Road Alignment and its Impact Assessment on environs in Himalayan Region using Geospatial Tools

Thesis submitted to the Andhra University, Visakhapatnam in partial fulfilment of the requirement for the award of *Master of Technology in Remote Sensing and GIS*

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Dedicated to all my well wishers

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Harjeet Singh

Disclaimer

I, Harjeet Singh, hereby declare that this dissertation entitled "Road alignment and its impact assessment on its environs in Himalayan region using geo spatial tools" submitted to Andhra University, Visakhapatnam in partial fulfilment of the requirements for the award of M.Tech in Remote Sensing and GIS, is my own work and that to the best of my knowledge and belief. It is a record of original research carried out be me under the guidance and supervision of Dr. Sadhana Jain Scientist SE, Urban and regional studies Department, and Mr. Kamal Pandey Scientist SD, Remote sensing and Geo-informatics group, IIRS. Indian Institute of Remote Sensing, ISRO, Dehradun. It contains no material previously published or written by another person nor material which to a substantial has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgement has been made in the text.

Place: Dehradun Mr. Harjeet Singh

Date: 16 July, 2015

Certificate

Abstract

Land use planning in a hilly region is usually dependent on an efficient transportation corridor and main road network system. In this study, Geographic Information System (GIS) tools were used to develop a least-cost path for a corridor to link two stations (Gairsain and Bageshwar) in the hilly region. Gairain is the proposed capital city of Uttarakhand state of India, which is located in the geographical center of the state hence, is a suitable site for state level administrative functions. Road connectivity of Gairsain with other district headquarters of the state is not well established yet. In order to develop the capital city, it is proposed to provide accessibility with other district headquarters. Delineated study area of Gairsain to Bageshwar is have 62 percent of forest coverage, 213 km of drainage network, total of 38 percent in the steep slope (> 45 degree) region. About 3 percent of study area is under high and very high percent of landslide hazard zone and 61 percent falls in moderate hazard zone. These environmental parameters are considered while aligning a new road, so that it is protected from the negative impacts that can be caused by the surrounding environment. Obtaining an optimal road route alignment, this is cost-effective, appropriate and compatible with the environment, is a challenging task. Tha data for tha analysis is prepared using the suitability index, i.e. area suitable for new alignment are assigned low suitable index whereas non suitable areas are assigned high suitable index. The factors like geology, landuse, drainage network, slope aspect, soil texture, distance from road, etc. have been considered for the suitability analysis. The suitability surface created for these factors were standardized, evaluated and combined together. . Environmental and economic factors were integrated through a spatial multi-criteria model using the Analytical Hierarchy Process. Four visions were modeled: an engineering vision, an environmental vision, landslide vision and composite hybrid vision for aligning the road and hybrid vision scored the highest and it is recommended. Traffic forecasting were also modeled using GIS for the recommended route.

Keywords

Road Alignment, Analytical Hierarchy Process, Engineering Vision, Environmental Vision, Landslide Vision, hybrid Vision and Traffic Forecasting

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List of abbreviations

GIS	Geographical Information System
2D	2 Dimensional
3D	3 dimensional
OD	Origin/Destination
PCU	Passenger Car Unit
DEM	Digital Elevation Model
CAD	Computer Aided Design
GCP	Ground Control Points
DTM	Digital Terrain Model
E,N,H	Easting, Northing And Height
GA	Genetic Algorithm
TAZ	Traffic Analysis zones
FSM	Four Step Model
TDM	Travel Demand Model
HFTDM	High Feasibility Travel Demand model
NS	North-South
NE	North-East
IDW	Inverse Distance Weighting
NRSC	National Remote Sensing Center
GPS	Global Positioning System
DRI	Drillability Index
AHP	Analytical Hierarchical Process

1. Introduction

1.1. Background

A road is a common term for designated way for the movement of vehicles (Kulshreshtha, 2006). “The position or the layout of the center line of the road on the ground is called Alignment” (Subramani and Kumar, 2012). Road alignment is the task associated with new as well as existing roads. Environmental impact assessment must be carried out on road construction and operation to promote the sustainable development of the economy and environment (Li et al., 1999).

Determining the best route between two stations is one of the oldest spatial problems. This problem can be resolved effectively using Geospatial technologies and during the last decade, a few attempts have been made to automate the route-planning process. Constructing a new road or railway, or aligning an old one can be very expensive, with costs depending on the alignment selected. Costs are increased by long structures, by large volumes of cut and fill, and by unbalanced cut and fill were discrepancy has to be dumped or borrowed. There are numerous environmental issues that need to be addressed to ensure that the alignment does not reduce bio-diversity or degrade the environment. The first step in producing high quality alignments depends on obtaining suitable data on geology, land use, slope, soil and drainage. In addition, there are issues such as land value and ownership, social and economic impact, and identifying environmentally sensitive areas (Subramani and Kumar, 2012)

Planning a new road or highway can be expensive and time consuming process. There are numerous environmental issues that need to be addressed. The problem is worsened, where the alignment is influenced by the location of services, existing roads & buildings, and the financial, social & political costs of land resumption. GIS, a powerful tool for the compilation, management and display of data associated with geographic space, is used for the preparation of digital maps and analysis purposes. The conventional manual methods were difficult, time consuming and expensive.(Subramani and Kumar, 2012).

Environmental impact assessment of new road alignment also involves lots of factors, and handling this factor simultaneously is not an easy task. Most of the information about environmental management and environmental impact assessment are related to geographical locations and can be stored in the GIS database. With its powerful function of handling 2D/3D maps and attribute data, GIS can manage vector data, grid images, and text attribute, to display and analysis of related parameters.

Another important task associated with road transport network is traffic forecasting. Traffic forecasting is expressed as the number of persons or vehicle per unit time that can be expected on a given segment of transport network under a set of given land use, socio-economic and environmental conditions (Garber and Hoel, 2009). Forecasting of traffic is used to establish the vehicular volume on future or modified transport system alternatives and to assess the pollution level in the environs of the road (Zhong and Hanson, 2009). Traffic forecasting is mostly done through the travel demand model which is most effective but it is very time consuming and results are varying because it is modeled through the too much unquantifiable and non-realistic parameters such as propose level of service, design speed, comfort, time etc. the judgment of these parameters is seems to be non-realistic because of their dependence is varying from person to person. Most reliable parameter for traffic forecasting is "**Distance to be travelled**", which is not using in most of the cases because of the handling problem of large extending of traffic origin and destination. GIS is a tool which can handle large extension of origin and destination and results of traffic forecasting can be improved to quantifiable and realistic.

1.2. Problem Statement and Motivation

Uttrakhand became a separate state in the year of 2000. Dehradun was selected as an interim capital of the state. Gairsain is proposed to be the future capital of Uttarakhand. Five regional roads are proposed originating from the proposed capital to the various district headquarters. Out of these five the Gairsain to Bageshwar route was selected. Region between Gairsain and Bageshwar is under large forest coverage, and dense vegetation, steep slope and also under high and very high landslide hazard zonation. It is required to predict the optimal possible route to maximize the efficiency of the road network and minimise the impact on its environs.

In other hand, there is no direct traffic movement between Gairsain and Bageshwar. But in future, road traffic is predicted to be increased rapidly and it would also effect the natural and ecological environment. It is required to forecast the traffic on the suggested proposed road without direct traffic movement.

1.3. Objectives:

The objectives of the study areas are as follows:

1. To model alternative road alignment connecting Gairsain to Bageshwar.

2. To quantify the impact assessment of each alignment on its environs and obtain optimal route alignment.

3. To forecast the traffic for the proposed road.

1.4. Research Questions:

The research questions for the above objectives are as follows.

1. What are the different alternatives for road alignment connecting Gairsain?

2. What are the different factors to assess the environmental vulnerability for road alignment?

3. Which route is optimum having minimal environmental effect?

4. What will be the forecasted traffic in the total PCU?

1.5. Data sets used

The data sets used in the study are as follows:

S.NO	DATA SET	SOURCE
1	Resourcesat 2, LISS IV DATA	NRSC, Hyderabad
2	Topographic maps	Survey of India
3	CARTO DEM	NRSC, Hyderabad
4	Geological Maps	Rajiv Gandhi Drinking water Mission, Uttrakhand
5	Soil Maps	National Bureau of Soil Survey and Landuse Planning (ICAR), Nagpur
6	Village & town map	Census of India (2011)
6	Traffic volume count data of existing transportation routes	Field Survey
7	Origin Destination Data of Existing Transportation routes	Field Survey

1.6. Thesis structure

This study is composed of six chapters.

Chapter one includes the background of using GIS in transportation and highway alignment, and traffic forecasting, objectives, research questions and the data set used.

Chapter Two presents a review of the developments in the application of GIS in the transportation sector, especially in road alignment selection, modeling environment vulnerability and traffic forecasting.

Chapter Three explains about the study area, its characteristics, and its challenges to carry out research work.

Chapter Four deals with the research methodology adopted for the preparation of data sets, road alignment, evaluation of various alternatives and traffic forecasting using geospatial tools.

Chapter five explains about the advantages, disadvantages and comparison of various alternatives produced at various stages of research.

Finally, **Chapter six** summarize the conclusions and recommendations of the research carried out.

2. Literature Review

2.1. Introduction

Development of Road transportation network is considered as one of the key to rapid modernization and development, particularly in developing countries like India. A basic road design problem is to find the most economical alignment connecting two given end points based on topography, socio-economic factors and environmental impacts, while satisfying a set of design and operational constraints (Awwad, 2005).

The literature review is divided into the following three parts dividing the work into three main parts:

1. Road alignment optimization
2. Modeling Environment vulnerability
3. Traffic Forecasting

2.2. Road Alignment optimization

Traditional road design requires experienced engineers to repetitively evaluate various alternatives in order to determine the most promising alternative which satisfies the needs, optimal in its location for minimizing the costs of its construction, and avoiding any environmental constraints in the area. Since the number of alternatives joining two road end points (**Figure 2-1**) is unlimited, a manual design may arrive at a merely satisfactory solution rather than a near-optimal design (Jha and Schonfeld, 2000).

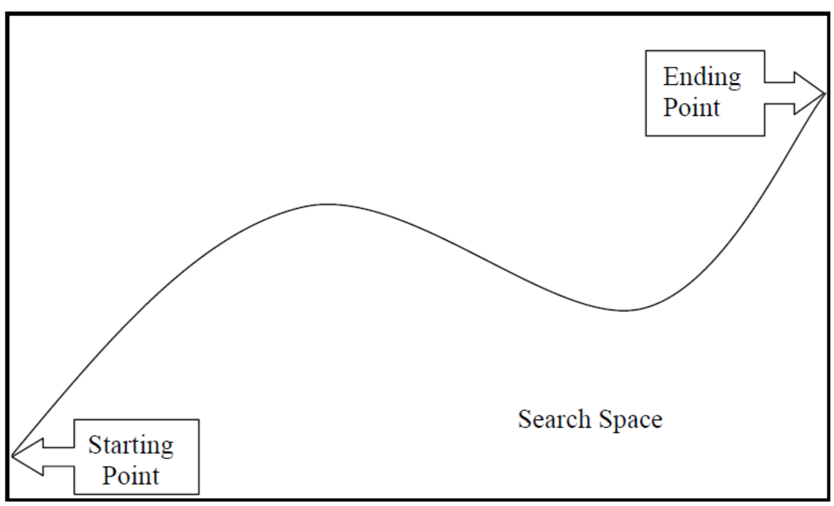


Figure 2-1- Road alignment optimization

Road alignment optimization is a computerized process that minimizes an objective function composed of alignment sensitive costs (AL-Hadad et al., 2010). Road design optimization models tend to identify the best possible road alignment while satisfying a set of design constraints such as minimum curvature, sight distance and gradient.

Road construction projects highly depend on geographical information obtained from field surveys such as topographical features, property parcels and environmental features such as floodplains and wetlands. Since, several costs of road alignments are sensitive to geography, using GIS as a tool to calculate these costs is very efficient and time saving. In the field of road alignment, various optimization techniques have been applied to locate a path between two known locations. Most of them employ GIS due to its powerful functionality in representing and analyzing geographic features.

Srirama et al., (2001) determined least cost path on grid based modeling and finalized the Least-Cost Path based upon weighted criterion. Spatial and non-spatial data both were used for this research work. LISS III Data, land use, lithology, roads, water bodies and slope were used as a spatial data which means land value and construction cost was considered as a non-spatial data. Using the gridded weighted method a shortest least cost path was finalized. Some observations from this research are (1) various physical characteristics of the terrain viz. land use / land cover, soil, lithology, slope, land values etc., have been considered in generating the road alignment. (2) Special attention has also been taken to check that the passage of road should not cross over the productive agricultural lands, forests, and it should not be affected by natural hazards such as floods, erosion etc., and high gradient areas. It has also been checked that it should not go amidst high land values areas.

Bose and Kupta, (2003) also indicated the significance of remote sensing data for landform and drainage pattern analysis for safety of infrastructural designs in the planning stage. They also recommended that appropriate integration of different Spatio-thematic information with non-spatial data in GIS environment demanded human resources development for handling and processing of the database of multidisciplinary nature to conclude on user orientation.

Dawwas, (2005) developed a GIS model for route location and highway alignment and used it to generate alternate highway route applications. These alternatives were preliminarily designed using CADD software (Soft desk 8.0), the model was used to analyze, evaluate, and then select the alternative with least impacts on environmental, economic, and political aspects. In this study, GIS model was also tested that aims to select the best alternative of three suggested highway alignments. In this application, the advantage of the developed model was clear in the preliminary stage of alternatives generation where it was possible to avoid impacting of the different sensitive areas. In addition, a lot of information can be concluded once the user identifies a suggested route because the profile can be developed and drawn immediately. In final stages of analysis and evaluation, the model showed high capabilities in analyzing the impacts of each alternative, using buffering and spatial relations between the different features and the suggested alternatives, and then evaluating these impacts. The results of this study clearly showed the applicability and potential of using GIS as a tool in route location and highway alignment with least potential impacts.

Jrew et al., (2008) demonstrated the ability of using remote sensing techniques in highway engineering during the evaluation process for road alignment. The research idea focused on an evaluation process for the alignment in reconnaissance and preliminary planning stages and making a comparison between the used conventional method which represents field survey operations and the new method which depends on remote sensing techniques and Digital Terrain Model design (DTM), using of the most important programs in Geographical Information System (GIS). A Landsat (Thematic Mapper) image taken for the study area and is used in the analytical part of the work after some pre-processing of the image, including the enhancement process that helps us in image interpretation and visualization especially in the determination of Ground Control Points (GCPs) which are distributed in the region. The study is divided in two parts: The first one represents road field survey measurements that lie on the road centerline and sides (5m distance from each side). The second part of the work consists of DTM generation, which gives three- dimensions (E, N, H) for each point in the region. The method for digital terrain model design is scanned contour lines method, which depends on the topographic map of the study area of 1:100.000 scale and 10 m contour interval, also using GIS program (Arc view, ver.3.1). A comparative study was conducted between the field measured coordinates and the corresponding coordinates extracted from digital model through plotting a longitudinal profile for field and DTM measurements together having the same scale, based on differences of heights. The study shows that the coincidence ratio between the two methods is 82%. After correcting the value of the contour interval of the base map that contains an error in contour interval values, the coincidence ratio between the two methods was increased to 95%. The results of the DTM by scanned contour line method are obtained in a short time in comparison with the conventional method (spot height method). In addition, the results are of high accuracy in representing the topography.

Naghdi et al., (2008) investigated the capability of utilizing GIS in improving the accuracy in quality of forest road planning based on soil stability. Therefore, Janbehsara, a forest district under the administration of Shafaroud watershed authority of Guilan province, northern Iran- was selected as the study area, covering approximately 1849 ha. Area. Extracting and overlaying the slope, aspect, soil texture, and drainage maps was carried out using Arc-GIS ver. 8.3. In order to prepare stability map for five classes, soil texture and drainage maps were merged based on FAO guideline. A questionnaire was prepared in order to get the experts view on effective factors of road planning which include, slope, aspect, altitude, stock per hectare and soil stability. The collected factors were analyzed. By giving a value (an impact factor) by comparison method. Based on these given values, the road crossing capability map were prepared for three levels of crossing, high, low and medium. Then PEEGER software was used to plan roads on land crossing capability map. The GIS planned road network was compared with current road network. The results show that the GIS planned road network crosses 75.5% of stable areas, while the current road network covers 60% of stable areas. With regards to drainage, the GIS planned road network covers 70% of good drainage areas while the current road network only covers 55.8%.

Kang, (2008) developed some model for the optimum highway alignment which deal separately with the problems of road alignment optimization and network design. However, no models have been found that integrate these problems comprehensively and effectively. This dissertation seeks to find a realistic three-dimensional highway alignment that best improves an existing network, while considering its costs, geometric design, and environmental impacts on the study area.

AL-Hadad et al., (2010) successfully applied genetic algorithms (GAs) for optimizing highway alignments. Genetic algorithms are very effective at finding good solution in a complex search space with many local optima (Kim et al., 2003). His representation of the area was in a matrix format as shown in **(Figure 2-2).** The decision variables were considered as the intersection points located on the vertical cuts on a horizontal plane connecting the start and ending points of the alignments **(Figure 2-2).** GIS was not used in this method and this created a problem of inefficiency as it is very time consuming to manually populate the cost and elevation matrices used in the input file required for running the model. The elevation and land unit costs have manually filled into the input file and this is an impossible process for a geographic region containing many features.

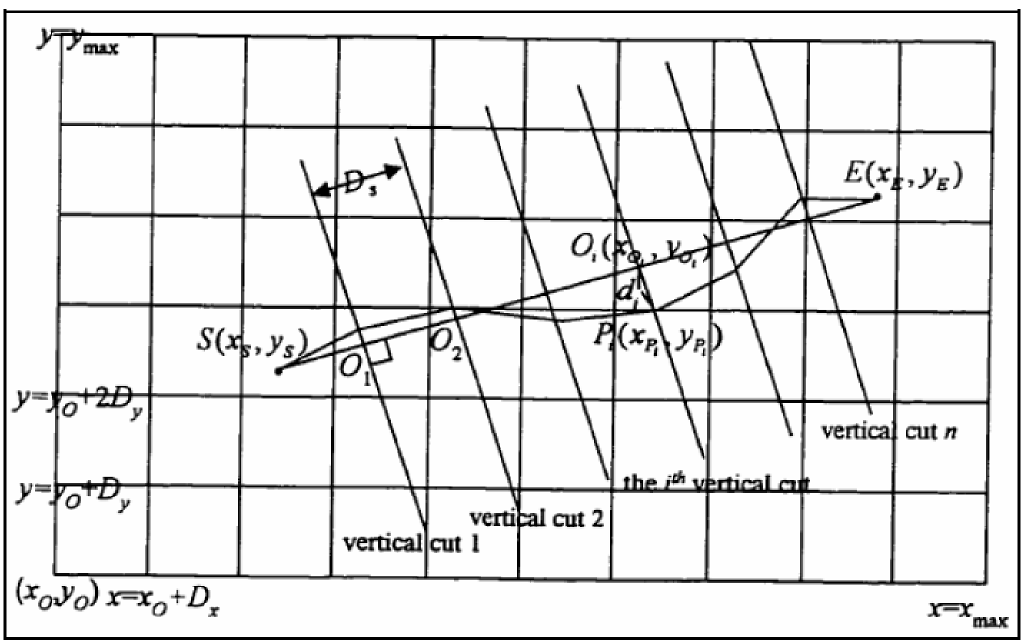


Figure 2-2 - Representation of study area and decision variable.

Subramani and Kumar, (2012) has identified the shortest and the economical path is identified using GIS software. The factors considered are mainly related to the land use, geology, land value and soil. The weights and ranks are assigned to each of the above themes, according to expert opinions, for GIS analysis. After assigning weights and ranks, these themes are overlaid to get an weighted map. The final weighted map has the most suitable area to align the highway.

Effat and Hassan, (2013) applied a GIS tool to develop a least cost path for the corridor to link three cities in Sinai Peninsula desert environment. Route has been selected having least cost and protected from the negative impacts that may be caused by the surrounding environment. Cost factors were identified and cost surface was created for each factor, standardized, weighted and aggregated. Three visions were modeled; an engineering vision, environmental vision, and hybrid vision. A multi-criteria evaluation was used to compare the three routes. The hybrid route was finally recommended.

Therefore, planning a new road or highway is an expensive and time consuming process. There are numerous environmental issues that need to be addressed. The problem and challenges will depend upon the characteristics of the study area. The issues needs to addressed varies with time With the help of remote sensing and GIS, every challenge of study area may be addressed because these are the powerful tool for the compilation, management and display data associated with geographic space, is used for the preparation of digital maps and analysis purposes rather than the conventional manual methods which are difficult, time consuming and expensive.

2.3. Modeling Environment vulnerability

With the development of economy, the road traffic increased so rapidly that it has promoted economic and social development but has also broken the natural environment and ecology balance, and brought much pollution and harm to life. Environmental impact assessment must be carried out on road construction and operation to promote the sustainable development of the economy and environment.

Affum and Brown, (1997) described a system which links land use information and output from travel forecasting modelling procedures through a simple GIS for the estimation of the environmental impacts of road traffic. GIS used for spatial analysis, improved display capacities and data integration capabilities. The system consists of four modules which permit for the estimation and evaluation of the environmental consequences of transport network planning proposals being tested. The outputs from the system are presented in easy way to understand maps and graphical formats.

Li et al., (1999) has integrated the merits of the map overlay method and the matrix method. A Geographic Information System (GIS) based map overlay method was developed to analyze comprehensively the environmental vulnerability around road and its impact on the environment. The assessment process of the GIS based map overlay method and detailed case study was presented, which include system structure and weights of assessment factors, making environmental vulnerability grade maps, calculating the respective coefficients of road impact extent for each factor, and evaluating the alternative alignments comprehensively to obtain the best one.

Rebolj and Sturm, (1999) had integrated existing emission calculation software with a graphical user interface, which includes a GIS (geographical information system) component focused on the design and implementation of the computer application with the emphasis on the used component and GIS technology. The integrated emission evaluation system offers entirely new ways of using the emission model and gives additional visualization and analysis possibilities.

M.Umit Gumusay et al., (2008) told that GIS is a computer based information system that enables capturing, modeling, manipulation, retrieval, analysis, and presentation of geographically referenced data. They compared measurements from the different vehicles, second by second vehicle speed and road altitude data was collected using GPS technology simultaneous with the emissions measurement. Analyses were carried out that increasing emission which several of vehicles sent out environment with GIS. The analysis of the amount of emission depending on the changes of the slopes, calculation of gases spread into air depending on traffic jam, the analysis of the amount of emission depending on the route selected in the city were also applied.

From the above discussions it can be concluded that there are numerous environment issues needs to be addressed whether these are Physical, Political, Environmental, Economical, Ecological, social, institutional etc. these issues needs to be evaluated before starting the road construction or the parameters to address these issues must be included as a input for the preparation of environment vulnerability maps. And these must be used as the input for the road alignment optimization.

2.4. Traffic forecasting

Traffic volume counts are used in planning, traffic operations, and asset management programs. Traffic counts are usually collected using sensor-based monitoring tools at limited locations in a network. The sensor-based method excludes low-class roads due to the cost involved. Therefore, in general, there is no volume count data available for local roads; even though they make up the majority of our highway network.

An extensive literature review revealed that using traditional factor approach, regression-based models, and artificial neural network models failed to present network-wide traffic/truck volume estimation because they rely on traffic counts for model development and they all have inherent weaknesses. Moreover, their traffic estimates have high estimation errors. Traditionally, four-step model (FSM) is based on traffic analysis zones (TAZs) structure which conveniently uses existing census geography to take advantage of socio-economic data available from Statistics departments. However, the coarse zone structure used in such models tends to exaggerate the intra zonal trips resulting in biased and unbalanced trip distribution over roadway network and high estimation errors. Also, their purpose is to guide infrastructure development and therefore, they are not appropriate as a tool for estimating traffic at network analysis, including low-class roads.

You and Kim, (2000) developed and evaluated a hybrid travel time forecasting model with geographic information systems (GIS) technologies for predicting link travel times in congested road networks. Using the core forecasting algorithm, a prototype hybrid forecasting model has been developed and tested by deploying GIS technologies in the following areas: (1) storing, retrieving, and displaying traffic data to assist in the forecasting procedures, (2) building road network data, and (3) integrating historical databases and road network data. This study shows that adopting GIS technologies in link travel time forecasting is efficient for achieving two goals: (1) reducing computational delay and (2) increasing forecasting accuracy.

Wang and Cheng (2001) developed a spatio-temporal data model to support activity based transport demand modelling in a GIS environment. This so-called mobility oriented spatio-temporal data model conceptualizes the spatial and temporal interaction of travel and activity behavior using the concept of mobility. In other words, activity patterns are conceptualized as a sequence of staying at or travelling between activity locations. The model can support the analysis and queries of activities from different perspectives, i.e. queries can be location-based, time-based, and person-based. It can also support activity-based modelling by identifying spatial and temporal opportunities for activity participation. A prototype system based on the data model is implemented in ArcView. The prototype is illustrated and tested by a case study based in Hong Kong.

Chris AYLES, (2005) reviewd the application of the latest modelling techniques using the Cube software package, developed by Citilabs. Cube is one of the world's leading travel forecasting software packages, and the first to develop a fully integrated approach to travel demand forecasting, from "traditional" 4-stage models to Micro-Simulation, together with Freight, Land-Use and Environmental modules.

Yaldi et al., (2008) proposed new method, called here the Fuzzy-Neuro approach, is proposed for modelling travel demand, focusing on trip distribution and mode choice, with the expectation that it can improve the accuracy of the resulting models.

Zhong and Hanson, (2009) examined the feasibility of using a TDM (Travel demand Model) to estimate low-class road traffic volumes. Two regions in New Brunswick were chosen to test and implement a TDM: York County and the CCS of Beresford. The results from the county case showed that estimates for arterial roads had the lowest average error (9%), followed by collectors (45%), and local roads (160%), as compared to observed traffic counts. An overall overestimation trend was found across nearly all study sites and thus indicates traffic was not effectively distributed at the collector and local road level. Existing traffic counts were used to develop the regression models for calibration purposes. Regression analysis was used to analyze the correlation between the forecasted traffic from the TDM and observed traffic counts, and linear regressions were developed to recast the forecasts from the TDM to more reasonable ones. It was found that the calibrated models were useful to remove overall overestimation trend from the TDM.

Riad Mustafa and Ming Zhong, (2010) developed a high-fidelity travel demand model (HFTDM) capable of achieving network-wide traffic volume estimation with improved accuracy. This will require all functional class roadways and spatially disaggregating census-based coarse TAZ structure into fine zones. A case study using an aerial interpolation technique, which is based on fine-scale grids, road density and a detailed road network was developed for the Beresford/Bathurst area in the province of New Brunswick.

Almasri and Al-Jazzar, (2013) applied TransCAD model in Gaza City for traffic estimation. This model estimates the origin-destination matrix based on traffic count. The traffic count was carried out at 36 intersections distributed around Gaza City. The results of traffic flow estimation ob-tained from TransCAD are assigned to the Gaza maps using the GIS techniques for spatial analysis. It is shown that the most congested area at present is the middle of the city especially at Aljala-Omer Almokhtar intersection. Therefore, improvement scenarios of this area should be carried out. The results of calibration of traffic flow estimation show that the differences between the estimated and the actual flows were less than 10%. In addition, network evaluation results show that the network is expected to be more congested in 2015. This work can be used by transportation planners for testing any network improvement scenarios and for studying their network performance

Mustafa and Zhong, (2014) focuses on the challenges and opportunities in achieving high-fidelity travel demand model (HFTDM) and opportunities in relation to both technological advances and intelligent data present a substantial potential in developing the proposed HFTDM for much more accurate traffic estimation at a network wide level.

Lopes et al., (2014) analyzed the results obtained from different approaches of spatial regression models considering the importance of spatial issues in transport planning. The main objective of this study was in the case of spatial autocorrelation, spatial dependence patterns should be incorporated in the models, since that dependence may affect the predictive power of these models. The results obtained with the spatial regression models were also compared with the results of a multiple linear regression model that is typically used in trips generation estimations. The findings support the hypothesis that the inclusion of spatial effects in regression models is important, since the best results were obtained with alternative models (spatial regression models or the ones with spatial variables included).

In the previous studies for traffic studies, most reliable parameter for traffic forecasting is "**Distance to be travelled**", was not used, because of the handling problem of large extending of traffic origin and destination. GIS is a tool which can handle large extension of origin and destination and results of traffic forecasting can be improved to quantifiable and realistic, So that an attempt has been made for the traffic forecasting for new proposed road to make result more realistic.

3. Study area and its characteristics

The selected route for the study is from Gairsain to Bageshwar. Boundary of study area has been delineated on the basis of origin, destination and existing approaching road network. Major part of Study area lies in the Chamoli, Almora and Bageshewar districts in the state of Uttrakhand and minor portion of study area is also falling in the Pithoragarh and Pauri-Garhwal district. The broad location of study area and its surrounding is shown in the **Figure 3.1.**

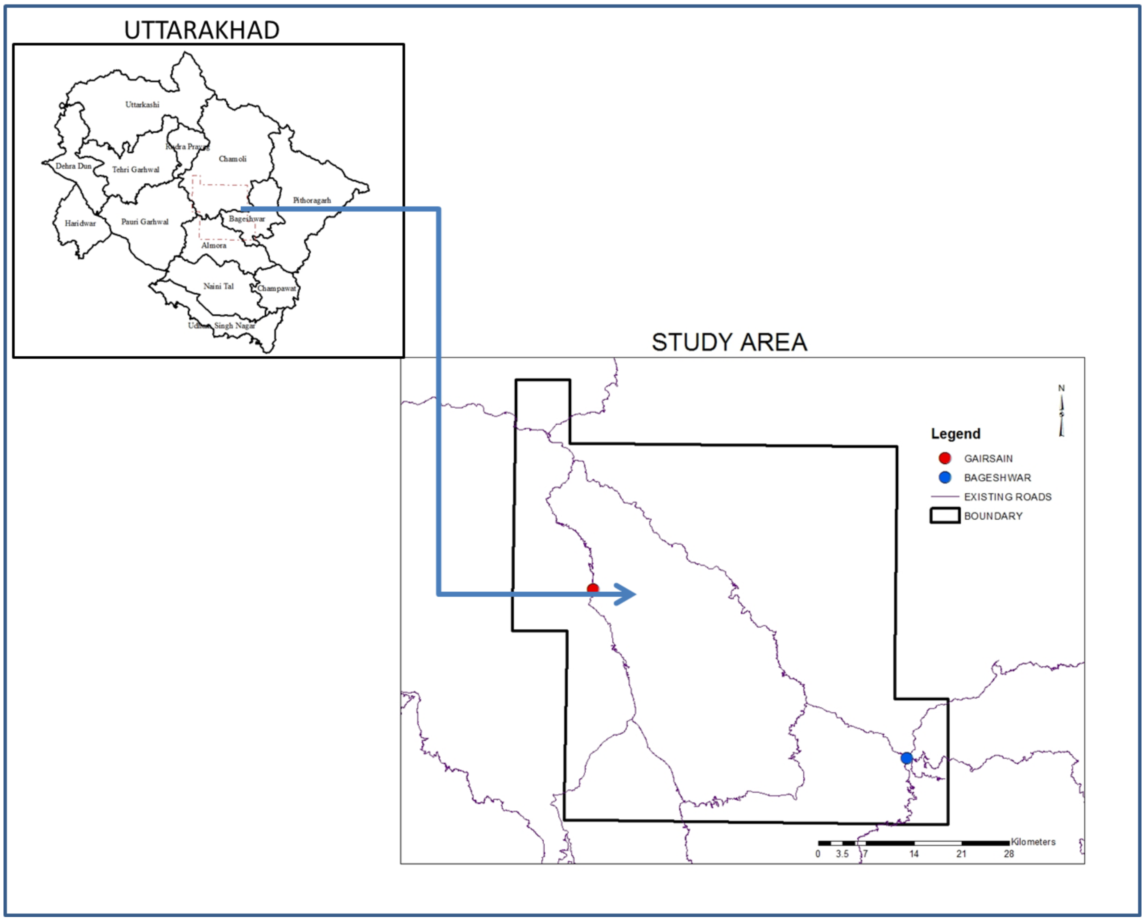


Figure 3-1: Delineated study area

Gairsain is a town and municipal board in the Chamoli district in central Uttarakhand. It is proposed to be future capital of Uttarakhand. It is being considered as a future capital of Uttarakhand. It is situated in the center of the Garhwal and Kumaon region. It has an average altitude of 1,750 metres (5,740 ft) above sea level. Gairsain is also the site of the source of Ramganga River, the nearby Dudhatoli Parvat, where the Ramganga River rises. Gairsain is just about 16 km from the Almora district border along National Highway 87. The nearest railway station to Gairsain is Ramnagar which is 150 km away. The nearest airport is Gauchar Airport, at Gauchar which is approximately 54 km.

Bageshwar is a city and a municipal board in Bageshwar district in the state of Uttarakhand, India. It is also the administrative headquarters of Bageshwar district. The town is situated on the confluence of Gomti river with Sarju river which is a tributary of Sharda or Kali river and joins Kali at Pancheswar. Sarju river is the same, which is known as Sharda till it meets Ghaghra Sarayu river on whose bank Ayodhya is situated. It has an average elevation of 1,004 m (3,294 ft). It is 150 km from Nainital city and 470 km (290 mi) from Delhi. The nearest airport is at Pantnagar, 180 km away to the south in Nainital district. The nearest railhead is Kathgodam, 160 km away to the south in Nainital district reached via Almora town (75 km). Tanakpur 230 km away to south-southeast near the border with Nepal is another railhead.

3.1. General characteristics of study area

The geographic Centre of the state lies on the border districts of Pauri, Garhwal and Chamoli. Culturally, the divisions of Garhwal and Kumaon people aspires the location of Gairsain as the one of the key location for capital. By population distribution in hilly regions, the center of absolute population as well as that of population density lies in these two districts.

Study area is basically hilly in nature, most dispersed over difficult terrain, are small and isolated. Majority of them are inaccessible due to poor transport and communication facilities. People live at the subsistence level and have to travel long distances to collect water. Certain specific tourist/pilgrim towns have grown rapidly. Some have the added advantage of being administrative centres like bageshwar, or an, educational centres, cantonments or supporting significant industrial activity. Towns and cities, in their distribution, show linear pattern along river valleys or important roads linking the plain with centers of tourism or religious importance. Isolated higher order settlements exist generally in the foothills. These are collection points (or trade center's) for agricultural and forest produce. These are few of the towns which can give impetus to growth in the surrounding areas. Settlements show potential for forest, livestock and horticulture-based economic activity.

3.2. Physiography of study area

The study area is represented by rugged and undulatory topography of Lesser Himalaya. This slide is located on a fairly steep slope adjoining Pinder river on its left bank. The Pinder river after originating from Pinderi glacier, flows from N-S up to Dhaura and then takes a sharp turn towards WNW and joins Alaknanda river at Karnaprayag. The Pinder River generally flows through a deep V-shaped valley in its entire course except at certain locations where the valley is wider due to presence of older river terraces.

This perennial river with high run-off, steep river bed gradient and tight V-shaped valley (50 - 60) degree indicates a young stage of regional geomorphologic development. The general slope is of the order of about 350 -400 while it becomes comparatively steeper (55 -60) degree just above the road. However the slope below the road level is of the order of 40-45 degree. The slope again becomes steeper (550 -600) close to ridge top.

The landforms of the study area are considerably steep and moderate slope which is not easy to handle for the road construction purpose. The climate also remains favorable conditions for the most of the months, since it lied in middle Himalayas, the winters remain fewer temperatures.

3.3. Drainage pattern of study area

The rivers Kali, Gaula, Kosi, Western Ramganga, Ganga, Yamuna and Tons drain this region. The Western Ramganga rises on the northeastern slopes of the Dudhatoli ranges. It is an antecedent river and flows transverse to the structural axes in gorgeous channels, with irregularly terraced patches of subrecent gravelly and sandy deposits along their paths, in the inner sedimentary belt of comparatively gentle gradient and milder topography. The small streams (gad) and ravines (gadhera) feeding the main rivers flow in a radial pattern in the Dudhatoli massif with the Ramganga flowing northeastwards, the Binau towards the southeast and the two Nayars draininge southwestwards.

3.4. Geological setting of study area

The study area is comprised of phyllites, quartzitic phyllites, phyllitic quartzites and massive quartzites of Proterozoic age. There are no rocks exposures present within the Harmony landslide area. The entire area is blanketed by debris material derived from an ancient landslide. As such it consists of assorted materials ranging from clay to big boulders, which have been obtained from the adjoining rock exposures.

On surface, loose materials consisting of rock blocks embedded within a matrix of fine soil (clay to silt size fraction), is observed. The in-situ rock exposures are expected to be present at deeper levels. Large scale slope movements are reported every year during rainy seasons. Because of repeated displacements, the Karnaprayag - Gwaldam road passing through the slide material got displaced down to lower levels in the past. One can see three of such roads at lower levels than the present level of the road. Water seepage can be seen at a number of locations within the study area. However no perennial stream flows through the slide area. On both the ends of the slide, two streams are seen flowing towards NE direction. A number of tension cracks are seen above the present pinder river. Though they are mostly filled by the soil around, the traces are still identifiable. The slide materials do not have uniform slope gradients from the crown to road level.

3.5. Geo-environment problems

Unstable geological conditions, heavy rainfall, anthropogenic activities (excessive construction, deforestation etc.) etc. have been mainly responsible for several landslides resulting into loss of life and property or both. Due to these natural hazards, in this region is facing major problems of environmental degradation.

As a result there is tremendous down cutting of the river valleys for which we get many gorges and V-shaped valleys in this region. This leads to toe erosion of the hill slopes especially along the river bends. Hence, any improperly planned construction and associated excavations, in the name of development, which lacks proper geological and geotechnical investigations, is a cause of concern for stability for that hill slope in the study region.

In this circumstances if there is human interaction by means of unplanned constructional activities like excavations, then it causes instability of slopes. So, the ultimate and cumulative effect of all of these factors is the sudden movement of slope forming materials, down the slope, mostly along a plane of discontinuity. This is called a landslide or in a broad sense, may be called as mass wasting.

3.6. Landuse/landcover

Most of the study area covered with forest which is seems to be the beauty of area. Constructions of road will disturb its ecology but roads are the key parameter for the development of the area. So it is necessary to take a suitable study to protect the forest and other environment sensitive areas while aligning the road.

3.7. Traffic characteristics

From the existing data collected it is observed that there is no significant direct movement of traffic from Bageshwar to Gairsain or Gairsain to Bageshwar. Traffic between bageshwar and Gairsain is running through two segments first via Gwaldan and second via dwarhat and further into small segments as shown in the **Figure 3.2.**

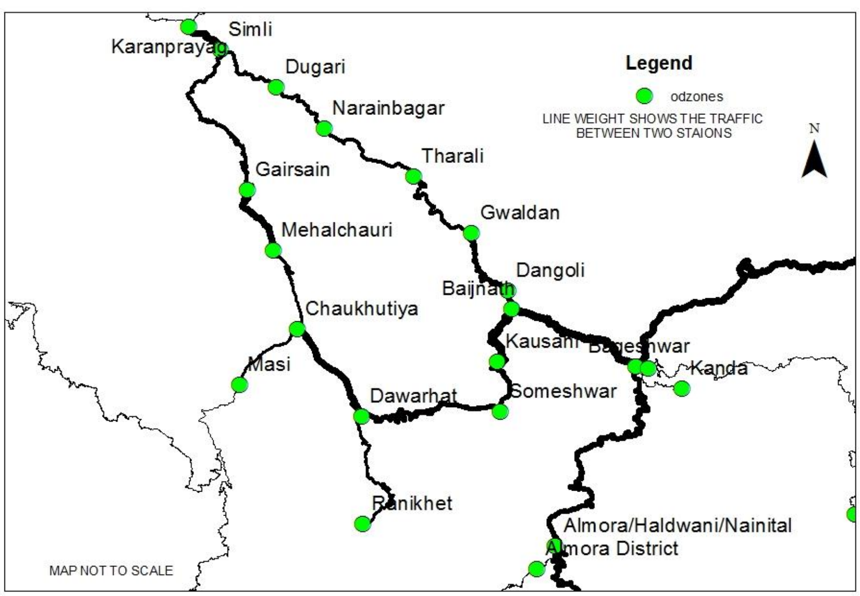


Figure 3-2 Stretch wise traffic flow in study area

Each segments is further divided into various segments like

- Bageshwar to Baijnath
- Baijnath to Kasauni
- Kasauni to Someshwar
- Someshwar to Dwarhat
- Dwarhat to Chaukhutia
- Chaukhutia to Mehalchuri
- Mehalchuri to Gairsain
- Baijnath to Gwaldan
- Gwaldan to Tharali
- Tharali to Narain bagar
- Narainbagar to Simli
- Simli to Karn Prayag
- Karn Prayag to Gairsain

Traffic forecasting methods are not applicable with this kind of traffic characteristics so there is a great challenge to develop a traffic forecasting for such kind of traffic characteristics.

3.8. Challenges of study area for research work

- How to protect the forest and environment sensitive area?
- How to minimize the impact of landslide from proposed road?
- How to reduce the engineering cost?
- How to forecast the traffic on proposed road without direct movement of traffic data available?

4. Research Methodology

This chapter explains how a new road alignment sections are made and highlights the major elements of the process. The process for road alignment selection is a rational one that intends, among other aims, to furnish unbiased information about the effects that the proposed highway will have on the road environment. The traditional road selection process is modified here to reflect use of GIS in an integrated model. The process therefore comprises six basic stages, which are interrelated. The information acquired in one stage of the process will be helpful in the later stages.

The various stages of methodology are as follows

Stage 1: Preparations of data sets

Stage 2: Preparation criteria vision maps

Stage 3: Defining possible route alternatives

Stage 4: Evaluation of each alternative and final selection

Stage 5: Visualization in 3D environment

Stage 6: Traffic forecasting for selected route

These stages are described in the following manner as shown in the flow chart in **Figure 4.1**

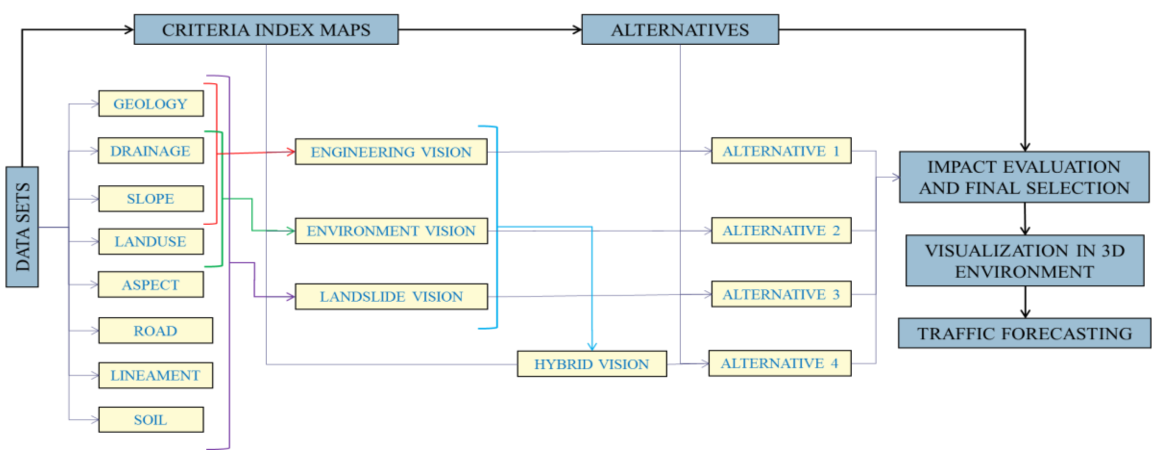


Figure 4-1: Research Methodology

4.1. Input data preparation and pre-processing

The data sets have been used and created in the study for optimum road alignment has been shown in the **Table no. 4.1**:

Table 4-1: Preparation of data sets

Input Data	Software used	Process	Output Layer
Resoucesat 2, LISS IV Data	ERDAS IMAGINE 2013	Supervised classification	Landuse/landcover
Carto- DEM	ARC HYDRO	Drainage network extraction	Drainage
	ARC GIS 10.1	Slope extraction	Slope
		Aspect extraction	Aspect
Geological maps (1:50000)	ARC GIS 10.1	On screen Digitization	Geology
			Lineaments
Soil Map	ARC GIS 10.1	On screen Digitization	Soil map
SOI Topo-sheets	ARC GIS 10.1	On screen Digitization	Existing roads
Village and town map	ARC GIS 10.1	On screen digitization	Villages & Towns

All the layers were converted into the raster format with same resolution and projection system.

4.2. Preparation of Criteria Maps

For analysis purposes, four alignments are obtained and then compared with each other. Suitability distance analysis relies on a ‘‘Suitability Surface’’, which is a raster dataset. The value of each cell represents the suitability level to align the road through that cell, higher the value of cell lesser will be the suitability and vice versa. According to the study area characteristics, the expenses is based on one or several variables such as slope, land cover, geology, soil, drainage, roads, aspect etc. For each single raster is created. An overlay function aggregates the suitability grids in a theme into one grid such as environmental suitability surface grid.

Scores from the various map attributes can only be compared if the measurement units are the same. Through the standardization procedure the measurement units are made uniform, and the scores lose their dimension along with their measurement unit. Standardization of the attributes was performed for each of the suitability surface maps.

Criteria weights

Weights have been given to the factors combined in the raster calculator. For example, if the study area has very steep slopes, a high weight has been given to the slope raster value, giving it a higher weight, more attention is given to avoid steep slope.

Following four suitability surfaces has been created:

1. Engineering Suitability surface
2. Environment Suitability surface
3. Landslide hazard Suitability surface
4. Hybrid Suitability surface

4.2.1. Engineering suitability surface

The engineering suitability surface has been prepared based on the flow chart shown in **Figure 4.2**.

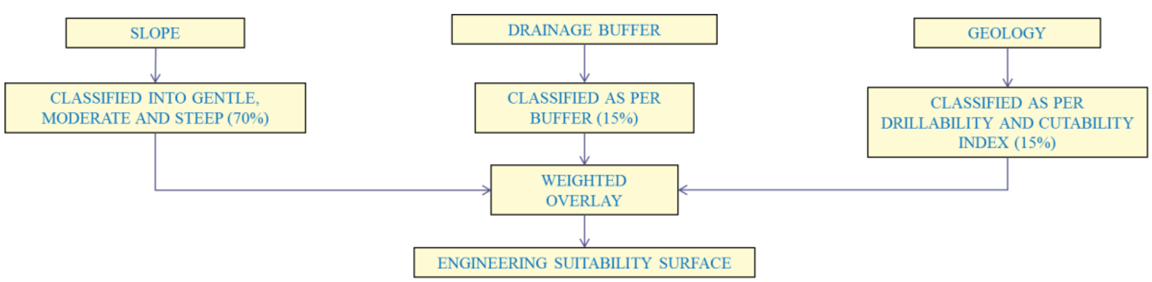


Figure 4-2: Methodology to prepare Engineering suitability surface

In this suitability surface three raster data sets have been used. Slope layer was given 70% weightage, drainage was classified along with protection buffer and given 15% weightage, Drill ability and cutability index of rocks has been given 15 percent weightage. The weightage of slope, drainage buffer, and geology has been given in the **Tables 4.2, 4.3, 4.4.**

Table 4-2: Slope Weightage in Engineering Suitability Surface

Class	**Slope**	**Suitability level**	**Weightage**
Gentle	0-15 Degree	Highly Suitable	1

Class	Slope	Suitability level	Weightage
Moderate	15-45 Degree	Moderately Suitable	3
Steep	>45 Degree	Less Suitable	7

Table 4-3 Weightage of Drainage Buffer in Engineering Suitability Surface

Buffer	Suitability level	Weightage
50 M	Very Less suitable	9
100 M	Less suitable	7
200 M	Moderately Suitable	5
500	Near High suitable	3
> 500 M	Highly suitable	1

Table 4-4 Weightage of rock drill ability index in Engineering Suitability surface

Rock DRI	Suitability level	Weightage
<55	Highly suitable	1
55-60	Moderately Suitable	3
60-70	Less suitable	5
>70	Very Less suitable	7

4.2.2. Environment suitability surface

The environment suitability surface have been prepared based on the flow chart shown in **Figure 4.3**

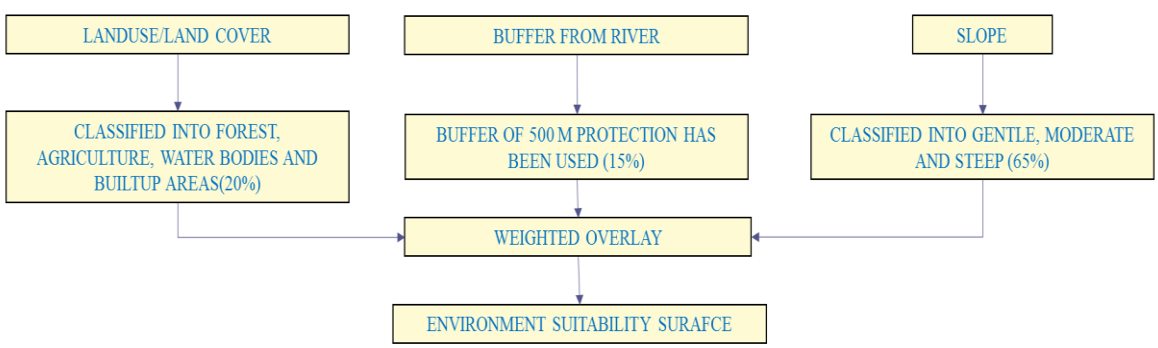


Figure 4-3 Methodology for Environment Suitability surface

In this surface raster, three raster data sets have been used. Slope layer was given 65% weightage, landuse was given 20% and remaining 15 percent was given to the buffer along the rivers. The weightage of slope, river buffer, landuse has been given in the **Tables 4.5, 4.6, 4.7.**

Table 4-5 Weightage of land use in environment suitability surface

Landuse	Suitability Level	Weight
Agriculture and scrub land	Highly Suitable	1
Water bodies	Moderately Suitable	3
Built-up	Less suitable	8
Forest	Very Less suitable	9

Table 4-6 Weightage of river buffer in environment suitability surface

Buffer	Suitability level	Weight
500 m	Less suitable	9
>500 m	Highly suitable	1

Table 4-7: Weightage of slope in environment suitability surface

Class	Slope	Suitability level	Weight
Gentle	0-15 Degree	Highly Suitable	1
Moderate	15-45 Degree	Moderately Suitable	3
Steep	>45 Degree	Less Suitable	7

4.2.3. Landslide suitability surface

To create landslide hazard suitability surface landslide hazard zonation map has been prepared and weight has been assigned to the hazard as shown in the **Figure 4.4**

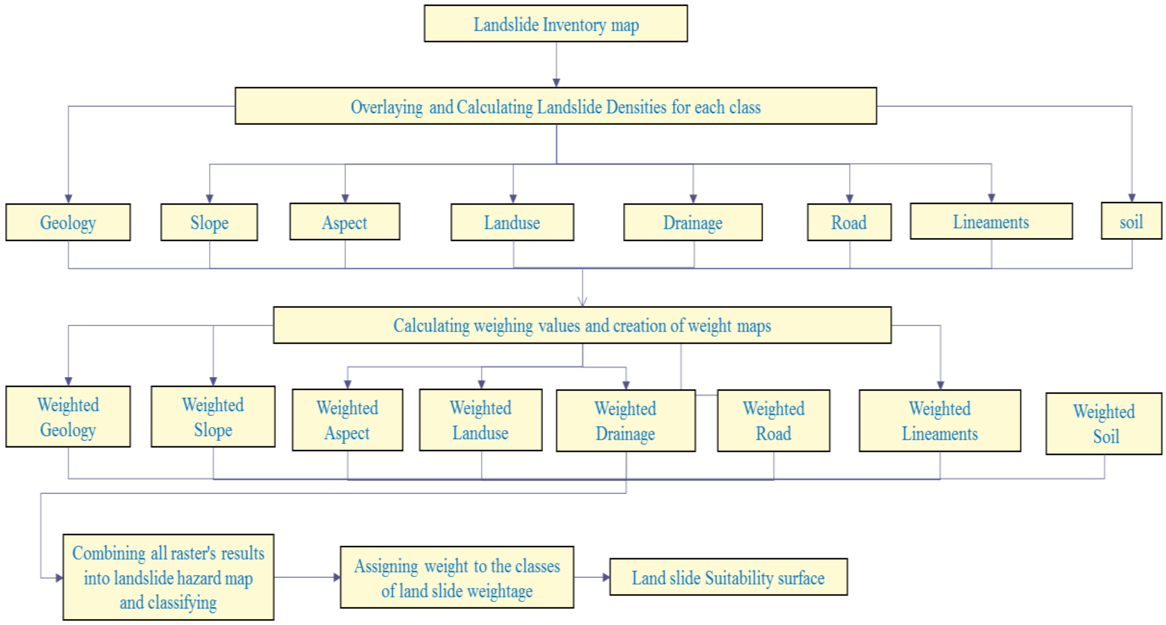


Figure 4-4 Methodology for landslide suitability surface

The method adopted for landslide hazard zonation is "information value" method. The information value as follows:.

Prior Probability = nslide/nmap

Information value = log (nsclass/nclass)/Prior probability

Where,

nmap = Total Number of Pixels in the Map

nslide = Total number of landslide pixels

nclass = Number of Pixels in each Class

nsclass = Number of pixels containing slides

To calculate the information value, each class of the thematic map is combined with the landslide map with the active landslides. Cross table were created which contain the pixel information value for various classes of individual layers. After crossing the landslides with all the individual layers, all the final maps were integrated to derive a landslide hazard map.

The method is based on the map crossing of land slide with each layer parameter map. The map crossing results in a cross table, which can be used to calculate the Density of landslides per parameter Class, A standardization of these values has been obtained by relating them to overall density in the entire area. Relation has been done by division or by subtraction. The landslide density per class is divided by the landslide density in the entire map. The natural logarithm was used to give to negative weights when the landslide density is lower than the normal. By combining all layer maps, a hazard map was created. The weight value has been assigned to the landslide hazard as shown in the **Table 4.8.**

Table 4-8 Weightage of landslide hazard zonation map in landslide hazard Raster

Landslide hazard zonation	Suitability level	Weight
Very high hazard	Very less suitable	9
High hazard	Less suitable	7
Moderate hazard	Moderately suitable	5
Low hazard	High suitable	3
Very low hazard	Highly suitable	1

4.2.4. Hybrid Suitability Surface

The environment suitability surface have been prepared based on the flow chart shown in **Figure 4.5** In hybrid suitability weightage was assigned to all the three surfaces are same i.e. 33.33 %. All the individual weightage have been assigned as such as in the input surface layers

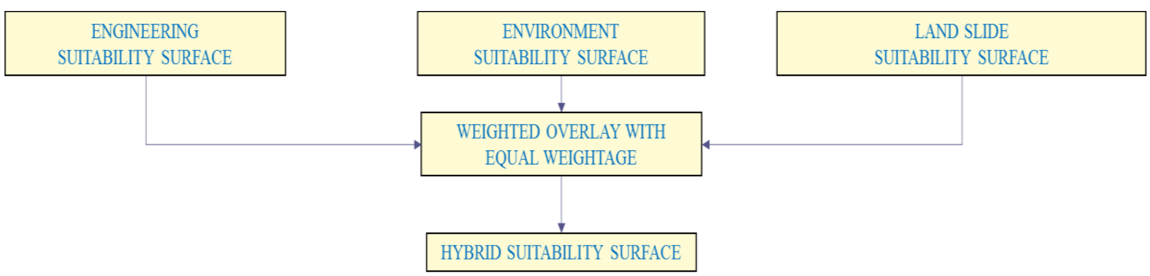


Figure 4-5 Methodology for Hybrid suitability surface

The Weighted Overlay function was used to get combined weighted surface for such themes. All these layers have been overlaid using weighted overlay function in spatial analysis tools of ARC Map 10.1. Weights were decided based on the pairwise comparison method developed by saaty in the context of analytic hierarchy process (AHP).

4.3. Defining possible route Alternatives:

This stage of research methodology cab be described into two parts as follows:

1. Creating a weighted surface distance raster and a direction raster

2. Obtaining route alternatives

4.3.1. Creating weighted surface distance raster and a direction raster

The weighted surface raster is created using the “Cost Weighted Distance” function. The function uses the starting point (Start Point) of the proposed road created earlier and the (Cost Raster) and produces an output raster (Cost- Weighted Distance Raster). In the (Cost-Weighted Distance Raster), a value is calculated and assigned to each cell; this value is the least accumulative cost of getting back from that cell to the (Start Point) along the least cost path. A (Cost-Weighted Distance Raster) is shown in **Figure 4.6**, in which the (Cost Raster) is used as the input raster.

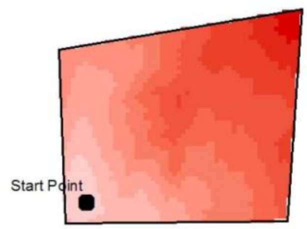
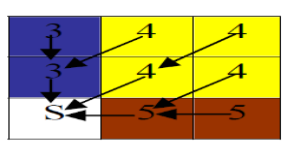
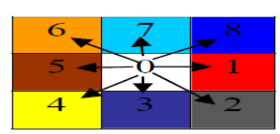


Figure 4-6 Example of cost weighted distance raster

When creating the weighted surface Distance Raster, the program prompts to create another layer which is the Direction Raster. The direction raster provides a road map, identifying the route to be taken from any cell, along the least-cost path, back to the nearest source. The algorithm for computing the direction raster assigns a code to each cell that identifies which one of its neighboring cells is on the least-cost path back to the nearest source. In the direction coding diagram in **Figure 4.7** represents every cell in the accumulative cost raster. Each cell is assigned a value representing the direction of the nearest, cheapest cell on the route of the least costly path to the nearest source **(Figure 4-7).** This process is done for all cells in the (Weighted surface Distance Raster), producing the direction raster, telling the direction to travel from every cell in the Weighted surface Distance Raster and back to the Start Point.

5	7	10
2.5	5	6
S	1.5	3





Costweighted Direction Ditection coding

Figure 4-7: Example showing how Codes are assigned and the direction coding used by the direction function in the spatial analyst

4.3.2. Obtaining the optimal alignment

All the steps described so far, end up in the formulation an optimal alignment connecting two points is to be located based on various factors represented in the raster, for which environmental factors were taken into consideration by giving them high unit cost and topography which is represented by the slope raster and the aim is to avoid traversing steep slopes as it constitutes to higher construction costs. And as mentioned earlier, two alignments are to be found, one based on the different weightage assigned. The tool used here is the "Cost Path" function. It is used to find the shortest path from a point, or a set of points to destination or a set of destinations, such as identifying the path to take from several suburban locations to the closest shopping mall. By creating the (Cost-Weighted Raster) and the (Direction Raster) based on cost units defined by the (Cost Raster), the function identifies the optimal path (road alignment) between two specified points. The output is a line **Figure 4.8** shows the result of an alignment as an example.

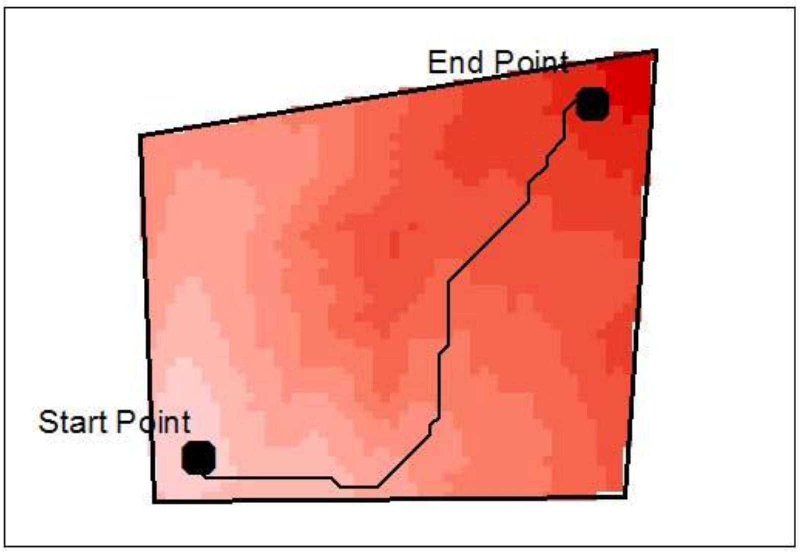


Figure 4-8 Example of Optimal Alignment Found by the Shortest Path Function

The process was repeated four times for all four surfaces created above which results one alternative route.

4.4. Evaluation of Each Alternative and Final Selection

4.4.1. Evaluation

The various parameters considered for the evaluation of each alternative are discussed below.

1. Population to be served with-in five kms

To analyses this parameter a village and town layer which constitute a village wise population is considered. A five km buffer was created around each alternative and intersect function was used to get the population wise list of villages.

2. Number of connecting nodes with existing network

Intersect function was used between Existing road network & each alternative separately to get the intersecting points as the number of nodes to be designed for each alternative.

3. Area of Forest covered to be disturbed

Firstly, forest layer was extracted from the land use land cover layer and secondly, 12 m buffer was created around each alternative to get its right of way. And then intersect function was performed to get area of forest covered to be disturbed.

4. Length of road passing though the distance of 500 m from rivers

A 500 m buffer was created along the river layer and intersection function was performed to get a length of road passing through the distance of 500 m road.

5. Area of agriculture land to be disturbed

Firstly, agriculture layer was extracted from the land use land cover layer and secondly, 12 m buffer was created around each alternative to get its right of way. And then intersect function was performed to get area of agriculture land to be disturbed.

6. No of bridges/culvert required.

Intersect function was used between drainage network & each alternative separately to get the intersecting points to get the number of bridges to be required for each alternative.

7. Volumetric analysis

Continuous points were created at a regular interval of 30 m on each alternative. An elevation of these points was extracted from DEM. Slope between consecutive points were calculated and the analysis were made as per the **Table 4.9** These points were interpolated with IDW with slope area.

Table 4-9: Volumetric Analysis

S.no	Slope	Volumetric requirement
1	Less than -15 degree	Bridge required
2.	-15 to 0 degree	Fill required
3.	0	No change

S.no	Slope	Volumetric requirement
4.	0-15 degree	Cut required
5.	More than 15 degree	Tunnel required

Source: (Manual of Highway Engineering IRC-201)

Points also interpolated by taking same height along the right way boundary and corresponding points on the center line to create an after raster. Then a cut/fill function was performed in ARC GIS 10.1 to get a quantity of cut and fill.

8. Quantity of buildable land available along each alignment.

A slope map was converted into the vector format and buffer of 200m was created along the right of way of each alignment then intersection function was performed between slope and 200m of each alternative separately and type of land available for future development was analyzed and compared.

9. Type of land available for future widening.

A landuse layer was converted into the vector format and a ring buffer of right of way of four lane road i.e. 30 m. a ring was created of future widening with Erase function and intersect function between ring and land use layer was performed to analyze the type of land available for future widening.

10. Final selection

Final selection was done though the weightage sum given to the each parameter. An alternative which has got the highest weightage has been selected as an optimum route out of the four alternatives. Weightage values have given as shown in the **Table 4.10:**

Table 4-10: Weightage assigned to each parameter for final route selection

S. no	Parameter	Weightage
1	Population to be served with in five kms	5
2	No. of connecting nodes with existing network	5
3	Area of Forest covered to be disturbed	20
4	Length of road passing though the distance of 500 m from rivers	10
5	Area of agriculture land to be disturbed	10
6	No of bridges culvert required.	10
7	Volumetric analysis	20
8	Quantity of buildable land available along each alignment.	15

S. no	Parameter	Weightage
9	Type of land available for future widening	5
	Total	100

The weight assigned to each alternative on the basis in two conditions such as follows:

If the high value is more preferable in any parameter then highest value will be the given the maximum weight assigned to that parameter for that alternative and weight assigned to other alternatives will be with the formula as

Current weight = Alternate value/ Maximum vale * Total weight assigned

If the lower value is most preferable in any parameter then lowest value will be given the maximum weight assigned to that parameter for that alternative for remaining and to assign weight to other alternative increase in percentages was calculated and percentage value of highest weight is assighned.

4.5. Visualization in 3D environment

The finally selected route was visualized in 3D environment. ISRO Bhuvan (www.bhwan.nrsc.gov.in) map service was consumed in the terra explorer software for visualization. The selected route was overlaid on the top of Bhuwan service and analyzed visually.

4.6. Traffic forecasting

Point shape files of origin destination zones and existing road network was created. Then from these files network data set was created. In the network analysis tools OD cost matrix function was performed to get origin and destination pairwise travelling distance. Similarly another network data set was created having proposed road alignment. Then those OD pair was identified which shows a changes in OD pair distance. With the help of statistical data of identified OD pairs growth rate of traffic calculated and assumed for while taking the considerations of future proposal and traffic growth rate assumed was used for the future forecasting of traffic. Then this traffic was converted into the PCU's. The research methodology for the traffic forecasting has been shown in the **Figure 4-9**:

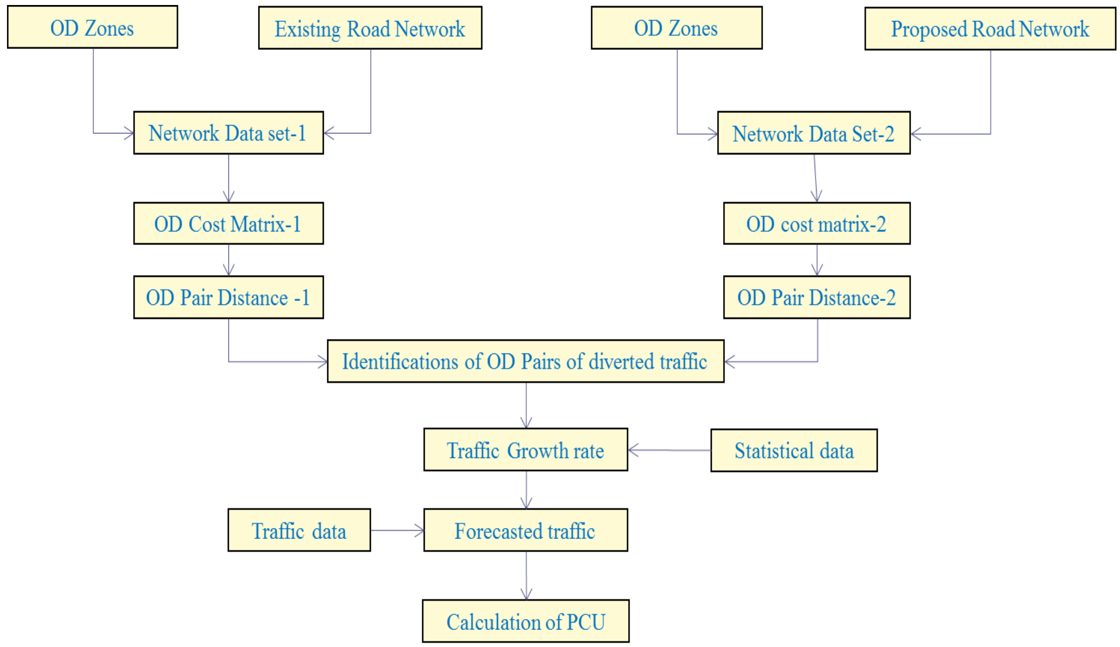


Figure 4-9: Methodology flow chart for traffic Forecasting

5. Results and Discussions

The results obtained during different stages of research are discussed under following categories.

1. Characteristics of data sets generated.
2. Characteristics of criteria surfaces generated.
3. Route Alternatives
4. Evaluation results and selected route
5. 3D visualization
6. Traffic forecasting

5.1. Characteristics of data sets:

5.1.1. Land-Use/Land Cover

Landuse/ land cover plays an important role in road alignment. Land use/landcover layer prepared for the study area consists of five classes viz. Water bodies, urban areas, scrub land, forest and agriculture land. Agriculture land and scrub land is considered more suitable for road alignment, forest areas needs to be protected from disturbance to maintain ecological balance, urban area should be avoided to cross but road should be accessible to it. Water bodies also need to be avoided for road alignment to reduce the bridge construction cost. Statistical analysis of landuse/landcover is shown in the **Figure 5.1** and spatial distribution of landuse/land cover is shown in the **Figure 5.2**.

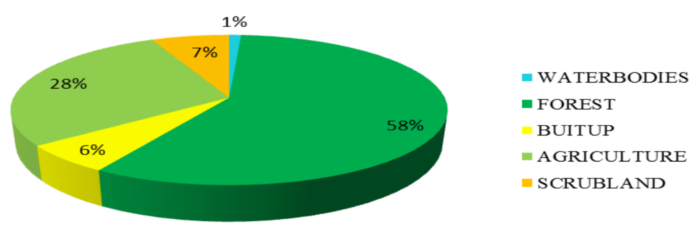


Figure 5-1: Landuse/landcover Distribution in the study area

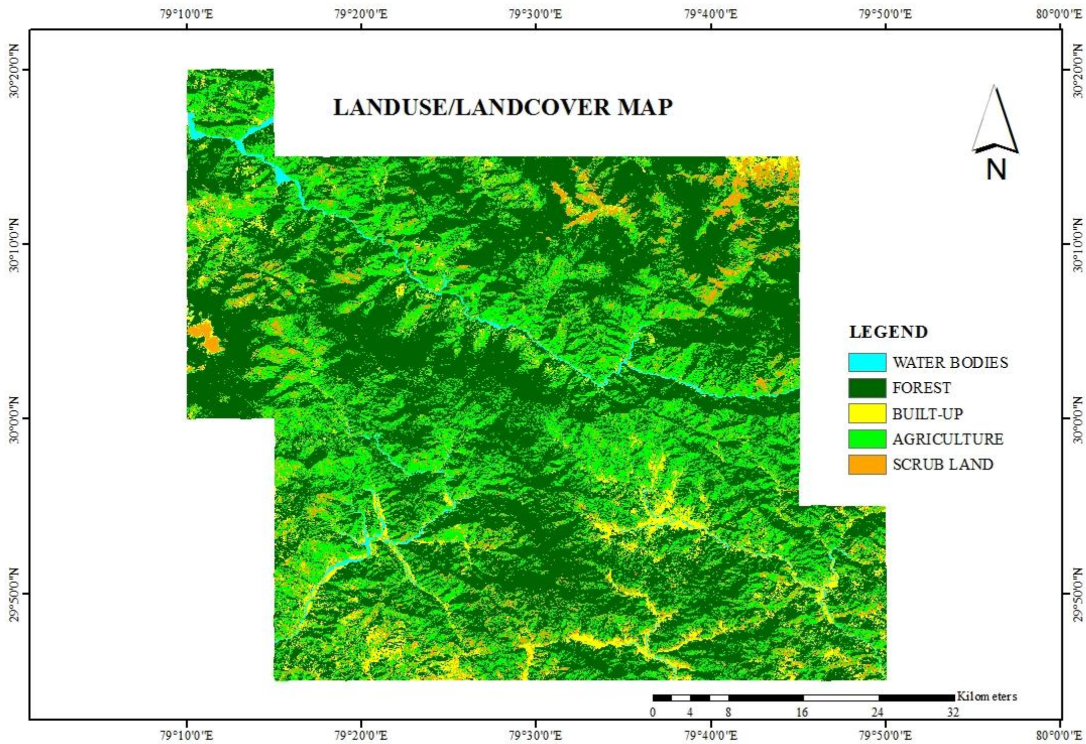


Figure 5-2 Landuse /Landcover map of study area

5.1.2. Drainage pattern

The overall drainage pattern of the study area represents a dendritic pattern. The drainage pattern map was prepared and is shown in the **Figure 5.3**. It was found that total 1032 km of length drainage is exists in the study area. It is preferred to avoid vicinity to the drainage it is provided to avoid vicinity to the drainage network during road alignment to cut short the cost of bridge construction. Parallel road along the drainage should also be avoided due to the existence of unstable slope along drainage line.

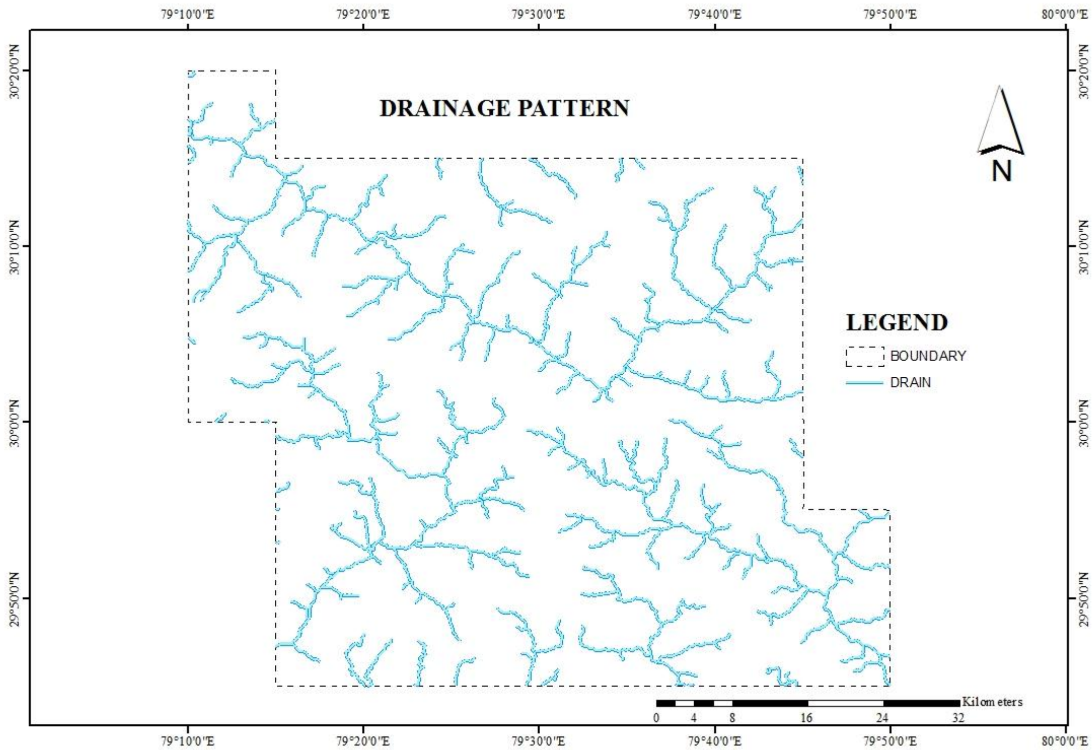


Figure 5-3 Drainage map of the study Area

5.1.3. Geology

Geology of the study area is dominated by the quaternary with metamorphic rocks having a Drillability Index of 73 which is very hard rock and not easy to excavate for road construction. But these types of rocks are good for stable road construction but it will increase engineering cost. Drillability index of rocks is directly proportional to hardness of rock. Higher the Drillability index, higher will be very hard and unsuitable for road construction (Engineering Vision) and suitable for road construction (Geotechnical vision). Geological map of study area has been shown in the **Figure 5.4**. The Drillability index of rocks in study area is given in the **Table 5.1**

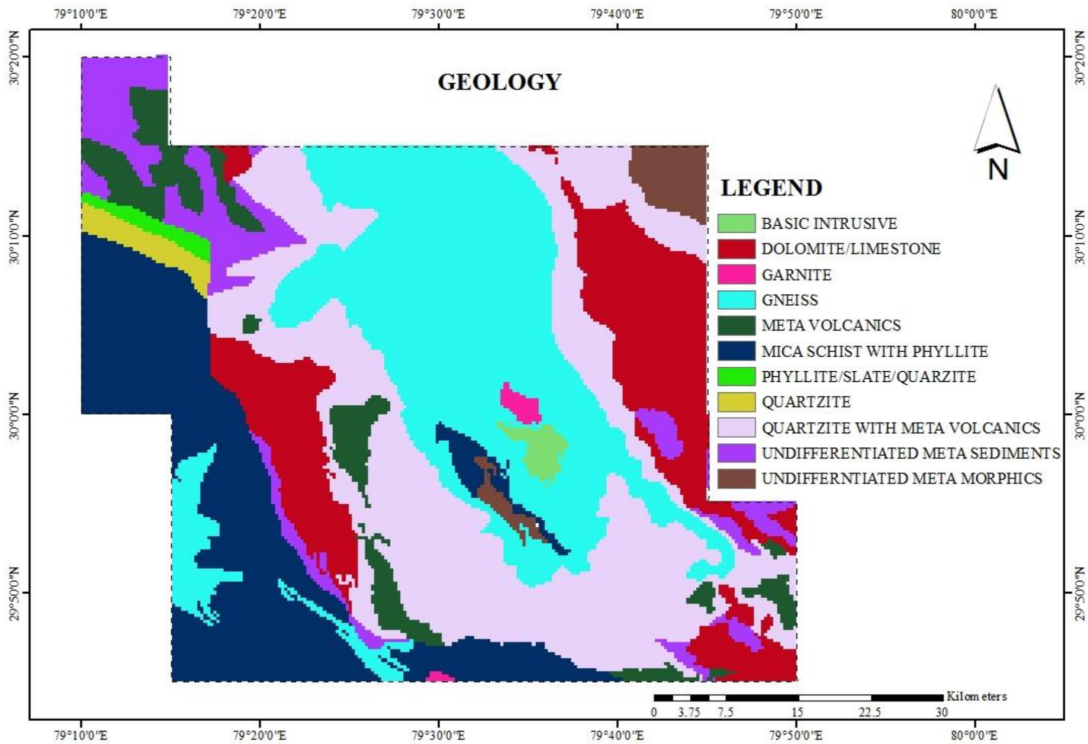


Figure 5-4 Geological map of study area

Table 5-1: Drillability index of Rocks

S.No	Rock Type	Drillability Index
1	Meta Volcanics	73
2	Undifferentiated Meta Sediments	53
3	Dolomite/Limestone	65
4	Phyllite/Slate/Quarzite	53
5	Quartzite With Meta Volcanics	73
6	Quartzite	53
7	Mica Schist With Phyllite	55
8	Gneiss	50
9	Undifferentiated Meta Morphics	73
10	Granite	55

S.No	Rock Type	Drillability Index
11	Basic Intrusive	55
		Source: Drillability Map of rocks

5.1.4. Lineaments

Lineaments are very important from stability point of view of soil as they control the movement and storage of ground water. Wherever, the ground is high; the area is not suitable for the road construction. **Figure 5.5** shows the lineament map of the study area and it is found that there is total 4232 km length of lineament exists in the study area.

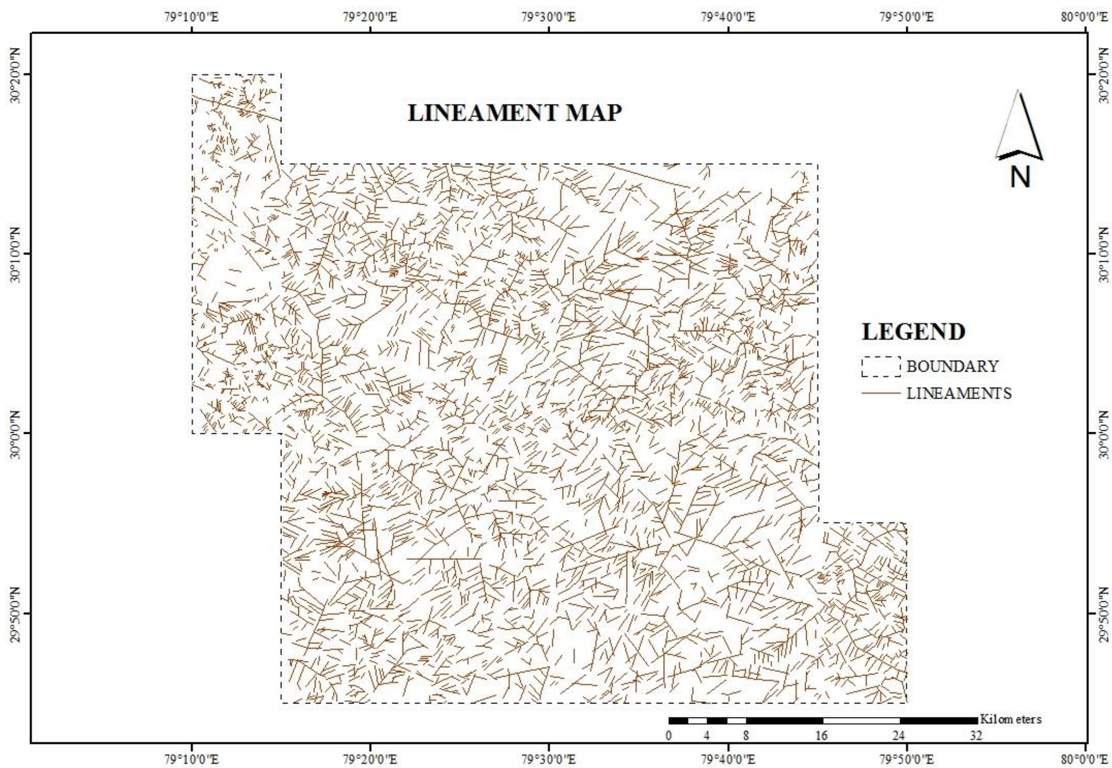


Figure 5-5: Lineament Map of Study Area

5.1.5. Slope

Slope plays an important role in road alignment. Areas having gentle slope (0-15 degree) are highly suitable for road alignment, areas having moderate slope (15-45 degree) are modernly suitable for road alignment and areas having steep slope (more than 45 degree) are less suitable for road alignment. Also, steep slopes are more prone to landslides. Study area covers 79 % of steep and moderate slope and only 21percent of gentle slopes which is shown in the **Figure 5.6**

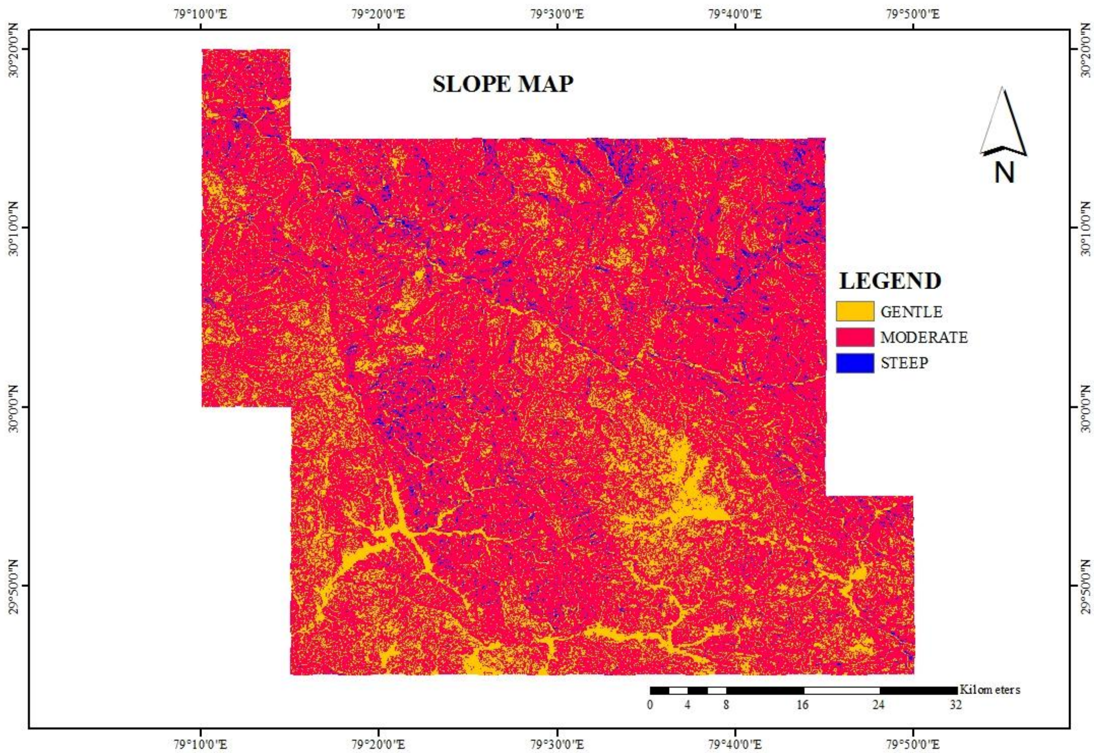


Figure 5-6 Slope map of study area

5.1.6. Aspect

Aspect does not play a direct role in role alignment but it is a key parameter to derive out the landslide hazard zonation in the study area. And it is preferred that for road alignment in hilly area landslide hazard zonation is key Aspect of the study area is complex in nature which is shown in the **figure 5.7**:

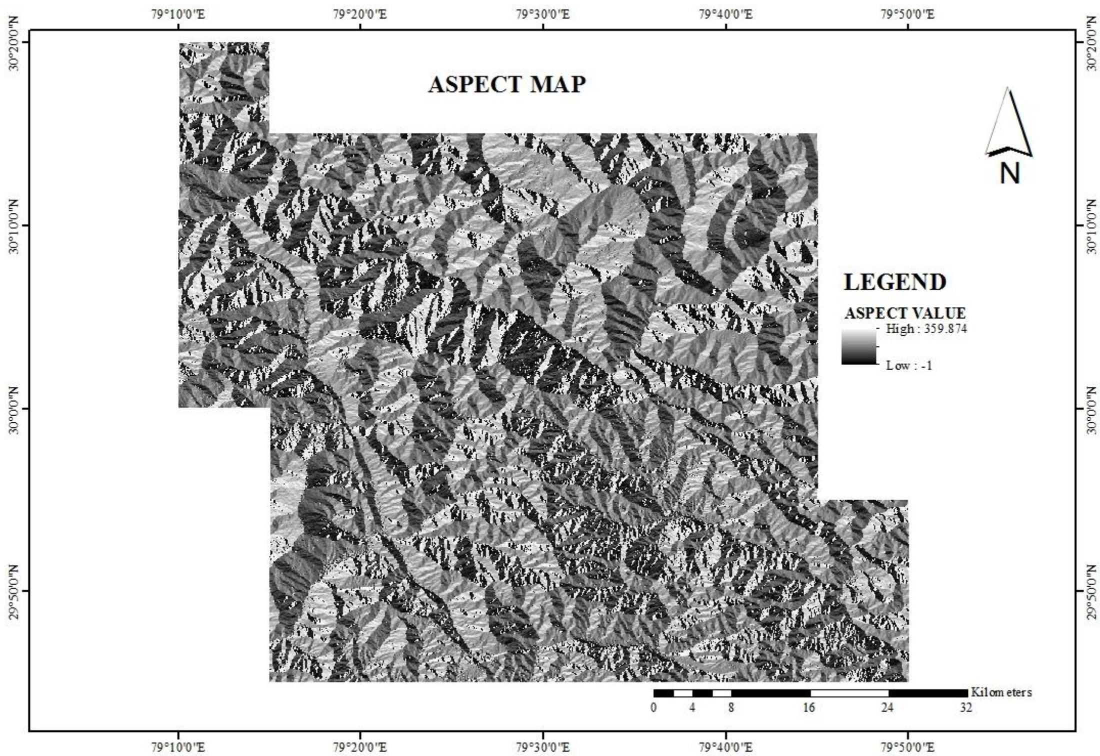


Figure 5-7: Aspect map of study area

5.1.7. Existing road network

Existing Road pattern should also analyzed before a new road alignment to ensure proper facilitation of road infrastructure to the population residing in the area. Existing road network of study area has been shown in the following **Figure 5.8:**

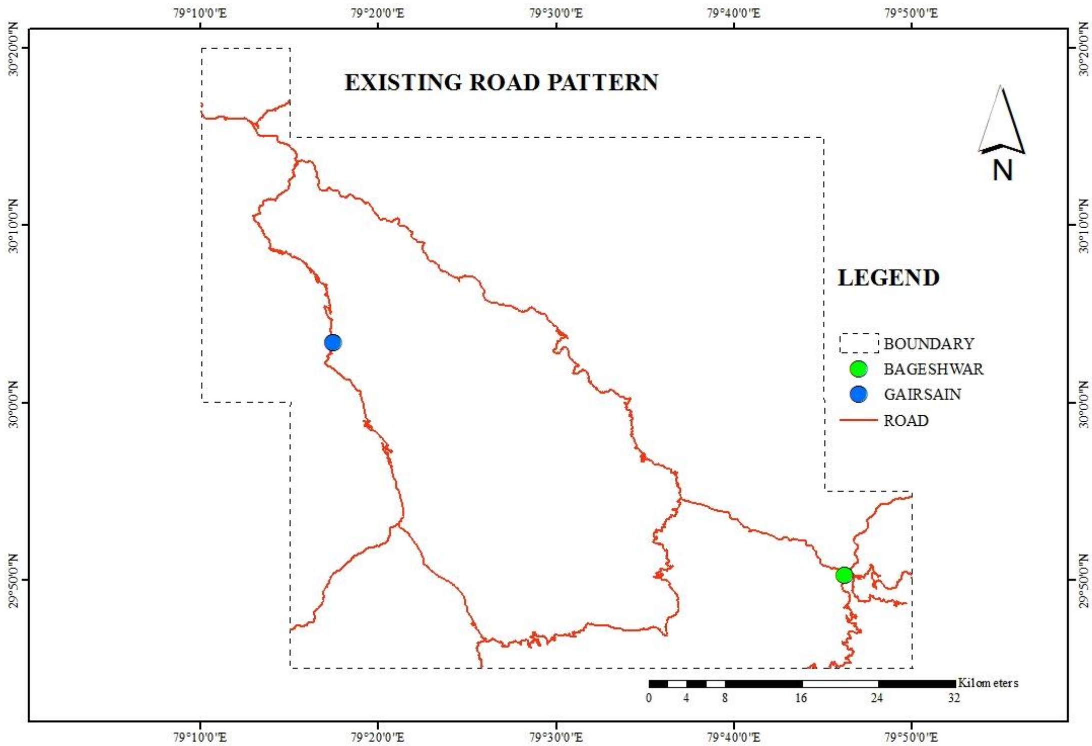


Figure 5-8: Existing road pattern

5.1.8. Soil

Soil texture defines the bearing capacity of construction material and strength of road construction. The study area is dominated by the rocky texture of soil cover out of which the 32 percent of surface is having good strength to hold the road. Then, followed by the finer than silty clay loam texture which covers 27 percent of study area. The different type of soil texture distribution over the study area is shown in **Figure 5.9:**

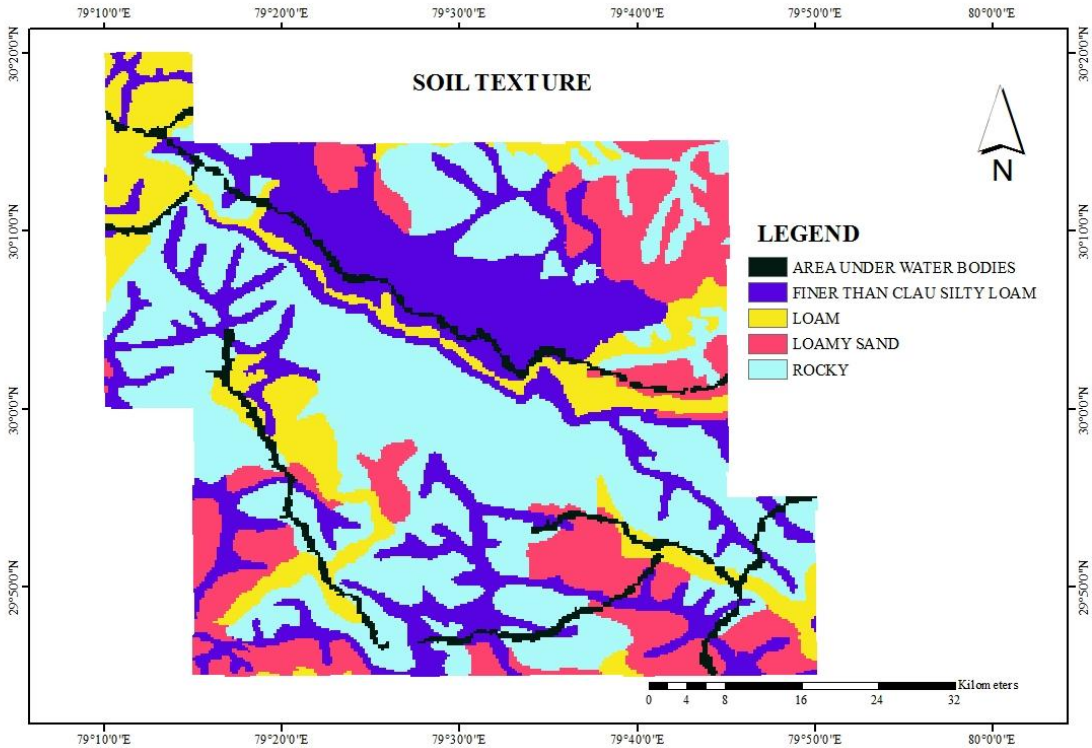


Figure 5-9: Soil Texture Map of study area

5.2. Characteristics of criteria surfaces

As discussed in the methodology section, methodology four criteria vision are prepared and suitability analysis for each is carried out as follows:

5.2.1. Engineering suitability surface

Engineering suitability surface was created on the basis of three weight layers viz. slope, drillability index of rocks and distance from drainage network. Weightage map of each of these three layers are created as follows:

a. Slope Suitability

Weightage map of slope as per engineering vision and its suitability level is shown in the **Figure 5.10**. Out of the total study area only 20 percent lies in the highly suitable slopes, followed by 76 percent area in moderately suitable slopes and remaining 4 percent in the less suitable slopes**. (Table 4.2)**

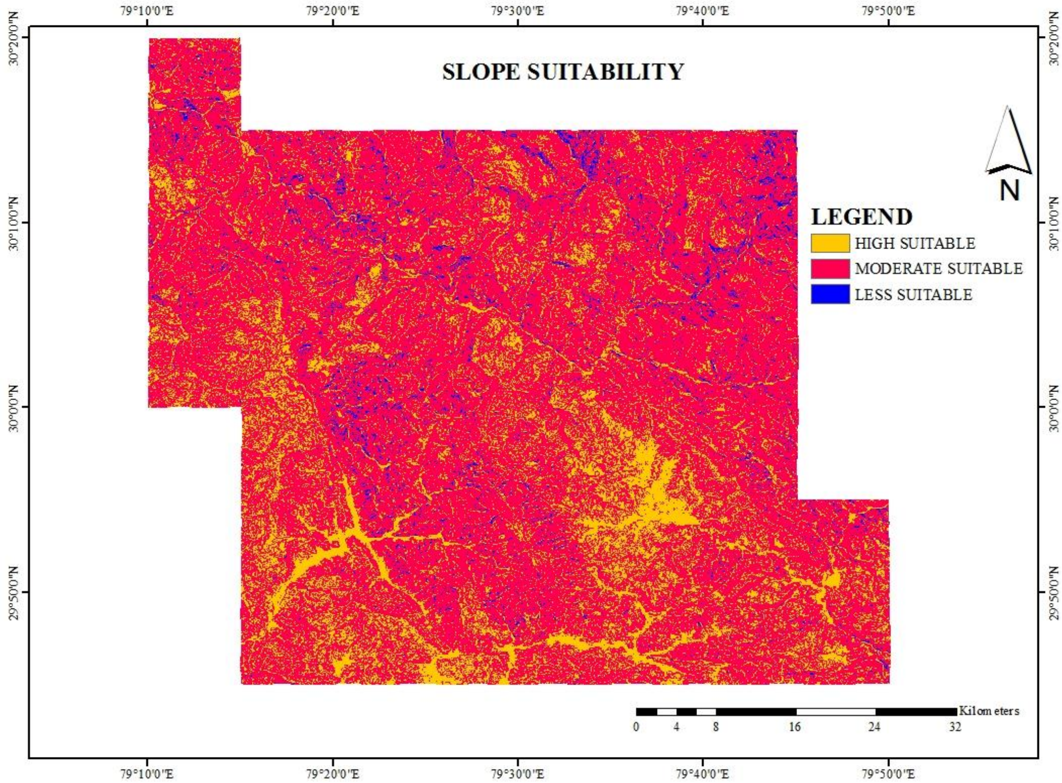


Figure 5-10: Slope suitability in engineering vision

b. Suitability as per distance from drainage:

As it has discussed in the methodology section, buffer has been created from the drainage network and area is divided into the five level of suitability viz. very highly, highly, moderately, low and very low suitability. As per distance from drainage about 79 percent of area lies in high and very high suitable zone, and 16 percent lies in the low and very low suitability zone and remaining 6 percent lie in the moderate suitability zone. **(Table 4.3)** Spatial distribution of site suitability as peer distance from drainage is shown in the **Figure 5.11**

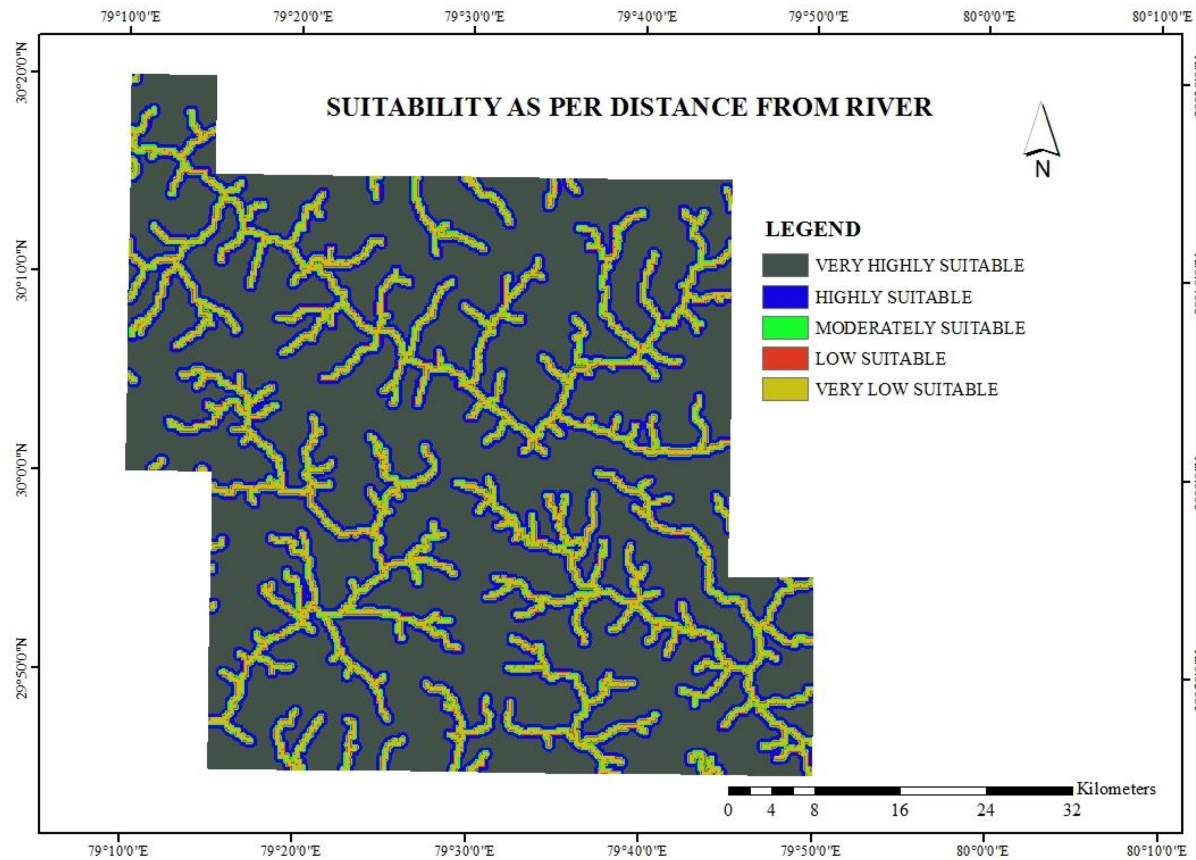


Figure 5-11 Suitability map as per distance from drainage

c. Suitability as per rock Drillability index

As discussed in the methodology section, suitability map has been prepared based on the drillability index of rocks. Study area has been divided into four level of suitability viz. high, moderate, less and very less. Out of the total 33percent of area lies in highly suitability zone, 14 percent lies in moderately suitability zone and remaining 53 under low and very low suitability zone **(Table 4.4)** Spatial distribution of Suitability as per rock Drillability index can be seen through the **figure 5.12.**

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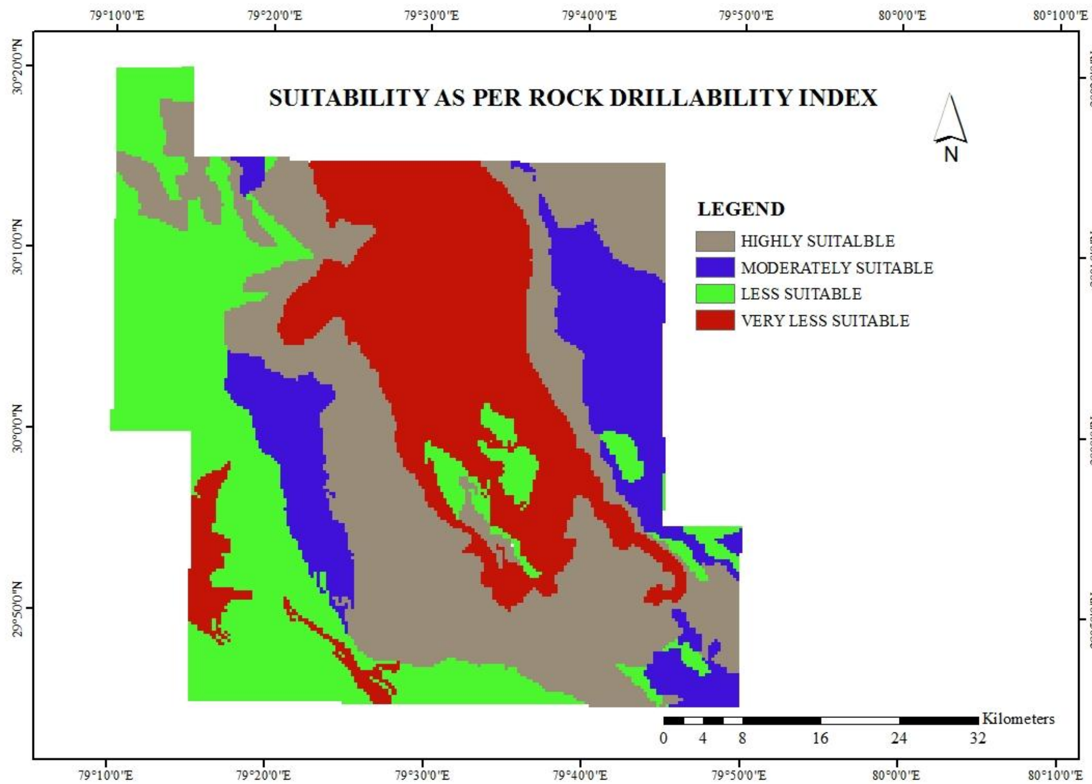


Figure 5-12 Suitability as per the rocks Drillability

Based on the above three suitability map viz. rocks Drillability, distance from drainage and slope the engineering suitability surface has been created**.** In the engineering suitability surface, study area is divided into three level of suitability viz. highly suitable, moderately suitable and less suitable. Out of the total study area 17 percent of area is under highly suitable, 81 percent of area is under moderately suitable and remaining 4 percent area is under low suitable. The spatial distribution of all these suitability as per engineering vision is shown in the **Figure 5.13**

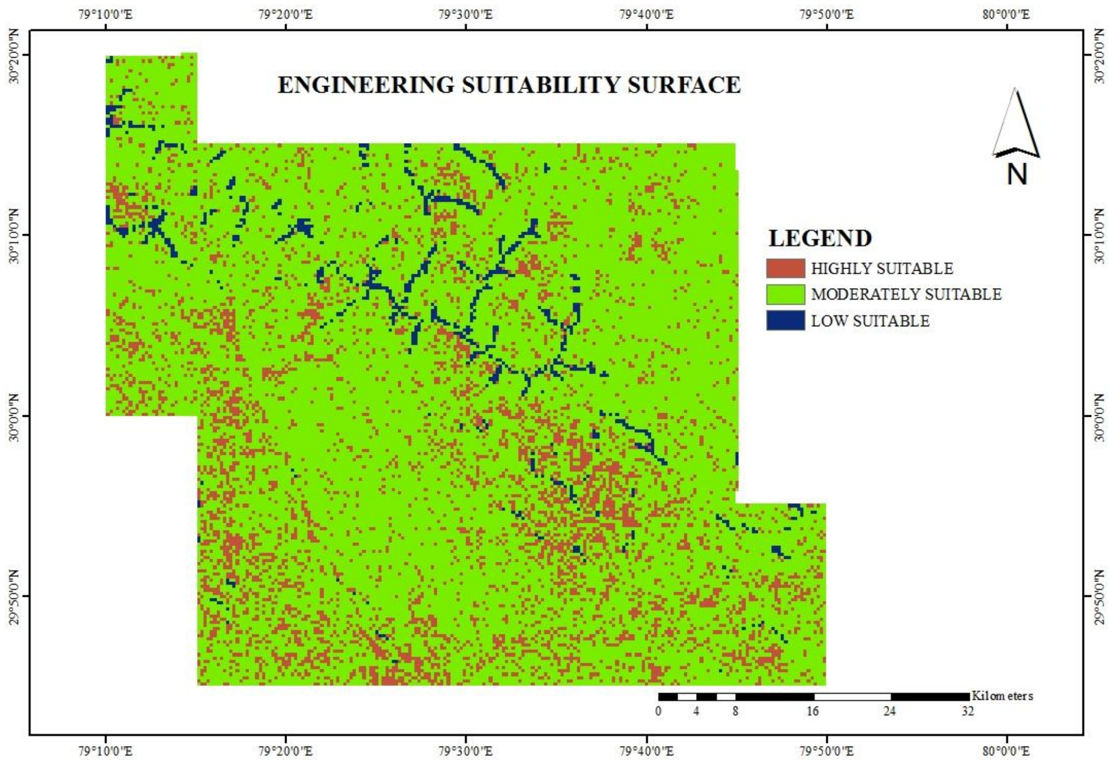


Figure 5-13 Engineering suitability surface map

5.2.2. Environment suitability surface

Environment suitability surface has been created on the weightage suitability level of three criteria viz. distance from the rivers, landuse/land cover and slope.

a. Slope:

In the preparation of environment suitability level the same slope suitability map has been used same as in the engineering vision **(Figure 5.10).**

b. Landsue/landcover

As discussed in the methodology section, suitability map has been prepared based on the land use/landcover map of the study area. Area has been divided into five level of suitability viz. high, moderate, less and very less. Out of total study area 35 percent of lies in the highly suitable, followed by 58 percent in less suitable and 7 percent lies in the moderately suitable. (**Table 4.5**) Spatial distribution of land use suitability is shown in the **figure 5.14.**

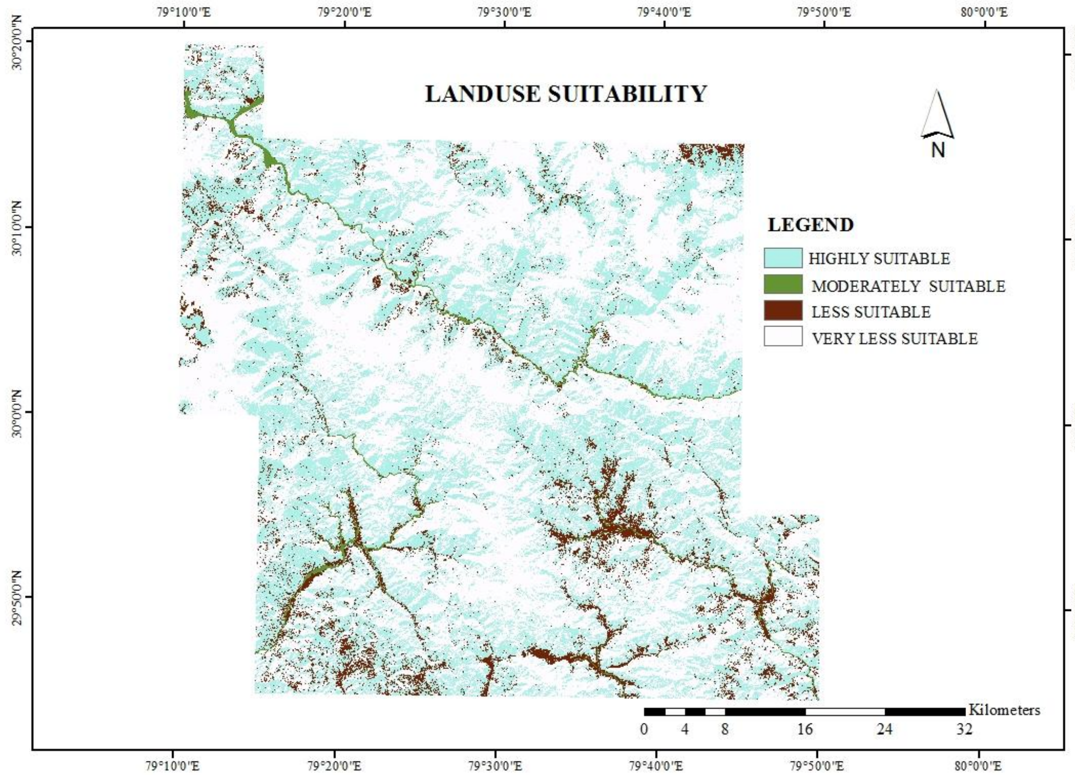


Figure 5-14: Landuse suitability in study area

c. Distance from the river:

To protect the river (environment point of view), 500 m distance protection buffer has been created which has been put under the least suitable and remaining area has been put under the highly suitable for road alignment. The remaining area has been assigned as a highly suitable for road alignment **(Table 4.6).**The spatial distribution of this criteria is shown in the **figure 5.15.**

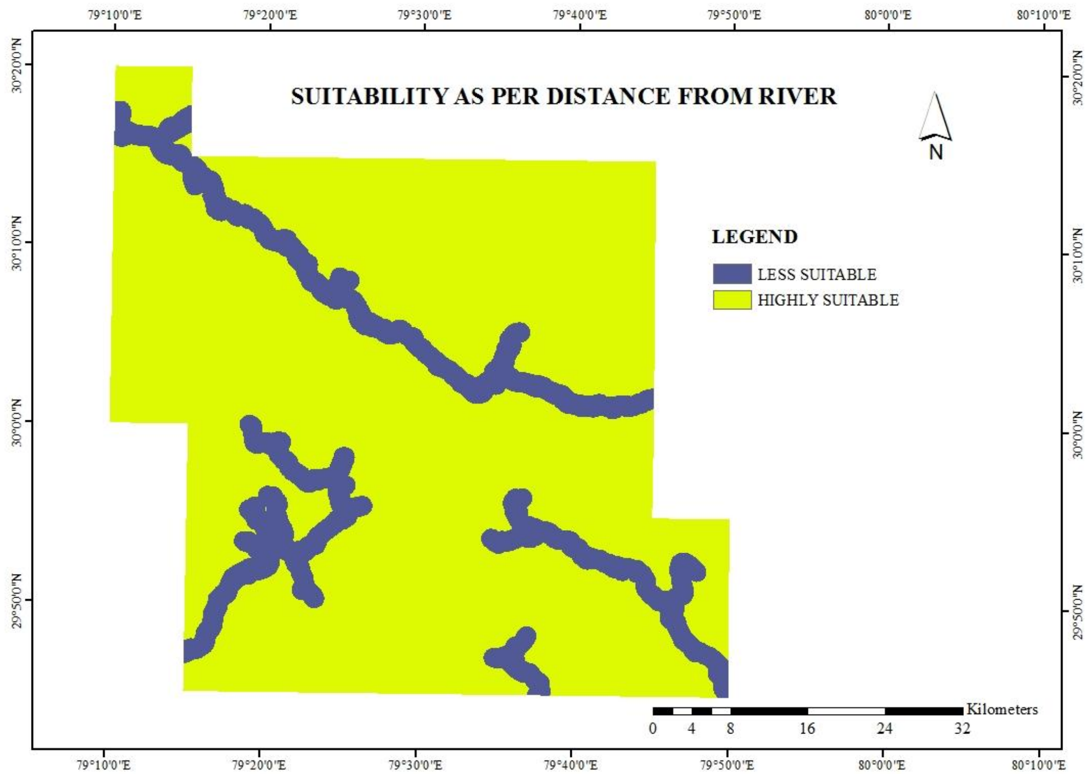


Figure 5-15: Suitability as per the Distance from buffer

In the environment suitability surface, study area is divided into five level of suitability viz. very highly suitable, highly suitable, moderately suitable, less suitable and very less suitable. Out of the total study area 34 percent of area is under very high suitable and high suitability, 61 percent of area is under moderately suitable area and remaining 5 percent area is under low and very low suitable area. The spatial distribution of all these suitability as per environment suitability is shown in **Figure 5.16**.

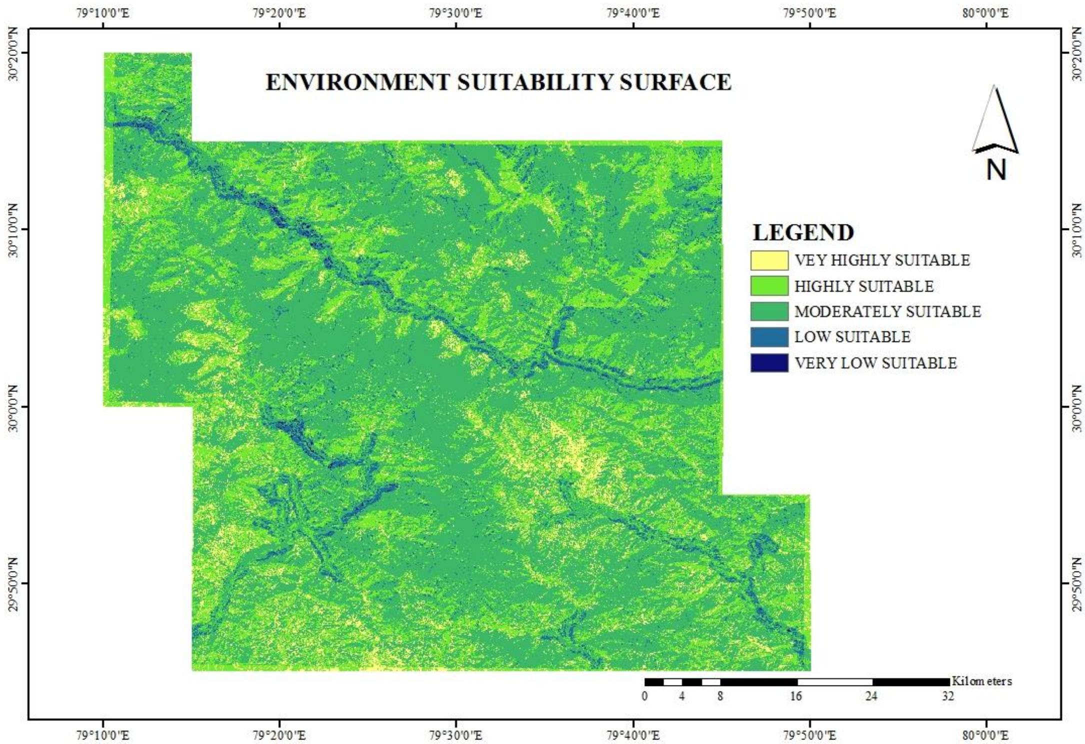


Figure 5-16: Environment suitability surface of study area

5.2.3. Landslide suitability surface

To prepare landslide hazard zonation map for study area. The base landslide layer is shown in the **figure 5.17** and the layer maps are used as such like Landuse/landcover **(figure 5.2),** Geology **(figure 5.4),** Slope **(figure 5.6),** Aspect **(figure 5.7)**, and Soil map **(figure 5.9)** have been used. Distance buffer was created with Euclidian distance function for the linear layers like drainage, lineaments and roads as per the following details and their classification has been discussed below:

a. Distance from drainage:

In this map drainage buffer has been created and classified for the preparation of landslide hazard zonation map. Map is divided into five classes based on the natural breaks. Areas which are near to drainage are more prone to landslide hazard and areas which are far from the drainage are less prone to land slide hazard. On the basis of this area is divided into five classes viz. Very near to drainage, near to drainage, moderately near to drainage, far from drainage and very far from drainage. Spatial distribution of distance from drainage is shown in **figure 5.18.**

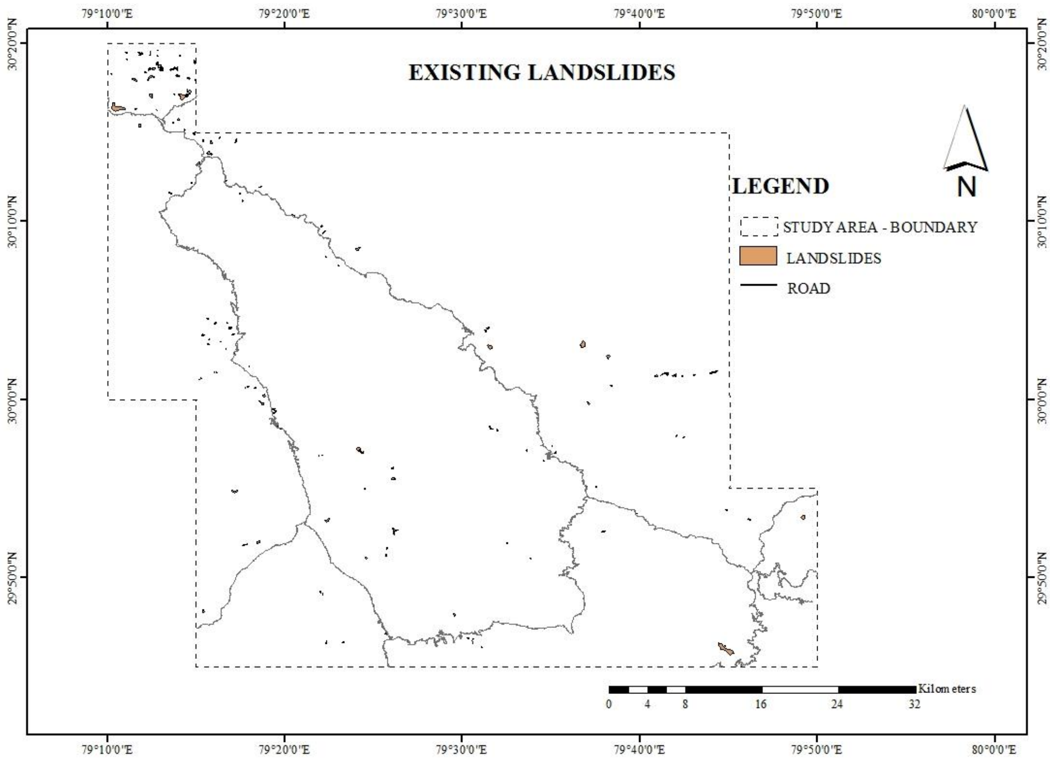


Figure 5-17 : Existing landslide with in the study area

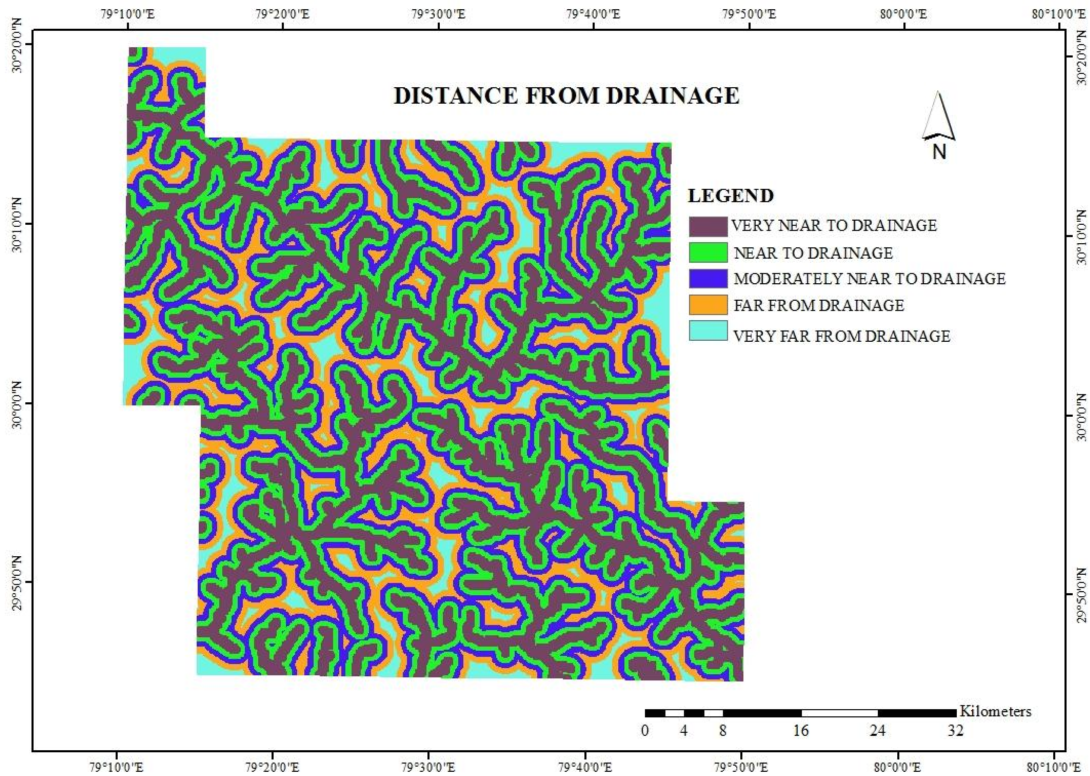


Figure 5-18: Distance from drainage

b. Distance from road

In this map road buffer has been created and classified for the preparation of landslide hazard zonation map. Map is divided into five classes based on the natural breaks. Areas which are near to road are more prone to landslide hazard and areas which are far from the road are less prone to land slide hazard. On the basis of this, area is divided into five classes viz. Very near to road, near to road, moderately near to road, far from road and very far from road. Spatial distribution of distance from road is shown in **figure 5.19.**

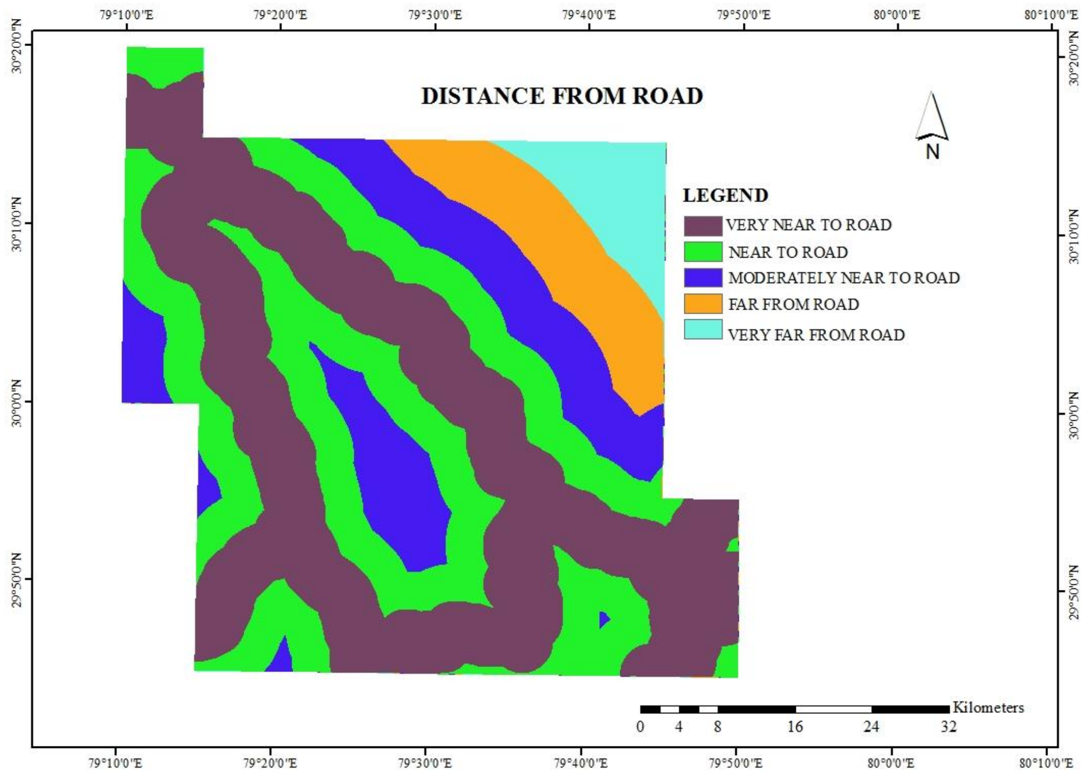


Figure 5-19 Distance from road

c. Distance from lineament

In this map lineament buffer has been created and classified for the preparation of landslide hazard zonation map. Map is divided into five classes based on the natural breaks. Areas which are near to lineament are more prone to landslide hazard and areas which are far from the lineament are less prone to land slide hazard. On the basis of this area is divided into five classes. Very near to lineament, near to lineament, moderately near to lineament, far from lineament and very far from lineament. Spatial distribution of distance from lineament is shown in **figure 5.20.**

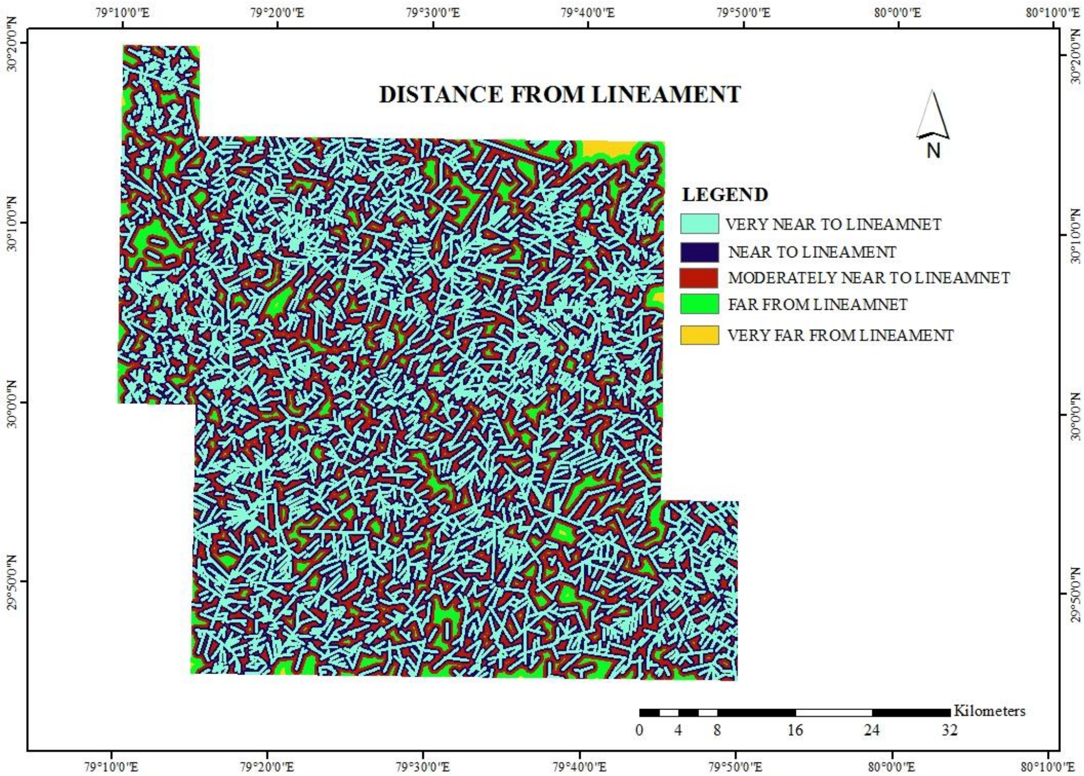


Figure 5-20 Distance from lineament

A most important geo-environmental problem of hilly areas is land slide. Study area is divided into the five major hazard zones i.e. very high, high, medium low andvery low. 29 percent of the study area lies in the high and very high hazard zone of landslide. Remaining 71 percent of study area is in the medium, low and very low hazard. Spatial distribution of landslide hazard zonation is shown in the **Figure 5.21.**

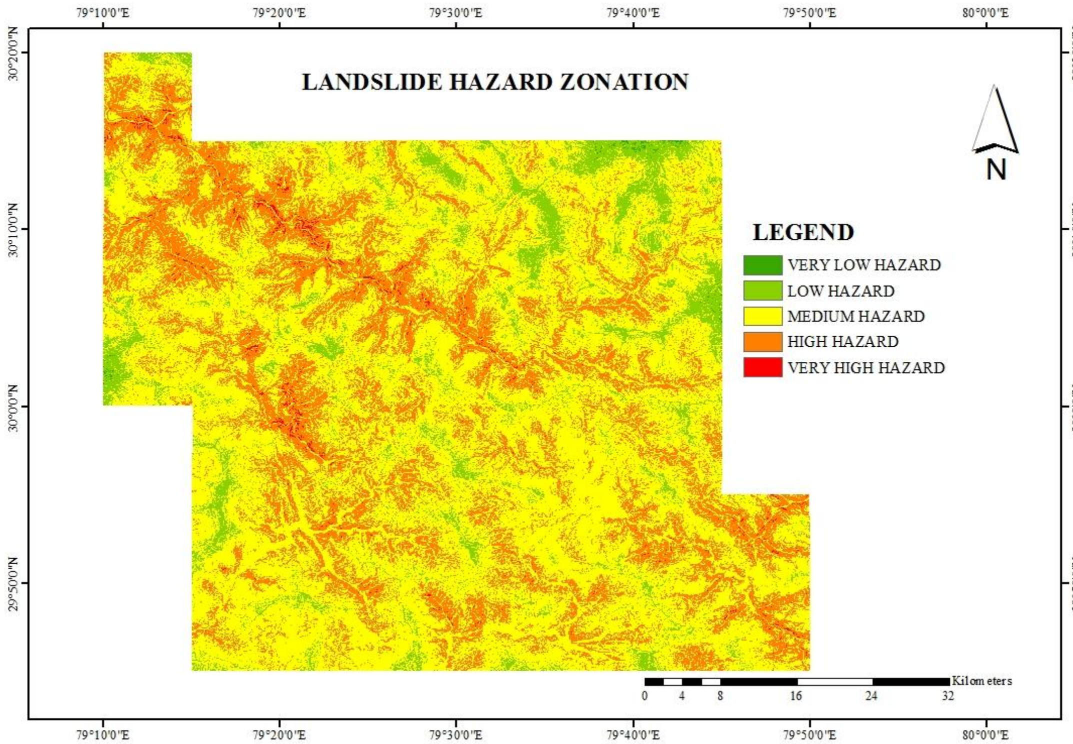


Figure 5-21: Landslide Hazard Zonation Map of Study Area

In the landslide suitability surface, study area is divided into five level of suitability viz. very highly suitable, highly suitable, moderately suitable, less suitable and very less suitable. Out of the total study area only 1 percent of area is under very highly suitable and highly condition , 71 percent of area is under moderately suitable condition and remaining 28 percent area is under low and very low suitable condition The spatial distribution of all these suitability as per landslide suitability is shown in the **Figure 5.22.**

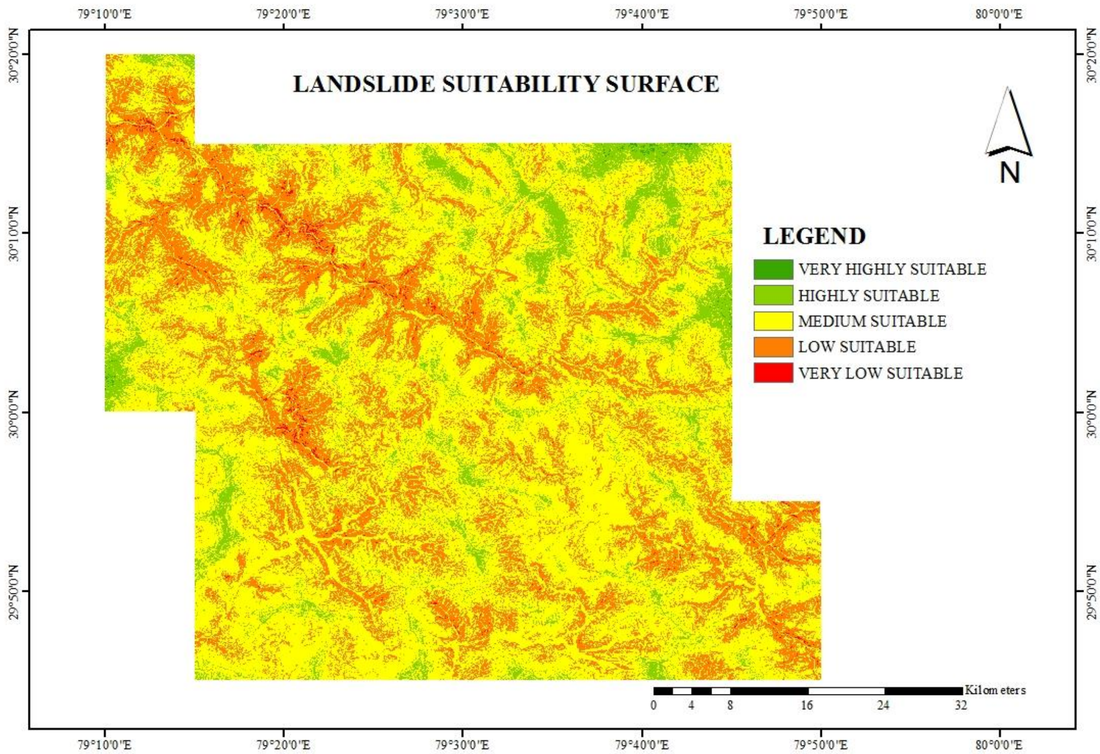


Figure 5-22: Landslide suitability surface

5.2.4. Hybrid suitability surface

In the hybrid suitability surface, study area is also divided into five level of suitability viz. very highly suitable, highly suitable, moderately suitable, less suitable and very less suitable. Out of the total study area 14 percent of area is under very highly suitable and highly condition , 77 percent of area is under moderately suitable condition and remaining 9 percent area is under low and very low suitability. The spatial distribution of all these suitability as per hybrid suitability is shown in the **Figure 5.23.**

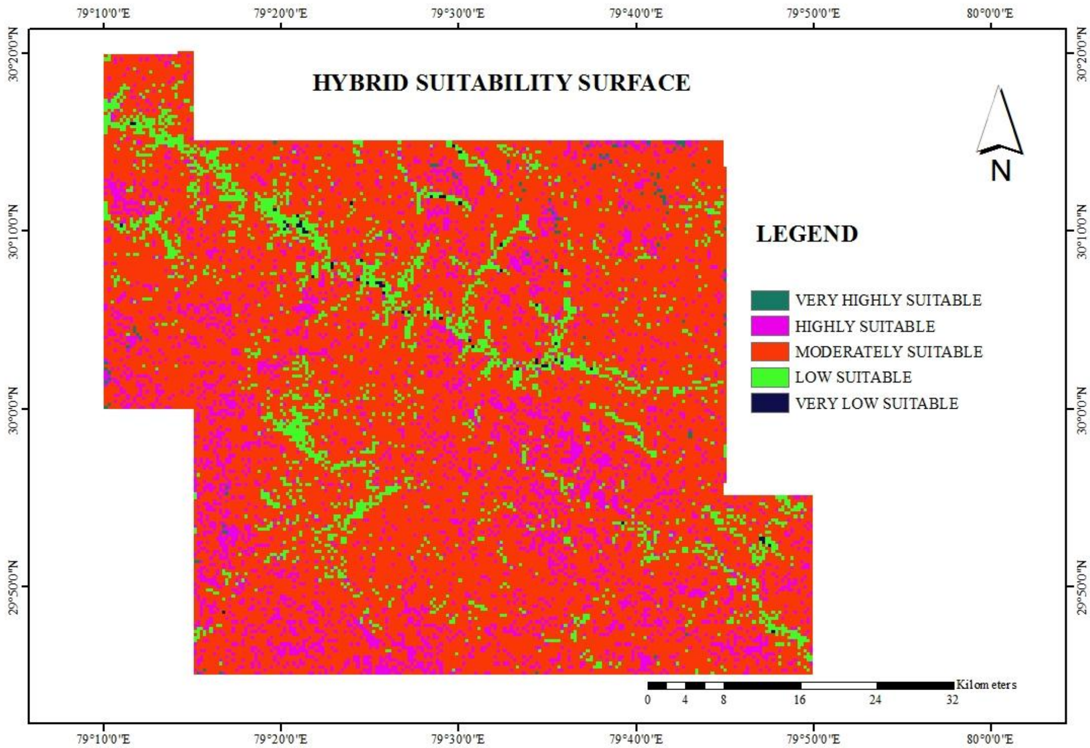


Figure 5-23 Hybrid suitability surface

5.3. Defined route alternatives

Each of the four vision discussed above provided route alternative as **Alternative 1** has been defined on the basis of engineering vision, **Alternative 2** has been defined on the basis of environment vision, **Alternative 3** has been defined on the basis of landslide vision and **Alternative 4** has been defined on the basis of hybrid vision. Spatial alignment of each route is shown in the **Figure 5.24.**

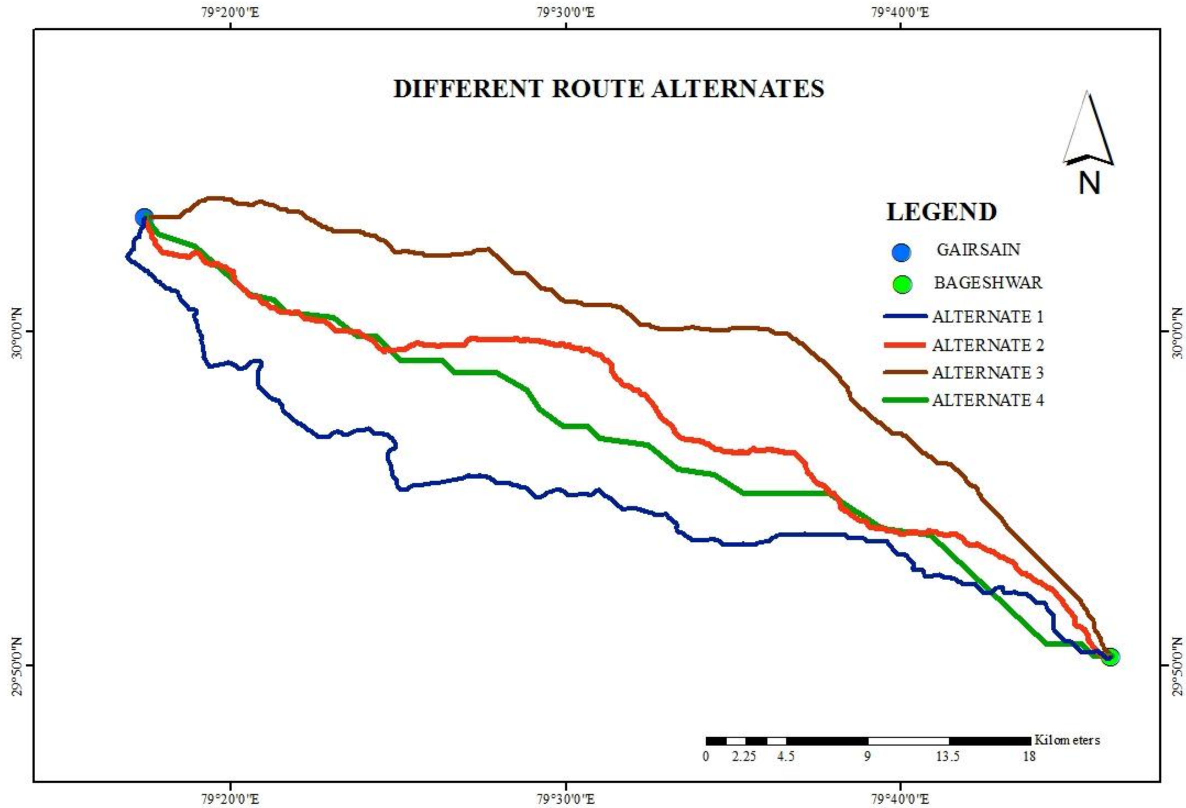


Figure 5-24 Different Route Alternatives from Gairsain to Bageshwar

5.4. Evaluation results

Each route alignment has been evaluated as discussed in the methodology chapter. Evaluation results are compared in the following table.

Table 5-2: Evaluation parametric results of each alternative

Parameter	Units	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Population to be served with in five kms	Number	155894	145618	169915	157096
No. of connecting nodes with existing network	Number	4	2	3	2

Parameter	Units	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Area of Forest covered to be disturbed	Sqm	262874	286949	409193	434945
Length of road passing within the buffer distance of 500 m from rivers	Km	119.1	1.3	46.1	0.588
Area of agriculture land to be disturbed	Sqm	159587	290868	186723	144090
No of bridges/culverts required.	Number	29	14	14	11
Cut volume	M^3	543441	1137217	2091327	1420877
Fill volume	M^3	678527	1464074	2717196	1490241
Total length	Km	69.4	60.3	59.8	57.8
Quantity of buildable land available along each alignment	Sqm	28046024	25231975	24411745	23408197
Quantity of agriculture and scrub land available for future widening	Sqm	328901	179014	227274	2236903

5.5. Final route selection results

As per the discussion in the methodology weight assigned to each alternative is shown in the **table 5.3**

Table 5-3: Weightage assigned to each parameter for evaluation

Parameter	Weightage to Alternative 1	Weightage to Alternative 2	Weightage to Alternative 3	Weightage to Alternative 4
Population to be served with in five kms	4.59	4.29	5.00	4.62
No. of connecting nodes with existing network	2.50	5.00	3.75	5.00
Area of Forest covered to be disturbed	18.32	20.00	12.85	12.09
Length of road passing though the distance of 500 m from rivers	0.05	4.52	0.13	10.00
Area of agriculture land to be disturbed	9.03	4.95	7.72	10.00
No of bridges/culverts required.	3.79	7.86	7.86	10.00
Cut volume	10.00	6.21	3.38	4.97
Fill volume	10.00	5.56	3.00	5.46
Total Length	4.16	4.79	4.83	5.00
Quantity of buildable land available along each alignment	12.52	13.92	14.38	15.00
Quantity of agriculture and scrub land available for future widening	2.72	5.00	3.94	0.40
Total weights	**79.36**	**80.42**	**66.83**	**82.55**

The following observations and conclusion are drawn from **table 5.3**:

Alternative 1:

This alternative was generated as per the engineering vision in which preference is given to the slope, geology and number of structures (bridges and culverts). The advantages and disadvantages of this alternate are as follows:

Advantages

1. Least impact to cut and fill compared to other alternative

Disadvantages

1. Maximum number of junctions are required
2. Maximum length of road passing along the drainage network so, there is a chance of landslide and slope unsuitability.
3. Maximum number of bridges and culverts required.
4. Minimum amount of buildable land available for future development
5. Longest path with compared to other alternatives

Alternative 2:

This alternative was created as per the environment vision, in which preference is given to the slope, landcover and distance from river. This path gives these advantages and disadvantages:

Advantages

1. Minimum number of junctions to be constructed.
2. Maximum amount of suitable land is available for future widening

Disadvantages

3. Maximum amount of agriculture land will be disturbed
4. Minimum population will be served

Alternative 3

This alternative has been chosen on the basis of landslide hazard zonation and have following advantages and disadvantages

Advantages

1. Maximum population will be served

Disadvantages

1. Maximum cut/fill will be required

Alternative 4

This alternative has been aligned on the basis of all the three vision and discussed in methodology and its advantages and disadvantages are listed below

Advantages

1. Minimum number of junctions to be constructed
2. Minimum length of road passing along the river
3. Minimum amount of agriculture land will be disturbed
4. Minimum number of bridges are required
5. Shortest path when compared to the other alternatives
6. Maximum amount of buildable land available along the road

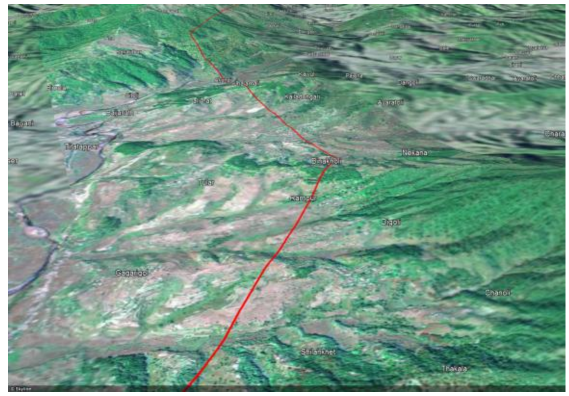
Disadvantages

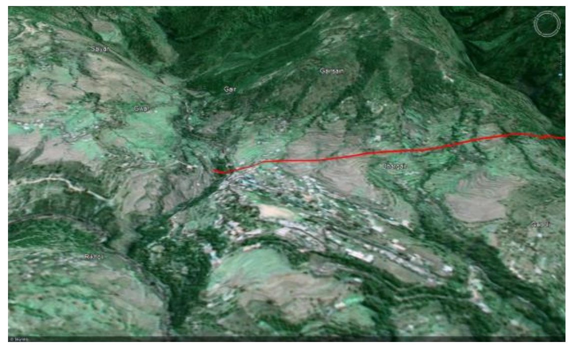
1. Lesser amount of suitable land available for future widening
2. Maximum forest coverage will be disturbed

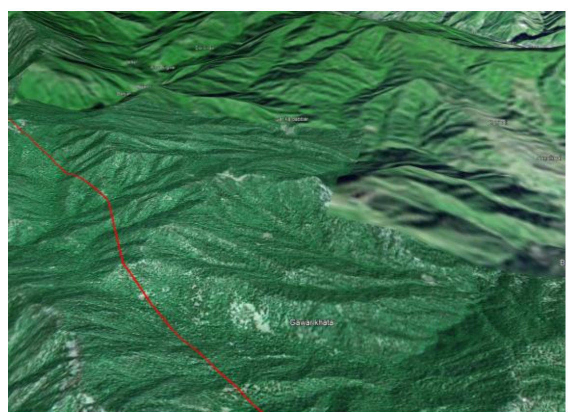
On comparing all the advantages and disadvantages and the weighted table above it is clear that out of hundred, higher weightage has been given to the alternative 4, which has been selected on the basis of hybrid vision.

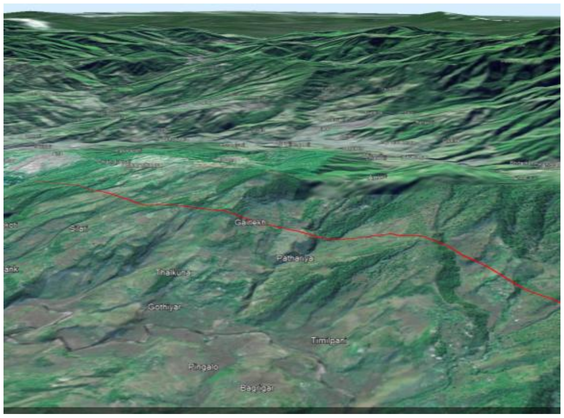
5.6. Results of 3D visualization

The finally selected route is visualized in the 3D environmentfor real time look and feel vizaualization is shown in the following **figure 5.25**







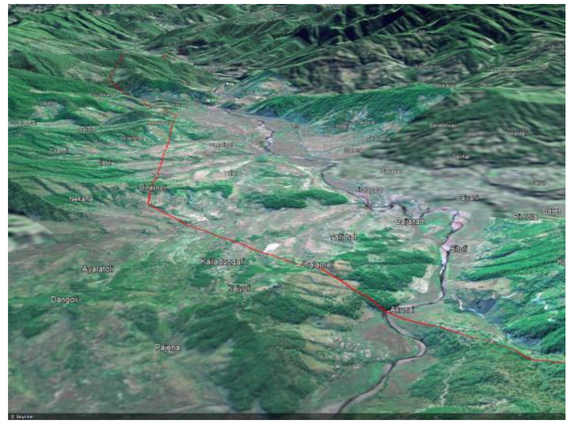


Figure 5-25: 3D view of recommended route alignment

5.7. Traffic forecasting

For the purposes of traffic forecasting the list of OD zones created with zone number shown in **table 5.4:**

Table 5-4: OD zones for traffic influence

Zone code	Zone Name	Remarks
1	Bageshwar	Project Road
2	Baijnath	Project Road
3	Kausani	Project Road
4	Someshwar	Project Road
5	Dawarhat	Project Road
6	Chaukhutiya	Project Road
7	Gairsain	Project Road
8	Kapkot/Tejam/Munsyari	Surroundings
9	Mantoli/Gangolihat	Surroundings
10	Almora/Haldwani/Nainital	Surroundings

Zone code	Zone Name	Remarks
11	Dangoli	Surroundings
12	Gwaldan	Surroundings
13	Tharali	Surroundings
14	Narainbagar	Surroundings
15	Dugari	Surroundings
16	Simli	Surroundings
17	Karanprayag	Surroundings
18	Ranikhet	Surroundings
19	Masi	Surroundings
20	Ramnagr	Surroundings
21	Almora District	Districts
22	Chamoli	Districts
23	Champawat	Districts
24	Dehradun	Districts
25	Haridwar/punjab	Districts
26	Nainital	Districts
27	Pauri Garhwal	Districts
28	Pithoragarh	Districts
29	Rudar Prayag	Districts
30	Tehri Garhwal	Districts
31	Udham Singh Nagar	Districts
32	Uttarkashi	Districts
33	Westren UP, Westren India	States

Zone code	Zone Name	Remarks
34	Eastren UP And East India	States
35	Kanda	Surroundings
36	Mehalchauri	Project Road

The geographical location of Od zones along with the existing transport network is shown in the **figure 5.26.** There are 36 OD zones identified from where the traffic is passing through the existing road network of Gairasin to Bageshwar. Out of these 36 zones, 8 are located on the existing network, 14 are located in the immediate surroundings, 13 are the district headquarters, out of which Bageshwar also lies in the project road and remaining 2 are in the the surrounding states of Uttrakhand. There are 18 road junctionsalso in the study area.

As discussed in the methodology section, two transport networks are prepared one on the basis of existing transport network and other is based on the existing as well as proposed route alignment. The proposed network section has same OD Zones and number of junctions has been increased from 18 to 21. The spatial distribution of proposed network data set has been shown in the **Figure 5.27.**

There are **1296 OD pair** identified which possible for traffic movement through the existing transport network and for each pair wise traffic volume data was collected from the field was also taken into consideration. OD cost matrix functions gives the results of OD pair and a shortest distance to be travelled between each OD pair. A field ‘Total length’ of attribute of OD cost matrix is as shown in the **Figure 5.28.**

Similarly, the process was repeated for the network having proposed alignment and shortest distance to be travelled was identified. The difference between shortest distances of each OD pair of both network dataset was calculated and provides two kind of result for the respective OD pair. One is zero which shows that OD pair is through the existing transport network and other the which is more than zero which shows that the OD pair is though the proposed route alignment.

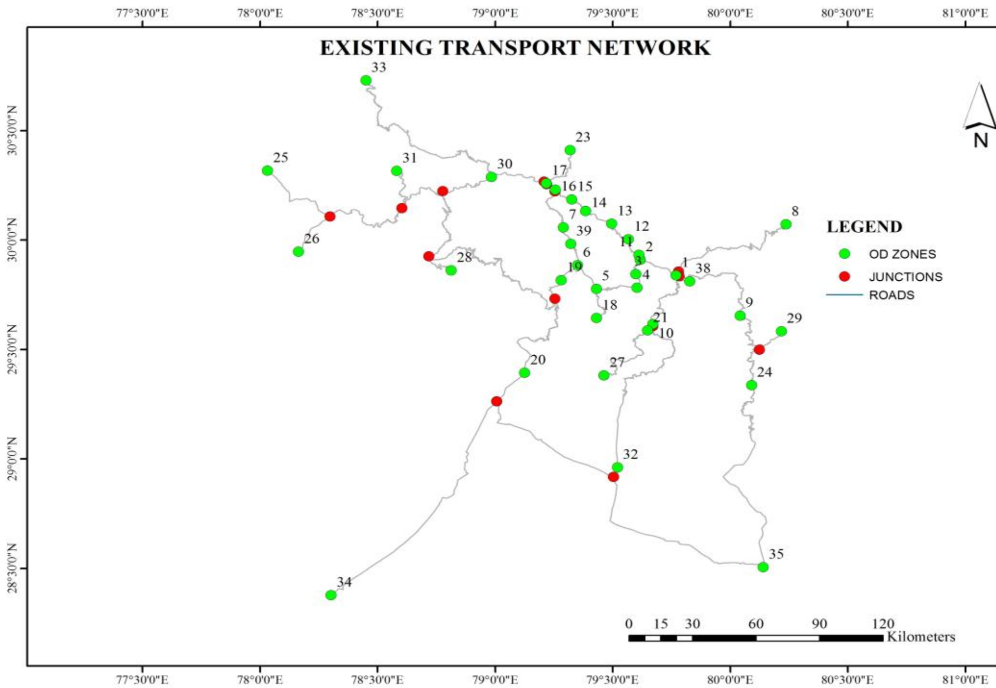


Figure 5-26: Existing Transport Network for OD pair Analysis

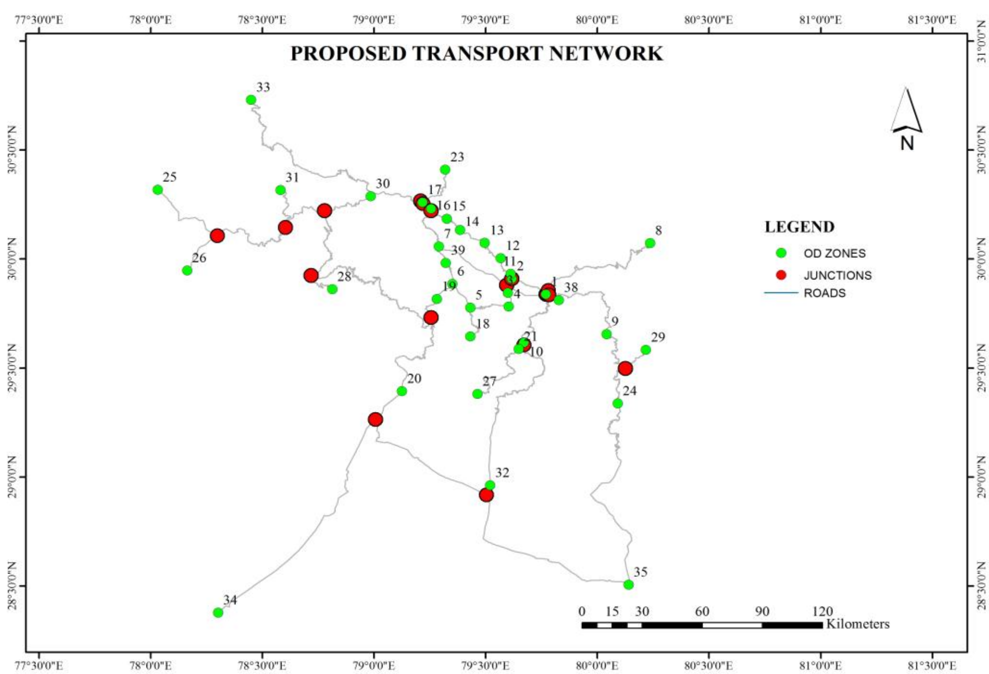
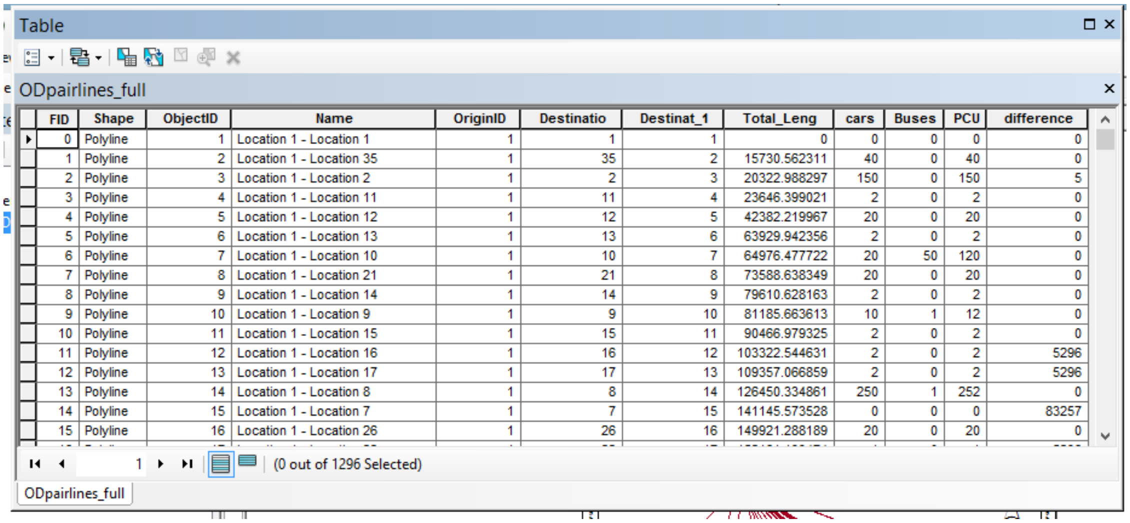


Figure 5-27: Transport Network along with proposed route alignment



Table

ODpairlines_full

FID	Shape	ObjectID	Name	OriginID	Destinatio	Destinat_1	Total_Leng	cars	Buses	PCU	difference
0	Polyline	1	Location 1 - Location 1	1	1	1	0	0	0	0	0
1	Polyline	2	Location 1 - Location 35	1	35	2	15730.562311	40	0	40	0
2	Polyline	3	Location 1 - Location 2	1	2	3	20322.988297	150	0	150	5
3	Polyline	4	Location 1 - Location 11	1	11	4	23646.399021	2	0	2	0
4	Polyline	5	Location 1 - Location 12	1	12	5	42382.219967	20	0	20	0
5	Polyline	6	Location 1 - Location 13	1	13	6	63929.942356	2	0	2	0
6	Polyline	7	Location 1 - Location 10	1	10	7	64976.477722	20	50	120	0
7	Polyline	8	Location 1 - Location 21	1	21	8	73588.638349	20	0	20	0
8	Polyline	9	Location 1 - Location 14	1	14	9	79610.628163	2	0	2	0
9	Polyline	10	Location 1 - Location 9	1	9	10	81185.663613	10	1	12	0
10	Polyline	11	Location 1 - Location 15	1	15	11	90466.979325	2	0	2	0
11	Polyline	12	Location 1 - Location 16	1	16	12	103322.544631	2	0	2	5296
12	Polyline	13	Location 1 - Location 17	1	17	13	109357.066859	2	0	2	5296
13	Polyline	14	Location 1 - Location 8	1	8	14	126450.334861	250	1	252	0
14	Polyline	15	Location 1 - Location 7	1	7	15	141145.573528	0	0	0	83257
15	Polyline	16	Location 1 - Location 26	1	26	16	149921.288189	20	0	20	0

1 (0 out of 1296 Selected)

ODpairlines_full

Figure 5-28: Attribute Table of OD pair Lines generated from OD Cost Matrix

There are 738 OD pair identified for which existing traffic have need to be diverted to the proposed route alignment. Out of which only 63 OD pairs total traffic of 628 PCU is moving and these 628 PCU need to be diverted to the proposed route alignment. For the purpose of traffic forecasting, OD pair has been identified and following assumption has been made.

1. If the origin and destinations both are the district headquarters then growth rate of personal vehicles like cars volume will be 15 percent per year for the duration of 2015-2020 for that respective OD pair.
2. If one of the either origin or destination is district head quarter then the growth rate of cars volume will be 12 percent per year for the duration of 2015-2020 for that respect OD pair.
3. If one of the either origin or destination is class one town as per census of India then the growth rate of cars volume will be 10 percent for the duration of 2015-2020 for that respect OD pair.
4. If one of the either Origin or Destination is Gairaisn (Proposed capital of Uttrakhand) then the growth rate of cars volume respective OD pair will be 20 percent per year for the duration of 2015-2020.
5. In all other cases growth rate of cars volume will be 5 percent per year for respective OD pairs for the duration of 2015-2020
6. Growth rate of buses volume will always be half of growth rate of cars volume for each OD pair.
7. There will be a two percent per increase in the growth rate of cars volume and one percent in the growth rate of buses volume after every 5 year.

8. For the OD pair having no existing traffic, it will remain same up to the year 2020 and will increase to 2 for the cars and 1 for the buses up to the year 2025 and then above said respective growth rate will be applied.

Based on the above assumptions forecasted traffic on the proposed road alignment is shown in the **table below:**

Table 5-5: Forecasted traffic volume on selected road

Year	Cars	Buses	PCU-ADT
2015	510	59	628
2020	718	78	874
2025	2493	829	4151
2030	4769	1048	6865

The above table shows that there are 628 PCU per day is the divertible traffic which will increase to 874 in the year 2020 and will divert to the proposed road alignment. This traffic volume will also be increase to 4151 PCU per day in the year 205 and 6865 in the year 2030.

6. Conclusion and Recommendation

6.1. Conclusion

In this study, Geographic Information System (GIS) was used to explore the various route alternatives that would cross Gairsin to Bageshwar. The Least Cost Path analysis (LCP) model applied for the mentioned route paths were quite successful in avoiding forest, faults, high slopes and zones of ecological importance and thus satisfying the objective of this study within the given criteria and data.

It is concluded that if Geographic Information System and shortest path algorithm should be embedded in the early planning system, it proves to be well suited, economic and time saving for a sustainable corridor location design. It can avoid many location problems; in addition, the ability of the technique to provide several alternatives and to compare such alternatives is a benefit for designers and planners. An additional advantage's of GIS model can also be helpful in the traffic forecasting for the suggested route:

Based on the study results, the following conclusions are made:

1. There are four route alternatives for road alignment are designed from Gairsain to Bageshwar city, based on the each of the four vision viz: Engineering vision, Environment vision, Landslide Vision and Hybrid vision.

2. To access the vulnerability of each vision, following suitable factor has been considered:

    a. Three factors layers i.e. Slope, distance from drainage and drillability index of rocks are considered to Access engineering vision.

    b. Three factors layers i.e. Slope, landuse/landcover and distance from river are considered to access the environment vision.

    c. Eight factors layers i.e. Landuse/landcover, geology, slope, aspect, soil, distance from drainage, distance from road and distance from lineaments are considered to prepare the land slide hazard zonation map. And this hazard zonation map was considered to access the landslide vision.

    d. All the three factor layers map i.e. engineering, environment and landslide are considered for the hybrid vision for road alignment.

3. The optimal route recommended from all the four vision is the route aligned based on the hybrid vision because it provided optimal path based on all the three visions i.e. engineering vision, environment vision and landslide vision.

4. The forecasted traffic volume on the suggested route is 874 PCU per day for the year 2020, 4151 PCU per day for the year 2025 and 6865 PCU per day for the year 2030.

6.2. Recommendations

The application of geospatial technology in the route alignment and traffic forecasting is still in the development stage. It is envisaged that with the continued process of usage, improvement, and modifications, will aid engineers and planners in all different stages of route alignment and design project. This study has shown the potential of GIS as a tool for route alignment. Recommendations for further studies are presented below:

1. Further detailed studies are recommended for using the Least Cost Path (LCP) in route planning and field investigations are a necessity prior to the final decision making. Some improvements in the route design are required to satisfy more detailed construction criteria.
2. High spatial resolution satellite data and high resolution DEM i.e. 1 m or less like below 1m is recommended to get more accurate results.
3. It is recommended to concentrate the efforts to develop GIS extensions for the design of highway, so that the roads can be designed without using non spatial tools. Therefore, GIS will help engineers and planners in the suggestion, design, analysis, and evaluation of road alignment.
4. It is recommended to develop a GIS model to be as decision making tool. So that, this model can, on one hand, automatically analyze and calculate the earthworks volumes and also calculate impact on surrounding areas. On the other hand, the developed model can select the best alternative using an input impact weightage system.
5. For the purpose of road alignment detailed field analysis of existing route and their existing condition data is also recommended to choose proper start and end point of route alignment e.g. in the present study it is recommend that route can be aligned more optimally from Gairsain to Baijnath and it can be connected to the existing route of Baijnath to Bageshwar.
6. To improve the results of traffic forecasting other factors like proper traffic volume data is also recommended to be collected, along with factors like level of service, traffic conditions etc. It is recommended to develop a GIS model for traffic forecasting model So that, this model can, on one hand, automatically analyze existing roads condition, level of service, and distance to be travelled simultaneously and calculate the forecasted traffic and also display the traffic volumes spatially based on the stretches (junction to junction and station to station).

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