	16.00	0.93	0.8238	4.50	0.037
9	Connection with NH	0.00	0.00	0.0000	8.68	0.000
10	Connection with FR	1.00	0.00	0.5000	9.25	0.046
11	Connection with LRN	18.00	0.33	0.6293	10.77	0.068
12	Upgrading Cost ('000)	17753.63	1.31	0.9049	-8.37	-0.076
13	Travel Time saving Cost ('000)	3659.86	0.90	0.8159	14.20	0.116
					Composite Index (CI)	**0.466**

4.10 Road Prioritization Summary

The case study shows the prioritization of roads based on the composite score calculation as shown in figure 4.12.

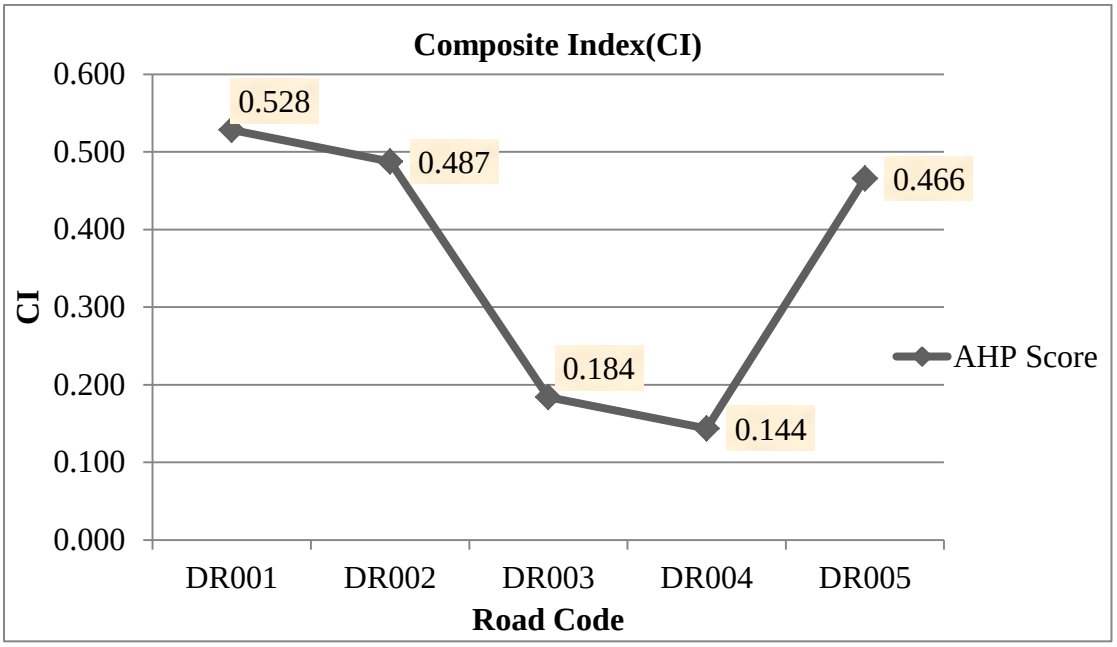


Figure 4. 12: The Composite Index of Roads Using AHP

The Besishahar-Kapurgaun-Bhujung road (DR001) is at the first priority with highest composite score and is followed by Siundibar-Sundarbazar-Khatrithanti-Satrasaya-Bimirebhanjyang-Bhorletar road (DR002) and other three roads Khatrithati-Kunchha Bhanjyang-Duipiple road (DR005), Rithebagar-Tiwaridanda-Hilebesi-Faleni road (DR003) and Udipur-Nauthar Sera-Kirtipur road (DR004) respectively. Udipur-Nauthar Sera-Kirtipur road (DR004) has lowest composite score of 0.144 among the selected DRCN hence it is placed in last priority of upgrading. The road Khatrithati-Kunchha Bhanjyang-Duipiple has third highest score among five roads. However, this road had been placed in fifth position during DTMP preparation.

CHAPTER FIVE: VALIDATION OF THE RESEARCH

5.1 Research Validation

In this research, the questionnaire has been distributed to know the relative importance of each identified road upgrading criterion occurring in the upgrading priority process practice in DRCN road to the thirty-experienced Government and consultant Engineer. From the perception about factors of pairwise comparison, the weightage factor for the upgrading priority process has been done separately for the AHP and Fuzzy method.

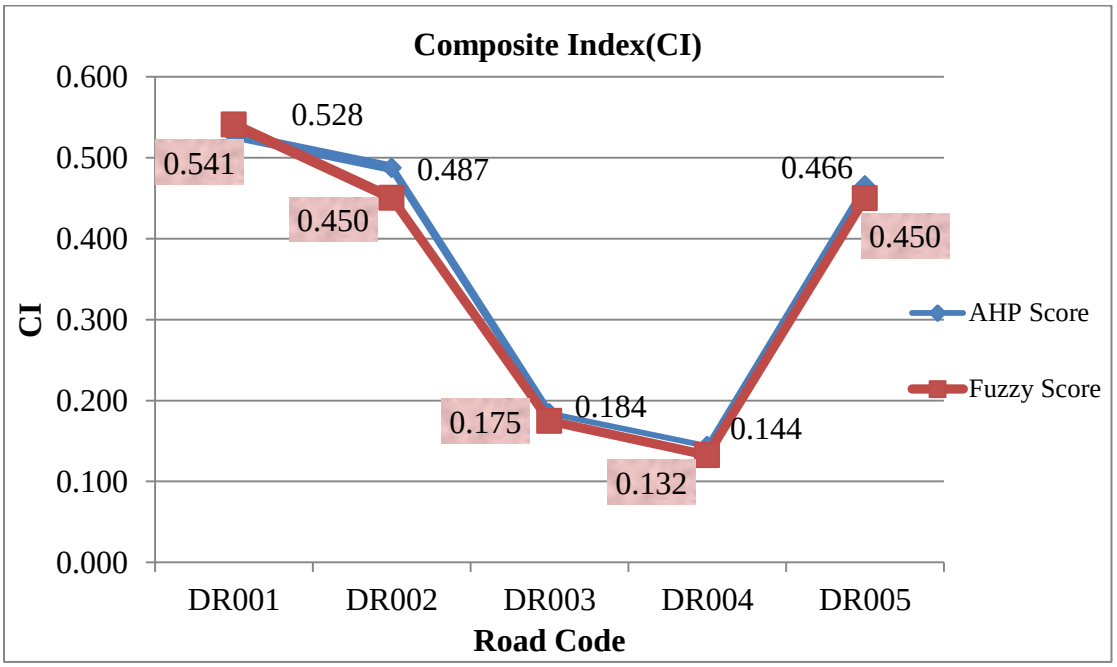


Figure 5. 1: The Composite Index of Roads Using AHP and Fuzzy Method

Defining a multi criteria model is difficult; therefore a more advanced model using fuzzy. If then rules is referred for verifying prioritization methodology. The comparisons by both methods are shown in figure 5.1.

To valid whether these weightage factors obtained from both methods are significant or not, significance test (t-test and correlation test) has been done.

5.2 Validation Tests: t-test and Correlation Test

To deal with small samples for testing of hypothesis concerning population means, difference between two population means and an observed sample correlation co-efficient, new techniques known as t-test has been developed. In this research, 30 experienced engineers, for the comparison of pairwise data were taken as sample to know the general perception of road upgrading prioritization process associated

with link performance, link accessibility, link connectivity and link associated cost criterion. Since the sample size is small, t- test has been applied.

5.2.1 t-test

The statistics test, t- test has been used here to test the significance of the difference between two independent mean. The t-test and correlation test is done between the data obtained from the comparison. In this research the p-value approach has been adopted for the t-test. The p-value is the probability of obtaining a test statistic equal to or more extreme than the result obtained from the sample data, given that the null hypothesis H0 is true hypothesis. If a population parameter is greater (or less) than some expected value; then one-tailed significance test is performed and if a population parameter is different from some expected value; two-tailed significance test.

In this research the difference of mean of the value obtained from Analytical Hierarchy Process and Fuzzy method is going to be computed, so two tailed test has been applied.

Hypothesis;

$\mu 1$= mean of the RRUI obtained from AHP method.

$\mu 2$= mean of the RRUI obtained from Fuzzy method.

Ho: There is no significant difference between the Index obtained from the AHP and Fuzzy method i.e. $\mu 1 = \mu 2$

Ha: There is significant difference between the Index obtained from the AHP and Fuzzy method.

Ho: $\mu 1 = \mu 2$, Ha: $\mu 1 \neq \mu 2$

n1= sample size for the number of road taken in AHP=5, n2= sample size for the number of road taken in Fuzzy method =5

Degree of freedom for t-test between data obtained from the 5 projects = n1 +n2-2=5+5-2=8

In this research, the t- value was computed and which was compared with 5% level of significance. If the obtained t- value is less than alpha value (α=0.05) we accept the null hypothesis and if the obtained t-value is greater than alpha value (α=0.05) the null

hypothesis is rejected, that means alternative hypothesis is accepted. The analysis has been shown below.

Table 5. 1.:t-test calculation

S.N	X(AHP method)	Y(Fuzzy method)	X-μx	Y-μy	(X-μx)*2	(Y-μy)*2
1	0.528	0.541	0.166	0.190	0.028	0.036
2	0.487	0.450	0.126	0.099	0.016	0.010
3	0.184	0.175	-0.178	-0.176	0.032	0.031
4	0.144	0.132	-0.218	-0.219	0.048	0.048
5	0.466	0.457	0.104	0.106	0.011	0.011

Where,

μx= 0.362

μy= 0.351

∑(X-μx)*2= 0.133

∑(Y-μy)*2= 0.136

n1=n2= 5

$$sp^{*2} = \frac{((\sum(X-\mu x)^{*2}+\sum(Y-\mu y)^{*2})}{n1+n2-2}$$

sp*2= 0.034

$$\text{test statistic}(t) = \frac{\mu x-\mu y}{\text{Sqrt}\ (sp^{*2}(1/n1+1/n2)}$$

test statistic(t) = 0.0936

From the above data, the obtained value of 't'(0.0936) is less than alpha value (α=0.05) in two tailed test is (2.306) for Rural Road Upgrading Index(RRUI).So the null hypothesis is accepted and concluded that at 95% confidence level the perception of the RRUI obtained from the AHP and Fuzzy method is no significantly different.

5.2.2 Correlation Analysis (test)

The degree of relationship between two variables is known as correlation. The most widely used in practice for calculating correlation co-efficient between two variables is Karl Pearson's coefficient. When conducting a statistical test between two variables, it is a good idea to conduct a Pearson correlation coefficient value to determine just how strong that relationship is between those two variables. The Karl Pearson's coefficient r value can range between -1.00 and 1.00.

Interpretation of co relation coefficient it lies between -1 and +1

When r=+1, there is perfect positive correlation

When r=-1, there is perfect negative correlation

When r=0 there is no correlation

When r lies between o.7 to 0.999 (-o.7 to-0.999) there is high degree of positive (or negative) correlation.

When r=0.5, there is low degree of correlation.

In this research this test is used to show how the road upgrading prioritization about the 5 local road networks from the 30 respondents as a pairwise comparison of criterion are related to each other. The correlation coefficient has been computed using the Excel software. The result obtained from the excel software has been presented below as correlation coefficient matrix:

Table 5. 2.: Calculation of Correlation coefficient'r'

S.N	X(AHP method)	Y(Fuzzy method)	X2	Y2	XY
1	0.528	0.541	0.279	0.293	0.286
2	0.487	0.450	0.238	0.203	0.220
3	0.184	0.175	0.034	0.031	0.032
4	0.144	0.132	0.021	0.018	0.019
5	0.466	0.457	0.217	0.208	0.213

Where,

$\sum X =$ 1.809

$\sum Y =$ 1.755

$\sum X2 =$ 0.788

$\sum Y2 =$ 0.752

$\sum XY =$ 0.769

$n =$ 5

$$\text{Correlation (r)} = \frac{n*\sum XY-(\sum X)*(\sum Y)}{\text{sqrt}((n*\sum X2-(\sum X)*2) * \text{sqrt}((n*\sum Y2-(\sum Y)*2)}$$

Correlation (r) = 0.995

From this table the value of the correlation coefficient between Analytical Hierarchy Process and Fuzzy Method has been obtained as 0.995.The index value obtained from the AHP and Fuzzy method are highly and positively correlated which shows that almost same perception about the road upgrading prioritization of rural road network from both methods. So, the concept can be applied in the road upgrading prioritization in the DRCN of Hilly and Mountainous region of Nepal.

CHAPTER SIX: CONCLUSIONS & RECOMMENDATIONS

6.1 Conclusions

This study deals with the prioritization of district roads based on different types of criteria and sub-criteria. The analysis was done by using Analytic Hierarchical Process (AHP) among 30 experts of rural road transportation field involving in different organizations. Consistency Ratio for Eigen value was computed as 0.055 which is less than 0.1. This makes the computation valid. Result shows that link connectivity factor has 30.54% weightage in prioritization of roads. Similarly, Link performance factor has 25.93% weightage in prioritization of roads. Furthermore link performance is followed by link associated cost factor (22.84%) and link accessibility factor (20.69%) respectively.

The value computed from AHP is used to determine the individual composite index score for five DRCN. The composite index score of Besishahar-Kapurgaun-Bhujung road (DR001) is 0.528. Likewise, the composite index score of remaining roads namely Siundibar-Sundarbazar-Khatrithanti-Bhorletar road (DR002), Rithebagar-Tiwaridanda-Hilebesi-Faleni road (DR003), Udipur-Nauthar Sera-Kirtipur road (DR004) and Khatrithati-Kunchhabhanjyang-Duipiple road (DR005) are 0.487, 0.184, 0.144 and 0.466 respectively. The upgrading priority of five DRCN based on composite index is finalized where Besishahar-Kapurgaun-Bhujung road (DR001) is at the first priority and is followed by Siundibar-Sundarbazar-Khatrithanti-Bhorletar road (DR002), Khatrithati- Kunchhabhanjyang-Duipiple road (DR005), Rithebagar-Tiwaridanda-Hilebesi-Faleni road (DR003) and Udipur-Nauthar Sera-Kirtipur road (DR004) respectively.

The Rural Road Upgrading Index calculated ranges from (0.528-0.144) and as seen from figure 4.12, Road No. DR001 has the highest composite score (0.528) and was ranked first. Similarly road No.DR004 had the lowest composite score (0.144) and was ranked as the road with least priority.

The same sets of roads were ranked from Fuzzy Method. Fuzzy set based method Rank and composite Index Rank calculated by AHP weights showed 99% correlation. Therefore this methodology gives a clear protocol for ranking roads and can be used practically in prioritization of road corridors for upgrading.

Previous DTMP guidelines were based on scoring system. Non-technical leaders were also involved in the team of stakeholders which caused the biasedness in the result of prioritization due to political pressure. This case study used the sophisticated tools of GIS to analyze field data. In addition, only technical personnel were engaged. This case study has included the social and technical features of road. The ranking of roads developed for upgrading in this case study has been found to be different than the prioritized list of district roads for upgrading developed by existing DTMP. Overall framework of case study is based on the accessibility objective of National Transport Policy 2001. Thus, the adopted methodology solves the problems for decision making bodies to develop reliable and transparent ranking process for upgrading works including both qualitative and quantitative aspects of each road.

6.2 Recommendations

The recommendations derived from this research are as follows:

- While preparing/upgrading DTMP, it is recommended to use developed weightage of prioritization indicators in Hill/Mountain region. In addition, it is also recommended to develop weightage of indicators using Analytical Hierarchy Process (AHP) in case of Terai region.
- While ranking the rural roads large number of data base has to be dealt. The re-arrangement of field based data and manipulation of data may lead to the time consuming and tedious work. So, that DoLI or concerned authorities should start to develop the software to simplify the calculations.
- It is recommended to establish and manage the database of the roads with the relevant information (such as traffic flow) for easy updating of the DTMP.

6.2.1 Recommendations for further research

- It is recommended that prioritization methodology for Urban Transportation Network would be applicable as the further stage of this case study with application of Origin-Destination survey and traffic analysis zones.
- It is recommended that appropriate traffic forecasting model for rural road in DRCN considering various parameters namely vehicle growth rate, employment generation, lifestyle of people, land use and economic growth should be included as further research.

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APPENDICES

ANNEX- I: Expert Opinion Survey

Relative importance scoring of pairwise comparison on criterion factor affecting the redefining of road Upgrading prioritization.																		
Criteria A	Criteria A is more important compared to criteria B								*=	Criteria B is more important compared to criteria A								Criteria B
Link Performance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Link Accessibility
Link Performance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Link Connectivity
Link Performance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Link Associated cost
Link Accessibility	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Link Connectivity
Link Accessibility	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Link Associated cost
Link Connectivity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Link Associated cost
Note: *= denote the equal importance of criteria A and B.																		

Relative importance scoring of pairwise comparison on sub-criteria factor (Under link performance Criteria) affecting the redefining of road Upgrading prioritization.																		
Criteria A	Criteria A is more important compared to criteria B								*=	Criteria B is more important compared to criteria A								Criteria B
Population Served	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Link Efficiency
Population Served	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Road utilization
Population Served	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Rate of Accident
Link Efficiency	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Road utilization
Link Efficiency	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Rate of Accidents
Road utilization	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Rate of Accidents
Note: *= denote the equal importance of criteria A and B.																		

Relative importance scoring of pairwise comparison on sub-criteria factor (Under link Accessibility Criteria) affecting the redefining of road Upgrading prioritization.																		
Criteria A	Criteria A is more important compared to criteria B								*=	Criteria B is more important compared to criteria A								Criteria B
Accessible to Educational Services	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Accessible to Markets
Accessible to Educational Services	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Accessible to Hospitals
Accessible to Educational Services	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Accessible to Tourism Centre
Accessible to Markets	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Accessible to Hospitals
Accessible to Markets	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Accessible to Tourism Centre
Accessible to Hospitals	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Accessible to Tourism Centre
Note: *= denote the equal importance of criteria A and B.																		

Relative importance scoring of pairwise comparison on sub-criteria factor (Under link Connectivity Criteria) affecting the redefining of road Upgrading prioritization.																		
Criteria A	Criteria A is more important compared to criteria B								*=	Criteria B is more important compared to criteria A								Criteria B
Connection with NH	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Connection with FR
Connection with NH	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Connection with LRN
Connection with FR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Connection with LRN
Note: *= denote the equal importance of criteria A and B. NH- National Highway, FR- Feeder Road, LRN-Local Road Network																		

Relative importance scoring of pairwise comparison on sub-criteria factor (Under link Associated cost) affecting the redefining of road Upgrading prioritization.																		
Criteria A	Criteria A is more important compared to criteria B								*=	Criteria B is more important compared to criteria A								Criteria B
Upgrading Cost/Km	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Travel Time cost
Note: *= denote the equal importance of criteria A and B.																		

ANNEX- II: Experts Ratings and Analysis

Expert Rating and Calculation In First Level Criteria

A Link Performance

B Link Accessibility

C Link Connectivity

D Link Associated Cost

S.N/ Expert	A over B		A over C		A over D		B over C		B over D		C over D	
	X	log X	X	log X	X	log X	X	log X	X	log X	X	log X
1.00	0.33	-0.48	3.00	0.48	4.00	0.60	3.00	0.48	4.00	0.60	5.00	0.70
2.00	0.50	-0.30	2.00	0.30	3.00	0.48	2.00	0.30	3.00	0.48	3.00	0.48
3.00	1.00	0.00	0.50	-0.30	2.00	0.30	0.50	-0.30	0.33	-0.48	2.00	0.30
4.00	0.33	-0.48	0.50	-0.30	3.00	0.48	0.20	-0.70	2.00	0.30	2.00	0.30
5.00	0.50	-0.30	2.00	0.30	3.00	0.48	0.33	-0.48	0.50	-0.30	3.00	0.48
6.00	3.00	0.48	0.33	-0.48	4.00	0.60	0.20	-0.70	3.00	0.48	4.00	0.60
7.00	3.00	0.48	0.50	-0.30	5.00	0.70	0.33	-0.48	2.00	0.30	3.00	0.48
8.00	2.00	0.30	1.00	0.00	1.00	0.00	0.33	-0.48	3.00	0.48	1.00	0.00
9.00	1.00	0.00	1.00	0.00	4.00	0.60	0.50	-0.30	2.00	0.30	0.25	-0.60
10.00	2.00	0.30	1.00	0.00	3.00	0.48	0.25	-0.60	3.00	0.48	0.25	-0.60
11.00	0.33	-0.48	2.00	0.30	2.00	0.30	0.33	-0.48	2.00	0.30	0.33	-0.48
12.00	4.00	0.60	0.33	-0.48	3.00	0.48	0.25	-0.60	3.00	0.48	1.00	0.00
13.00	2.00	0.30	0.50	-0.30	2.00	0.30	0.20	-0.70	2.00	0.30	3.00	0.48
14.00	3.00	0.48	2.00	0.30	2.00	0.30	0.33	-0.48	1.00	0.00	1.00	0.00
15.00	2.00	0.30	2.00	0.30	1.00	0.00	0.33	-0.48	0.33	-0.48	0.20	-0.70
16.00	1.00	0.00	2.00	0.30	3.00	0.48	0.50	-0.30	0.50	-0.30	0.25	-0.60
17.00	1.00	0.00	2.00	0.30	1.00	0.00	2.00	0.30	2.00	0.30	1.00	0.00
18.00	2.00	0.30	1.00	0.00	3.00	0.48	1.00	0.00	2.00	0.30	2.00	0.30
19.00	3.00	0.48	2.00	0.30	1.00	0.00	0.25	-0.60	2.00	0.30	0.25	-0.60
20.00	0.33	-0.48	1.00	0.00	2.00	0.30	1.00	0.00	1.00	0.00	1.00	0.00
21.00	0.33	-0.48	2.00	0.30	1.00	0.00	0.33	-0.48	2.00	0.30	0.50	-0.30
22.00	0.50	-0.30	0.50	-0.30	4.00	0.60	0.33	-0.48	0.50	-0.30	3.00	0.48
23.00	0.50	-0.30	3.00	0.48	2.00	0.30	1.00	0.00	2.00	0.30	0.33	-0.48
24.00	2.00	0.30	2.00	0.30	2.00	0.30	0.50	-0.30	0.17	-0.78	1.00	0.00
25.00	0.33	-0.48	0.33	-0.48	3.00	0.48	0.33	-0.48	3.00	0.48	3.00	0.48
26.00	0.50	-0.30	0.50	-0.30	2.00	0.30	3.00	0.48	2.00	0.30	2.00	0.30
27.00	0.20	-0.70	1.00	0.00	0.33	-0.48	0.33	-0.48	3.00	0.48	0.25	-0.60
28.00	2.00	0.30	1.00	0.00	0.50	-0.30	0.50	-0.30	1.00	0.00	0.50	-0.30
29.00	0.33	-0.48	1.00	0.00	0.33	-0.48	0.33	-0.48	1.00	0.00	2.00	0.30
30.00	1.00	0.00	2.00	0.30	2.00	0.30	0.33	-0.48	0.33	-0.48	0.33	-0.48
∑(log X)		**-0.96**		**1.01**		**8.37**		**-9.63**		**4.13**		**-0.09**
G.M=antilog ((∑log(X)/n))		**0.93**		**1.07**		**1.90**		**0.48**		**0.73**		**0.99**

Expert Rating and Calculation In Second Level Criteria(Link Performance)

A Population Served

B Efficiency of links

C Road Utilization

D Rate of Accidents

S.N/ Expert	A over B		A over C		A over D		B over C		B over D		C over D	
	X	log X	X	log X	X	log X	X	log X	X	log X	X	log X
1.00	3.00	0.48	0.25	-0.60	0.50	-0.30	0.20	-0.70	0.33	-0.48	0.25	-0.60
2.00	1.00	0.00	2.00	0.30	0.50	-0.30	2.00	0.30	0.50	-0.30	0.33	-0.48
3.00	2.00	0.30	0.33	-0.48	2.00	0.30	0.33	-0.48	0.20	-0.70	1.00	0.00
4.00	0.20	-0.70	2.00	0.30	2.00	0.30	0.33	-0.48	1.00	0.00	0.50	-0.30
5.00	2.00	0.30	0.33	-0.48	0.50	-0.30	0.33	-0.48	0.25	-0.60	0.20	-0.70
6.00	1.00	0.00	0.33	-0.48	0.25	-0.60	0.20	-0.70	0.50	-0.30	0.25	-0.60
7.00	3.00	0.48	0.50	-0.30	2.00	0.30	0.50	-0.30	2.00	0.30	2.00	0.30
8.00	2.00	0.30	1.00	0.00	1.00	0.00	0.50	-0.30	2.00	0.30	0.50	-0.30
9.00	0.50	-0.30	2.00	0.30	3.00	0.48	0.50	-0.30	0.25	-0.60	0.20	-0.70
10.00	2.00	0.30	0.50	-0.30	1.00	0.00	0.25	-0.60	1.00	0.00	0.50	-0.30
11.00	2.00	0.30	0.33	-0.48	2.00	0.30	0.20	-0.70	1.00	0.00	0.20	-0.70
12.00	0.33	-0.48	0.20	-0.70	3.00	0.48	0.50	-0.30	2.00	0.30	2.00	0.30
13.00	0.50	-0.30	1.00	0.00	0.33	-0.48	0.20	-0.70	2.00	0.30	2.00	0.30
14.00	2.00	0.30	2.00	0.30	2.00	0.30	0.50	-0.30	1.00	0.00	1.00	0.00
15.00	3.00	0.48	1.00	0.00	1.00	0.00	0.25	-0.60	0.33	-0.48	0.20	-0.70
16.00	0.50	-0.30	2.00	0.30	0.50	-0.30	0.20	-0.70	0.50	-0.30	0.25	-0.60
17.00	2.00	0.30	0.33	-0.48	0.50	-0.30	0.25	-0.60	1.00	0.00	2.00	0.30
18.00	3.00	0.48	2.00	0.30	2.00	0.30	0.50	-0.30	0.50	-0.30	0.50	-0.30
19.00	1.00	0.00	1.00	0.00	2.00	0.30	0.33	-0.48	0.25	-0.60	0.33	-0.48
20.00	0.20	-0.70	0.50	-0.30	3.00	0.48	0.50	-0.30	2.00	0.30	0.50	-0.30
21.00	0.25	-0.60	1.00	0.00	0.50	-0.30	0.50	-0.30	1.00	0.00	0.33	-0.48
22.00	0.33	-0.48	0.25	-0.60	2.00	0.30	0.25	-0.60	0.33	-0.48	2.00	0.30
23.00	0.25	-0.60	2.00	0.30	1.00	0.00	2.00	0.30	1.00	0.00	0.50	-0.30
24.00	2.00	0.30	3.00	0.48	3.00	0.48	0.33	-0.48	0.20	-0.70	2.00	0.30
25.00	0.50	-0.30	0.50	-0.30	2.00	0.30	0.33	-0.48	0.17	-0.77	2.00	0.30
26.00	2.00	0.30	0.25	-0.60	1.00	0.00	2.00	0.30	0.20	-0.70	1.00	0.00
27.00	3.00	0.48	2.00	0.30	0.50	-0.30	0.50	-0.30	2.00	0.30	0.50	-0.30
28.00	1.00	0.00	1.00	0.00	0.20	-0.70	0.30	-0.52	3.00	0.48	0.25	-0.60
29.00	0.50	-0.30	2.00	0.30	0.33	-0.48	0.20	-0.70	1.00	0.00	1.00	0.00
30.00	2.00	0.30	0.50	-0.30	1.00	0.00	0.25	-0.60	0.50	-0.30	0.25	-0.60
∑(log X)		**0.33**		**-3.23**		**0.25**		**-12.42**		**-5.34**		**-7.25**
G.M=antilog ((∑log(X)/n))		**1.03**		**0.78**		**1.02**		**0.39**		**0.66**		**0.57**

Expert Rating and Calculation In Second Level Criteria(Link Accessibility)

A Accessible to Educational Services

B Accessible to markets

C Accessible to Hospitals

D Accessible to Tourism Centre

S.N/ Expert	A over B		A over C		A over D		B over C		B over D		C over D	
	X	log X	X	log X	X	log X	X	log X	X	log X	X	log X
1.00	3.00	0.48	0.25	-0.60	4.00	0.60	0.20	-0.70	4.00	0.60	5.00	0.70
2.00	2.00	0.30	0.33	-0.48	3.00	0.48	0.33	-0.48	0.33	-0.48	0.50	-0.30
3.00	1.00	0.00	0.20	-0.70	2.00	0.30	0.20	-0.70	2.00	0.30	3.00	0.48
4.00	3.00	0.48	0.25	-0.60	1.00	0.00	0.50	-0.30	2.00	0.30	0.50	-0.30
5.00	0.50	-0.30	0.20	-0.70	0.50	-0.30	2.00	0.30	0.20	-0.70	0.33	-0.48
6.00	1.00	0.00	0.33	-0.48	2.00	0.30	1.00	0.00	0.25	-0.60	0.50	-0.30
7.00	3.00	0.48	0.50	-0.30	3.00	0.48	0.33	-0.48	2.00	0.30	0.33	-0.48
8.00	2.00	0.30	2.00	0.30	0.33	-0.48	0.50	-0.30	0.33	-0.48	0.20	-0.70
9.00	2.00	0.30	0.33	-0.48	0.50	-0.30	0.33	-0.48	0.25	-0.60	0.20	-0.70
10.00	3.00	0.48	0.25	-0.60	3.00	0.48	0.33	-0.48	0.20	-0.70	1.00	0.00
11.00	1.00	0.00	0.20	-0.70	0.50	-0.30	0.25	-0.60	2.00	0.30	0.50	-0.30
12.00	0.33	-0.48	0.20	-0.70	2.00	0.30	0.20	-0.70	3.00	0.48	0.25	-0.60
13.00	3.00	0.48	2.00	0.30	3.00	0.48	2.00	0.30	0.33	-0.48	2.00	0.30
14.00	2.00	0.30	1.00	0.00	0.50	-0.30	2.00	0.30	0.20	-0.70	0.17	-0.77
15.00	1.00	0.00	0.25	-0.60	0.50	-0.30	0.33	-0.48	2.00	0.30	0.33	-0.48
16.00	0.50	-0.30	0.50	-0.30	1.00	0.00	0.20	-0.70	0.33	-0.48	0.25	-0.60
17.00	0.33	-0.48	0.33	-0.48	2.00	0.30	0.50	-0.30	2.00	0.30	0.20	-0.70
18.00	0.20	-0.70	0.25	-0.60	3.00	0.48	1.00	0.00	0.33	-0.48	0.50	-0.30
19.00	0.33	-0.48	0.20	-0.70	4.00	0.60	2.00	0.30	0.20	-0.70	2.00	0.30
20.00	0.50	-0.30	0.33	-0.48	2.00	0.30	0.25	-0.60	3.00	0.48	0.33	-0.48
21.00	0.25	-0.60	2.00	0.30	3.00	0.48	0.20	-0.70	2.00	0.30	2.00	0.30
22.00	0.33	-0.48	0.33	-0.48	3.00	0.48	0.33	-0.48	1.00	0.00	0.20	-0.70
23.00	3.00	0.48	1.00	0.00	2.00	0.30	0.25	-0.60	0.33	-0.48	0.33	-0.48
24.00	2.00	0.30	2.00	0.30	3.00	0.48	0.50	-0.30	0.20	-0.70	4.00	0.60
25.00	2.00	0.30	0.25	-0.60	2.00	0.30	1.00	0.00	0.33	-0.48	0.33	-0.48
26.00	4.00	0.60	0.20	-0.70	4.00	0.60	0.33	-0.48	0.50	-0.30	0.50	-0.30
27.00	2.00	0.30	0.50	-0.30	3.00	0.48	0.25	-0.60	3.00	0.48	0.33	-0.48
28.00	3.00	0.48	3.00	0.48	1.00	0.00	0.20	-0.70	0.20	-0.70	0.50	-0.30
29.00	2.00	0.30	2.00	0.30	3.00	0.48	0.33	-0.48	0.50	-0.30	0.33	-0.48
30.00	1.00	0.00	0.33	-0.48	2.00	0.30	0.20	-0.70	0.20	-0.70	2.00	0.30
∑(log X)		**2.22**		**-10.10**		**7.00**		**-11.15**		**-5.93**		**-7.75**
G.M=antilog ((∑log(X)/n))		**1.19**		**0.63**		**1.71**		**0.45**		**0.84**		**0.93**

Expert Rating and Calculation in Second Level Criteria(Link Connectivity)

A Connection with NH

B Connection with FR

C Connection with LRN

S.N/ Expert	A over B		A over C		B over C	
	X	**log X**	**X**	**log X**	**X**	**log X**
1.00	3.00	0.48	5.00	0.70	5.00	0.70
2.00	2.00	0.30	4.00	0.60	4.00	0.60
3.00	1.00	0.00	3.00	0.48	3.00	0.48
4.00	0.50	-0.30	4.00	0.60	2.00	0.30
5.00	0.33	-0.48	0.33	-0.48	0.25	-0.60
6.00	2.00	0.30	0.25	-0.60	0.20	-0.70
7.00	0.25	-0.60	0.20	-0.70	0.33	-0.48
8.00	1.00	0.00	0.25	-0.60	0.50	-0.30
9.00	0.33	-0.48	0.33	-0.48	0.25	-0.60
10.00	2.00	0.30	0.50	-0.30	2.00	0.30
11.00	1.00	0.00	2.00	0.30	3.00	0.48
12.00	0.25	-0.60	3.00	0.48	0.50	-0.30
13.00	0.50	-0.30	0.33	-0.48	4.00	0.60
14.00	0.33	-0.48	2.00	0.30	5.00	0.70
15.00	0.20	-0.70	1.00	0.00	0.25	-0.60
16.00	0.33	-0.48	0.20	-0.70	0.33	-0.48
17.00	2.00	0.30	0.50	-0.30	0.25	-0.60
18.00	3.00	0.48	3.00	0.48	0.25	-0.60
19.00	1.00	0.00	1.00	0.00	0.33	-0.48
20.00	0.25	-0.60	0.33	-0.48	0.50	-0.30
21.00	0.33	-0.48	3.00	0.48	0.33	-0.48
22.00	4.00	0.60	5.00	0.70	0.25	-0.60
23.00	2.00	0.30	4.00	0.60	0.33	-0.48
24.00	3.00	0.48	2.00	0.30	0.25	-0.60
25.00	0.20	-0.70	0.33	-0.48	0.20	-0.70
26.00	0.25	-0.60	1.00	0.00	3.00	0.48
27.00	3.00	0.48	0.50	-0.30	4.00	0.60
28.00	0.33	-0.48	0.50	-0.30	0.33	-0.48
29.00	0.50	-0.30	3.00	0.48	0.25	-0.60
30.00	0.20	-0.70	2.00	0.30	0.20	-0.70
∑(log X)		**-4.28**		**0.58**		**-5.47**
G.M=antilog ((∑log(X)/n))		**0.72**		**1.05**		**0.66**

Expert Rating and Calculation in Second Level Criteria(Link Associated Cost)

A Upgrading Cost/Km

B Travel Time Cost

S.N/ Expert	A over B	
	X	log X
1.00	3.00	0.48
2.00	2.00	0.30
3.00	1.00	0.00
4.00	0.25	-0.60
5.00	0.20	-0.70
6.00	0.33	-0.48
7.00	2.00	0.30
8.00	1.00	0.00
9.00	3.00	0.48
10.00	0.25	-0.60
11.00	0.20	-0.70
12.00	0.33	-0.48
13.00	0.25	-0.60
14.00	2.00	0.30
15.00	0.33	-0.48
16.00	3.00	0.48
17.00	2.00	0.30
18.00	0.33	-0.48
19.00	0.25	-0.60
20.00	0.20	-0.70
21.00	0.50	-0.30
22.00	1.00	0.00
23.00	2.00	0.30
24.00	0.25	-0.60
25.00	0.33	-0.48
26.00	0.20	-0.70
27.00	3.00	0.48
28.00	0.25	-0.60
29.00	0.33	-0.48
30.00	0.20	-0.70
∑(log X)		**-6.88**
G.M=antilog ((∑log(X)/n))		**0.59**

ANNEX- III: Annual Average Daily Traffic (AADT) of Selected Roads

Name of Road: Besishahar-Baglungpani-Kapurgaun-Bhujung Road

S.N/Date	Vehicle Type												Total	Remarks
	Bicycle	Motorbike	Rickshaw	Animal Freight (Bulloc cart)	Tractor	Car	Jeep	Microbus	Mini-Bus	Bus	Mini-Truck	Truck		
PCU Factor	0.5	0.5	1	6	3	1	1	3	3	4	3	4		
11-Oct-19	0	91	0	0	21	0	56	0	0	2	0	0	170	
12-Oct-19	0	85	0	0	18	0	54	0	0	2	0	0	159	
13-Oct-19	0	84	0	0	15	0	55	0	0	0	0	0	154	
14-Oct-19	0	75	0	0	17	0	56	0	0	2	0	0	150	
15-Oct-19	0	79	0	0	18	0	53	0	0	1	0	0	151	
16-Oct-19	0	93	0	0	17	0	58	0	0	2	0	0	170	
17-Oct-19	0	95	0	0	16	0	57	0	0	2	0	0	170	
Total	0	602	0	0	122	0	389	0	0	11	0	0	1124	
Average Daily Traffic(ADT)	0.00	86.00	0.00	0.00	17.00	0.00	56.00	0.00	0.00	2.00	0.00	0.00	161.00	
Composition	0%	54%	0%	0%	11%	0%	35%	0%	0%	1%	0%	0%		
AADT In PCU's	0.00	43.00	0.00	0.00	51.00	0.00	56.00	0.00	0.00	8.00	0.00	0.00	158.00	

Name of Road: Siundibar-Sundarbazar-Khatrithanti-Satrasaya-Bimirebhanjyang-Bhorletar Road

S.N/Date	Vehicle Type												Total	Remarks
	Bicycle	Motorbike	Rickshaw	Animal Freight (Bulloc cart)	Tractor	Car	Jeep	Microbus	Mini-Bus	Bus	Mini-Truck	Truck		
PCU Factor	0.5	0.5	1	6	3	1	1	3	3	4	3	4		
18-Oct-19	0	45	0	0	17	1	18	0	0	4	0	6	91	
19-Oct-19	0	47	0	0	19	0	17	0	0	4	0	5	92	
20-Oct-19	0	42	0	0	15	0	18	0	0	4	0	8	87	
21-Oct-19	0	49	0	0	14	0	18	0	0	2	0	8	91	
22-Oct-19	0	55	0	0	13	0	16	0	0	4	0	7	95	
23-Oct-19	0	59	0	0	19	0	19	0	0	4	0	8	109	
24-Oct-19	0	45	0	0	21	0	14	0	0	2	0	6	88	
Total	0	342	0	0	118	1	120	0	0	24	0	48	653	
Average Daily Traffic(ADT)	0.00	49.00	0.00	0.00	17.00	0.00	17.00	0.00	0.00	3.00	0.00	7.00	93.00	
Composition	0%	30%	0%	0%	10%	0%	11%	0%	0%	2%	0%	4%		
AADT In PCU's	0.00	25.00	0.00	0.00	51.00	0.00	17.00	0.00	0.00	12.00	0.00	28.00	133.00	

Name of Road: Rithebagar-Tiwaridanda-Tinpiple-Tilahar-Hilebesi-Faleni Road

S.N/Date	Vehicle Type												Total	Remarks
	Bicycle	Motorbike	Rickshaw	Animal Freight (Bulloc cart)	Tractor	Car	Jeep	Microbus	Mini-Bus	Bus	Mini-Truck	Truck		
PCU Factor	0.5	0.5	1	6	3	1	1	3	3	4	3	4		
31-Oct-19	0	59	0	0	18	0	28	0	2	4	0	6	117	
1-Nov-19	0	51	0	0	11	0	31	0	2	4	0	5	104	
2-Nov-19	0	52	0	0	15	0	25	0	2	3	0	5	102	
3-Nov-19	0	45	0	0	12	0	29	0	2	2	0	7	97	
4-Nov-19	0	44	0	0	14	0	28	0	2	4	0	7	99	
5-Nov-19	0	57	0	0	13	0	27	0	3	4	0	6	110	
6-Nov-19	0	41	0	0	15	0	27	0	2	2	0	6	93	
Total	0	349	0	0	98	0	195	0	15	23	0	42	722	
Average Daily Traffic(ADT)	0.00	50.00	0.00	0.00	14.00	0.00	28.00	0.00	2.00	3.00	0.00	6.00	103.00	
Composition	0%	31%	0%	0%	9%	0%	17%	0%	1%	2%	0%	4%		
AADT In PCU's	0.00	25.00	0.00	0.00	42.00	0.00	28.00	0.00	6.00	12.00	0.00	24.00	137.00	

Name of Road: Udipur-Ramchokbesi-Nauthar Sera-Kirtipur Road

S.N/Date	Vehicle Type												Total	Remarks
	Bicycle	Motorbike	Rickshaw	Animal Freight (Bulloc cart)	Tractor	Car	Jeep	Microbus	Mini-Bus	Bus	Mini-Truck	Truck		
PCU Factor	0.5	0.5	1	6	3	1	1	3	3	4	3	4		
31-Oct-19	0	48	0	0	11	0	45	0	0	4	0	7	115	
1-Nov-19	0	45	0	0	16	0	40	0	0	4	0	5	110	
2-Nov-19	0	37	0	0	14	0	42	0	0	2	0	6	101	
3-Nov-19	0	53	0	0	15	0	43	0	0	2	0	6	119	
4-Nov-19	0	44	0	0	12	0	46	0	0	4	0	3	109	
5-Nov-19	0	51	0	0	18	0	48	0	0	3	0	5	125	
6-Nov-19	0	36	0	0	15	0	35	0	0	2	0	4	92	
Total	0	314	0	0	101	0	299	0	0	21	0	36	771	
Average Daily Traffic(ADT)	0.00	45.00	0.00	0.00	14.00	0.00	43.00	0.00	0.00	3.00	0.00	5.00	110.00	
Composition	0%	28%	0%	0%	9%	0%	27%	0%	0%	2%	0%	3%		
AADT In PCU's	0.00	23.00	0.00	0.00	42.00	0.00	43.00	0.00	0.00	12.00	0.00	20.00	140.00	

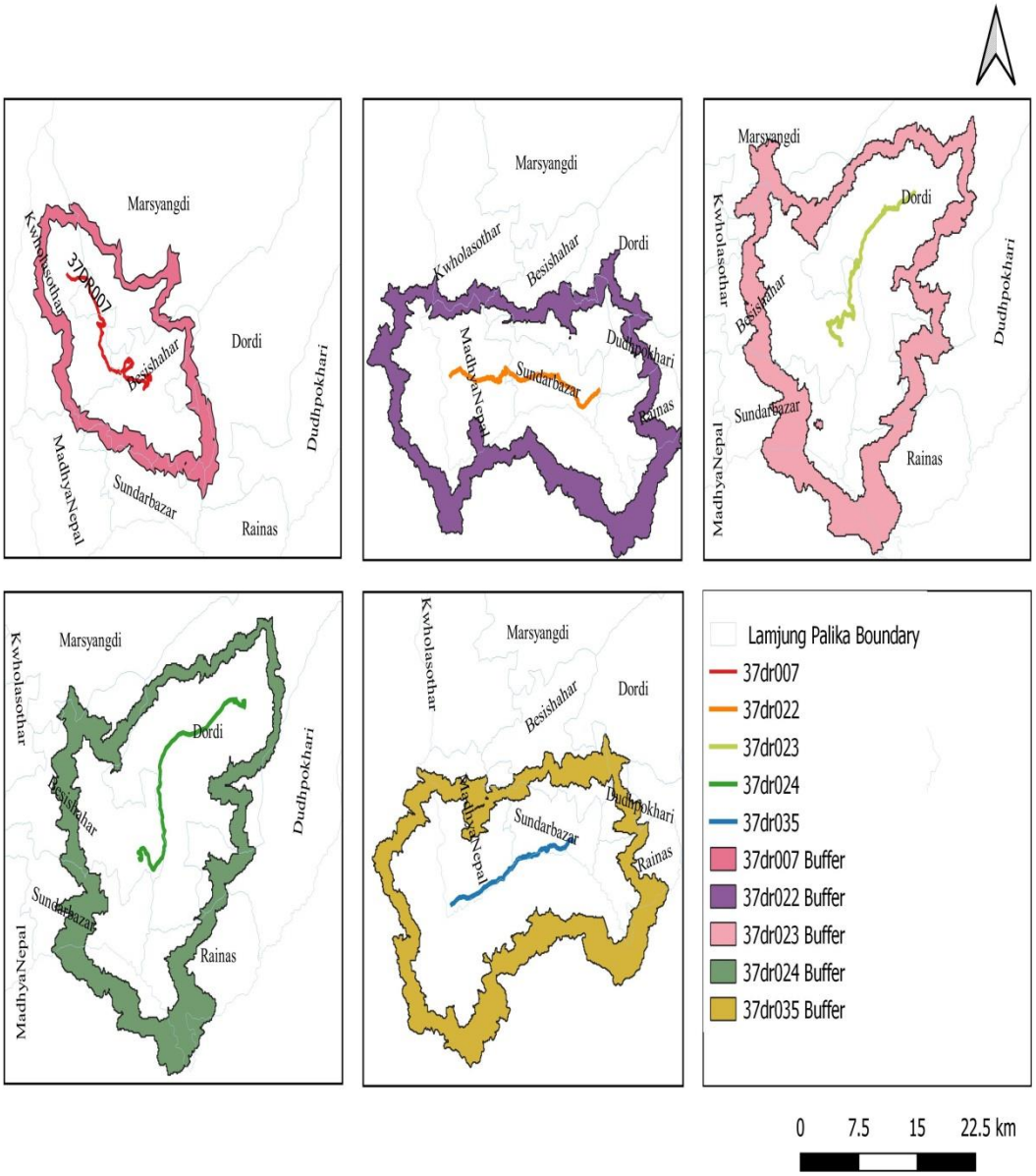
Name of Road: Khatrithati-Kunchha Bhanjyang-Sotipasal-Sundaradihi-Duipiple Road

S.N/Date	Vehicle Type												Total	Remarks
	Bicycle	Motorbike	Rickshaw	Animal Freight (Bulloc cart)	Tractor	Car	Jeep	Microbus	Mini-Bus	Bus	Mini-Truck	Truck		
PCU Factor	0.5	0.5	1	6	3	1	1	3	3	4	3	4		
18-Oct-19	0	79	0	0	11	0	4	0	6	6	3	5	114	
19-Oct-19	0	51	0	0	10	0	7	0	6	6	5	5	90	
20-Oct-19	0	59	0	0	13	0	5	0	6	6	2	8	99	
21-Oct-19	0	54	0	0	15	0	5	0	6	5	5	5	95	
22-Oct-19	0	55	0	0	19	0	7	0	5	6	4	7	103	
23-Oct-19	0	71	0	0	14	0	8	0	6	4	7	7	117	
24-Oct-19	0	43	0	0	17	0	5	0	6	6	4	3	84	
Total	0	412	0	0	99	0	41	0	41	39	30	40	702	
Average Daily Traffic(ADT)	0.00	59.00	0.00	0.00	14.00	0.00	6.00	0.00	6.00	6.00	4.00	6.00	100.00	
Composition	0%	37%	0%	0%	9%	0%	4%	0%	4%	3%	3%	4%		
AADT In PCU's	0.00	30.00	0.00	0.00	42.00	0.00	6.00	0.00	18.00	24.00	12.00	24.00	156.00	

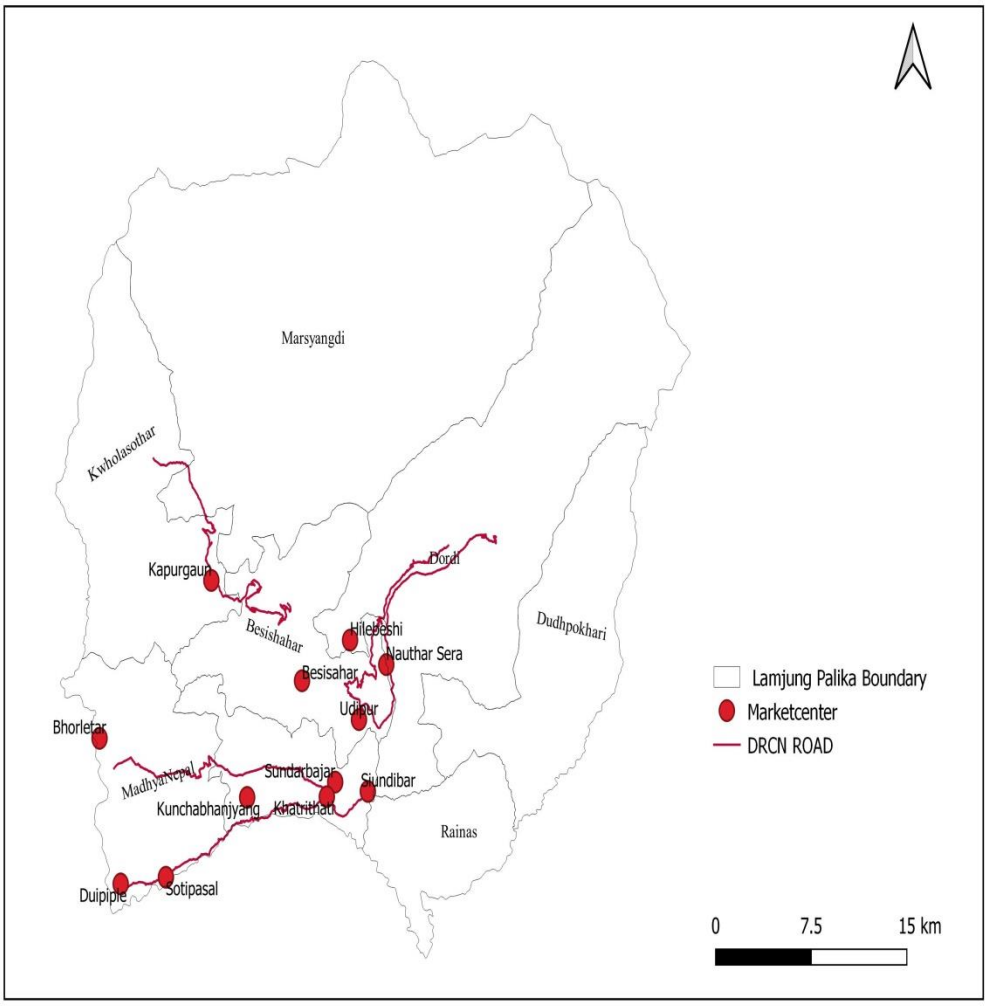
ANNEX- IV: Road Utilization

S.N	Name of Road	Road Code	Traffic Volume(V)	Design Capacity (C)	Road Utilization (V/C)	Remarks
1	Besishahar-Baglungpani-Kapurgaun-Bhujung Road	DR001	158.00	400	0.40	
2	Siundibar-Sundarbazar-Khatrithanti-Satrasaya-Bimirebhanjyang-Bhorletar Road	DR002	133.00	400	0.33	
3	Rithebagar-Tiwaridanda-Tinpiple-Tilahar-Hilebesi-Faleni Road	DR003	137.00	400	0.34	
4	Udipur-Ramchokbesi-Nauthar Sera-Kirtipur Road	DR004	140.00	400	0.35	
5	Khatrithati-Kunchha Bhanjyang-Sotipasal-Sundaradihi-Duipiple Road	DR005	156.00	400	0.39	

ANNEX- V: GIS based Buffer Analysis (4 hours Walking Distance)



ANNEX- VI: GIS based Location of Market Centres/Settlements



ANNEX- VII: Distance Matrix between Market Centres/Settlements

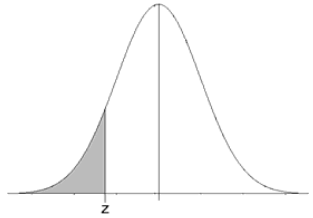
Matrix	1	2	3	4	5	6	7	8	9	10	11	12
1	0	18.35	16.07	19.87	21.26	43.07	23.72	11.07	28.07	29.56	36.99	44.49
2	18.35	0	34.42	38.22	43.41	70.41	42.07	29.42	46.42	47.91	54.04	63.11
3	16.07	34.42	0	3.8	5.19	27	17.65	5	22	13.49	19.62	28.69
4	19.87	38.22	3.8	0	1.39	23.2	21.45	8.8	25.8	9.69	15.82	24.89
5	21.26	43.41	5.19	1.39	0	21.81	22.84	10.19	27.19	8.3	14.43	23.5
6	43.07	70.41	27	23.2	21.81	0	44.65	32	49	30.11	36.24	45.31
7	23.72	42.07	17.65	21.45	22.84	44.65	0	12.65	29.65	31.14	37.27	46.34
8	11.07	29.42	5	8.8	10.19	32	12.65	0	17	18.49	24.62	33.69
9	28.07	46.42	22	25.8	27.19	49	29.65	17	0	35.49	41.62	50.69
10	29.56	47.91	13.49	9.69	8.3	30.11	31.14	18.49	35.49	0	6.13	15.2
11	36.99	54.04	19.62	15.82	14.43	36.24	37.27	24.62	41.62	6.13	0	9.07
12	44.49	63.11	28.69	24.89	23.5	45.31	46.34	33.69	50.69	15.2	9.07	0
∑dij	292.52	487.78	192.93	192.93	199.51	422.8	329.43	202.93	372.93	245.51	295.85	384.98

ANNEX- VIII: Force of Interaction between Market Centres/Settlements

Matrix	1	2	3	4	5	6	7	8	9	10	11	12
1	0.00	309.81	39.23	899.66	849.38	44.62	30.01	9.02	0.23	2.21	1.40	20.81
2	309.81	0.00	8.55	243.16	203.73	16.69	9.54	1.28	0.08	0.84	0.66	10.34
3	39.23	8.55	0.00	24598.46	14252.64	113.53	54.20	44.20	0.38	10.59	4.98	50.04
4	899.66	243.16	24598.46	0.00	198701.22	153.76	36.69	14.27	0.27	20.52	7.65	66.48
5	849.38	203.73	14252.64	198701.22	0.00	173.99	32.36	10.64	0.25	27.97	9.20	74.58
6	44.62	16.69	113.53	153.76	173.99	0.00	8.47	1.08	0.08	2.13	1.46	20.06
7	30.01	9.54	54.20	36.69	32.36	8.47	0.00	6.91	0.21	1.99	1.38	19.18
8	9.02	1.28	44.20	14.27	10.64	1.08	6.91	0.00	0.63	5.64	3.16	36.29
9	0.23	0.08	0.38	0.27	0.25	0.08	0.21	0.63	0.00	1.53	1.11	16.03
10	2.21	0.84	10.59	20.52	27.97	2.13	1.99	5.64	1.53	0.00	50.98	178.26
11	1.40	0.66	4.98	7.65	9.20	1.46	1.38	3.16	1.11	50.98	0.00	500.65
12	20.81	10.34	50.04	66.48	74.58	20.06	19.18	36.29	16.03	178.26	500.65	0.00
∑Fij	2206.37	804.68	39176.80	224742.16	214335.96	535.86	200.93	133.11	20.79	302.65	582.62	992.72

ANNEX- IX: Intensity of Market Centres/Settlements

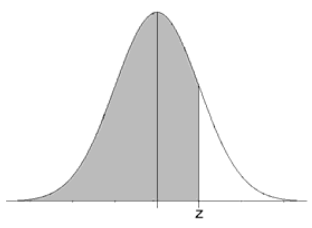
S.N	Name of Market Centrre/Settlements	Centrality Index	Population	∑Fij	∑dij	Intensity of Market Centre/Settlement (∑Fij/∑dij
1	Besishahar	564.65	34642	2206.37	292.52	7.54
2	Kapurgaun	81.29	6230	804.68	487.78	1.65
3	Siundibar	121.10	40842	39176.80	192.93	203.06
4	Sundarbazar	334.04	40842	224742.16	192.93	1164.89
5	Khatrithanti	103.89	40842	214335.96	199.51	1074.31
6	Bhorletar	194.49	22367	535.86	422.8	1.27
7	Hilebesi	62.25	5708	200.93	329.43	0.61
8	Udipur	96.17	5708	133.11	202.93	0.66
9	Nauthar Sera	101.76	5708	20.79	372.93	0.06
10	Kunchha Bhanjyang	86.66	22367	302.65	245.51	1.23
11	Sotipasal	82.83	22367	582.62	295.85	1.97
12	Duipiple	165.16	22367	992.72	384.98	2.58



ANNEX- X: Z-Table

Cumulative probabilities for NEGATIVE z-values are shown in the following table:

z	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
-2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.011
-2.1	0.0179	0.0174	0.017	0.0166	0.0162	0.0158	0.0154	0.015	0.0146	0.0143
-2	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
-1.9	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.025	0.0244	0.0239	0.0233
-1.8	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
-1.7	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
-1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
-1.5	0.0668	0.0655	0.0643	0.063	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
-1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
-1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
-1.2	0.1151	0.1131	0.1112	0.1093	0.1075	0.1056	0.1038	0.102	0.1003	0.0985
-1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.123	0.121	0.119	0.117
-1	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
-0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.166	0.1635	0.1611
-0.8	0.2119	0.209	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
-0.7	0.242	0.2389	0.2358	0.2327	0.2296	0.2266	0.2236	0.2206	0.2177	0.2148
-0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
-0.5	0.3085	0.305	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.281	0.2776
-0.4	0.3446	0.3409	0.3372	0.3336	0.33	0.3264	0.3228	0.3192	0.3156	0.3121
-0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.352	0.3483
-0.2	0.4207	0.4168	0.4129	0.409	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
-0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
0	0.5	0.496	0.492	0.488	0.484	0.4801	0.4761	0.4721	0.4681	0.4641



Cumulative probabilities for POSITIVE z-values are shown in the following table:

Z	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0.5	0.504	0.508	0.512	0.516	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.591	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.648	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.67	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.695	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.719	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.758	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.791	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.834	0.8365	0.8389
1	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.877	0.879	0.881	0.883
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.898	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.937	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.975	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.983	0.9834	0.9838	0.9842	0.9846	0.985	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.989