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Route Alignment Planning for a New Road between Obligatory points using Geoinformatics Techniques: A Case Study in Dupcheshwor Rural Municipality, Nuwakot, Nepal

Rakesh Sunari Magar [a], Pradeep Kumar Shrestha [b]

[a] *Technical Department, Dupcheshwor Rural Municipality, Samundratar, Nuwakot, Nepal*
[a, b] *Department of Civil Engineering, Pulchowk Campus, IOE, TU, Nepal*
Corresponding Email: [a] rakeshsnrmgr@gmail.com, [b] pradeep.shrestha@gmail.com

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Abstract

This paper studies the geoinformatics techniques for selecting appropriate horizontal road alignment between two obligatory points referred to as origin and destination considering various factors with multiple scenarios under technical, environmental and combination of technical and environmental themes suitability perspective. Specific objectives were to determine the factors responsible for road route alignment selection and to generate Least Cost Paths (LCPs) under several scenarios. A multi-criteria spatial based analysis was carried out giving equal proportional weightage to each factors considered in the geo-database followed by a weighted overlay to produce friction surface cost maps. Then LCP analysis was carried out to produce three route paths considering technical factors only, environment factors only and combining both technical and environment factors. LCPs thus generated were compared with each other with respect to their relative costs. Route developed considering both technical and environment factors was found as the best one in this study in terms of the relative cost. Furthermore, the new road route alignment, which is still alternative considering technical and environment factors, was found if the mandatory control point is added between original origin and destination points. This study suggests further research can be done for accurate and realistic automatic optimization techniques and improvements for preliminary to detailed road alignment planning and design coordination.

Keywords

Road Route Alignment, GIS, Multi Criteria Analysis, Least Cost Path Analysis

1. Introduction

1.1 Background

In any transportation infrastructure development, today's proper decision of appropriate linear positioning of the road alignment plays a great role in the future performance/service of land utilization/exploitation scenario for cost-effective, efficient, and sustainable accessibility and mobility to carry out spatial human activities such as business, recreation, education, etc.

New routes that are proposed should be made such that they satisfy the construction possibility, cost, and current as well as future demands (Acharya et al., 2017). Over the long term, road network affects patterns of growth, land use and economic activities along with its fundamental support of providing the nation's economic and social well-being for the mobility of individuals and goods (Karna, 2017).

There is a common practice of using topographical maps to change road alignment placing based on the terrain's allowable slope. After generating of several alternative routes, a full investigation, analysis, and design considering terrain suitability is carried out (Sekulic et al., 2020).

The traditional method of aligning road routes consumes huge time and requires a lot of manual effort and thus is costly. Therefore, new technologies must be adopted in order to save time and money while designing and evaluating road routes (Wahdan et al., 2019). According to Sunusi et al. (2015), Least Cost Path Analysis (LCPA) allows designers to determine the cheapest route to connect two places within a cost friction surface by combining several variables such as environmental impact, economic investment, and so on.

Magar et al. (2021) used LCP model to compare existing route and various routes for engineering and environment themes using GIS. This paper extends the study of new road route planning between two obligatory points under the presence of the third control points in between them.

1.2 Statement of Problem

Road alignment design has been carried out manually with decisive actions which take a lot of effort and time which might not be efficient. Also several fields are not considered holistically at once like socio-economic conditions, land features, geological conditions etc. So, this study tries to give explanations for the possibility of using Geoinformatics techniques with Geographic Information System (GIS) as assistant tool to define a search corridor where the global optimum alignment is existed and bringing robustness in road alignment fixing approach discarding the trend of merely depending on geometric or technical factors only but also considering several other influencing factors like stream order, geohazard (here landslides), landcover(LC)/landuse (LU), slope aspect, protected areas, etc.

1.3 Research Objectives

The main objective of the study is to get the optimal route alignment with the identified factors' friction cost raster maps as input.

Specific objectives are:

- To determine the factors or variables affecting road route alignment selection
- To know the accumulated cost required at each grid cell level (fishnet) of road corridor
- To generate least cost paths against several friction surfaces of corresponding scenarios of themes

2. Literature Review

2.1 Road Alignment Optimizations

As per Belka (2005), route aligning is primarily based on the three steps. Geographic data is initially recorded in the form of a square grid or cell. Second, each cell in the grid is given a 'suitability score', which indicates how well it is suited for a specific purpose. And finally, from origin to destination, the shortest path (e.g., least impact or cost path) method is used to generate a series or linear form of neighboring cells with the lowest sum of cost. Since 1990, multi-criteria evaluation (MCE) and geographic information systems (GIS) have been widely used to solve a variety of problems in different fields (Malczewski, 2006). In Wahdan et al. (2019), methodology steps embrace criteria identification, data preparation, Weighted Linear Combination (WLC), and decision-making method. Remote Sensing (RS) was used for obtaining land use data such as cultivated land, urban areas, water bodies etc.

As per Saha et al. (2005), a concept of thematic cost map for route development and maintenance was developed. To create a 'thematic cost' map, several thematic data layers were combined. The 'neighborhood movement cost' (i.e., the cost of travelling from a source pixel to its possibly connected neighbors) was then calculated, taking into account the direction-dependent terrain gradient, distance, and the thematic cost. Least-cost route selection procedure adopts Dijkstra's Algorithm. Finally, this developed approach was put to the test in the study region under various terrain circumstances (Saha et al., 2005). A decision rule is a technique for combining criteria. The additive decision rules are commonly utilized in the Geographic Information System–Multi Criteria Decision Analysis (GIS-MCDA) approach (Malczewski, 2006). Weighted linear combination (WLC) is the most often used additive decision method. The primary reason for WLC's popularity is that the method is very easy to implement within the GIS environment using map algebra operations and cartographic modeling. The method is often applied in land use/suitability analysis, site selection, and resource evaluation problems. It can be implemented in both raster and vector GIS environments (Malczewski, 2000). Utility/value method is another additive decision rule which defines expressions that determine the degree of satisfaction of the criteria. These functions convert the ratings that define the behaviour of the alternatives in relation to the criteria into their degree of satisfaction according to the methods viz. multi-attribute utility theory (MAUT) or Multi-attribute value theory(MAVT). The expression of the function can model different shapes to relate the ratings and the degree of satisfaction (Penadés-Plà et al., 2016).

WLC approach is used in this study as discussion is limited here to the raster based implementation. TThe weighted overlay strategy is used in this procedure. The weight allocated to each criterion is multiplied by the criterion (attributes) values in the WLC approach as shown in equation 1. Mahavar et al. (2019) applied this method to find out the alternative path based on the least cost analysis considering topography (slope) and land use pattern of the area. However, the environment aspects were not considered for the development of the model. First step is the collection of several influencing factors and discovering their values and classes available accordingly, second step includes the conversion to general comparable score and finally third step is the summing of the obtained products as shown in figure 1 to generate a rank map and the alternative with the highest (benefit) or lowest (costs) score is chosen.

$$A_i = \sum_j w_j x_{ij} \tag{1}$$

where,
w_j is normalised weight
x_{ij} is an attribute transformed in comparable scale

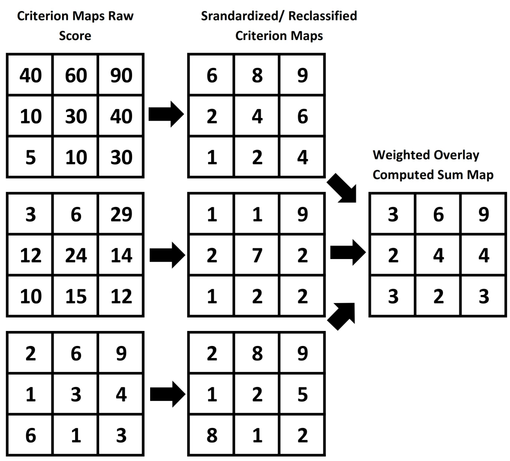

Figure 1: Weighted Linear Combination Performed on Raster Datasets

2.2 Least Cost Path (LCP)

The least-cost path algorithm is generally available in almost all commercial GIS. It computes and traces out the least cost as well as short path between any predefined origin and destination through any prepared cost friction surface. The cost is defined by its neighbouring cells' relations i.e., difference in adjacent values which can be called as gradient according to which it chooses one with the lowest gradient among the eight neighbour cells at eight different directions. And as the process starts from the source, it would keep on repeating the same process itself until it reaches the predefined destination. The cost of anything can be expressed in monetary or non-monetary terms. As a result, the weighted distance is assessed in relative cost value rather than geographic value (Miller and Shaw, 2015).

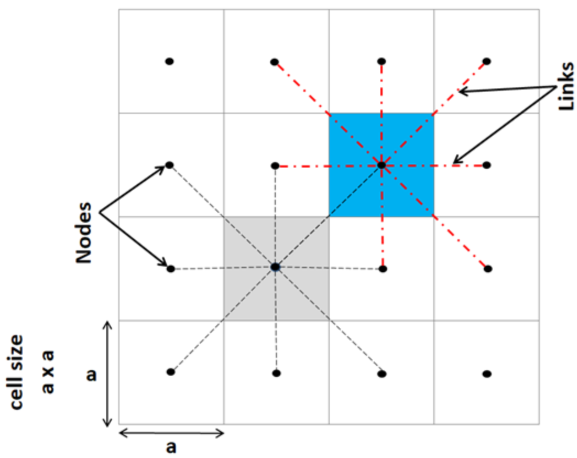

Figure 2: Node/Link Representation of Raster

The method of generating the least-cost path in GIS can be split into two steps. A cost surface raster and a source raster are used in all calculations (figure 2). Every node is assigned a value from the cell, and every link is assigned a resistance value indicating the cost of passage between the two neighbouring cells, using a node/link model. While moving in horizontal or vertical direction the resistance value. i.e. the cost to move across the links to the neighboring cell is the cost of cell 1 plus the cost of cell 2, divided by 2 as shown in equation 2.

$$a_1 = \frac{cost_1 + cost_2}{2} \tag{2}$$

While moving along diagonal, the cost to travel the link is $\sqrt{2}$ times the cost of cell 1 plus the cost of cell 2, divided by 2 as shown in equation 3.

$$a_2 = \sqrt{2} * \frac{cost_1 + cost_2}{2} \tag{3}$$

The accumulative cost is the summation of all costs of each cell from the source to the destination cell. The repeated process of calculating the least accumulative costs for each cell leads to the production of a weighted-distance raster. To begin, the source cells are identified and given a zero value because traveling to them is free. Then, for each of their near neighbours, a cost of travel from them to the source is allocated, and the cell with the lowest cost is chosen and added to the output raster. Simultaneously, the selected cell's movement direction is encoded as a back link raster.

3. Methodology

3.1 Methodology

The first step includes the identification of factors and determination of class themes. The second step consists of the selection of the study area and the available spatial data collection of the study area. Third step is reclassification/standardization of the collected data of several scales to bring them to the same scale. The fourth step includes the preparation of a friction surface map for each predetermined alternative. LCPs were generated using LCP function for each alternative which were further compared to find out the best route.

3.2 Step 1: Identification and Classification of Factors, Alternatives and Criteria

Three technical factors namely slope, stream order, and landslide area, and three environmental factors namely land cover, slope aspect and protected area etc. which are presented in figure 3 were selected. All six selected factors are mandatory for route alignment but with a different priority level. Therefore, multi criteria decisions are to be made in route alignment selection activities. Three scenarios combining these factors were considered. First scenario only combines technical factors, second scenario only combines environmental factors and the third scenario combines both technical and environmental factors.

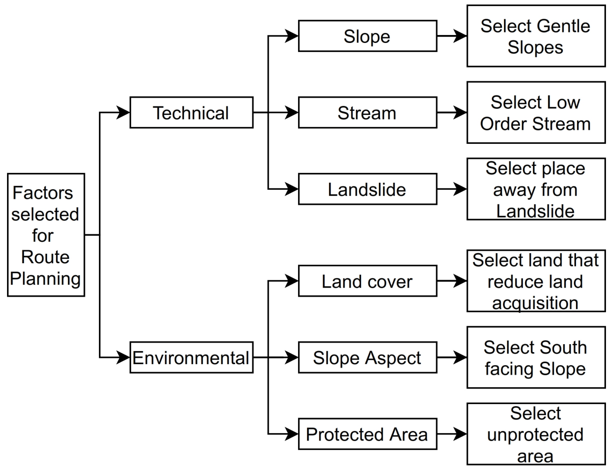

Figure 3: Factors and Selection Criteria

3.3 Step 2: Selection of Study Area and Data Collection

3.3.1 Study Area

Study area encompasses Dupcheshwor Rural Municipality(DRM) and some part of Langtang National Park in Nuwakot District. The study area lies between longitudes 3,38,934.7 m to 3,52,272.5 m East and latitudes 30,84,544.4 m to 31,07,339.3 m North as per WGS_1984_45N Coordinate System as shown in figure 4. The Topo sheets 278502A(Kharanitar), 278502B (Samundratar) and 288514 (Dhunche) from the Department of Survey, Nepal were used. The terrain is highly rugged with elevations ranging from 837.687 m to 5050.650 m above mean sea level (msl). Road routes and network of the Rural Municipality is not well planned. Population of Rural Municipality is 22,106 (Census 2011). The Rural Municipality is developing fast therefore requires more and better well planned infrastructure facilities.

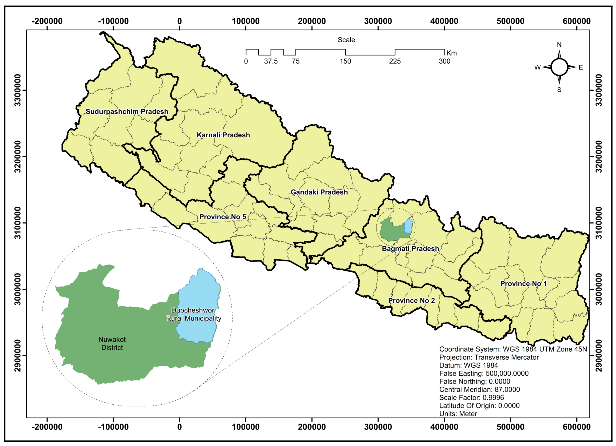

Figure 4: Selected Study Area

3.3.2 Data Collection

The study has utilized three main types of data:

(1) Remote Sensing Data

Here, remote sensing data includes Digital Elevation Model (DEM). A digital elevation model is a computer depiction of a terrain surface (DEM). A DEM is an important layer that depicts the spatial elevation distribution of existing earth surface or terrain feature which is very useful in several analysis of hydrology, geology etc. In this study using DEM as shown in figure 5, several maps representing spatial variations of slopes, aspects (landmass face direction) and stream orders were generated. It is a remotely sensed data prepared by survey made by USGS SRTM (file named'$n27\_e085\_1arc\_v3.tif$'). DEM is used to generate slope, aspect and stream order maps.

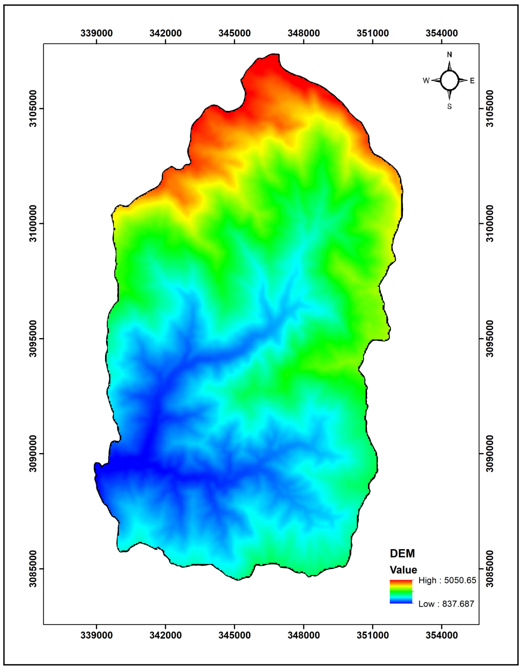

Figure 5: Digital Elevation Model (DEM)

(2) Ancillary Data

Ancillary data means data (shape files, drawing files, published maps etc.) collected from department of survey and online sources. E.g. Landslide map, LandCover(LC), protected area map etc.

3.4 Step 3: Reclassification/Standardization

The criteria attributes are transformed into a cost scale that ranges from 1 to 9 where the value 1 is the least cost and 9 is the highest cost using Linear transformation (inbuilt GIS function). As every data have a different scale of measure, they were brought down to common scale which is called the reclassifying process or standardizing process.

3.5 Step 4: Preparation of Cost Friction Surface Maps as per Themes

The re-classed slope, land cover and other data are used as input independently in six individual scenarios and overlaid in other scenarios after giving equal weights to each factor. Equal weight was determined between all the criteria factors in each alternative because they have almost equal priorities according to the goals and objectives of each scenario. Thus weight re-classed output generated may be named as relative cost which is unitless (brought down to comparable common value) in the model. The influence factor of each layer is weighted with between 0 to 1 values so that the whole summation of influence of the thematic cost raster is 1 or 100 %. As per Saha et al. (2005) Multi Criteria Evaluation (MCE) is used for the thematic cost raster generation and is computed as

$$Scenario\ Cost\ Value = \sum_{Data\ Layer} Weight * Attribute \qquad (4)$$

Figure 6 shows the summation of multiple values or weighted overlay where the weightage or proportional factor of each data layer or map is assigned and summed up to get the corresponding cost surface as per several scenarios.

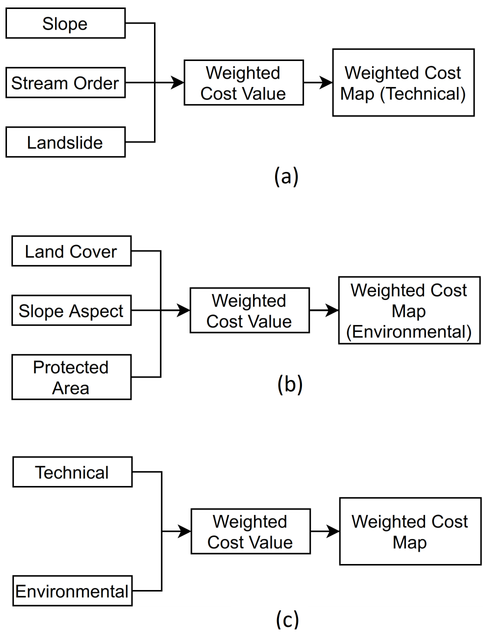

Figure 6: Schematic Diagram for Generating the Cost Maps (Step 4)

3.6 Step 5: LCP Function and Alternative Route Alignments

The least cost path function operates or processes on resistive friction surface cost map (raster file) with respect to the positions of primarily origin point and then destination point (both of them as point shape files). As shown in figure 7, the cost distance function includes cost distance and cost backlink raster preparation. Firstly, cost backlink and cost distance are calculated as per the origin point position and resistive friction surface cost map. Then, the least cost path according to the position of the destination point against the cost distance surface raster is generated.

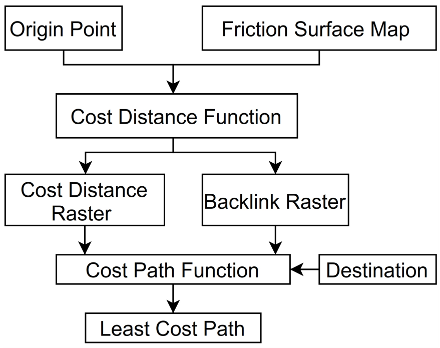

Figure 7: Flowchart of Functional Relationship in LCP process (Step 5)

3.6.1 Cost Distance and Backlink Raster

In this step destination in .shp format and 'cost surface' in raster format are used as input in the 'cost distance' function of calculation to obtain cost distance and back-link as output.

a. Cost Forward Link Analysis:
Cost is considered here in terms of the distance of the path travelled. Less distance path means less cost and more the distance greater the cost. In the GIS model cost distance gives value to each cell as the distance attribute from the source to each cell in the raster. It is based on the lowest-cumulative cost over a cost surface. An output of cost distance represents accumulated value getting from each cell to reach the destination. It is a total value of all cells from origin to destination. In the model, the optimum cost path has been calculated based on the availability of gentle slopes/gradient of values in between the origin (O) and destination (D) points (figure 8).

As shown in figure 9 in order to get the least cost path while travelling from origin cell to the destination cell, the accumulated cost value is 9 which is the minimum possible optimally least cost value (Cost Distance) from the predetermined destination cell to reach the predetermined source/origin cell.

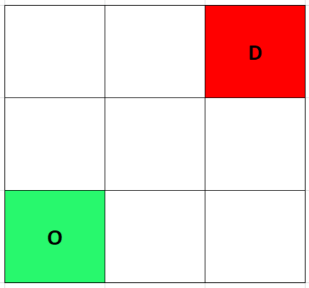

Figure 8: Diagram Showing the Input Locations

Figure 9: Diagram Showing the Output of Cost Distance

b. Cost Back Link Analysis:
This analysis provides direction to the cost path model, the value of each cell represents the direction to reach the destination. The figure 10 indicates the code number of the direction, the value 0 represents the source location where, code number is given in clockwise direction from the right direction of the source. Here, 1-8 code numbers are given which will give the direction from origin to destination. This Back-link analysis helps in the cost path model to trace an optimum road path.

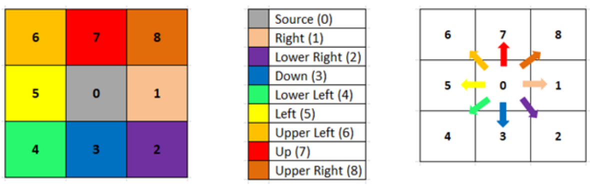

Figure 10: Diagram of Code Number and Direction

3.6.2 Cost Path

In the final step output cost distance, output back-link, and origin are fed as input and the least cost path is obtained as output after running the model. Least-cost path routes can be generated from any destination location after the computation and development of cost distance and back-link raster is completed. The Cost Path tool inbuilt in ArcGIS then traces the alignment connecting predefined destination cell to the origin cell through the cost distance and back-link raster The route or road path alignment that covers the least cost accumulated is the best or optimal route. Figure 11(a) shows the direction of steepest or lowest difference value near neighbourhood giving the possible direction of a path which is the output of the previous step. In figure 11(b), the best / least cost route has been determined as a green coloured path as it has the least accumulated values to reach the destination from the source.

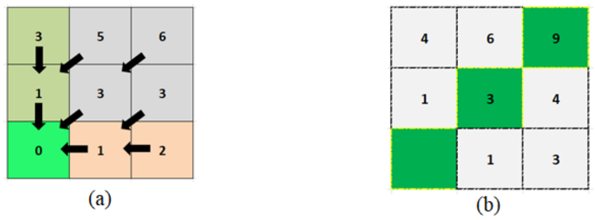

Figure 11: LCP Output: (a)Output of Backlink (b)Cost Path

4. Result Analysis

4.1 Data Preparation for GIS

Required data were acquired from several sources then processed for the digital purpose and afterward reclassified or standardized with cost rating given to each subclass as per their corresponding nature in order to bring all of them in equivalent or comparable common scale. Several procedures were followed in accordance to the predetermined methodology as mentioned in the previous section 3.

4.1.1 Slope

The slope map (figure 12) of the area was prepared from the DEM. DEM contains several cells which represent an elevation. Output slope raster file can be generated either in degree or percentage slope. Each cell of the output raster generated from DEM has a slope value. Classification was performed in Esri ArcGIS using reclassify tools (Sekulic et al., 2020). Nine classes of slopes are presented here in table 1. The low value of the slope suggests flatter slope and vice versa.

Table 1: Rating Scheme of Slope Data Layer

Factor Sub Classes	Cost Rating	Coverage %	Remarks
a) 0° – 11°	1	1.83%	Very low cost
b) 11° – 17°	2	4.92%	Low to very low cost
c) 17° – 22°	3	8.36%	Low cost
d) 22° – 27°	4	12.84%	Low to moderate cost
e) 27° – 31°	5	16.91%	Moderate cost
f) 31° – 35°	6	19.83%	Moderate to high cost
g) 35° – 39°	7	18.13%	High cost
h) 39° – 45°	8	11.94%	High to very high cost
i) >45°	9	5.23%	Very high cost

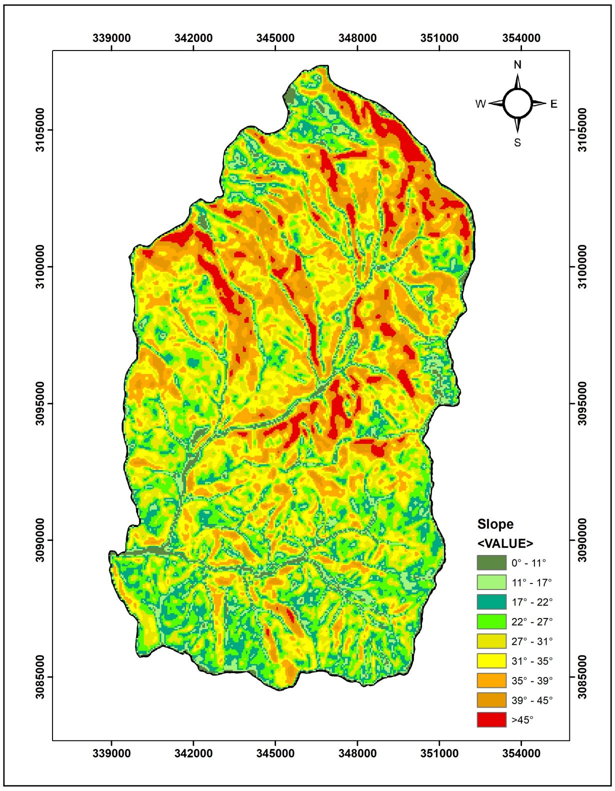

Figure 12: Slope

4.1.2 Stream Order

Stream Order is derived from DEM using the hydrology toolbox inbuilt in ArcMap. It works on the

Table 2: Rating Scheme of Drainage / Stream Order Data Layer

Factor Sub Classes	Cost Rating	Coverage %	Remarks
a)No Drainage	1	96.28%	Very low cost
b) 1st order	3	0.90%	Low to very low cost
c) 2nd order	4	0.95%	Low cost
d) 3rd order	6	1.05%	Moderate cost
e) 4th order	8	0.79%	High cost
f) >5th order	9	0.05%	Very high cost

Strahler principle, the method of stream ordering proposed by Strahler in 1952. There is an inbuilt function under spatial analyst toolbox in ArcMap which generated 5 classes of stream order as shown in figure 13 and presented in table 2.

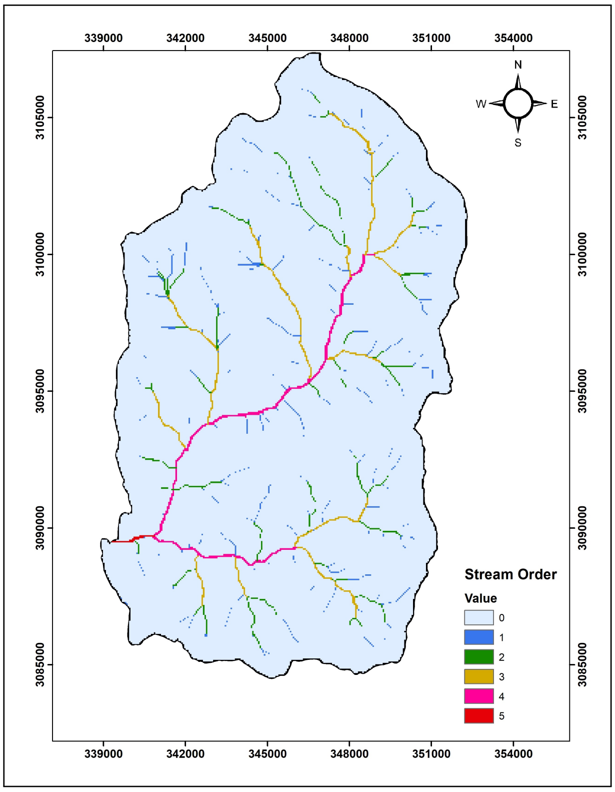

Figure 13: Stream Order

4.1.3 Landslides

In this study, it has been categorized with respect to area range classes as shown in figure 14 and table 3 below.

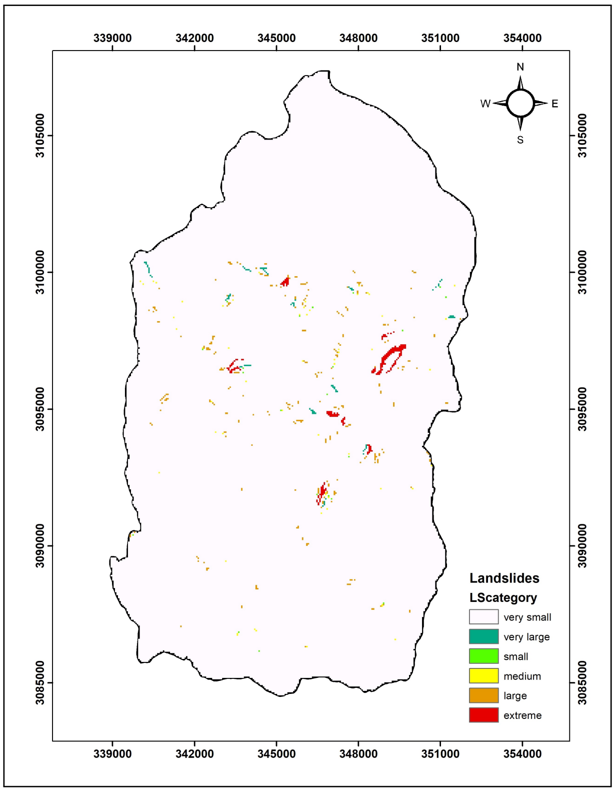

Figure 14: Landslides

From the above table, different classes of landslides can be observed to be ranged as per area from "no landslides" to "$>85459m^2$ " described as very low risk or costly to very high risk or costly respectively. The classes were auto generated by ArcGIS according to the distribution of number and area of the feature available in the map.

4.1.4 Land Cover

It includes the different categories of land features on the earth's surface like rivers, forest, barren land, grassland, shrubs, farmland, etc. Land cover shape file were collected authentically from the Department of Survey, Nepal as shown in figure 15. Construction through rivers, cliffs, cultivation land (land acquisition), forests (community forests) is costlier than bush land, grasslands, barren land.

Table 3: Rating Scheme of Landslide Data Layer

Factor Sub Classes	Cost Rating	Coverage %	Remarks
a) No Landslide	1	99%	Very low risk / cost
b) <3588m^2	3	0.02%	Low risk cost
c) 3588m^2 to 15944m^2	4	0.38%	Moderate risk / cost
d) 15944m^2 to 38037m^2	6	0.10%	Moderate to high cost
e) 38037m^2 to 85459m^2	8	0.07%	High cost
f) >85459m^2	9	0.3%	very high cost

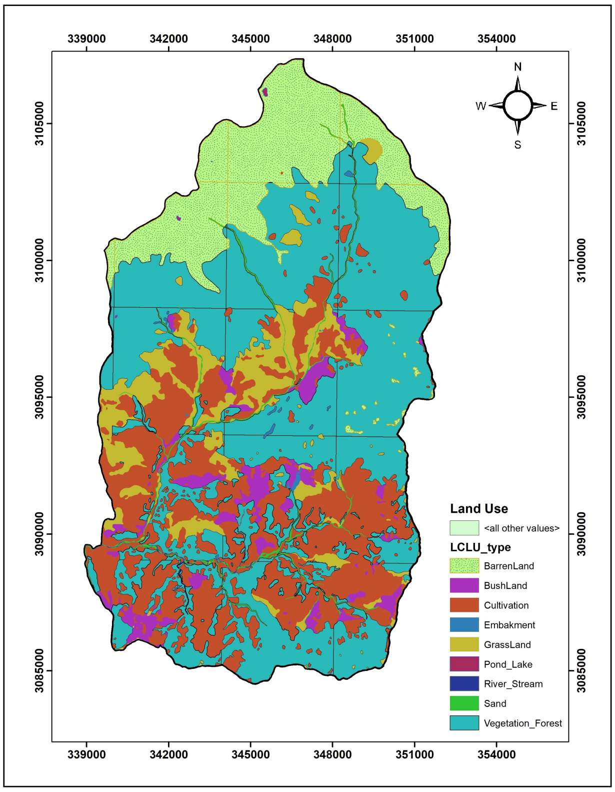

Figure 15: LCLU

The table 4 shows that vegetation forest occupies the largest area of 46.03% while pond, lake occupies very little space of 0.03% of the study area. It means the activities of road construction may result in deforestation and land acquisition of cultivated lands.

Table 4: Rating Scheme of LandCover/LandUse Data Layer

Factor Sub Classes	Cost Rating	Coverage %	Remarks
a) Barren Land	1	15.5%	Very low cost
b) Bush Land	2	3.85%	Low to very low cost
c) Grass Land	2	8.26%	Low cost
d) Vegetation Forest	3	46.03%	Low to moderate cost
e) Cultivation Land	4	24.81%	Moderate cost
f) Sand	7	1.15%	Moderate to high cost
g) River, Stream	7	0.18%	High cost
h) Pond, Lake	8	0.03%	High to very high cost
i) Embank-ment, Cutting, Cliff	9	0.18%	very high cost

4.1.5 Slope Aspect

This is generated using surface analysis of DEM which is calculated using the inbuilt aspect function within the surface analyst arc-toolbox. It corresponds to the compass bearing of 0° to 360°in clockwise direction. North aspect is 0° or 360°, North East is 45° East is 90°, South East is 135°, South is 180°, South West is 225°, West is 270° and North West is 315°. The figure 16 and table 5 indicates that 15% of the total area is south which is most favorable for alignment. In total 45.1% aspects are south, south east and south west which is quite favorable overall.

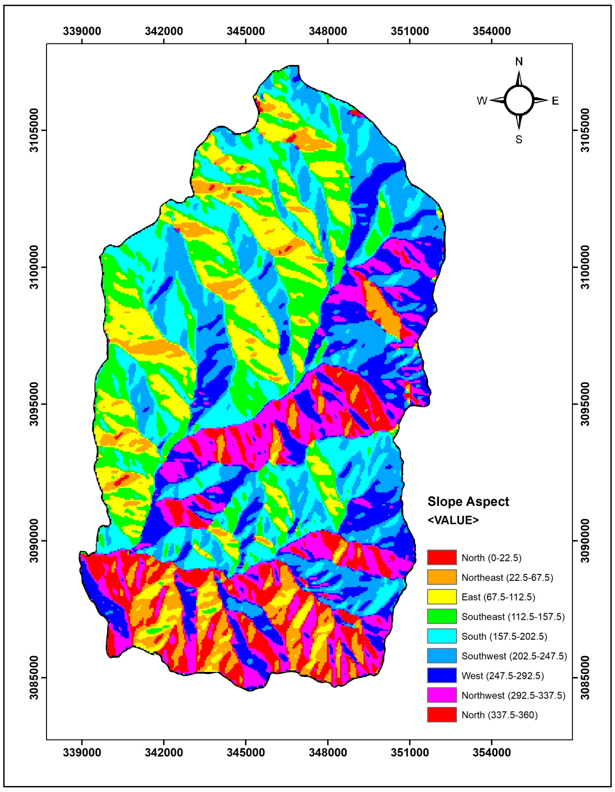

Figure 16: Slope Aspect

Table 5: Rating Scheme of Slope Aspect Data Layer

Factor Sub Classes	Cost Rating	Coverage %	Description
a) South	1	15.02%	Favourable
b) South East	3	14.59%	Moderately favourable
c) South West	3	16.25%	Moderately favourable
d) East	5	12.36%	less favourable
e) West	5	13.40%	less favourable
f) North West	7	8.74%	unfavourable
g) North West	7	8.74%	unfavourable
h) North	9	8.61%	very unfavourable

4.1.6 Protected Area

National Parks are more restricted than a buffer zone. Similarly, regions other than conserved areas are comparatively unrestricted for road construction. From table 6 and figure 17, it can be observed that in an average nearly 31.08% area is occupied by national park and 30.06% area occupied by a buffer zone. The buffer zone is the transition area between the protected area and local area. This may address that the remaining 38.86% area is a non-conserved area which can be used for road construction with comparatively low cost than that for protected and buffer area for which requires high authority of getting governmental permission. However, naturally the activities of road construction can bring land acquisitions of community forests and also cultivated lands from the local people in such areas and as a result several compensations and social issues are to be dealt with. But these are not considered in this study.

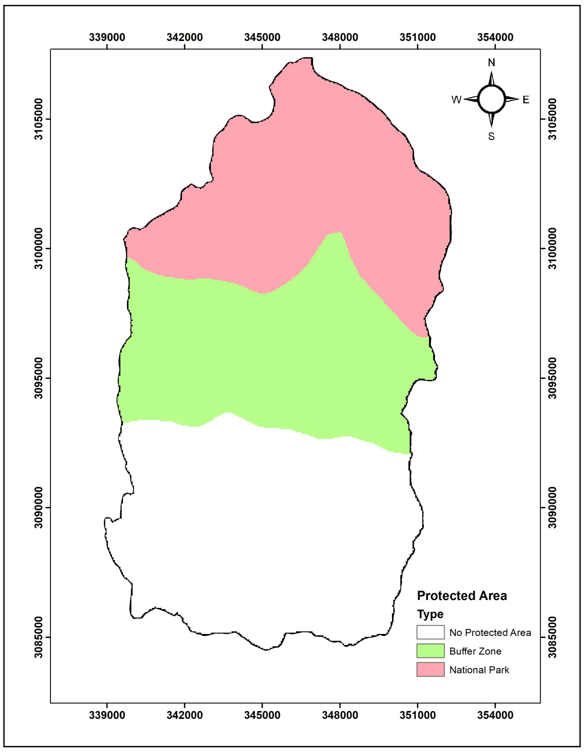

Figure 17: Protected Area

Table 6: Rating Scheme of Protected Area Data Layer

Factor Sub Classes	Cost Rating	Coverage %	Remarks
a) No Protected Area	1	38.86%	No restriction
b) Buffer Zone	5	30.06%	Moderate restriction
c) National Park	9	31.08%	High restriction

4.2 Reclassify

Required six factors after collection and digitization, were reclassified. The cost ratings ranging from 1 to 9 were reclassified according to the general statistics division converted into a comparable common scale using linear scale transformation to obtain output as a reclassed feature raster.

4.3 Preparation of Cost Friction Surface Maps by Weighted Overlay

Thematic cost surface map is prepared by 'overlay by weight' toolset in arc toolbox using the equal proportional weights in this case of study. Equal weight was determined between all the criteria factors in each alternative because they have almost equal priorities according to the goals and objectives of each scenario. Weighting means the contribution of the categories to the accumulative friction cost surface for road construction as per their corresponding characteristic or nature. Hence, in this case,

$$\begin{aligned} 1.\ & Alternative\ 1 \\ & -Technical \\ & FactorsOnly \\ & Cost\ Value = 33.33\% * S + 33.33\% * SO + 33.33\% * LS \end{aligned} \tag{5}$$

$$\begin{aligned} 2.\ & Alternative\ 2 \\ & -Environment \\ & FactorsOnly \\ & Cost\ Value = 33.33\% * LCLU + 33.33\% * SA + 33.33\% * PA \end{aligned} \tag{6}$$

$$\begin{aligned} 3.\ & Alternative\ 3 \\ & -Technical\ and \\ & Environment \\ & Factor\ Combined \\ & Cost\ Value = 50\% * Alternative\ 1\ Cost\ Value + 50\% * Alternative\ 2\ Cost\ Value \end{aligned} \tag{7}$$

where,

S = Slope
SO = Stream Order
LS = Landslide
LCLU = Land Cover / Land Use
SA = Slope Aspect
PA = Protected Area

Alternative 1 = Combination of 3 Technical Factors (Slope, Stream Order and Landslides)
Alternative 2 = Combination of 3 Environment Factors (Landcover/Landuse, Aspect and Protected Area)
Alternative 3 = Combination of Alternative 1 and Alternative 2 (All Technical and Environment Factors)

4.4 Model Development of LCP

In the model builder shown in figure 18, blue colored oval shape represents the input, brown colored hexagonal shape represents iteration, orange colored square shapes represent the process/function and green colored oval shape represents the output. And the shadow indicates that it has been processed. Here in this case, 'fricsurfaces.gdb' is the geodatabase file within which three friction cost map raster files in .tif format are confined, produced by weighted overlay raster calculation in the previous step of predefined methodological process. Origin is the source point shape file used in all of the scenarios in Cost Distance function that gives outputs as '%name% [1]CostDist' as distance cost rasters and '%name% BackLinkFinal' as backlink raster files (direction rasters) as the result for three scenarios respectively. Then after, these two type of outputs (distance cost raster and backlink raster) and Destination (destination point shape file) are used by function Cost Path to generate LCPs in each scenarios with mentioned file name '%name%CostPath' as shown in figure 18.

4.4.1 Cost Distance

Three cost distance raster surfaces were prepared as per the corresponding scenarios. It is like distance contour map as per the impedance or friction value calculated by the function as per the input raster dataset.

[1] %name% is the code that makes the output file generated by the same name as that of input parent file

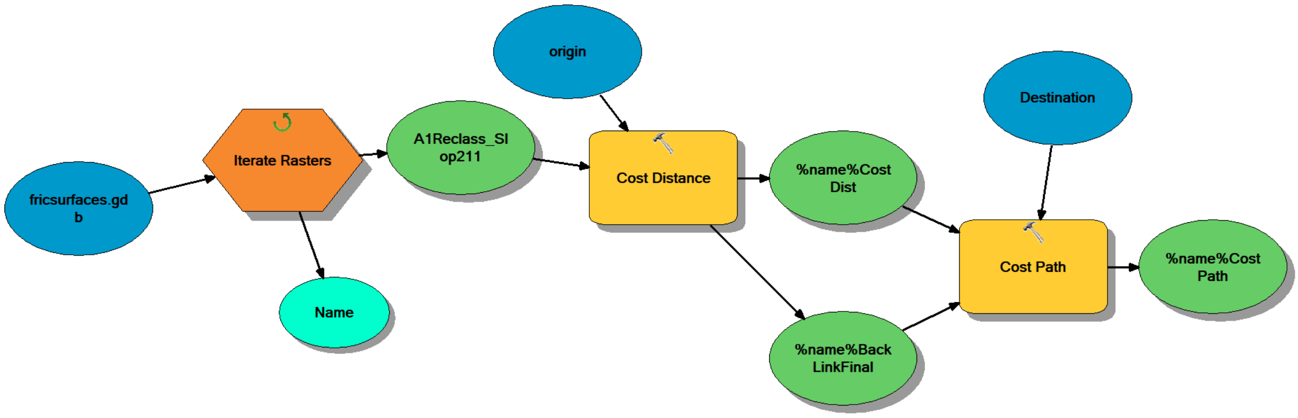

Figure 18: Iterative Model Builder for Multiple Rasters (Scenarios) to run LCP Function

4.4.2 Backlink Raster

Three backlink raster surfaces were prepared as per the source position in corresponding scenarios. It is the direction value raster calculated by the function as per the input friction raster dataset and the source position.

4.4.3 Least Cost Route

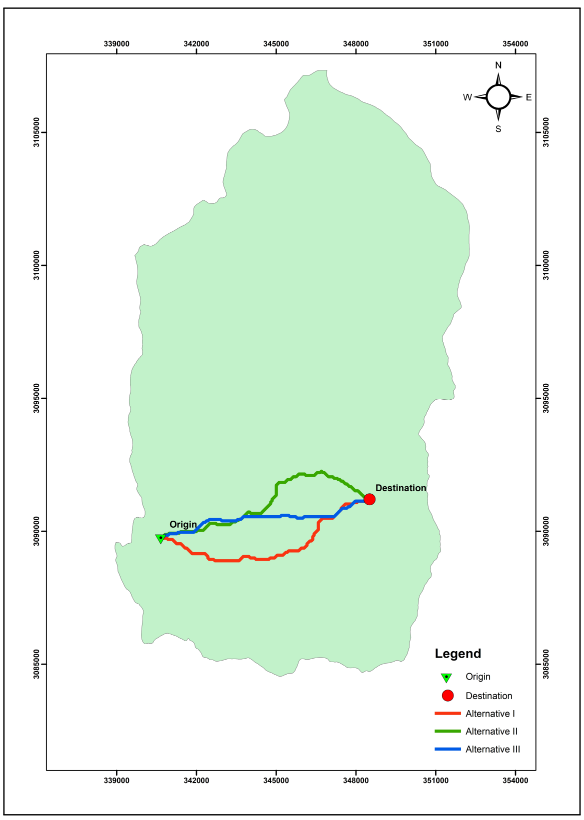

Figure 19: Alternative Routes between origin and destination

Three least cost routes were prepared as per the destination position considering Technical factors only, Environment factors only and Combination of both technical and environment factors as shown in figure 19. It is the selection of least accumulated raster value while extending from source to the destination calculated by the function as per the input cost distance, backlink raster dataset and destination position.

4.4.4 Selection of Best Alignment

Grid based raster road alignments produced were converted to linear features using iteration model with 'raster to polyline' function which were buffered by 50 m each side of the center-line of the alignment using iteration model with 'buffer' function. Fifty meter cellular sized raster was used for the whole raster calculation process so at least total buffer of 100 m was considered for basis of evaluation check and comparison among several results. The area covered by buffered polygons of each alternative with respect to several factor maps were extracted out using iteration model with the 'mask' function.

As per raster classes available in each scenario, the number of these raster classes of the corresponding friction surface were extracted whichever falls within the polygon boundary of the existing road. Similarly the friction raster extracted by the buffered polygons of generated alignments of other scenarios were extracted. The count of the value classes of each scenario was collected and analyzed in MS Excel. Multiplying the rating cost values as per the factor feature classes with the number of the count of cells, the total summation in each three scenarios were calculated as the relative costs and thus calculated costs were compared with each other.

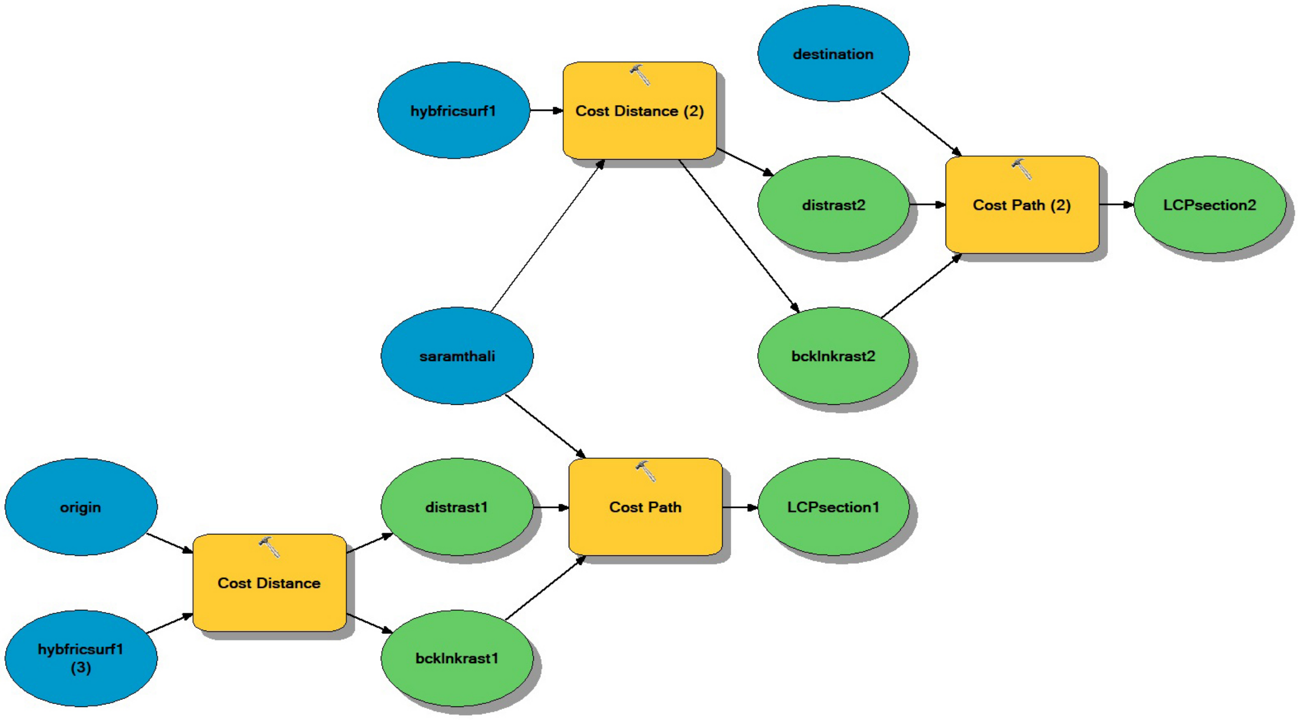

Figure 20: Model for LCP with Obligatory Point in between Origin and Destination

Here in the route selection criteria analysis shows that out of the three alternatives, Alternative 3 (combined theme) cost summation gives lowest cost among the studied alternative scenarios. This addresses Alternative 3 (combined theme) to be more selective or attractive in case of the studied region is best one as the relative cost of the route is least.

4.4.5 Scenario Analysis with Mandatory Control point or or location

Furthermore, obligatory locations are possible to get existed due to social and political pressure / strict compulsion. Such cases can arise while planning route between two locality and third important place exist between them and road planner want to provide access to it as well. Further analysis was done by adding a third mandatory contol point between original origin and destination points. The model used for such process is shown in figure 20. The route alignments for three scenarios changes from the previous position to the new position as shown in figure 21. More over best alignment with least relative cost was found to be alternative 3 (combined theme) as shown in table 7. Thus, the best route alignment differs if mandatory control point is added between origin and destination while alignment planning.

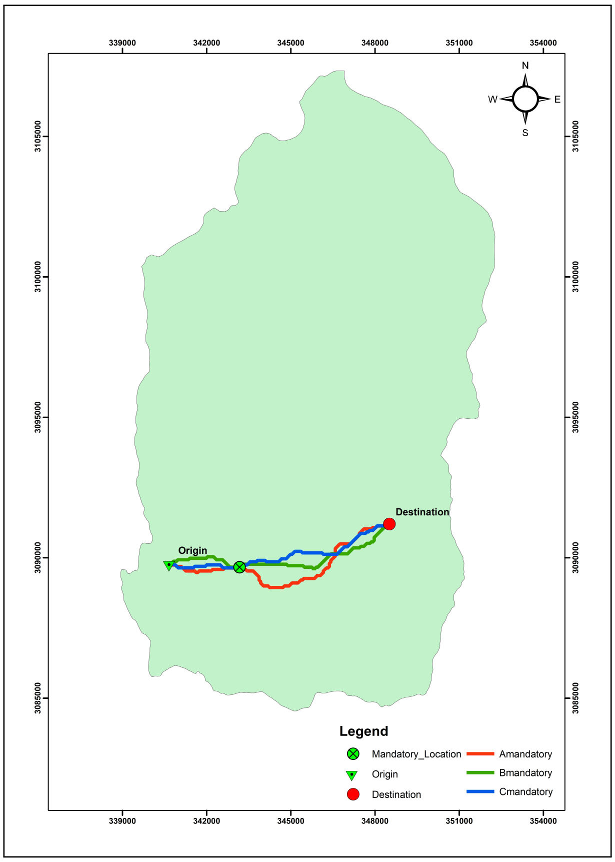

Figure 21: Alignment changed due to Obligatory Point or Location

Table 7: Analysis Result Summary

Alternative Scenarios	Route with Obligatory points (origin and destination)			Route with Obligatory points (origin and destination) and One Control Point (Mandatory)		
	Relative Cost	Length (in km)	Rank	Relative Cost	Length (in km)	Rank
1. A1	12,290	9.53	3rd	10,540	9.64	2nd
2. A2	9,570	9.67	2nd	10,590	8.88	3rd
3. A3	9,080	8.49	1st	9,710	8.70	1st

where,
A1 = Alternative 1 (Technical Factors only)
A2 = Alternative 2 (Environment Factors only)
A3 = Alternative 3 (Both Technical and Environment Factors)

5. Conclusion and Recommendations

5.1 Conclusion

This study used the GIS model for planning of the best route alignment based on the least cost analysis. The weightage assigned influencing factors such as slope, stream order, landslide, land cover, aspect, protected area generated from the base map were prepared with remotely surveyed data. Thus Geoinformatics techniques was utilized for generation of auto detected optimal i.e. least cost path alignments accordingly. Among the three alternatives, the alternative which combines both technical and environment factors gives the lowest cost and is found to be more attractive in case of the studied region so it is called as the best route alignment.

5.2 Recommendations

Further research can be done for accurate and realistic automatic optimization techniques and improvements for preliminary to detailed road alignment planning and design coordination. Also, the outcome of the LCP calculations depends on the cost model, several cost components and weight assigned to them. Plan curvatures, annual rainfall, geology, soil texture (lithology), structural features (shear zones, faults, thrusts, lineaments) etc. also can be used as responsible factors and determine their corresponding weightage in upcoming studies.

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