ADDIS ABABA UNIVERSITY

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SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

GIS BASED NEW ROUTE ALIGNMENT SELECTION BETWEEN DABAT AND KERAKER TOWNS

A Thesis in Geodesy and Geomatics Specialization in Geomatics

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A Thesis

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The undersigned have examined the thesis entitled 'GIS Based Route Alignment Selection Between Dabat and Keraker Towns.' presented by Hiwot Yitayew, a candidate for the degree of Master of Science and hereby certify that it is worthy of acceptance.

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UNDERTAKING

I certify that research work titled “GIS Based Route Alignment Selection Between Dabat and Keraker Towns.” is my own work. The work has not been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged/referred.

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ABSTRACT

Road network connectivity improves socio-economic development and functionality as well as quality of life through enabling sustained and all-inclusive growth. It also enhances mobility of people and goods providing access to market - value chain and services on top of creating an opportunity to discover our most valued resources such as land. However, practical aspects of road network optimization require designing best route alignment selection. Usually, route alignment selection is governed by many factors. Multi-criteria decision analysis is well adopted method that considers the effect of various factors such as engineering, social, economic and environmental factors on route planning. The aim of this study is to use a multi-criteria approach specifically Analytic Hierarchy Process (AHP) pairwise compression analysis for route planning that connects Dabat and Keraker towns located in northern region of Ethiopia. The operations to select the least cost route depend on the effective collection, processing, storing and analysis of spatial data such as slope, drainage, land use, soil type, geology, existed road and drainage. The weight overlay analysis was considering seven factors that affect route planning. The value of the factor is unique because of distinctiveness of geographic, socio-economic, and environmental situations of the study area. The results suggest that the first governing factor for the route selection in the study area is slope. While fault and soil are the second and third most governing factors for the road alignment selection, respectively. The length of the proposed route is 65 km compared to the existing road of 90 km length. The new alignment is 34 km shorter than the existing road, implying the novelty of the multi criteria approach.

Keywords: Route selection, Multi-Criteria Decision Approach, factors governing route selection.

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LIST OF ACRONYMS

AHP	Analytic Hierarchy process
ALOS	Advanced Land Observation Satellite
AOI	Area of Interest
ASTER	Advanced Space Borne Thermal Emission and Reflection Radiometer
AVNIR-2	Advanced visible Near-Infrared type 2
CR	Consistency Ratio
CSA	Central Statistical Agency
DEM	Digital Elevation model
DSM	Digital Surface Model
DTM	Digital Terrain Model
ERA	Ethiopia Road Authority
ERDAS	Earth Resource Data Analysis System
FAO	Food and Agriculture Organization
GIS	Geographic Information system
GPS	Global Positioning System
H	Height
IFOV	Instantaneous Field of View
INSAR	Synthesis Aperture Radar
JERS-1	Japanese Earth Resource Satellite unit 1
JPEG	Joint Photographic Expert Group
KM	Kilo Meter
LCP	Least Cost Path
LCPA	Least-Cost Path Analysis
LIDAR	Light Detection and Ranging
LULC	Land Use Land Cover
M	Meter

MCD	Multi-Criteria Decision
MCDA	Multi-Criteria Decision Approach
METI	Ministry of Economy, Trade, and Industry
N	North
NASA	National Aeronautical and Space Administration
PALSAR	Phased Array Type L-band Synthesis Aperture Radar
PH	Power of Hydrogen
PRISM	Panchromatic Remote Sensing Instrument Stereo Mapping
SRTM	Shuttle Radar Topography Mission
SWIR	Shortwave Infrared
TIR	Thermal Infrared
USA	United States of America
USGS	United State Geological Surveying
UTM	Universal Transvers Mercator
VNIR	Visible Near Infrared
WGS	World Geodetic System
WSM	Weighted Sum Model
3D	Three Dimensional
Λ	Longitude (lambda)
Φ	Latitude

CHAPTER 1 INTRODUCTION

1.1 Background

Effective road improves any inhabited area's socio-economic functionality and quality of life as it optimizes connectivity, enabling sustained and all-inclusive growth to peoples living in remote area. Transportation allow movement of people and goods and influences patterns of growth and economic activity by providing access to productive lands and inaccessible communities. It is also multi-faceted and sensitive in that its performance affects public policy concerns such as environmental resource consumption, social equity, land use, urbanization, economic growth, safety and security. However, constructing proper road requires time and considerable effort (Muriki. et al, 2014).

The development of a robust transportation involves the selection of appropriate road alignment that can optimize the geometric connectivity of the existing road network infrastructure. Alignment or route planning is the procedure of selection the best alignment within desired route corridor based on the overall influences of driving factors. The 'footprint' of each route option should be defined necessarily to consent its feasibility from the perspective of engineering, social and environmental aspects. In essence, the best alignment should enhance connectivity between urban and rural development corridors as well as minimize construction and maintenance cost beyond ensuring efficient fuel consumption. Ethiopian Road Authority term of reference for road design experts defines the purpose of the route selection process as; according to the Ethiopian standard, the identification of best routes depends on various parameters such as technical, financial and economic, environmental, social and planned terms (ERA manual, 2013).

Whereas, conventional route planning is solely based on topographical factors such as slope and curvature. Common pattern involves manually marking segments of acceptable gradients for route alignment on large-scale topographical maps. Such an approach is cumbersome and boring, and it may not be feasible when a variety of factors such as landslides, geology, soil type, vegetation, land use, and land cover are considered (Yildirim et al, 2006).

Geographic Information System (GIS) are becoming widely used in transportation organization agencies, specially among metropolitan transportation organizations. In several developed countries, highway maintenance administration is becoming a serious issue. Many more authorities are now able to use GIS for highways and transport management, due to dropping costs and GIS increasing friendliness (Al-Ramadan, 2006). Route selection is a critical first step in the procedure of design and construction and has a potentially significant impact on the construction and environment of the area (Barzilai, 1997).

The uncertainty of various factors that affect the route alignment makes this process more complicated. The alignment of a route is to be decided by balancing the economical and engineering aspects of the project. Transportation and highway engineering is the same field that has been affected by developments in GIS aspects, as spatial variables including environment, topography, built-up areas, land use/land cover, can be easily modeled. The first concept of GIS application in route planning developed ranges from digitizing, geo-referencing and inclusion of all driving factors. Factors governing the selection of alignment are usually weighted according to their influence or importance. The weighted factors are now standardized and overlaid in the proposed map with the help of Arc GIS tools. GIS plays an crucial role for road alignment selection, it provides optimum routes across any topographic nature that varies from moderately flat to extremely rugged topography. GIS is a very efficient tool in route planning, because it is easy to model various factors affecting the route alignment (Dell, 2011).

In particular, multi-criteria decision analysis is a good method to rank the degree of influence of the driving factor like engineering, social, economic and environmental in the process of route planning.

This study aims to use GIS - based multi- criteria approach to select optimal route that consider the existed socio- economic development. Currently, accessibility modeling in the GIS has attained many possible developments using the least cost path analysis to find the best route for roads and additional linear infrastructures. This study considers factors related to engineering requirements, social and economic developments as well as environmental issues. The weights and ranks are assigned to each of the above themes based on expert opinions. Finally, all factors are integrated in a weighted overlay analysis resulting in the selection of the best route that connects Dabat and Keraker.

1.2 Statement of the problem

Limited infrastructure and high transport costs are considered as a key constraint of socio-economic development in most low-income countries. Specifically, industrial economic transportation requires a robust transport infrastructure in order to reduce the cost of manufacturing and increase return on investment. However, poor transport infrastructure services will increase cost of manufacturing. Tybout (2000) said that one of the reasons why the industrial landscape of low-income countries is dominated by small and micro enterprises is that the marketplace for manufactured goods is small and disjointed due to poor infrastructure sited in (Shiferaw et al, 2012)

Route planning should consider least cost and minimum travel time; rising customer services. In doing so, it is intended to reduced fuel usage there by reducing carbon emission and contributing positively to a global climate change(Kiema and Karanja, 2007).

The problem of selecting and designing new roads between cities is considered a common problem in transportation engineering, many papers presented in a try to solve the problem depending on many techniques like mathematics, optimization, and judgment. The basic highway design problem is to find the highest economical alignment linking two particular endpoints based on topography, socio-economic factors, and environmental impacts while satisfying a set of design and operational constraints. In the primary planning stages of the highway, it is very important to make the right decisions as far as selecting alternative alignments and screening them as it verifies to be the time and money-saving methods (Suleiman et al, 2015).

The Ethiopian Road Authority follows many steps in road construction such as project identification, route selection, preliminary design (feasibility study), detailed design, and construction (ERA manual, 2013).

In this case, a GIS technique provides planners and engineers the opportunity to determine the most suitable land along a Least Cost Path. GIS plays an important role in transportation planning. Because the objective of transportation planning is to guide the development of a land-use transportation system to achieve economic, social and environmental benefits. In addition, GIS greatly contributes to this process through its powerful features in database management, geographic visualizations of possible circumstances, and tools for processing geographic data into geographic information.

Generally, this research aims to determine seven factors that affect route planning for selecting the least cost route by using GIS software in a case of Dabat – Keraker alignment.

1.3 The objective of the study

1.3.1 General Objective

The general objective of the research was to investigate the usability of the ArcGIS software for route selection in the case of Dabat to Keraker.

1.3.2 Specific objective

The specific objective of the study should be-

- Characterize factors that affecting route selection and identify the most governing factors.
- Select the best road alignment between Dabat and Keraker, and evaluate its feasibility against the existing road.

1.4 Research Question

When to conduct the study the researcher were answer all the following questions:

- What are the factors that affect route selection and which is the most governing factors?
- Is the proposed road alignment feasible to the existing road between Dabat and Keraker?

1.5 Significance of the Study

The study should emphasize how GIS and remote sensing technologies are important for route selection analysis. It is used to determine the geographic suitability, the shortest path and least cost so as to make a decision to the construction cost and time, a material used and the maintenance cost. Moreover, the shortest route is used for community service such as economic benefit, it saves time when traveling and, transporting goods by the low cost from place to another place as well as for emergency service. Therefore, the shortest route is best to travel relative to the long route.

1.6 Scope of the study

This thesis is focused on to make analysis for factors affecting route selection. The processing and preprocessing as well as interpretation of remote sensing data and other vector data prepared for analysis. Select and discuss the factors that relatively superior to other factors for route selection, comparison of the result of the proposed route with the existing road and selecting the least cost route by using GIS software in the case of Dabat to Keraker by using multi-criteria approach (pairwise compression).

1.7 Structure of the Thesis

The study is organized into six chapters. The second chapter is a literature review related to the research topic. The third chapter describes the study area such as geographic settings, topography, hydrology, geological setting, and population distribution of the study area. In the fourth chapter, the methodology and data source used for the research will be discussed. The fifth chapter presents the results and discussion of the study. The sixth chapter highlights the main conclusions of the study and points out future recommendations.

CHAPTER 2 LITERATURE REVIEW

2.1 Transportation

Effective road improves any inhabited area's socio-economic functionality and quality of life as it optimizes connectivity, enabling sustained and all-inclusive growth to peoples living in remote area. Transportation allow movement of people and goods and influences patterns of growth and economic activity by providing access to productive lands and inaccessible communities. It is also multi-faceted and sensitive in that its performance affects public policy concerns such as environmental resource consumption, social equity, land use, urbanization, economic growth, safety and security. However, constructing proper road requires time and considerable effort (Muriki et al, 2014).

According to the argument of Ethiopian Road Authority the development of a robust transportation involves the selection of appropriate road alignment that can optimize the geometric connectivity of the existing road network infrastructure. Alignment or route planning is the procedure of selection the best alignment within desired route corridor based on the overall influences of driving factors. The 'footprint' of each route option should be defined necessarily to consent its feasibility from the perspective of engineering, social and environmental aspects. In essence, the best alignment should enhance connectivity between urban and rural development corridors as well as minimize construction and maintenance cost beyond ensuring efficient fuel consumption. Ethiopian Road Authority term of reference for road design experts defines the purpose of the route selection process as; according to the Ethiopian standard, the identification of best routes depends on various parameters such as technical, financial and economic, environmental, social and planned terms (ERA manual, 2013). The aim of this study is to improve the least cost route for the development of economic growth, transportation of goods and peoples in a minimum cost while considering the engineering, social, environmental and economical requirements.

2.2 Route planning and Geographic information system

The determination of an optimal road or railways alignment is essential to develop transport infrastructure cost-effectively as well as to enhance the connectivity of the existing network. The optimization of the transport network through the selection of proper routes requires quality spatially referenced data sets and computational procedures. Advancement in spatial analyses through the development of Geographic Information System (GIS) has significantly contributed to the selection of new alignments as well as optimization of the network. New alignments are usually selected based on various data sets that include physical, environmental, social and economic (Preda et al, 2017; Yildirimet al, 2014). In this study, GIS used for the analysis, extracting, manipulation and storing the special data of the required governing factors for route selection. The analyses combine the parameters governing the alignment in a weighted approach, based on their respective degree of comparative influence. Examples of some commonly used methods discussed here.

2.2.1 Multi-criteria analysis

The multi-criteria approach is used to determine the comparative weight of each parameter. The number of route selection criteria is set in the Analytic Hierarchy Process (AHP) to derive weight for each criterion. Multi-criteria parameter analysis is the determination of the comparative importance (weights) of each parameter with respect to the other. Multi-Criteria Analysis (MCA) involves the ranking of route alternatives based on their performance against a set of criteria to combine economic, social, environmental and other considerations. Methods such as MCA are dependent upon the subjective values of those involved in the process of developing the criteria (Malczewski, 2006). The Weighted Sum Model (WSM) is the better and simplest way of multi-criteria decision analysis (MCDA). It is applicable only when all the data are expressed in exactly have the same unit. MCDA suppose the problem is defined on alternatives and decision criteria. Also, let us assume that all the criteria are benefit criteria, that is, the higher the values are, the better it is (Nedevska, 2017). MCA giving weight for each factor according to the perspective of ERA route alignment selection considers environmental, social, economic and engineering requirements. So, the MCA applies for route selection the comparisons of governing factors and give the priority according to their weight. The multi-criteria weighted sum is the sum of each proposed weight multiplied by each parameter thematic layer.

2.2.2 Analytic hierarchy process

The analytic hierarchy process (AHP) is a pairwise comparison method, developed by Saaty (1987). The AHP method is recognized as a powerful tool for Multi-Criteria Decision Approach (MCDA), to solve complex decision problems (Saaty, 1987). The AHP method includes all factors in a hierarchical arrangement. It consists of three steps: first, the definition of the complex decision problem, second, pairwise comparison of the selection factors, and lastly generation of the decision result using a hierarchical structure. The decision-maker ranks the factors based on the relative significance of them.

Pairwise comparisons are vital in the use of the AHP. The members of parliament must first set up priorities for their main criteria by judging them in pairs for their relative importance, thus producing a pairwise comparison matrix (Whitaker, 1987).

2.3 The role of earth observation for alignment selection

Remote sensing is the technology that observes the earth's system and its dynamics. Data taking from remote sensing, specifically satellite images, have a purpose to observe and study the Earth from space; it's land surface, the oceans, and the atmosphere (Nations, Government, and Scientific, 2017).

A Digital Elevation Model (DEM) is used to represent 3D ground surface topography or terrain. It is also widely known as the Digital Terrain Model (DTM) (Hirano et al, 2003). There are some methods for obtaining DEM data such as terrestrial surveying, stereo photogrammetry, GPS data, and topographic maps. However, those are required high cost, limited access to the study area, time-consuming procedures and inadequate updating of maps group scientific researches to new techniques for generating DEM maps. The diverse use of DEM and the drawbacks of traditional method drastically have increased the importance of using satellite images (Deilami et al, 2012). Earth observation is an important source of datasets used for route selection due to freely access it; do not require cost and labor to collect the data. In route alignment selection, many factors are direct, extract from remote sensing data (e.g. land use, slope, and drainage)

2.3.1 Land Use Land Cover

Different land use/land cover types have their own comparative importance depending on their suitability for the construction of transport infrastructures. LULC map of the area prepared by supervised classification primarily using Landsat 8 imagery (Suleiman et al, 2015). Land use is very important in showing the environmental and socio-economic impact of a road project. Environmental analysis is used to specify the impacts of the proposed highway on the surrounding environment where the highway will be laid down. This data can be divided into several classes (Sunusi et al, 2015). LULC categories tell differently in terms of their suitability to passing a railway line through them, with regard to construction and operation costs (Kiema and Karanja, 2011). The historical and cultural resources in the area gazette and should have been avoided or declared as no go during corridor selection (ERA manual, 2013). Different LULC classifications have different level of suitability for new road alignment selection for the perspective of construction cost. Certain land use/land cover categories are better suited for the construction of a road alignment than others considering the construction and operating costs involve. The score values are assigned to each LULC category based on expert judgments, mainly consultants and highway engineers. LULC with higher value indicates more costly and therefore less suitable for road construction (Kiema and Karanja, 2011). Land use land cover data is required to estimate cost of land acquisition or compensation cost during route planning (Saha et al, 2013). The route should go through bare land instead of agricultural and forest land (Anon, 2017). Land use is important for route alignment selection to identify the land cover class, which is the most favorable for route alignment according to environmental, social and economic impact. The land use land cover layer generated after the following processes.

2.3.1.1 Image pre-processing

Image pre-processing is a task on images at the deepest level of thought. Image pre-processing is an improvement of the image data that limits undesired distortions or enhances some image features applicable for further processing and analysis tasks (Math, 2009). The first step in image pre-processing is image extraction. Some unrelated parts of the image can be removed and the image region of interest is concentrated. Taking out the project area from the whole part of the image is important to reduce the size of the image file to include only the Area of Interest (AOI). This does not only eliminate the extraneous data in the image. However, it speeds up processing due to the smaller amount of data to process (Chander et al, 2009).

2.3.1.2 Image classification

Image classification is the process of categorization of pixels into a fixed number of individual classes or categories of data according to their data file values. Unsupervised and Supervised classifications are two general approaches in digital image classification and the thematic mapping process (Bakker et al, 2000).

Supervised classification: Image classification in the field of remote sensing, is the process of assigning pixels or the basic units of an image to classes (Jensen, 2005). It is likely to accumulate groups of identical pixels create in remotely sensed data, into classes that match the informational categories of user interest by relating pixels to one another and to those of known identity (Palaniswami et al, 2006).

Unsupervised classification: is a method of identifying, grouping, and labeling features in an image according to their spectral values (Schulz et al, 2010). It is a computer-automated process. It allows the image analyst to specify parameters that the computer uses as guidelines to uncover statistical patterns in the data. It is in contrast to supervised classification, it involves natural grouping or clustering of the pixels in the image using the computer algorithm followed by the analyst's determination of the land cover identity of these spectral classes (Gonzalez et al, 2006). This research uses the supervised classification technique to categorize the land cover class, and it was six classes such as built-up, agriculture, bare land, shrub land, forest, and water. It used to identify the class of the land covers that are more favorable for route planning according to cost and suability.

2.3.1.3 Classification accuracy assessment

The most important final step at the classification process is accuracy assessment. The purpose of accuracy assessment is quantitatively assessed how effectively the pixels were sampled into the correct land use land cover classes. Additionally, the main emphasis for accuracy assessment of pixel selection was on areas that could be distinctly identified on both Landsat high-resolution images and Google earth (Rwanga and Ndambuki, 2017). Land use is very important in showing the environmental and socio-economic impact of road construction. The land use in this study area was developed by interpretation and classification using the ArcGIS image classification tool, by loading the longitude and latitude points obtained from the Goggle Earth map, which were used to generate a supervised land use map and the accuracy assessment was carried out (Snusi et al, 2015).

The accuracy of image classification can estimate in terms of an error matrix that explains the errors associated with each class, namely omission error and commission error. It is a very effective way to represent classification accuracy in that the individual accuracies. A commission error is including an area in a category when it does not belong to that category. An omission error defined as excluding an area from which it belongs to that category. Each error is an omission from the correct category and a commission to a wrong category (Congleton et al, 2009). Congleton et al, (2009) suggested that classification is acceptable when an overall accuracy is 85%.

2.3.2 Topography

Topography has the main important for route selection. Satellite data are now using to generate digital terrain or digital elevation data. The data can be used as topographical mapping as well as for drainage and catchment area mapping. The digital elevation model (DEM) can be used as a base layer upon which other satellite imagery can be draped in order to enhance 3D visualization (ERA manual, 2013). The choice of the cross-section for a new road in rolling, mountainous and escarpment terrain can be critical importance in terms of cost and impact on the landscape, and these considerations are therefore required at the route selection stage (ERA manual, 2013). The slope is an essential factor in road alignment location because steep slope should be avoided as much as possible to prevent accidents and give driving comfort to the user. The slope is crucial to the route selection process. The slope of the study area was derived from a USGS 30-meter resolution Digital Elevation Model (DEM) (Sunusi et al, 2015). The slope of the terrain is considered very critical in railway routing as it straight powered the construction and operating costs. The higher the slope, the higher the costs and vice-versa (Kiema and Karanja, 2011).

The Digital Terrain Model (DTM) is an ordered array of numbers that represents the spatial distribution of terrain characteristics. In the most usual case, the spatial distribution represented by an XY horizontal system and the terrain characteristic that is recorded the terrain elevation, Z value. An alternate approach is to define position by latitude (ϕ), longitude (λ), and the terrain height (h) (Doyle, 1978).

A DEM is a 3D projection of the Earth that can be classified into two groups: digital terrain models (DTMs), which are loose of trees, buildings, and all kind of objects, and digital surface models (DSMs), which indicate the Earth's surface, including all man-made and natural objects (Alganci et al, 2018). Alganci, says DSMs can be prepared to obtain a DTM by applying the required filters based on the use of use. DSMs mostly used for visualization applications, landscape modeling, and 3D digital city applications, while DTMs usually used for drainage modeling, land use studies, geological concern, and Orth-rectification of satellite images or aerial photographs (Alganci et al, 2018).

2.3.2.1 Advanced Land Observing Satellite (ALOS)

Japan's Earth-observing satellite program contains two sequences, conforming to different objectives of observations; one type includes satellites mainly for atmospheric and marine observations and the other type mainly for land observations. The objective of the ALOS is to modify to regional observation, resources surveying, cartography, and disaster monitoring by further advancing land observation profession applied to the Japanese Earth Resources Satellite Unit 1 (JERS-1), and the Advanced Earth Observing Satellite (ADEOS). ALOS is equipped with three Earth observation sensor instruments: The Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) to observe what covers land surfaces, the Panchromatic Remote-sensing Instrument Stereo Mapping (PRISM) to measure precise land elevation, and the Phased Array Type L-band Synthetic Aperture Radar (PALSAR) to enable day-and-night and all-weather land observations. ALOS is expect to show high-resolution capability inland observations. The ALOS satellite was successfully launched from the Tanegashima Space Center on January 24, 2006 (Japan Standard Time) using an H-IIA launch vehicle (ALOS Data Users Handbook, 2008).

2.3.2.2 The Shuttle Radar Topography Mission (SRTM)

The Shuttle Radar Topography Mission (SRTM) was launch on February 22/2000 Space Shuttle Endeavour landed at Kennedy Space completing the highly successful 11-day flight of the Shuttle Radar Topography Mission (SRTM) (Farr, 2015). In the 11-day mission of SRTM, obtain data in order to generate the most complete high-resolution digital topographic database of the Earth. SRTM InSAR was using two radar systems with different wavelengths.

- The C-band radar system having a wavelength λ=5.6cm and it was operated by the United States of America (USA).
- The X-band radar system with λ=3cm and it was operated by Germany and Italy.

The two antenna systems of the SRTM isolated by a fixed distance of 60 meters (the staff) were collecting two radar data sets. The main antenna operated in active and passive mode. Because it transmitted and received signals while the outboard antenna was passive. The X-band dataset can be accepted with a point spacing of 1 arc-second (30m) while the C-band data are existing free of charge with a reduced spacing of only 3 arc seconds (90m). InSAR is used to related its high spatial resolution and good potential precision and to the highly automatic DEM generation capabilities (Ramaraju and Mittapalli, 2015).

2.3.2.3 Advanced Space Borne Thermal Emission and Reflection Radiometer (ASTER)

The Advanced Space Borne Thermal Emission and Reflection Radiometer (ASTER) is operating on NASA's Earth Observing Terra morning orbital platform in 1999 (Yamaguchi, 2014). ASTER built and provided by Japan's Ministry of Economy, Trade, and Industry (METI). ASTER has three deferent optical sub - systems: -

- The visible and near-infrared (VNIR) radiometer acquiring images in three bands with a 15 m instantaneous field of view (IFOV), and an additional backward-looking band for stereo.
- The thermal infrared (TIR) radiometer, acquiring images in five bands with a 90 m IFOV.
- The shortwave infrared (SWIR) radiometer, acquiring images in six bands with a 30 m IFOV. ASTER acquires images in all bands with a swath width of 60 km (Abrams et al, 2015).

ASTER is an imaging instrument flying on Terra and is one of the widely used sources of DEM images and data (Oliveira and Paradella, 2009).

2.3.2.4 Photogrammetric stereo pair

Stereo photogrammetry is a digital image processing method that allows the user to incur spatial measurements and ascertain geometrically reliable shapes of surface features from photographs or digital images of a planetary surface. In addition to many other outputs, photogrammetric process produce elevation models include terrain elevation and heights of objects on a planet's surface. The main task lies in this, reconstruction of 3D objects from two dimensional, plane photographs. This reconstruction of the 3D requires overlapping aerial photographs in order to obtain stereo image pairs over the same area (Cukrov, 2014).

The DEM could be acquired through techniques such as photogrammetry, LIDAR, land surveying, etc.(Khan et al, 2017).

2.3.3 Hydrology

Drainage densities calculated dividing the total stream length (km) by the total watershed area (km^2). The drainage density layer has used to estimate the cost of bridge construction. Generally, the width of the river channel larger with increasing order of drainage or drainage density, which consequence in a corresponding increase in the cost of bridge construction. The first- and second-order drainages have been appointed very low ratings, as these are generally quite narrow, and in the most cases, the water may be drained using underground tube, or by render small culverts. For higher drainage density, there may be requirements for bridge construction; the construction cost increases with the width of the channel. Therefore, higher ratings have been assigned to higher- Drainage density. The pixels without any channel were allocated a zero value. Drainage map has produce by digitizing the drainage lines from the topographical maps. The drainage order map has been used early to make estimation the cost of bridge construction, if required, during route planning (Shah et al, 2015). In this research, the drainage density extracted from the Digital Elevation Model (DEM). The route lies in the relatively high drainage density requires high bridge construction cost and Vis Versa.

2.4 The soil and geology

Soils are susceptible to erosion and unconsolidated materials cost due to constructing a railway line. Poorly drained soils are also unwanted for railway route construction. Therefore, relatively cheaper to construct a railway on the ground with soil that is unconsolidated and well-drained. Rocky grounds should be void as they increase construction costs due to dense excavation of rocks (Padaya et al, 2017). Soils that susceptible to erosion and unconsolidated materials cost more to construct a railway line. Poorly drained soils are also unfavorable for railway line construction. It is therefore relatively cheaper to construct a railway on the earth with soil that is unconsolidated and well-drained. Rocky grounds should be deflect as they increase construction costs due to heavy excavation of rocks(Kiema and Karanja, 2011). Soil porosity is a measuring of the number of spaces or openings in the soil that can fill with either air or water. Permeability is a measure of the easiness with which water and air move through the soil pores. A combination of texture, structure, and organic matter content determine the porosity and permeability of soils. For a good balance between small pores that retain a lot of water, and large pores that allow easy movement of air and water. Medium- textured loam soils with good structure and plenty of organic matter are best. While clayey soils have higher porosity, and so can hold more water than sandy soils, they also have lower permeability because the pores (opening) are so small. Soils with a small pore size (less than 0.03 mm; 0.0012 in), characteristic of clay soils. Large pore size, and thus poor water-holding capacity, is a problem only in very sandy soils. Both situations can be improved by adding organic matter to the garden soil (Cleveland and Soleri, 1991).

Geology is a vital significance in construction from the time when construction operations take place either on or in the ground. Several means have used in rock masses to offer support prior to the placement of the permanent lining. In some weak rocks and soils, the permanent lining may have to place almost instantly. Since highways are linear structures, they are expected to encounter different ground conditions besides their length. Obviously, they need stable foundations and they may contain the excavation of cuttings and/or tunnels, the construction of enclose and/or bridges, and construction material (Bell, 1974). Geo-hazards can pose important constraints to the construction and operation of road infrastructure and are therefore critically important to route selection in all terrain types. Even fault zones are regularly connected with weakened rocks and pre-existing shear surfaces and shear zones and must be avoided where it is possible by route selection (ERA manual, 2013).

2.5 Cost distance analysis

The cost distance function is available in the Spatial Analyst Module. It uses the cost raster and the source, the cost distance command produces an output raster in which each cell is assigned a value that has the least accumulative cost of getting to the source. The purpose takes the cost raster and calculates the value for each cell, in the output cost weighted raster that is accumulated least cost of receiving from that cell to the nearest source. Every cell in the cost raster is assigned a value representing the sum of the minimum traveling costs back along the least-cost path to its nearest source (Chandio et al, 2012).

CHAPTER 3 THE STUDY AREA

3.1 Study area

The road alignment connecting Dabat and Keraker is located in the Amhara regional state of Ethiopia (Figure 3.1). The study area is a part of north Gonder zone, and it is geographically situated between 12° 52’52’’and 13°27’40’’ latitudes, and 37°17’00’’ and 37° 52’25’’ longitudes. The study area covers different woredas such as Wegera, Lay Armachih, Tach Armachih, Debarq, Addi Arekay, Tegede and Tsegede. Towns in the study area include Dabat, Wekin, Zarima, Sanja, Ketema Nigus and Keraker. The origin of the new road alignment (Dabat), is located 255km north of Bahir Dar city and 983km from Addis Ababa. The area coverage of the study area is 3741square kilometers.

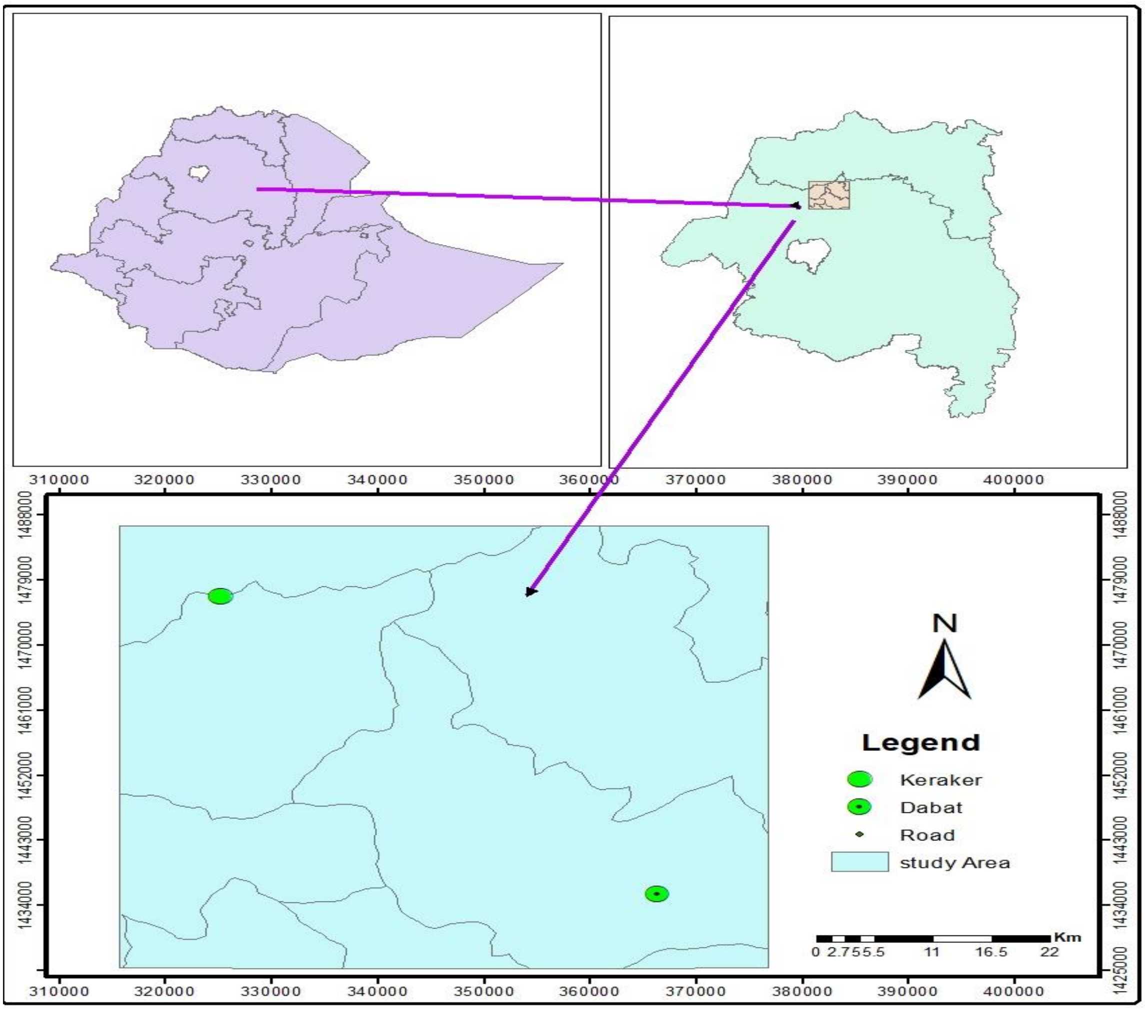

Figure 3.1: Map of the study area

3.2 The topography of the study area

The study area characterized by extremely undulating topographic landscape. It is a part of Semein Mountains. The highest elevation (RasDashin Mountain) is located in the study region. In the study area elevation varies from 896m to 3069m above mean sea level. Although the study area is placed in the northern highlands of Ethiopia, fortunately, it is relatively characterized by flat terrain with less soil eroding as compared with the lowland area. In general, the study area is represented by different terrain classes such as flat, rolling, mountainous and escarpment (Figure 3.2).

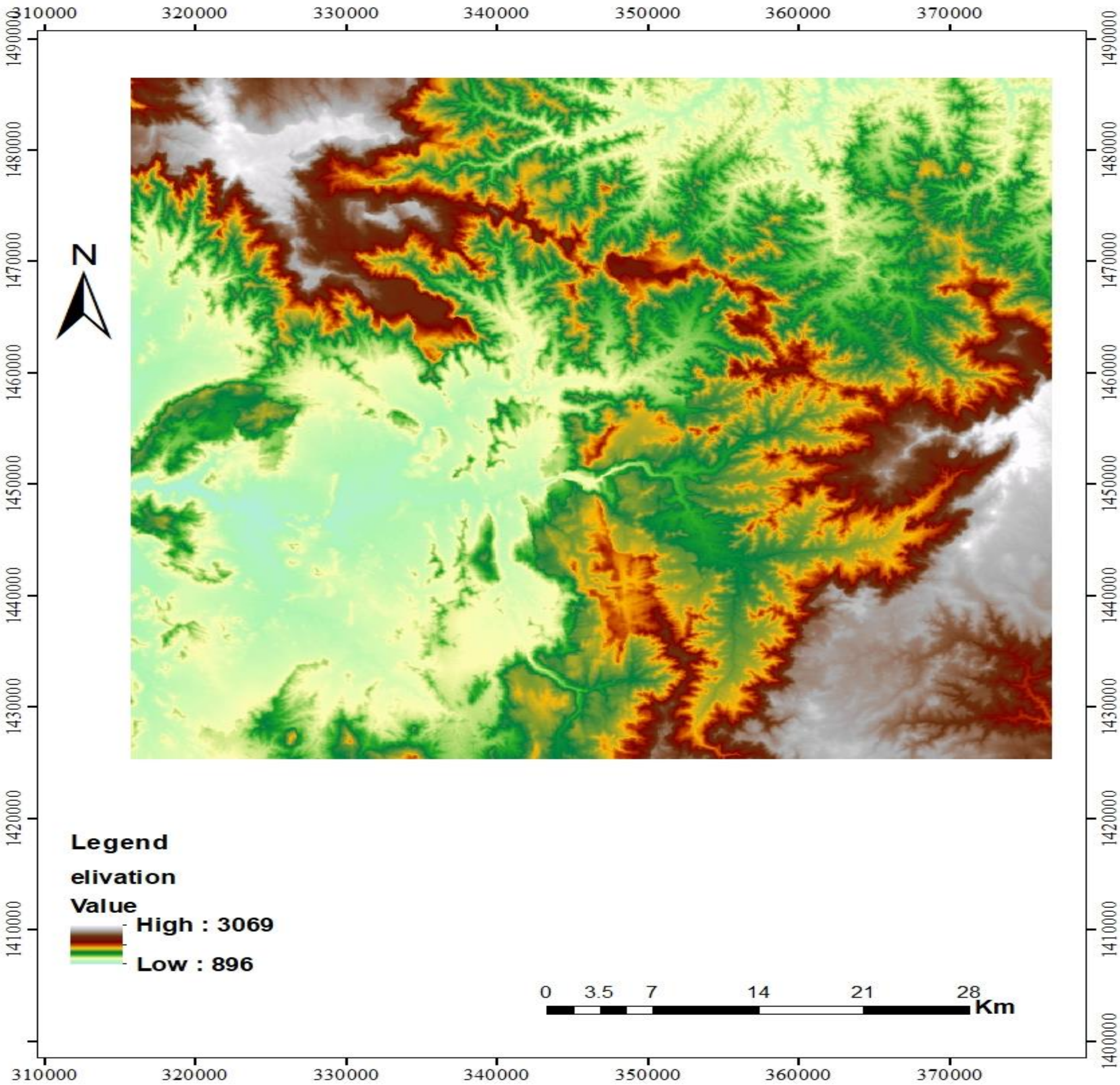

Figure 3.2: Elevation of the study area

3.3 Geology of the study area

The study area is characterized by four geological formations such as Ashange Formation, Aiba Basalts, Tarmaber Gussa Formation, Alluvial and Lacustrine deposits. Most (Ethiopian geological map,) part of the study area is covered by Ashange Formation (55.6%) and Aiba Basalts (35.9%), while the proportion of Tarmaber Gussa Formation and Alluvial and Lacustrine deposits is respectively 6.7% and 2.8%. Figure 3.3 illustrates the geology of the study area.

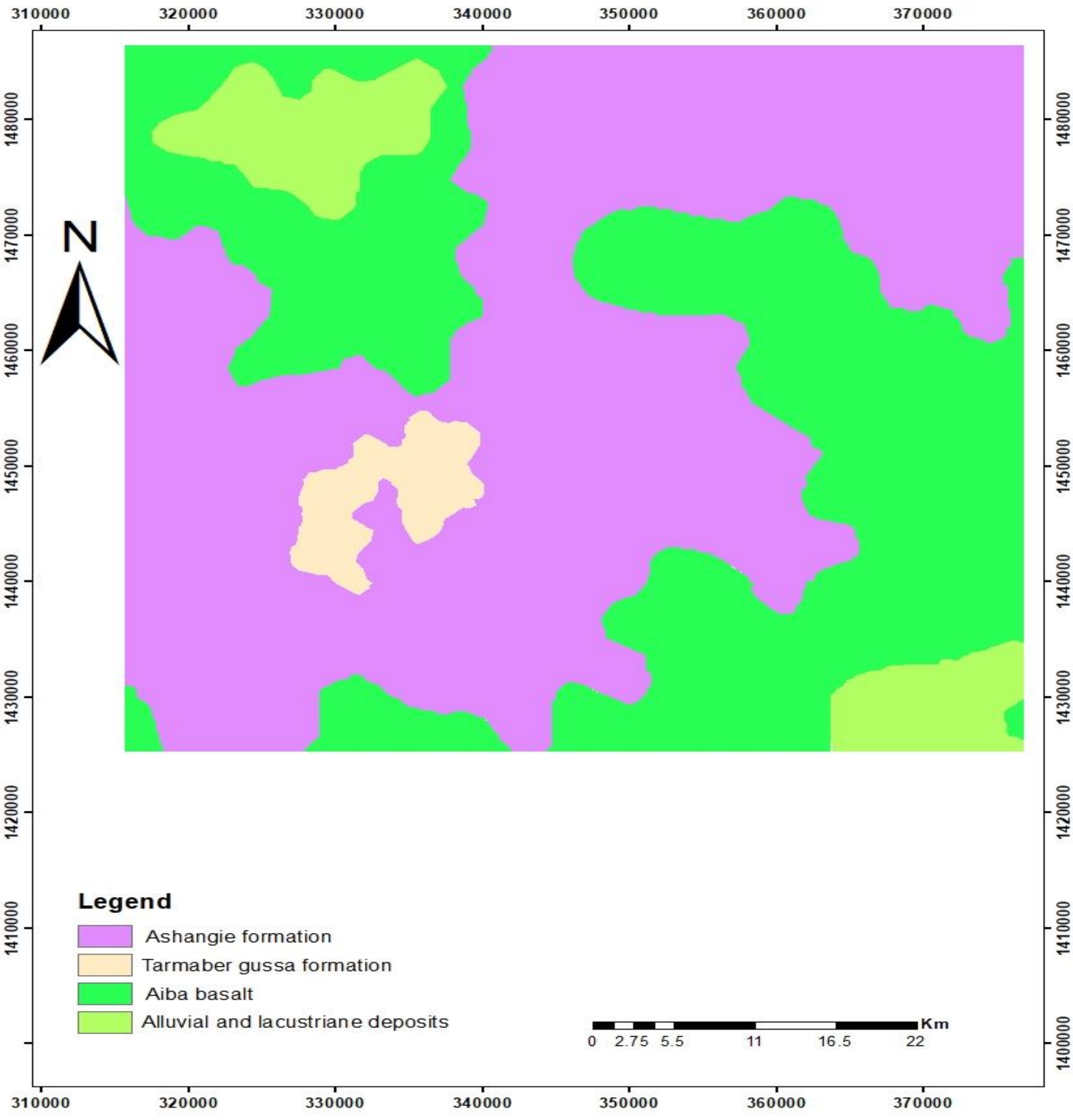

Figure 3.3: Geological type of study area(digitize from Ethiopian Geological Map)

3.4 The soil type of the study area

Various soil types are found in the study area. This includes Chromic Luvisols, Dystric laptosols, Eutric Laptosols, Eutric Vertisols, Haplic Luviosols, Humic Nitisols and Lithic Laptosols (Figure 3.4). Types of the soil texture commonly found in the study area consist of loam, Sandy loam and clay.

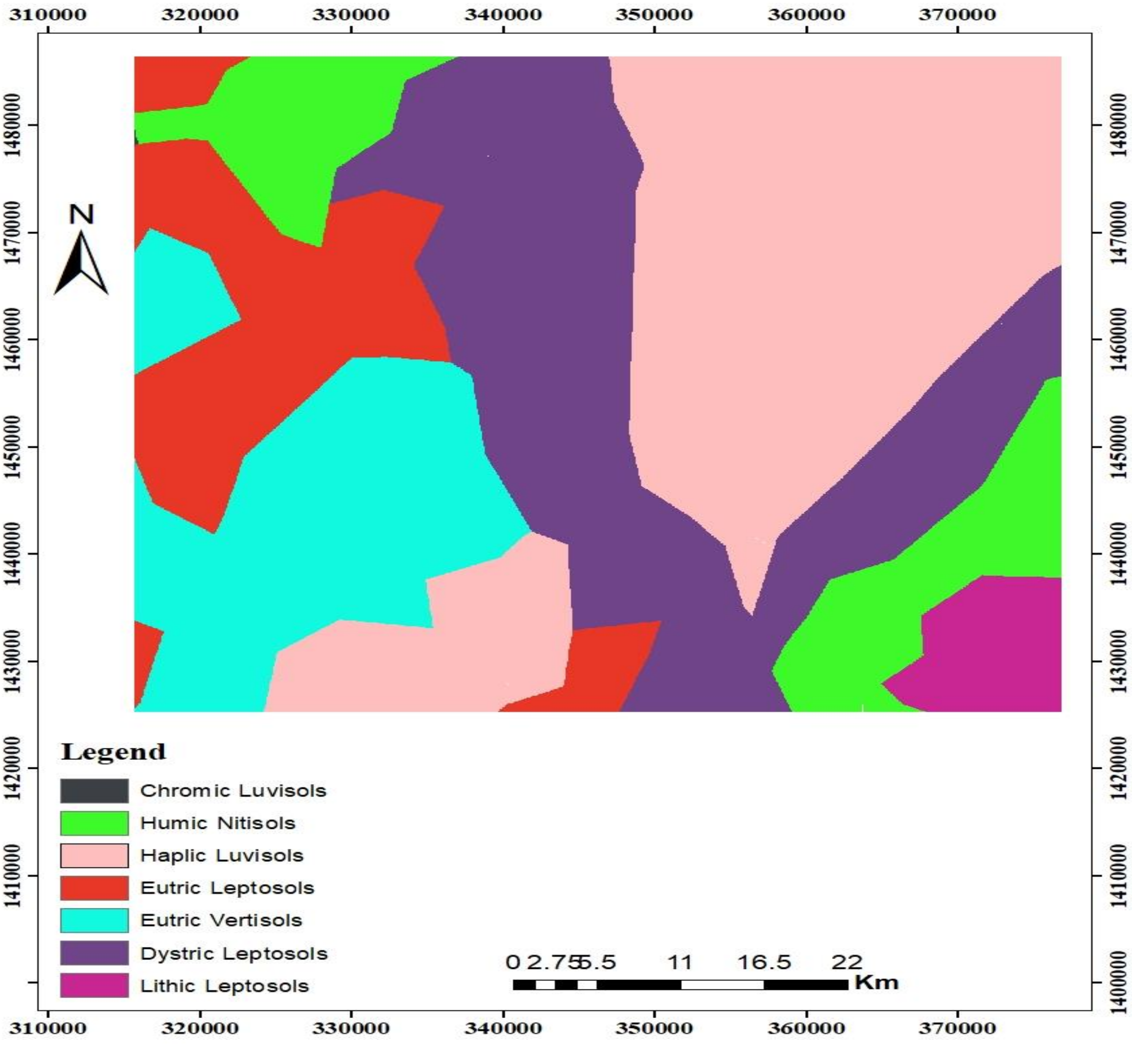

Figure 3.4: Soil type of the study area (from Ministry of Water Irrigation and Energy)

3.5 The population of the study area

The total population of the study are projected at woreda level based on data collected between, 2014 to 2017. The data is obtained from the Central Statistical Agency of Ethiopia. Dabat woreda has total population of 168,331: 83,344 women and 84,987 men.

Of which 23,363 or 13.87% are urban inhabitants and 144,968 or 86.13% are rural inhabitants. On the other hand, Tegede woreda has a total population of 84,542: 41,590 women and 42,952 man. In Tegede woreda 7,926 or 9.37% of inhabitants live in urban while 76,616 or 90.62% resides in rural areas. Figure 3.5 shows the population density map of the study area.

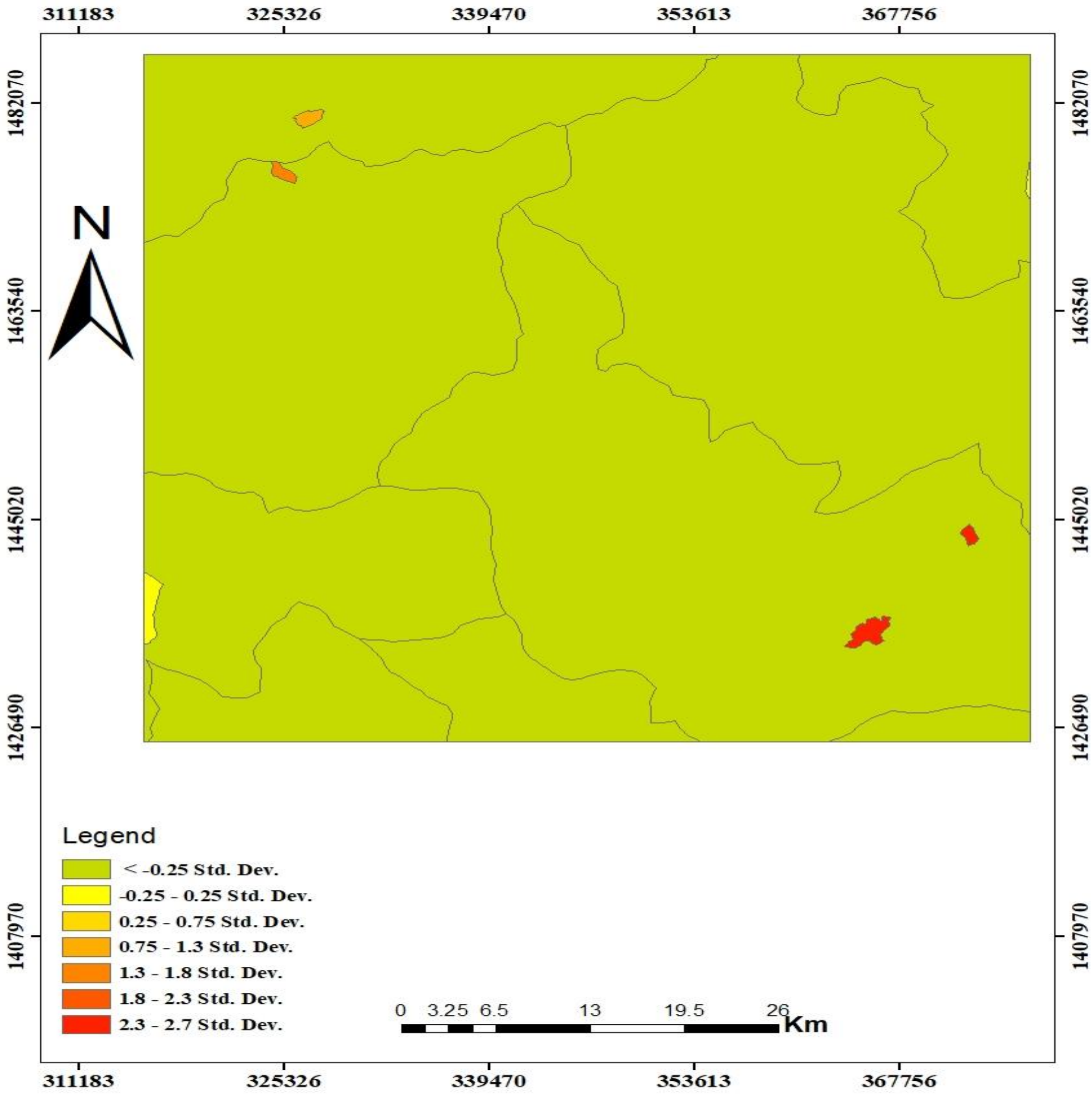

Figure 3.5: Population density map of the study area(CSA)

3.6 Hydrology of the study Area

The study area is a part of the Tekeze basin. Tekeze River is one of the major rivers in Ethiopia and its headwater rises from the central highland of Ethiopia. The main rivers in the study area are Angerb, zarema and gorezen. Angerb River has the largest length of 173,020.8 m.

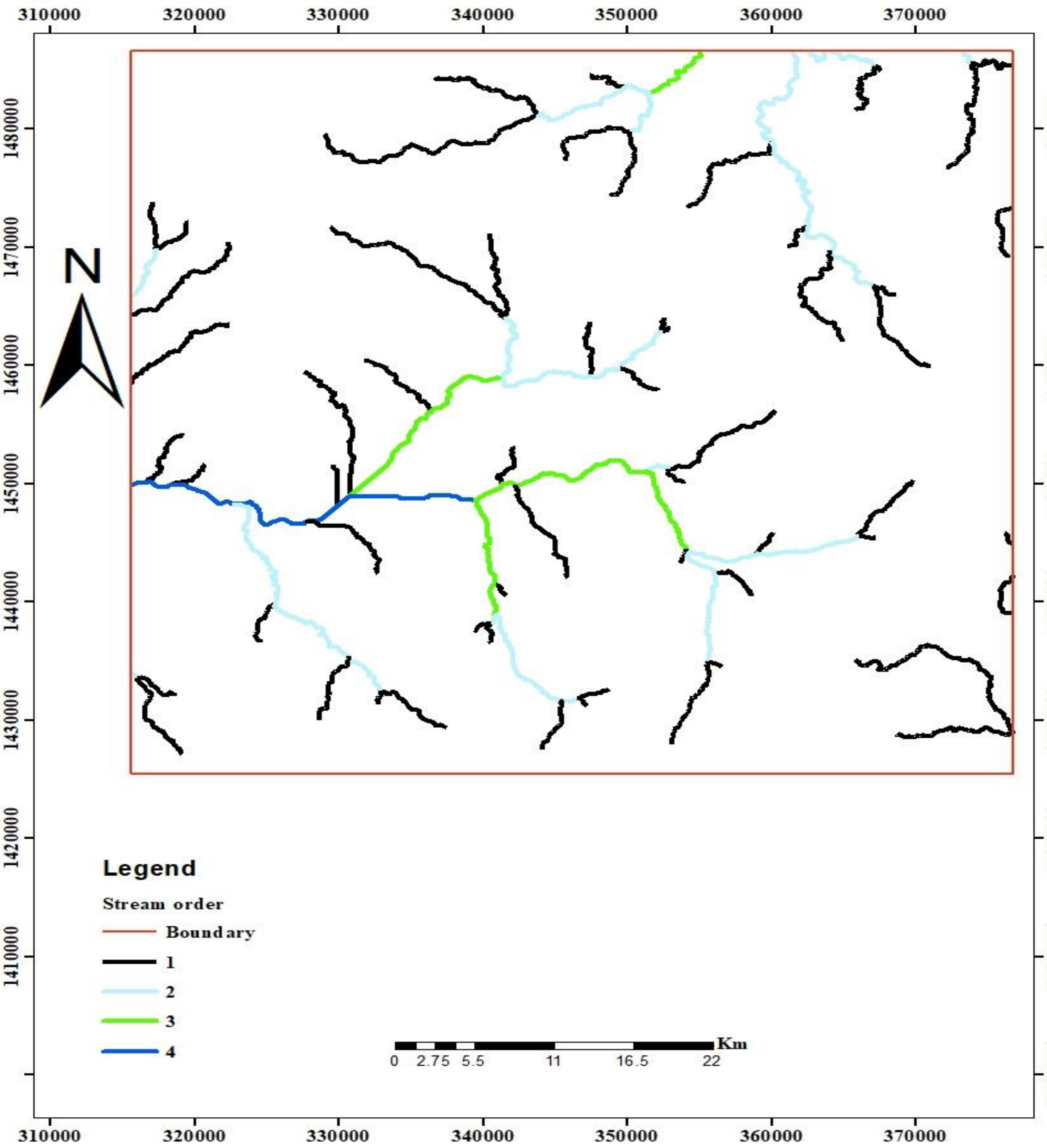

Figure 3.6: Drainage order map of the study area

CHAPTER 4 DATA SOURCE AND METHODOLOGY

4.1 Data and methods

4.1.1 Data source

Different types of satellite imageries and various ancillary data have been collected in order to identify land use land cover, slope, and other factors governing the route selection. List of data sets used for this study is summarized in Table 4.1 below.

Table 4.1: Criteria's for route selection

No	Parameter	Explanation	Source
1	LULC	• Livestock grazing land cross corridor • Impacts on existing surface water resources • Indicate the size and status of natural forest, plantation, conservation areas, national parks; biologically sensitivity areas or high-risk species in the area of the route options	USGS Landsat 8
2	Soil	Soils type	The Ministry of Water, Irrigation and Energy
3	Drainage	Determined drainage density	DEM
4	Slope	Identify Topographical stability	Extracted from DEM
5	Geology	Identify rock type and fault	Geological survey
6	Fault	Liniments	Geological survey
8	Existed Roads	Road network connectivity	ERA

4.1.1.1 Land Use Land Cover Classification

Land use land cover is generated from the satellite imageries; Remotely sensed data from the Landsat 8 mission is required from the United States Geological Survey (USGS) archive.

The landsat8 data collected on October 03/2018 ID NO: LC81690512018276LGN00 with specific path (169) and row (51) have 0% cloud cover. This remotely sensed data is georeferenced with regard to the 1984 world geodetic system (WGS84) UTM projected coordinates and can be legitimately transformed to local Clarke 1880 reference ellipsoid defined by Adindan origin and UTM zone 37N. To qualify for further analysis this remotely sensed data sets are usually corrected from radiometric error.

4.1.1.2 Digital Elevation Model

Elevation data is commonly starting point of design because elevation data is necessary for route selection since the suitability of the terrain can substantially be determined by the elevation data and slope layer generated by elevation data.

This study used digital elevation model recovered from the Advanced Land Observing Satellite (ALOS) mission. The elevation model is called ALOS DEM and it has a spatial resolution of 12.5 m and defined a UTM coordinates with regard to the WGS84.

4.1.1.3 Slope Layer

Slope is the most essential factor for route selection to decide the suitability of the topography. Based on topographic nature of the study area, Ethiopian Road Authority classified slope in to four classes. such as flat terrain, rolling terrain, mountainous terrain, escarpment terrain.

4.1.1.4 Drainage Density

Drainage density is derived from the ALOS DEM. It is a measure of how well or how poorly a watershed is drained by stream networks. It is equal to the reciprocal of the constant of network maintenance and equal to the reciprocal of two times the length of overland flowing. The streams or rivers are extracted from the digital elevation model (DEM). The drainage data include fill, flow direction, flow accommodation, stream definition, and stream order.

4.1.1.5 Soil Layer

One of the essential layers for route selection is the soil layer. In this study, the soil layer contains valuable information in vector format about the features of terrain such as; soil type, soil texture, and hydrological parameters. It is one of the significant pieces of information to understand fertility and the strength of the soil. The data is obtained from the Ministry of Water, Irrigation and Energy. This soil data contains various information such as soil type, soil texture, hydrological parameters, etc. Soil texture is classified into three categories: namely sandy loam, clay and loam. While the study area is characterized by seven major soil types like Chromic Humic Nitisols, Luvisols, Eutric Laptosols, Dystric Leptosols, Eutric Vertisols, Haplic Luvisols, Lithic Leptosols.

4.1.1.6 Geology type

The analysis of geological type is the most necessary factor for the least-cost route selection. The geology layer contains information about the symbols and color of the geologic categories. The features define the route foundation type and it is directly related to the construction cost. The geology layer contributes to the synthetization of the Landslide layer. The geological data is acquired at a map scale of 1:2,000,000 from the Geological Survey of Ethiopia; the data is referenced to WGS84 UTM projection.

4.1.1.7 Fault layer

The fault is a planar break or gap in a volume of rock, across which there has been important shift because of rock-mass movement. Plate tectonic forces are the cause of large faults within the Earth's crust, with the big forming the boundaries between the plates, such as subduction zones or change faults. The cause of most earthquakes is energy release associated with rapid movement on active faults. In this study, fault are determined from geological map of Ethiopia with a scale of 1: 2,000,000 by digitizing technique. Finally, the fault layer is projected from WGS84 into Adindan UTM zone 37N.

4.1.1.8 Existed roads in the study area

The road development is essential for socio-economic growth by securing the efficient and safe movement of the peoples and goods in the scope of continuing the inter-connectivity between rural areas and urban areas. The accessibility is the significant development factor in all facets of economic activities such as tourism, marketing, logistics and farming in the country (Business & Section, 1997).

Existed road networks mean roads already constricted and giving service in that area. Thus, the construction of new roads involves the task of connecting the existing roads to the new alignment in a cost effective approach. This study has four types of existed roads such as primary, tertiary, track, and road.

4.2 Methods

The first step of the study is to determine factors affecting route planning or road alignment selection in a rugged terrain area, quite similar to our study area. This section presents method and techniques applied for analyzing the data as well as for modeling road alignment selection. The details of computational scheme are presented in Figure 4.1.

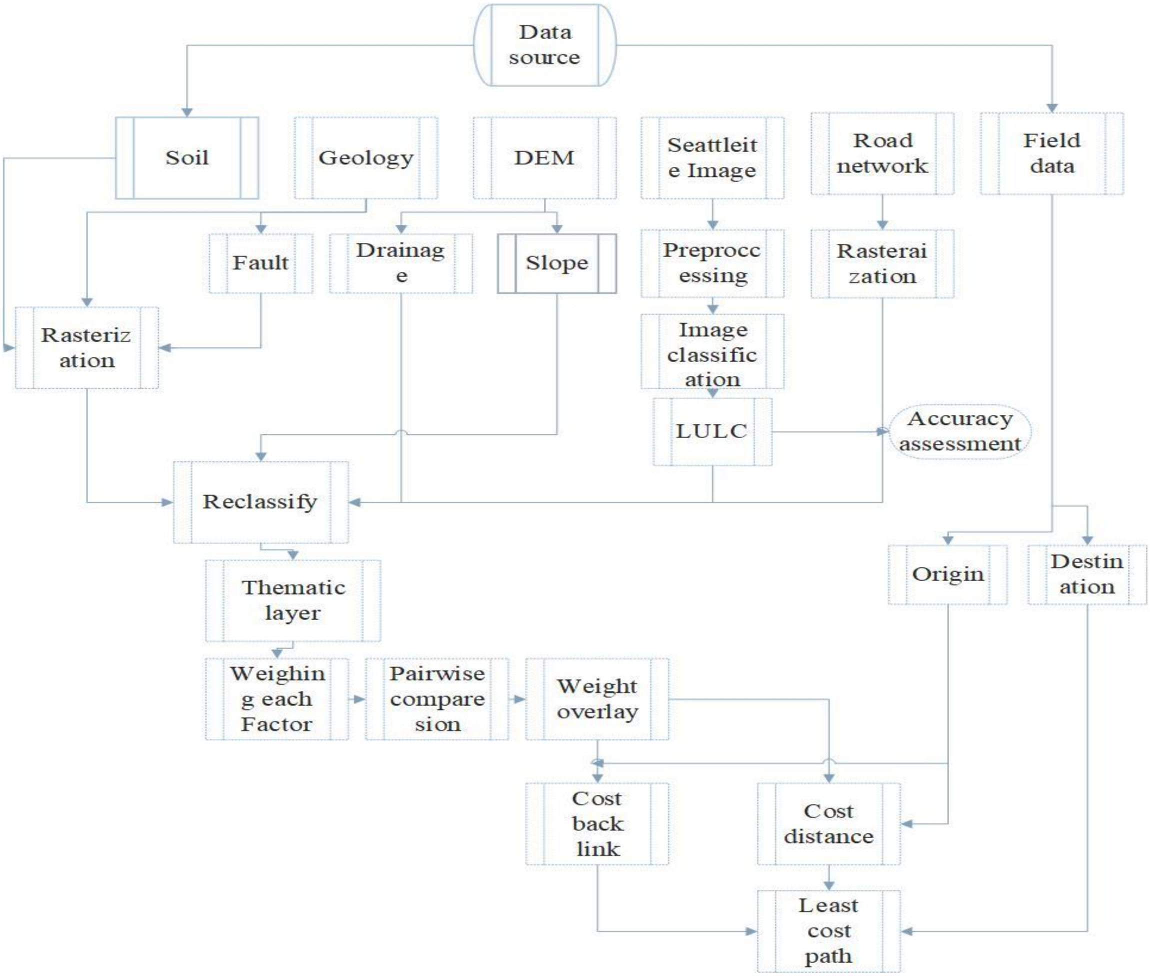

Figure 4.1: Flow chart of the methodology

4.2.1 Analytical Hierarchy Process (AHP)

AHP is usually used to priorities the driving factors in order to make proper decisions. The following step are required to implement this approach.

1. Define the problem and determine the kind of information required.
2. Structure the decision order from the best with the goal of the decision, then the objectives from a broad viewpoint, through the intermediate levels (criteria on

which later elements depend) to the highest level (which typically is a set of choices).

3. Construct a set of pairwise comparison matrices. Each element in a high value is used to compare the elements in the level directly under with regard to it.
4. Use the priorities found from the comparisons to weight the priorities in the level directly. Do this for all element. Then for each one element in the level add its weighted values and acquire its overall (Saaty, 2008).

4.2.2 Criteria weighting using Multi-Criteria Decision Making (MCDM) Techniques

The multi-criteria decision analysis (MCDA) and least-cost path analysis (LCPA) are used to determine the best route based on analyzing main drivers such as topography, slope, land use and other socio- economic factors (chandio, 2012).

Multi-Criteria Decision Making (MCDM) is part of an AHP; problems typically involve criteria of varying importance to decision-makers. Consequently, information about the comparative importance of the criteria is required. One of the ways of achieving this task is by assigning a weight to each criterion. The weight is a value assigned to a criterion that indicates its importance relative to other criteria under consideration. The larger the weight, the more important is the criteria in the overall value. In this study, pairwise comparison methods were initially considered to derive weightings for each criterion; however, as the number of criteria to rank was on a higher side, it was decided that pairwise comparison method would be more appropriate for this study and hence chosen.

4.2.3 Pairwise comparison

The pairwise comparison method were used for the assignment of weight for criteria layers. Pairwise comparison matrices were create for each one of the lower hierarchical levels one matrix for each element in the level. This done by considering which layer effect is dominant than the other. The pairwise compression matrix formed by interview conduct with various experts and knowledge of the researcher based on the Ethiopian Roads Authority’s (ERA’s) standard.

In this study, eight factors was prepared for route selection such as land use land cover, slope, drainage, fault, soil type, geology, towns and existed road. Give the comparative weight for those. The pairwise compression rating for comparing the relative importance of the two criteria (Saaty, 1987). See Table 4.2.

Table 4.2: Rating for comparing the relative importance of the two criteria

Importance	Rating
Equal Importance	1
Equal or Moderate Importance	2
Moderate Importance	3
Moderate to Strong Importance	4
Strong Importance	5
Strong to Very Strong Importance	6
Very Strong Importance	7
Very To Extreme Strong Importance	8
Extremely Important	9

a) Computation of the criterion weights

To complete the matrix of pairwise comparisons comparing two criteria at a time in the right upper and assigning scores according to Table 4.2. The main diagonal of the matrix is equal to 1 because the comparison of anything to itself results 1. the comparison matrix is reciprocal; that is, if criterion 1 is twice as preferred to criterion 2. It can be concluding that criterion 2 is preferred only one-half as much as criterion 1. Thus, if criterion 1 receives a score of 3 relatives to criterion 2, criterion 2 should receive a score of 1/3 when compared to criterion 1. According to Saaty (1987), a simple method was proposed in this thesis, which involves the following steps:

$$A= \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} & a_{17} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} & a_{26} & a_{27} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} & a_{36} & a_{37} \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} & a_{46} & a_{47} \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} & a_{56} & a_{57} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & a_{66} & a_{67} \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & a_{77} \end{bmatrix}$$

1. Calculating the sum of the values in each column of the pairwise comparison matrix.

$B = \sum_{i}^{n} a_{ij}$ Then, B Matrices were; B = $[b_{11} \quad b_{12} \quad b_{13} \quad b_{14} \quad b_{15} \quad b_{16} \quad b_{17}]$

2. Dividing each element in the matrix by its column sum; the result of this computation is called the normalized pairwise comparison matrix and is an estimate of the eigenvalues of the matrix. N = 7x7 matrices.

$$N = \frac{a_{ij}}{b_{ij}}$$

3. Computing the average of the elements in each row of the normalized matrix that is dividing the sum by the number of factors/criteria in this case by 7.

$$W = \frac{\sum_{i}^{n} a_{ij}}{7}$$

These averages provide an estimate of the relative weights of the factors/criteria being compared. From the eigenvalues of the comparison matrix, the criterion weights in percent where total importance must equal 100%.

b) Check the Consistency

In this step, the consistency ratio of matrices is checked to ensure that the judgments of decision makers in creating pairwise matrix were randomly or not. It involves the following steps:

1. Determining the weighted sum vector by multiplying the weights for their corresponding values of the original pairwise comparison matrix, sum values over the rows.

$$P = \sum_{i}^{n} a_{ij} * \ w_{ij}$$

Where p is the weight sum vector.

a_{ij} : - is the original matrix of each element

wij : - is the row average or the weight of factors

2. Determining the consistency vector by dividing the weighted sum vector by the criterion weights determined previously.

$$Cv = \frac{\sum_{i}^{n} p_{ij}}{w_{ij}}$$

3. After completing the previously calculations, it need to compute values for lambda (λ) and the consistency index (CI). Lambda (λ) represents the average of the consistency vector.

$$\lambda = \frac{\sum_{i}^{n} Cv_{ij}}{n}$$

4. The CI depends on the observation that λ is always greater than or equal to the number of criteria under consideration (n) for positive.

$$CI = \frac{\lambda - n}{n - 1}$$

5. The last ratio that has to be calculated is consistency ratio (CR), which is calculated as follows:

$$CR = \frac{CI}{RI}$$

As a rule, if CR is less than 0.1, the judgments are consistent. But if CR is larger than 0.10 should be re-calculated. The RI is the random index, depends on the number of elements were used in comparison matrix. The table of random indexes of the matrices of order 1–10 (Saaty, 1987). See in Table 4.2.

Table 4.2 Random Index

N	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.14	1.45	1.49

4.3 The governing factors for route selection

Route planning considers safety, construction cost and shortest path. Conventional route planning is only based on topographical considerations such as slope and curvature (Yildirim et al, 2006). The holistic approach considers the major factors governing the route selection such as environmental, socio-economic and engineering perspectives. In this case, the evaluation assigns weight to each parameter based on its degree of influence.

i) Slope is the significant factor that affect route selection. The choice of the cross-section for a new road in rolling, mountainous and escarpment terrain can be critical importance in terms of cost and impact on the landscape, and these considerations are therefore required at the route selection stage. Nevertheless, practical solutions will observe in cross-sections such as; full-cut, part cut and part fill, and full fill (ERA manual, 2013). Therefore, the cost of cut and fill requires high cost during construction; larger slope values are not suitable specifically for driving.

ii) Fault includes geological structural features such as thrusts, fault and lineaments. As the frequency of landslide bend with increasing distance from structural features, a buffer zone has been created along with each structural feature and sliced with regard to distance (504 m each) (Saha et al, 2005).

Faults have positive and negative importance. Cutting the side slope above the road on the mountainous area to fit with the road should see as a positive effect. The negative effects side slope blows the road and underground on the road will be the cause of erosion and landslide.

iii) Soil is an important factor for route selection. Most road authorities effectively determine and succeed the physical properties of soil when project road construction and maintenance. However, identification and dealing of soil natural properties and background of soil-landscape, how they may affect road construction and maintenance nowadays, and in the future, is highly variable (Biggs and Mahony, 2004). The core properties requisite of a road ridge are insignificant potential for movement and erosion. The general properties of soil for road pavement are strength, durability, impermeability, volume stability, wear resistance and workability during construction.

iv) Geology, Engineering geological investigations are usually carried out along the route selection corridor. Risks related to landslide that could occur in the future because of natural processes or, more commonly, due to the effects of road construction, including embankment loading, slope excavation, and drainage disturbance are derived from the nature of the local geology (ERA manual, 2013). Geology together with its influence on topography and geomorphology, significantly controls route selection, through earthworks and cease of excavation, foundation conditions, topographic steepness and complexity, geo-hazards. However, if the depth of the rock is less than 50cm we can remove by cutting.

v) Land Use Land Cover layer is required to estimate the cost of land acquisition during route planning (Saha et al, 2005).

vi) Drainage is the factors that influences route selection. In general, highway drainage is the process of removing and controlling excess surface and sub-surface water within the right way. This includes interception and diversion of water from the road surface and subgrade. The installation of suitable surface and sub-surface drainage systems is an essential part of highway design and construction (Vitalis et al, 2016).

The implications of routes located on ridge tops, valley floors (including flood Plain routes), and valley sides and flat to rolling terrain. Ridge routes typically cross only small watercourses fed by small catchments whereas lower valley side and valley floor routes usually encounter a smaller number of much larger rivers that often require expensive bridging. Furthermore, v-shaped valley side slopes usually border active valley floor channels with minimal river terracing providing a little option for avoiding flooding and scour hazards (ERA manual, 2013). In road construction, high cost is usually associated to bridge construction. Due to economical perspective drainage is the second governing factor.

vii) Road, it is the conduit of life's activities. Roads form a critical donation to economic development and growth and take essential social benefits. They are of energetic grandness in order to make a country grow and develop. In addition, supply access to employment, social, health and education facilities makes a road network critical in fighting against poverty.

The main welfare of road transport are not only transporting passengers, and also carrying goods regardless of distance to destination, the relatively high speed, and no time restrictions. Road transport and its infrastructure enable the transfer of people as well as materials, semi-finished and finished products from one place to another place. Road infrastructure affects the flexibility and mobility of the workforce, which is reflected in the employment level (Ivanova and Masarova, 2013). Roads open up more areas and motivate economic and social development. For those reasons, road infrastructure is the most important of all public assets.

4.3.1 Cost surface

After the determination of the comparative weight of factors, the derived weights from a pairwise matrix in Multi-Criteria Analysis (MCA), inserting the particular value to the map layers, weighted thematic maps for each factor were prepared. The thematic cost map is characterized as a raster map, where the value at each pixel gives the estimated relative cost of route improvement through the pixel (Saha et al, 2005). It is dependent upon a number of factors and the most important of these being, slope, drainage density, land use land cover, geology, soil, fault (liniment), and existing road. As per the weighted values are given in the pairwise matrix and ranked values given, all those cost maps were produced. The final thematic map is presented by adding this weighted raster.

4.3.2 Raster Direction

The cost distance raster displays the least accumulated cost of each cell to the nearest source, but it does not decide as to which way to go to get there. The direction raster delivers a road map, distinguishing the route to take from any cell, along the least-cost path, back to the nearest source. The function is all so accessible in the Spatial Analyst tool. The input data of this direction raster are the origin and the weighted raster calculator. Based on the above cost raster surface information and cost backlink the least cost path was obtained. The cost is based on several variables, used for the analysis. When to specification the cost distance, the least accumulative cost distance should compute for each cell to the nearest source over a cost surface. The cost to travel between origins to the destination is depending on the spatial orientation. In addition, when the cells are connected will be impacts the travel cost. This is identified as 'node travel cost' (Understanding Cost Distance Analysis, 2012).

4.3.3 Least Cost Path Analysis

The determination of the least cost path the necessary input data are destination raster, cost distance raster and direction raster. After preparing all the required inputs, spatial analyst tool is used to generating the least cost path and the results of the analysis.

CHAPTER 5 RESULTS AND DISCUSSIONS

5.1 Land Use Land Cover Layer

(Kiema and Karanja, 2011) identifies the LULC with higher value indicates more costly and therefore less suitable for road construction. (Saha et al, 2013) and (Anon, 2017) investigates Land use land cover data is required to estimate cost of land acquisition or compensation cost during route planning. The route should go through bare land instead of agricultural and forest land. In this research, the significance of LULC is to identify what class (land cover) is feasible for road alignment selection. After the preprocessing and image classification as well as validation of accuracy assessment give the rank to each class according to its cost implication. The following ratings are applied to identify the suitability, and cost of compensation and clearing.

Table 5.1: Retting of land use land cover class

LULC Category	Cost Implication	Score
Bare Land	Land clear	1
Shrub Land	Clearing cost	3
Agriculture	Land clear but compensation required	6
Built-up	Social factor but need compensation	5
Water/River	Cost of bridge	7
Forest	Clearing of trees and transportation, wild animals	9

The above Table 5-1 shows Bare land (rating=1) is relatively favorable for route planning due to the fact that such areas are under government control, involve no compensation cost and are devoid of environmental problems like cutting of trees. Shrub land (rating=3) are relatively favorable for route planning due to the fact that such areas are under government control, but need some clearing cost. Agricultural land (rating=5) is relatively suitable due to the fact that the compensation cost less than building cost. So, best for route selection. But other researchers identify fertile soil favorable for agriculture is not favorable for road construction. Built-up (rating=6) is relatively favorable due to the fact that social criteria such as town and population. That means so many peoples settle into the town. Therefore, settlements are classified as built-up. Water (rating=7) are not suitable for route selection.

Because constructing roads across the waterbodies involves heavy investment such as overpass bridge construction and under water tunnels Forest (rating=9) is not suitable for route selection because it contains lots of biodiversity including wild animals (e.g. Nyala, Lion, Wolf, Gelada Baboon, etc.). Roads passing through forest will increase the death of wildlife. Also the cost of cutting dense trees is expensive.

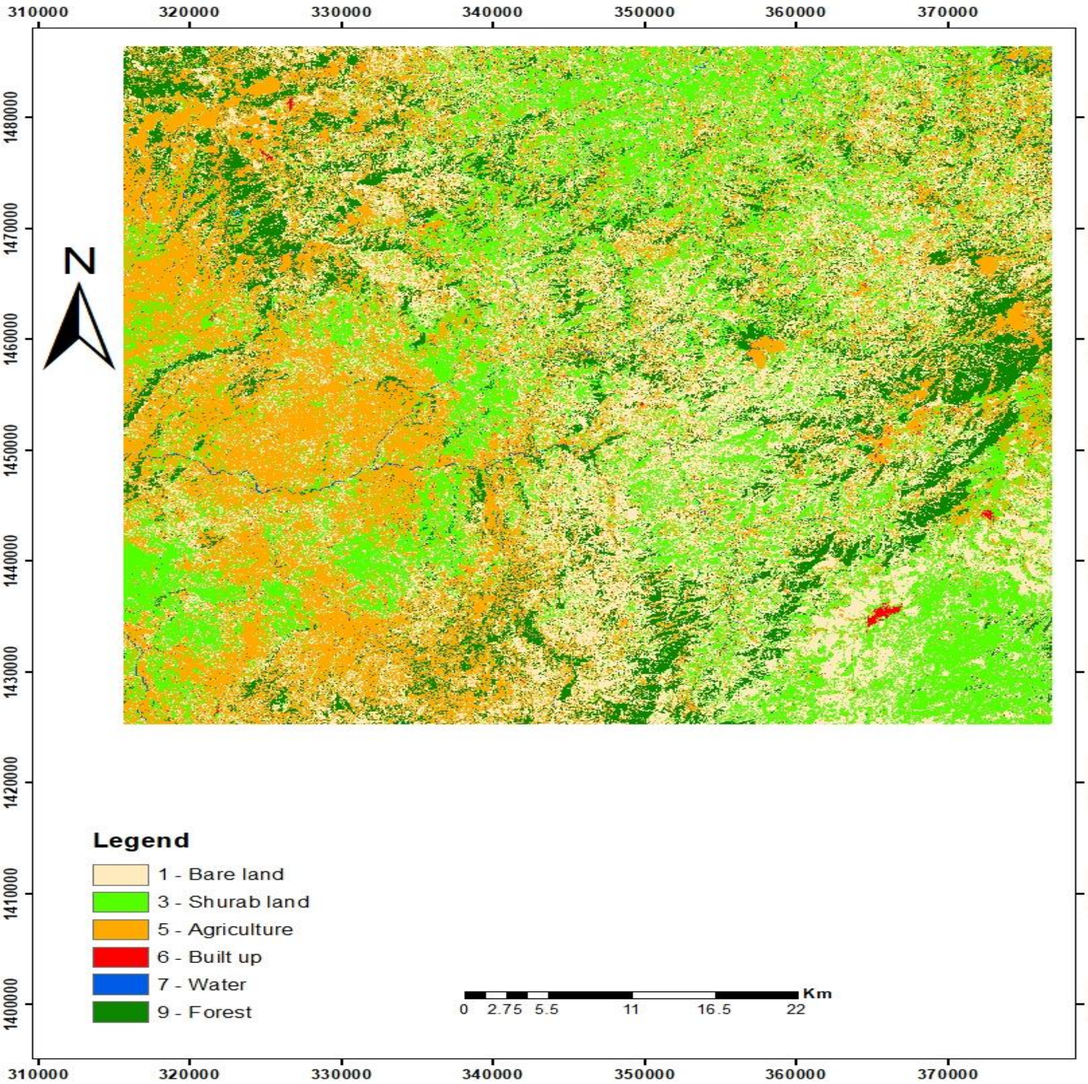

Figure 5.1: Reclassify LULC

5.1.1 Accuracy Assessment

(Sunusi et al. 2015) and (Rwanga and Ndambuki, 2017) Emphasis for accuracy assessment of pixel selection was on areas that could be clearly identified on both Landsat high-resolution images and Google earth (Rwanga and Ndambuki, 2017). According to

(Congleton et al, 2009) omission and commission error, use and producer accuracy will have calculated under here.

This study has used Google earth as a reference data to evaluate the accuracy of remotely sensed data. Also used supervised classification method. The result should that user's accuracy is maximum (100%) for built-up and water area. The minimum accuracy was obtained for the shrub land class. Agriculture, forest and bare land has an accuracy of 96.6%, 98.3% and 95%, respectively, see Table 5.2. The lowest values of class accuracies were misclassified due to spectral properties similarity among other land cover classes.

The producer's accuracy refers to the number of correctly classified pixels in each class (category) divided by the total number of pixels in the reference data to be of that category (column total). Were largely classified as 100% built up and 93% which is shrub land areas became relatively low accuracy, and agricultural land 96.67%, forest 97%, bare land 95% and water 98.3%.

Table 5.2: Accuracy assessment of LULC

		Reference Images								
	Class	Water	Bare land	Forest	Built-up	Agriculture	Shrub	Total	omission error (%)	User Accu Racy (%)
Classified Images	Water	59	0	0	0	0	0	59	0	100
	Bare land	1	57	0	0	1	1	60	5	95
	Forest	0	0	58	0	0	1	59	1.7	98.31
	Built-up	0	0	0	60	0	0	60	0	100
	Agriculture	0	1	0	0	58	2	60	5	96.66
	Shrub	0	2	2	0	1	56	61	8.2	91.8
	Total	60	60	60	60	60	60	360		
	omission error	1.67	5	3.3	0	3.33	6.67			
	producer accuracy%	98.3	95	97	100	96.67	93.3			
	Overall accuracy	96.7								
	Kappa	0.96	It is acceptable							

Overall Accuracy (96.7%) is computed by dividing the total number of correctly classified pixels (i.e., the sum of the elements along the major diagonal) by the total number of reference pixels (total number of sample points). Table 5.2 shows an overall result of the tabular error matrix. The standard of the lowest overall accuracy value computed from an error matrix must be 85% (Congalton, et al 2009). Therefore, the overall accuracy value of 96.7% obtained in this research is acceptable.

In order to have look at non-diagonal cells in the matrix. These cells contain classification errors, i.e. the reference image and the classified image do not match. Another accuracy indicator is the kappa coefficient. The value of the kappa coefficient varies from zero to one. If the kappa coefficient equals zero, there is no agreement between the classified image and the reference image. If the kappa coefficient equals one, then the classified image and the ground truth image are identical. The value of k >0.8 (80%) represents strong agreement, values between 0.4 and 0.8 (40%-80%) represents moderate agreement and values <0.4 (40%) represent poor agreement (Jyothi et al, 2012).

Therefore, the higher the kappa coefficient, the more accurate the classification. In this research, the result of the kappa coefficient was 0.96. Therefore, it is acceptable.

5.2 Reclassifying Soil Layer

Access to good sub grade soil is very important for construction road and other infrastructure. There are many significant engineering decisions that drive into developing safe buildings, roads, bridges, and other structures. The best sub grade soil types for infrastructure have the following properties, see Table 5.3

i. composed chemistry and neutral pH, so that the building materials are didn’t corroded;
ii. stability through wetting and drying cycles, so which expanding soil does not crack roads or foundations of infrastructure;
iii. strength under pressure, therefor the weight of the building doesn’t cause it to sink into the ground; and
iv. Capability to capture precipitation, so that runoff and erosion do not damage structures (Soils Support Buildings or Infrastructure, 2015).

Soil porosity is a measuring of the number of spaces or openings in the soil that can be filled with either air or water. Permeability is a measuring of the easiness with which water and air move through the soil pores. A combination of texture, structure, and organic matter content determine the porosity and permeability of soils. Sub grade soil type suitable for construction require good balance between small pores that retain a lot of water, and large pores that allow easy movement of air and water. Medium- textured loam soils with good structure and plenty of organic matter are excellent for road construction. While clayey soils have higher porosity, and so can hold more water than sandy soils, they also have lower permeability because the pores (opening) are so small. Clay soils are characterized by a small pore size (less than 0.03 mm; 0.0012 in), and therefore not suitable sub grade soil for road construction. Large pore size, and thus poor water-holding capacity, is a problem only in very sandy soils (Cleveland and Soleri, 1991).

Coarse-textured soils (loamy sands, sands and sandy loams) has large particle size and do not have the nutrient holding capacity and great water. They tend to be well dry out faster, drained, and are less probable to compact.

Fine-textured soils (sandy clays, clays, and silty clays) have a small particle size. They can hold water and nutrients, take a long time to dry out, and can be easily compacted when wet and often are connected with poor drainage that limits the use of the fields during wet weather. Table 5.3 shows the importance of sub grade soil physical property.

Table 5.3: Importance of sub grade soil physical property

Soil texture	Drainage	Susceptibility to compaction	Water & nutrient-holding capacity
sandy loam	Good	limited to moderate	Moderate
Loam	good to fair	Moderate	moderated – substantial
Clay	Poor	Substantial	Substantial

Information on soil suitability for route selection was acquired through literature and highway-engineering experts, and consultants. According to the engineers and literature review, soil type are the properties considered in soil suitability analysis (Table 5.4).

Table 5.4: Ratting of sub grade soil texture

Soil category	Score
Sandy loam	1
Loam	2
Clay	3

Sandy loam (rating=1) is a type of coarse-textured soils; it has a large particle size and does not have the nutrient holding capacity and great water. This soil type is normally a combination of sand along with varying amounts of clay and silt.

Loamy (rating=2) soils are an intermediate soil halfway between sand and clay. It has typically a mix of organic material, sand, and clay. This is advised by builders to be capable for building on, which means they are best than clay but inferior to sand. Loamy soils will not displacement due to the presence or absence of water.

Clayey (rating=3) is a type of fine-textured soils have a small particle size, it is unfavorable. Because of this happens flood by soil erosion. See Figure 5-2.

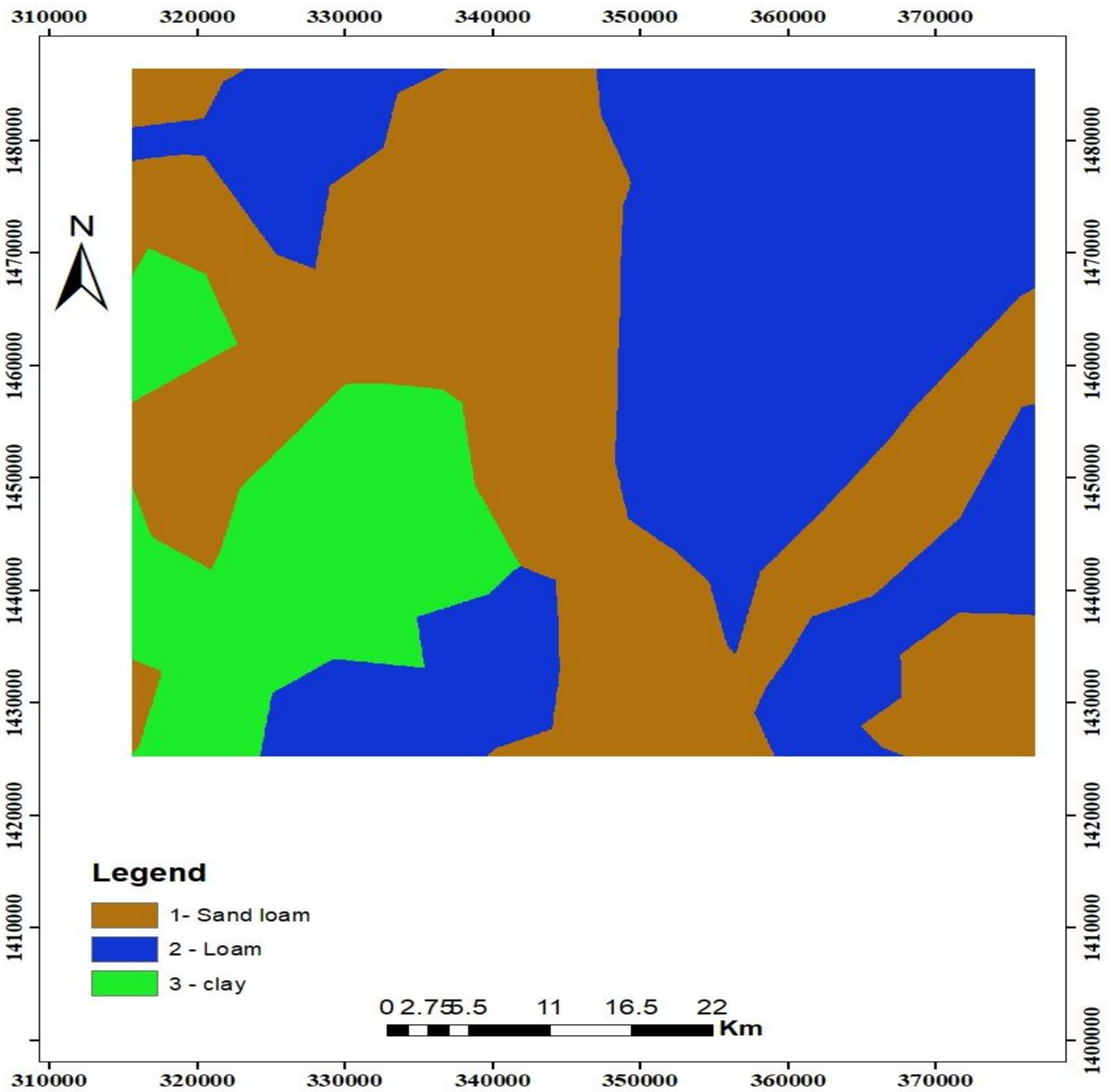

Figure 5.2: Reclassify sub grade soil texture

5.3 Reclassifying Geology

Geology is obviously one of the most significance factors for construction since construction takes place either on the surface or below the ground. Hence, it has an important influence on most construction operations and helps to determine their nature and cost (Table 5.5). For example, route design and tenable construction are largely dependent on geological consideration (Bell, 1978).

Table 5.5: Ratting of geology type

Category	Description	Score
Ashangie formation	characterized by strong weathering, different, columnar jointing, intense fracturing and crushing	1
Tarmaber gussa formation	Alkaline to transitional basalts	3
Aiba Basalt	flood basalt with rare basic tuff	5
Alluvial and lacustrine deposits	Black cotton & reddish-brown silty to sandy soil with few outcrops of diatomite	7

Table 5.5 representing Ashangie geological formation the Eocene-Oligocene period is the most suitable for route selection (ratting=1) due to the fact that it is characterized by strong weathering, different directional tilting, columnar jointing, intense fracturing, and crushing. In many of its exposure, inclined columnar jointed aphanitic basalts dominate it. The unit also contains intercalated layers of agglomerate and volcano - clastic sediments and vesicular basalt. Therefore, relatively this is suitable for route selection. Tarmaber gussa (rating=3) is formed during the Oligocene-Micocene (Cenozoic) period. It is suitable for route selection, which is Alkaline to transitional basalts often forming shield volcanoes with minor trachyte and phonolite flows. Aiba Basalt (rating=5) which is formed in middle-late Oligocene period is relatively not suitable for route selection. That is flood basalt with rare basic tuff. Alluvial and lacustrine deposits (rating=7) is formed during the period of Quaternary undifferentiated. This is characterized by sand, silt, clay, diatomite, limestone and beach sand. Black cotton & reddish-brown silty to sandy soil with few outcrops of diatomite. so, it is not suitable for route selection. See the Figure 5.3 below.

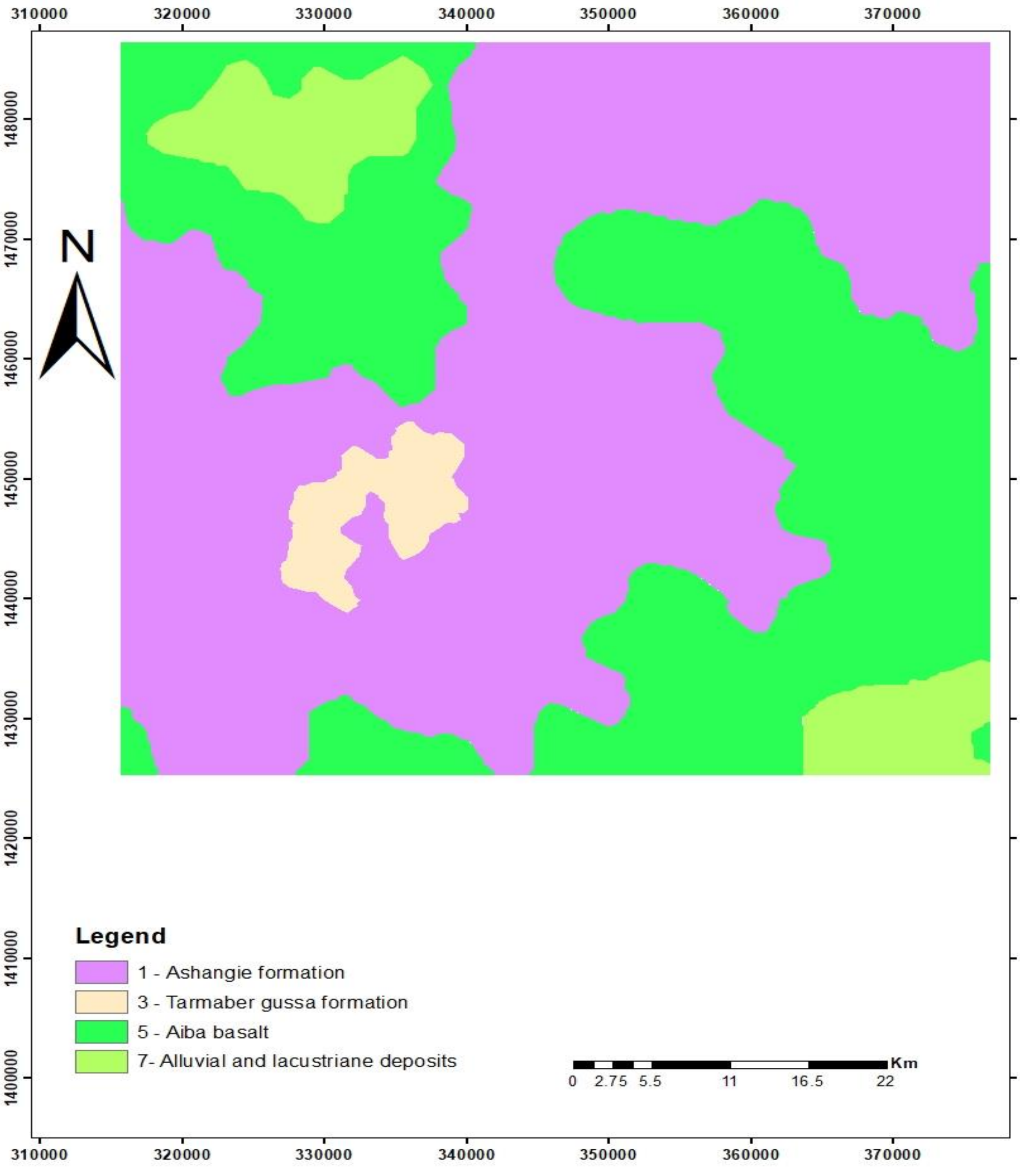

Figure 5.3: Reclassify geology type

5.4 Slope Classification

Slope is an important factor in route alignment selection since steep slope should be avoided in order to prevent accidents and give driving comfort to the user (Sunusi et al., 2015). Steep slopes are disadvantageous for construction. Steeper slopes increase the construction cost of the road and cause erosion during construction and subsequent use. Slope is used to classify the topography according to the steepness and the gentleness of the terrain. The ERA design manual divides the topographic land mass of Ethiopia into four types of terrain namely: i) Flat terrain below (2° slope), ii) Rolling terrain (2° to 14° slope), iii) Mountainous terrain (14° to 37° slope), and iv) Escarpment terrain slopes are greater than (37° slope). According to ERA's standard the slope classification and rating are shown in Table 5.6.

Table 5.6: Rating of the slope

Slope category in percent	Score	Description
0 – 2.22	1	Highly suitable
2.22 – 15.55	2	Suitable
15.55 – 41.1	3	moderately suitable
>41.1	4	Unsuitable

Table 5.6 shows that flat terrain (<2.22 percent) is highly suitable, the rolling terrain (2.22 – 15.55 percent) is suitable, the mountainous terrain (15.55 – 41.1 percent) is moderately suitable, the escarpment terrain (>41.1 percent) is unsuitable for road construction. The geological distribution of terrain classes is presented in Figure 5.4.

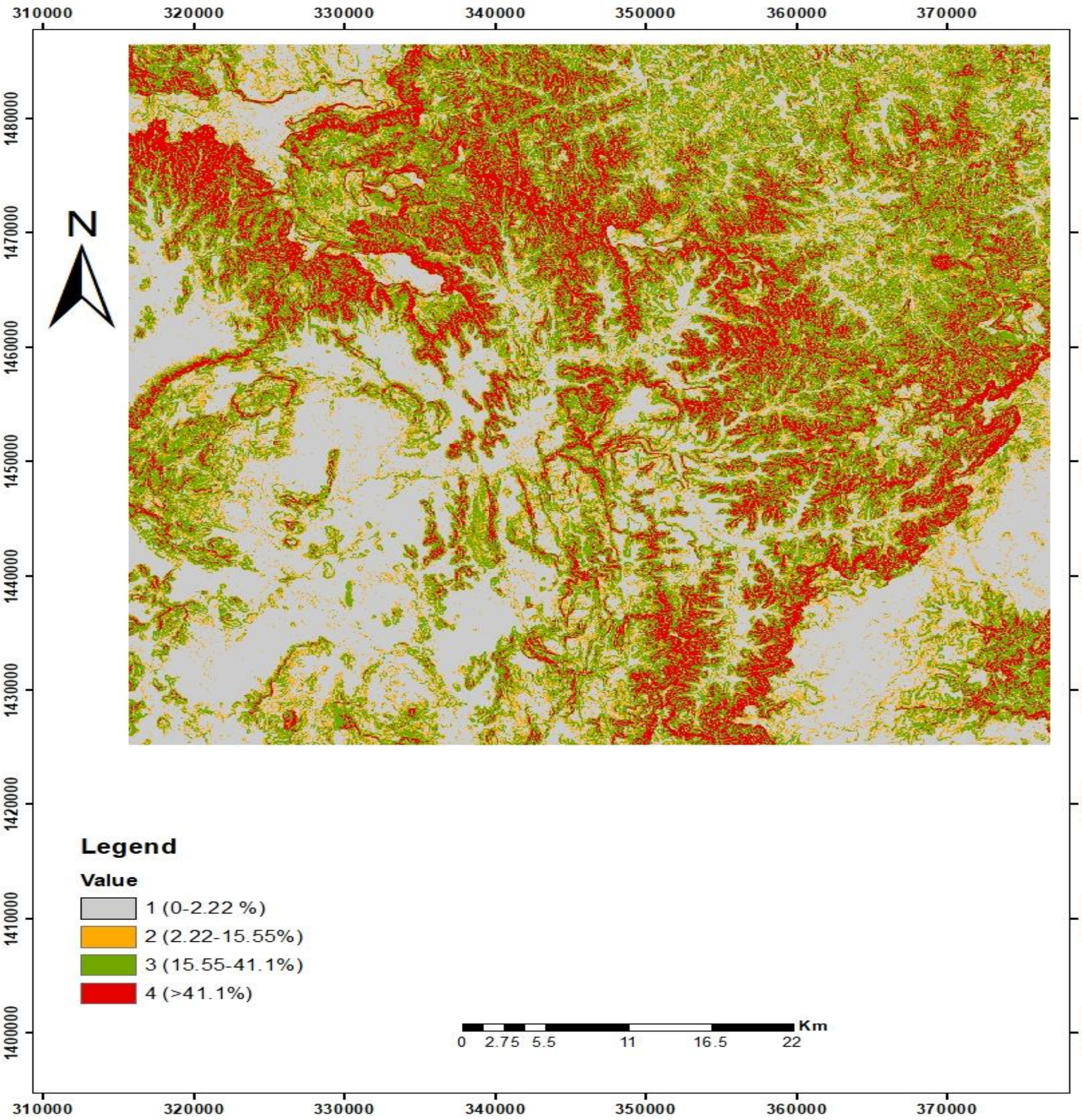

Figure 5.4: Reclassify slope

5.5 Reclassify Drainage Order

Drainage densities is calculated by dividing the total stream length (measured in km) by the total watershed area (km^2). The drainage density layer is used to estimate the cost of bridge construction. Generally, the width of the river channel gets larger with increasing order of drainage or drainage density, which results in a corresponding increase in the cost of bridge construction. The first- and second-order drainages have been assigned very low ratings, as these are mostly quite a narrow, and in most cases, the water may be drained using underground pipes, or by supply small culverts. For high drainage density, there may be requirements for bridge construction; the construction cost increases with the width of the channel. Therefore, higher ratings have been assigned to higher drainage density see Table 5.7. Drainage map is usually generated by digitizing the drainage lines from the topographical maps. The drainage order map can be used to figuring the cost of bridge construction, if required, during route planning (Saha et al, 2005).

Table 5.7: Rating drainage order

Drainage order	Score	Suitability
1	1	High suitable
2	3	Suitable
3	5	Moderate
4	7	Unsuitable

In this study, drainage density was generated from DEM, and reclassified into four-drainage density classes. The narrow the stream, the more it is suitable for route selection while the wide streams are unsuitable, because it incurs higher cost for the bridge construction. Table 5.7 illustrates the suitability level various drainage densities. The suitability rating is based on cost of bridge construction. The narrow stream requires low cost while wider stream demands high cost. On the other hand, the larger the length of classification the more generalized is the drainage density, whereas, the smaller length of the raster corresponds to detail drainage density (Figure 5.5).

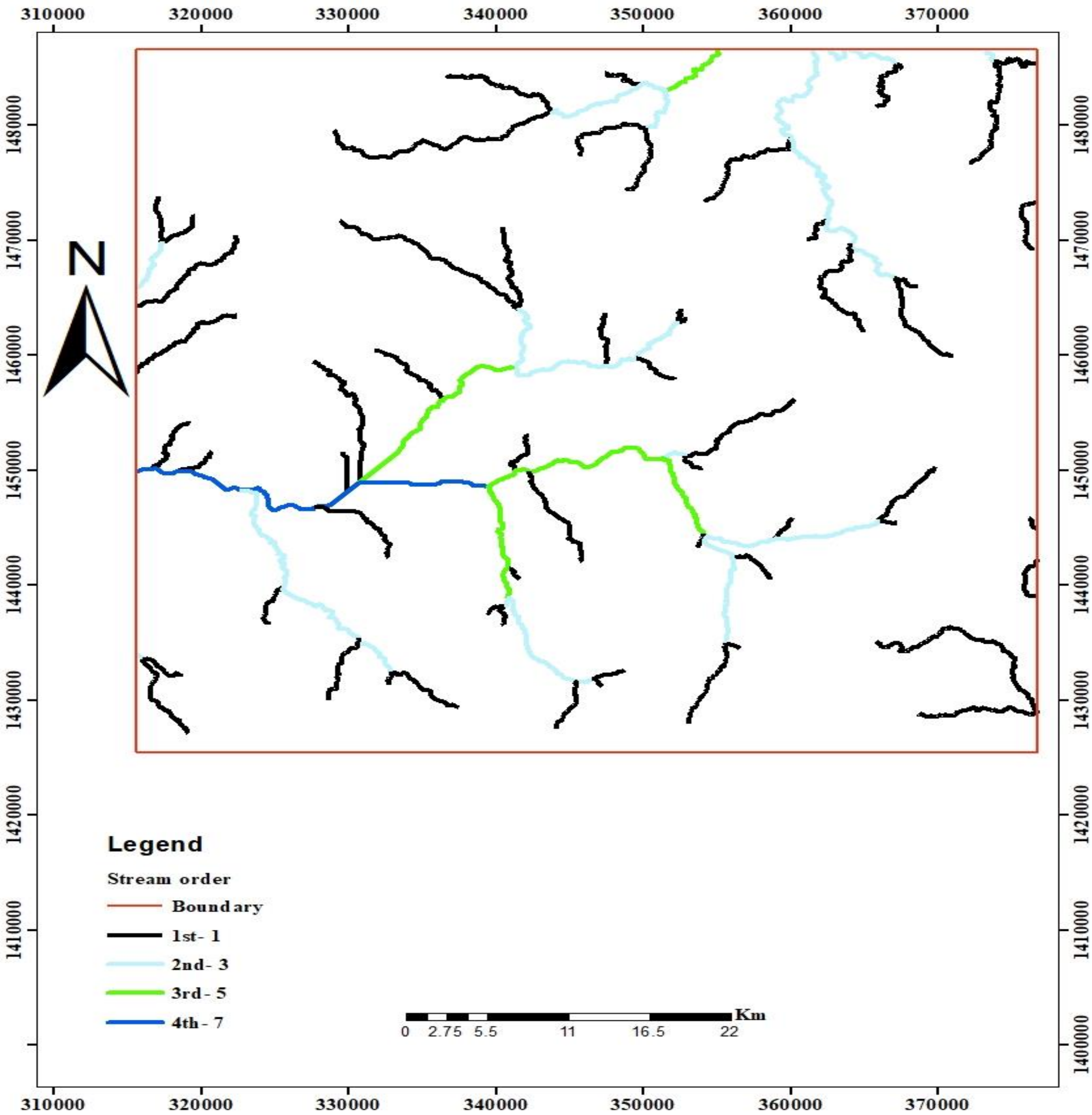

Figure 5.5: Reclassify drainage order

5.6 Road Network Classification

Road network is a system of interconnected roads. For example, highways connecting to cities, streets interconnected to each other at street intersections, etc. GIS has a great function for road network analysis used to calculate the time necessary for routing such as emergency vehicles to travel from the fire stations to different areas of the city. One of the major use of road network analysis for transportation planning. It is used to, find paths corresponding to certain criteria like finding the shortest or least-cost path between two or more locations or to find many locations within a given travel cost from a specified origin (Kumar et al, 2017).

Road alignment and length are also important criterions for the least cost path analysis. The newly proposed area did not have adequate connectivity with sufficient road network. Therefore, road alignment selection is mainly dependent on socio-economic factors in addition to optimization of connectivity to existing roads. Weights assigned to the existing road network is based on distances nearest to the origin of the new route. See Table 5.8.

Table 5.8: Rating existed road

Road category (type)	Score
Road	1
Track	3
Primary	5
Tertiary	7

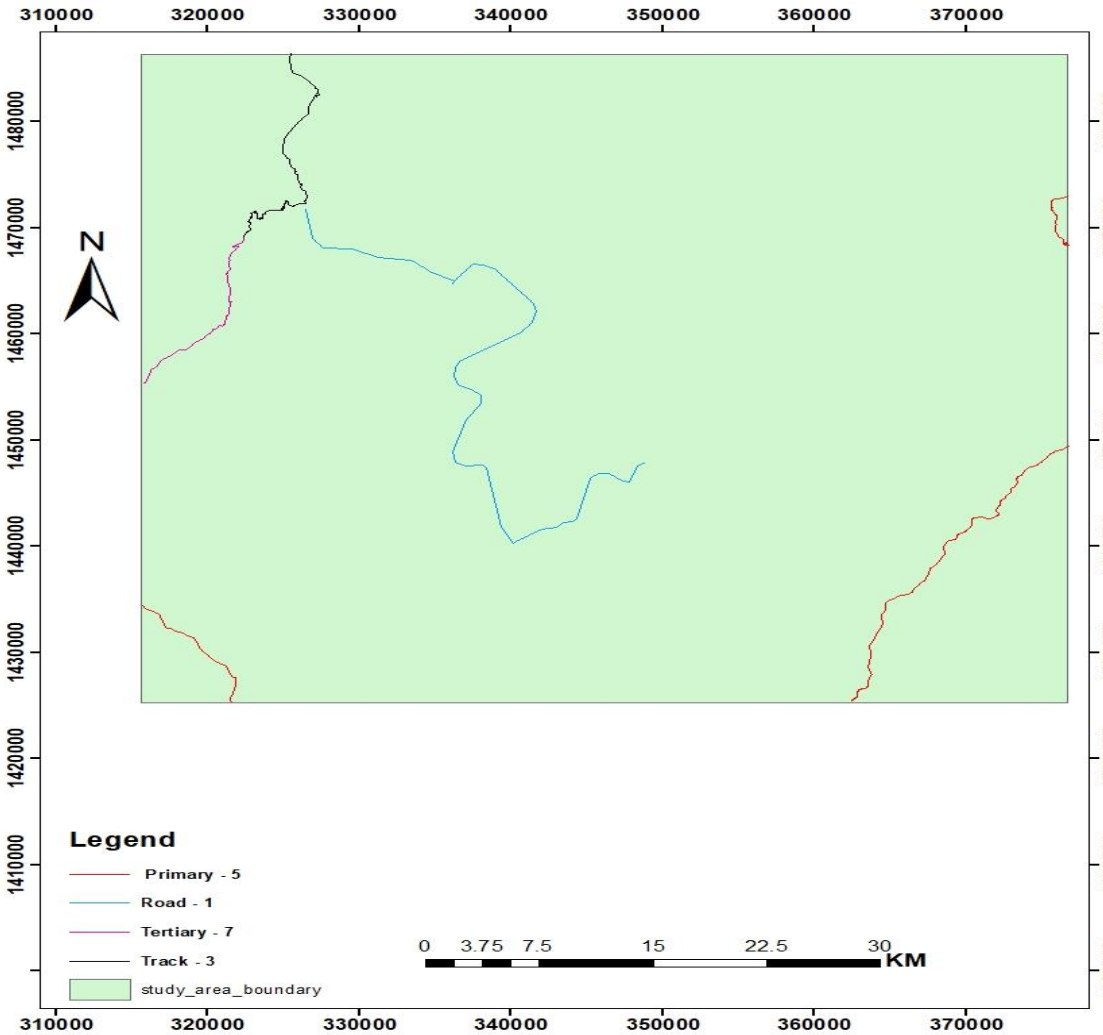

Figure 5.6: Reclassify road network

5.7 Reclassify Fault

Geo-hazards can causes significant constraints to the construction and operation of road infrastructure and; hence critically important for route selection. In Ethiopia, geology and tectonic setting, mutual with climate and hydrology, create conditions that encourage the occurrence of a range of geo-hazards (ERA manual, 2013). In geological hazards, alternate routes were designed away from faults or lineaments and escarpments by a minimum of two km distance (Fekerte and Muse, 2007).

In this research, the reclassification of fault was weighting based on the line density of the lineament (Table 5.9 and Figure 5.7). The higher value of the liniment density is not suitable for route selection and the minimum density is not dangerous for road construction.

Table 5.9: Rating fault

Density level of fault	Score	Description
0 – 0.101	1	Not dangerous
0.101 – 0.201	3	Moderately less dangerous
0.202 – 0.302	5	Dangerous
0.303 – 0.402	7	Highly dangerous
0.403 – 0.503	9	Extremely dangerous

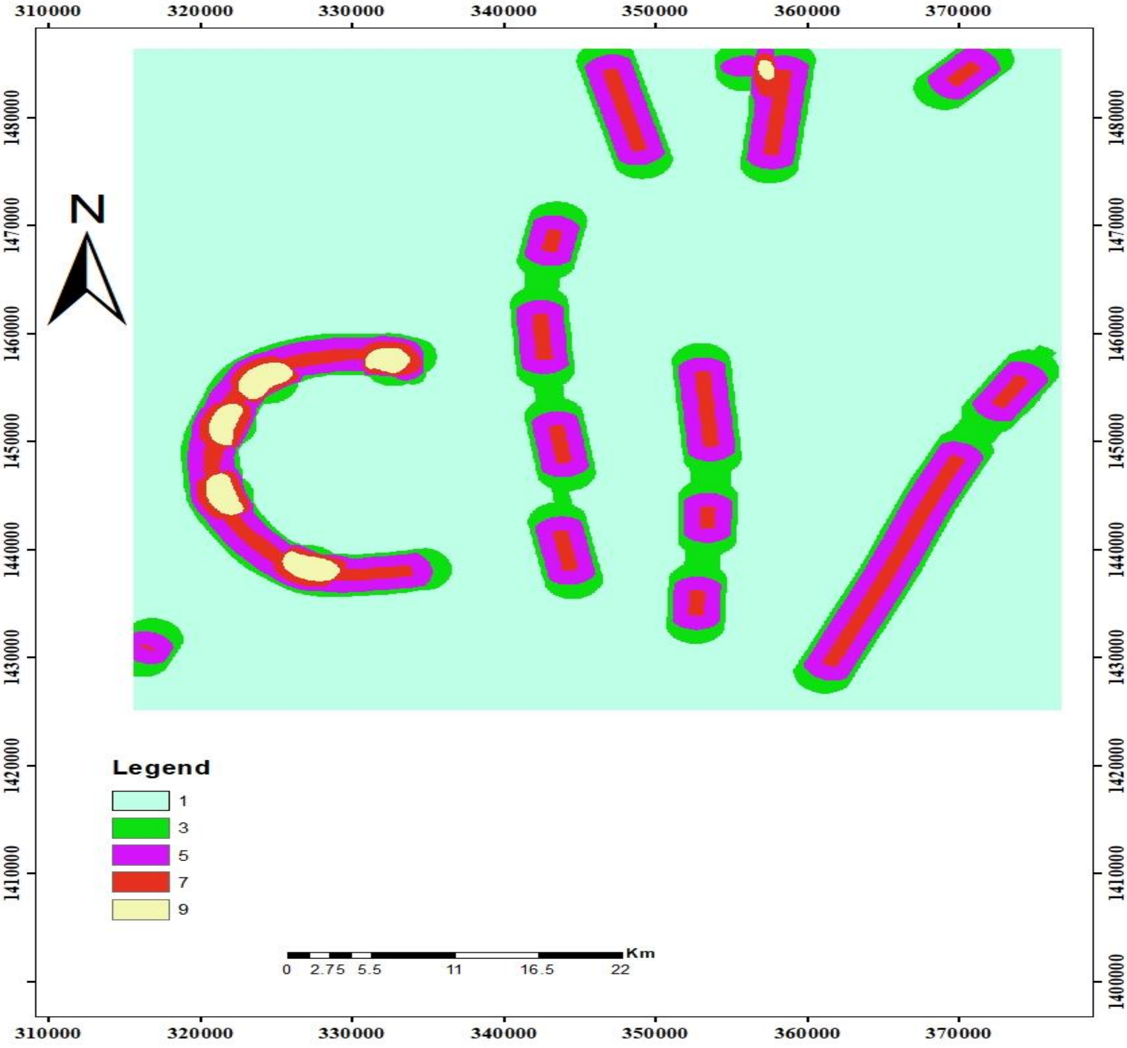

Figure 5.7: Reclassify fault density

5.8 Weighting – The Analytic Hierarchy Process (AHP)

It is problematic to improve a weighting procedure that is truly objective. In all cases, it depends on degrees of subjectivity and only relates to making a comparison between choices; in most cases, the absolute value of a characteristic (e.g. social characteristics) is not being evaluated (ERA manual, 2013).

In this study used seven interrelated components of the environment factors to generate road alignment. Parameters used for road selection are land use land cover, existing roads, geology, slope, fault, drainage, soil, and towns. For each factor, a map was produced from remotely sensed data, topographic maps, and other different maps. Before combining the factors governing the route selection the following procedures were taken place. First, rasterization was done for the vector data layers in order to produce similar data layers with 15m resolution, for the purpose of further data analysis. In the second stage, reclassified each subclass using ArcGIS software package. Prior to combining the factors, weights have to be given based on (Satty's, 1987) Analytic Hierarchy Process (AHP), where a pair-wise comparison matrix will be prepared for each map using a nine-point importance scale (Table 5.11). Weighting is used to express relative importance of each factor compared to another factor. The larger the weight, the more important is the factor. Table 5.11 shows the pairwise comparison matrix.

Table 5.10: Pairwise compression

Criteria	LULC	Slope	Geology	Soil	Fault	Road	Drainage
LULC	1	0.167	0.5	0.333	0.2	2	2
Slope	6	1	4	3	1.333	7	6
Geology	2	0.25	1	0.5	0.25	3	3
Soil	3	0.333	2	1	0.5	4	4
Fault	5	0.75	4	2	1	5	7
Road	0.5	0.143	0.333	0.25	0.2	1	0.5
Drainage	0.5	0.167	0.333	0.25	0.143	2	1
Sum	18	2.921	12.367	7.5	3.769	24.5	23.83

Dividing each column value for the sum of the column, and averaging over normalized columns to estimate the weight of the matrix (which represent the distribution of the parameters) to generate, Tables 5.12 and 5.13.

Table 5.11: Estimation of Eigenvalue

Criteria	LULC	Slope	Geology	Soil	Fault	Road	Drainage	Sum
LULC	0.055	0.057	0.040	0.044	0.053	0.082	0.084	0.415
Slope	0.327	0.342	0.324	0.4	0.354	0.286	0.252	2.534
Geology	0.109	0.086	0.081	0.067	0.066	0.123	0.126	0.796
Soil	0.164	0.114	0.162	0.133	0.133	0.163	0.168	1.203
Fault	0.272	0.257	0.323	0.267	0.265	0.204	0.294	2.077
Road	0.027	0.049	0.027	0.033	0.053	0.041	0.021	0.307
Drainage	0.027	0.057	0.027	0.033	0.038	0.082	0.042	0.390
Sum	1	1	1	1	1	1	1	7

Allocate each requirement of its relative value based on the estimated weight value.

Table 5.12: Weight for the criteria

Criteria	Weight
LULC	0.0899
Slope	0.3203
Geology	0.1030
Soil	0.1539
Fault	0.2732
Road	0.0419
Drainage	0.0279

Where Table 5.13 shows the slope factor gets the maximum weight which is 0.3203(32.03%), the second score gets fault 0.2732(27.32%), the soil factor is 0.1539(15.39%), geology is weighted 0.1030(10.30%), LULC 0.0899(8.99%) and the minimum weight gives to road and drainage which is 0.0419(4.19%) and 0.0279 (2.79%), respectively.

5.8.1 Consistency Index

To examine rationality of the AHP, it is necessary to determine the degree of consistency that has used in developing the judgments. In AHP, an index of consistency, known as the consistency ratio (CR), is used to indicate the chance that the matrix decisions were randomly generated. The following mathematical expressions are used to calculate the consistency index. See the following solutions.

Given: -

- Principal Eigenvalue of the matrix, (λmax)= 7.266845837 ~ 7.267
- order of the matrix, (n) =7
- Random consistency index, (RI) =1.14 ------ obtained from Table 5-14

$$\text{Consistency index} = \frac{\lambda\max - n}{n-1} = \frac{7.266845837 - 7}{7-1} = 0.0444743061 \sim 0.0445$$

$$Consistency\ ratio = \frac{CI}{RI} = \frac{0.0444743061}{1.14} = 0.0390125492 \sim 0.039$$

Table 5.13: Table of random consistency index (Saaty, 1987)

N	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.14	1.45	1.49

Consistency Ratio (CR) is calculated to measure the consistency of the solution. If the value of CR< 0.10, then the ratio is defined as a reasonable level of consistency. It means that the values assigned to the parameters are considered correct. If the value of CR is more than 0.10 then the preferences are to be revised to get the consistency result. When CR value is less than 0.10, then the results are considered as consistent and can be used for the analysis (Saaty, 1987). If the solution are found to be consistent, then the calculated weights can be assigned to each criterion and sub-criteria. Therefore, in this research, the assigned weight is acceptable to the CR values less than 0.10, which is 0.039.

5.9 Thematic cost map generation

Usually weight is given to each thematic data layer. The subclasses within each thematic data layer carry a rating, which is used as 'attribute data'. Weighted Linear Combination and Multi – Criteria Evaluation methodologies can be used to find the interrelation among the weights and to accumulate various data layers (Voogd, 1983). The thematic cost map is calculated using the following equation.

$$\text{Thematic Cost} = \sum \text{Weight} * \text{Thematic Data Layer (attribute)}$$

Hence in this case

$$\text{Thematic Cos} = \sum(0.3203 * \text{SL}, 0.1030 * \text{GE}, 0.0899 * \text{LU}, 0.1539 * \text{SI}, 0.2732 * \text{FA}, 0.0419 * \text{ER}, 0.0279 * \text{DR})$$

Where: - SL is the slope map, GE is the geology map, LU is the land use/land cover map, SI is the soil type map, FA is the fault (liniment density) map, ER is the existed road map and DR is the drainage density map. Figure 5.9 represents the thematic cost map, that is found to vary between 9.16 and 35.7. Lower values indicate favorable pixel sites for route planning, whereas higher values indicate relatively unfavorable or less favorable sites. For route planning, particularly in a hilly region, topography plays a very important role. The next section presents result of methodological approach incorporating the thematic cost factor, distance factor and direction factor for route planning along with least-cost route selection.

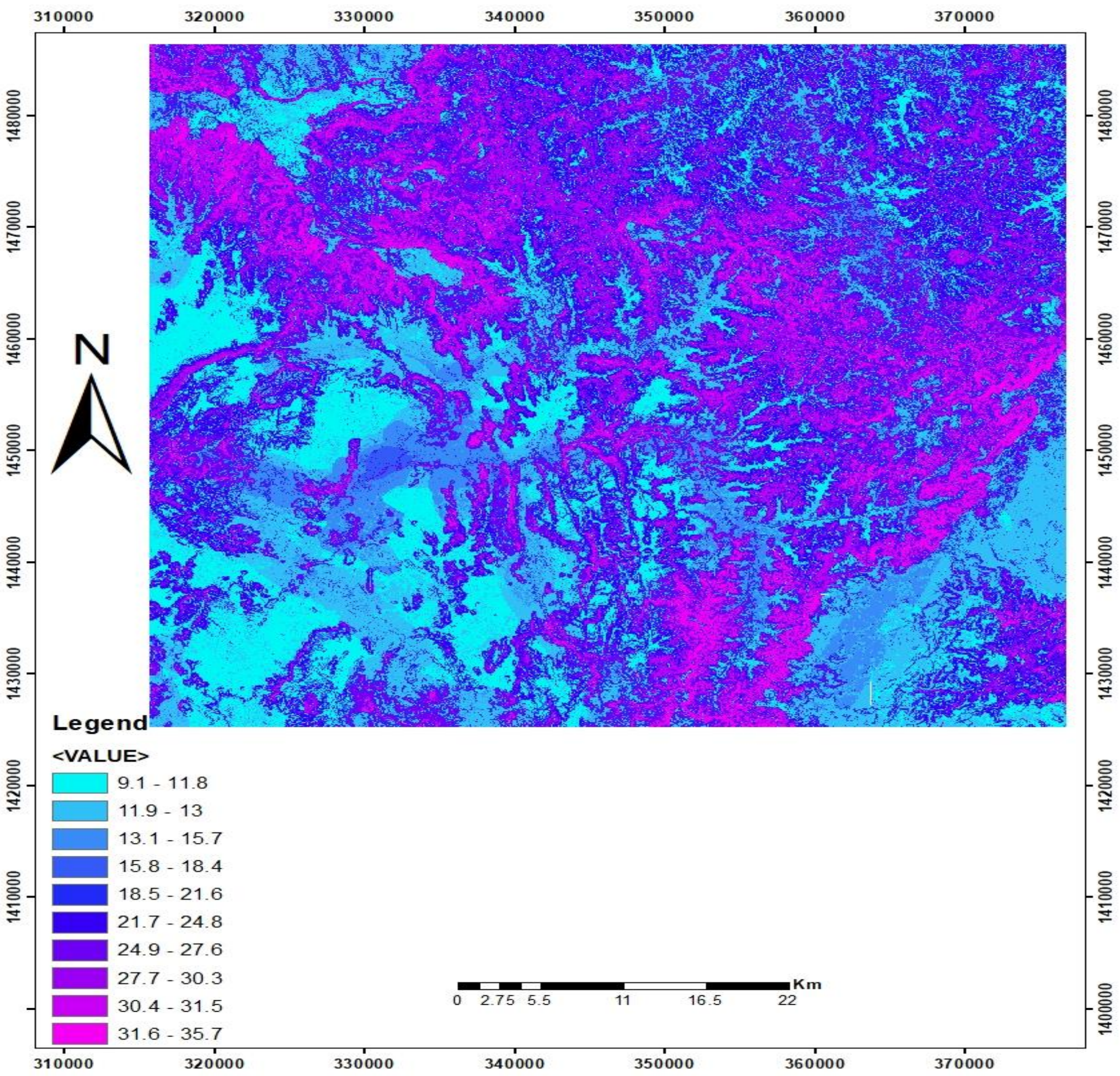

Figure 5.8: Weight overlay

5.10 Cost Distance

Using the weighted overlay layer and the source, the cost weighted distance function produces an output raster in which each cell is assigned a value that identifies the least accumulative cost distance over a cost surface to the identified source raster locations. Each cell in the cost-weighted raster was allocated a value representing the summation of the smallest travel cost that would acquire by traveling back to the nearest source raster. However, it does not tell how to get there (Suleiman et al, 2015).

In this research, the input layer for cost distance is the weighted overlay raster layer and the source point feature. The cost distance ranges from 0 to 1100.323, see Figure 5.10. The minimum values are the most favorable for travel or the least cost estimation. In addition, higher values are relatively not - comfortable or requires high travel cost.

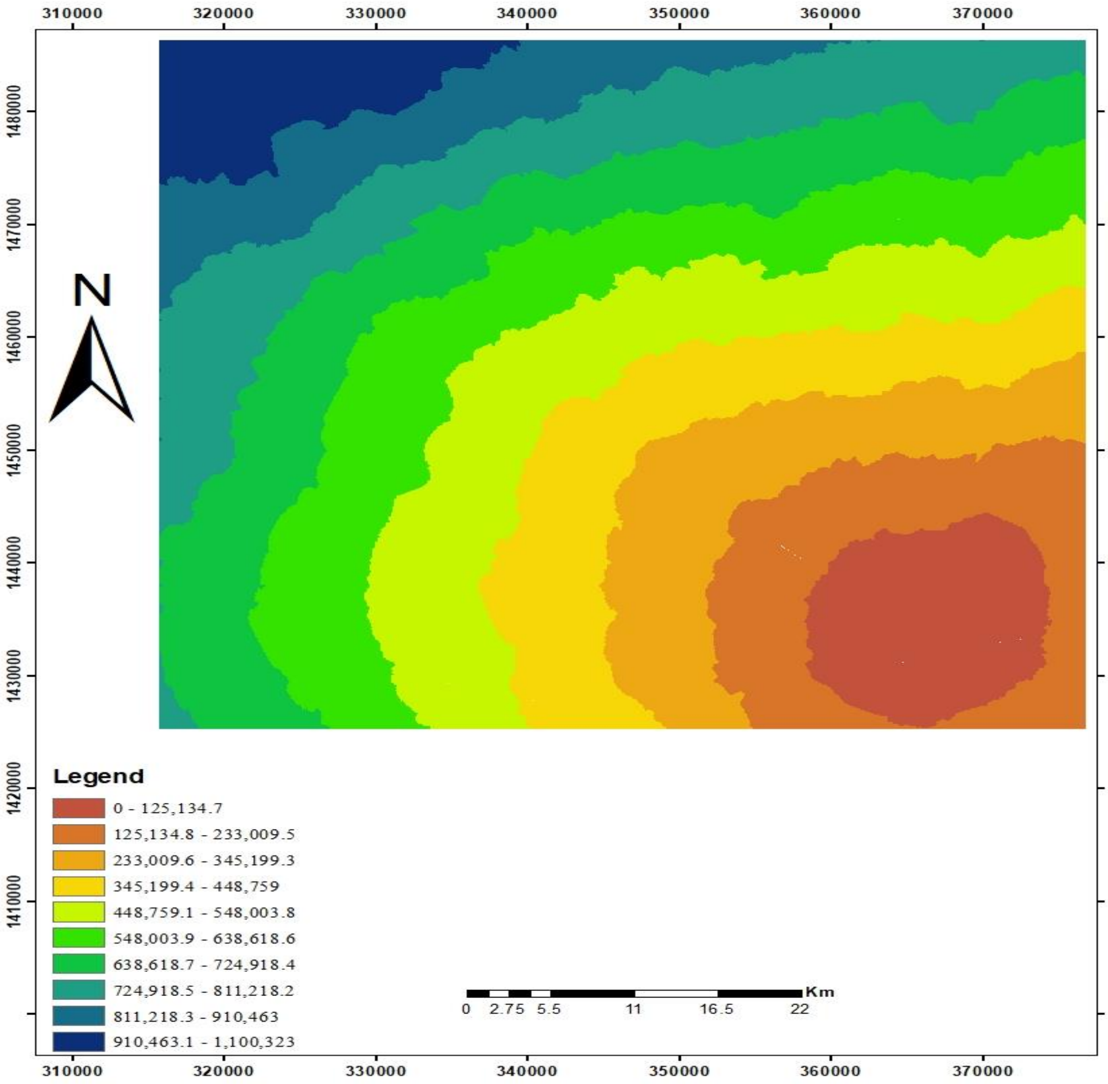

Figure 5.9: Cost distance

5.11 Cost Direction

In an attempt to create the cost weighted distance raster, another program is prompt which is the backlink raster this also makes use of cost raster and source feature. The direction raster provides a road map to identify the route to take from any cell, along with the cheapest path, back to the nearest source (Suleiman et al. 2015). The algorithm for calculating the direction of the raster to each cell to determine the code is identical to the neighboring cells is the best way back to the nearest integer numbered 0 to 8 (Figure 5.11).

The value zero is used to symbolize the source raster locations. The values from 1 through 8 encode the direction.

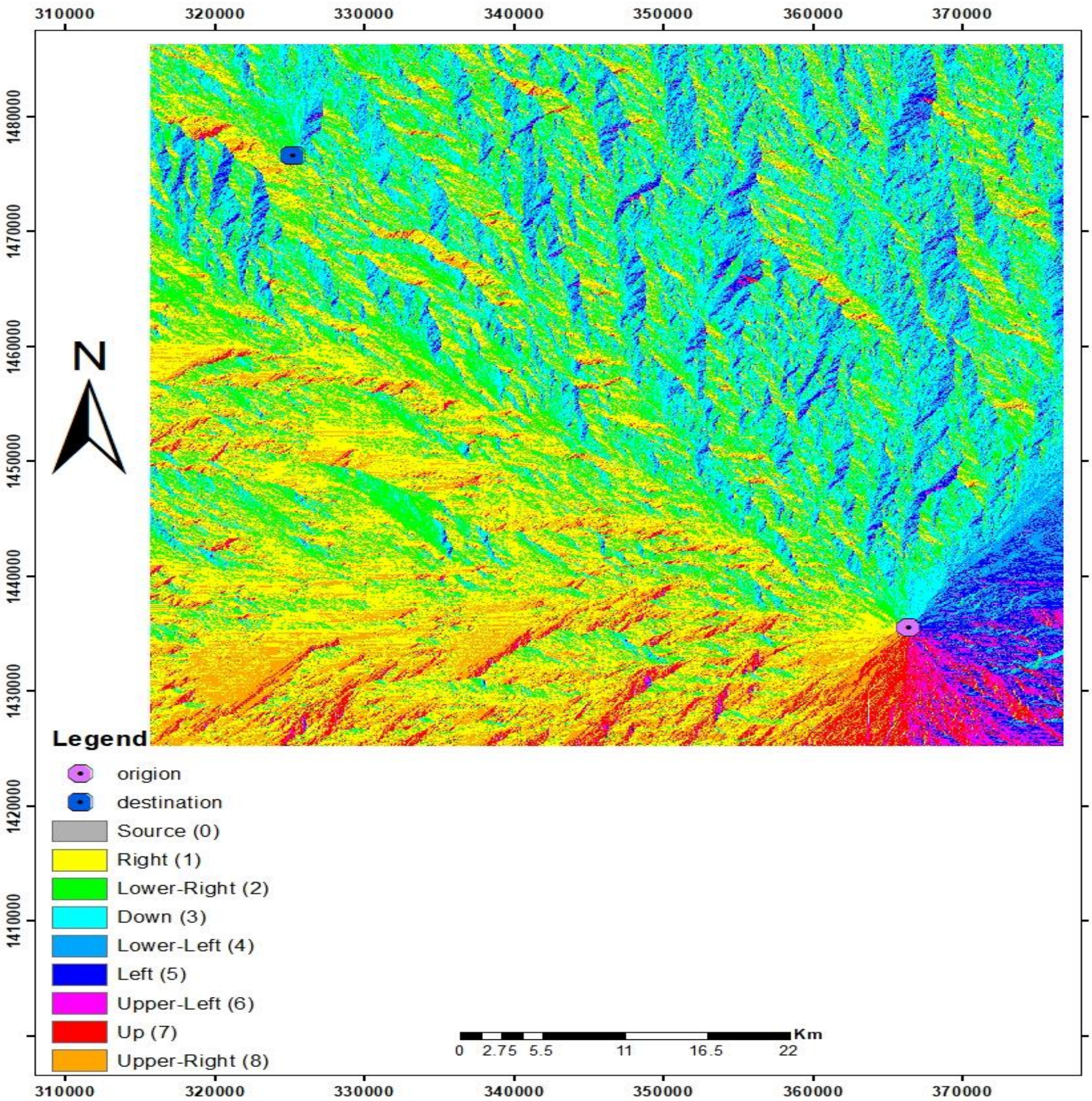

Figure 5.10: Cost backlink

5.12 Least Cost Path Analysis

The inputs of this step are Destination feature, Cost distance raster, and Backlink raster, after generating all these inputs, the cost path tool of the spatial analyst extension is used to generate the shortest path, which will have the least cost (suleiman et al, 2015). Here, generated the least cost path from the input data of destination feature, cost distance raster, and cost direction raster. The pass through the coding 0 to 4. The output of this result has

65km length, 1118-2831m elevation from mean sea level, 0-66° slope, do not cross the highest drainage density level. See Figure 5.12.

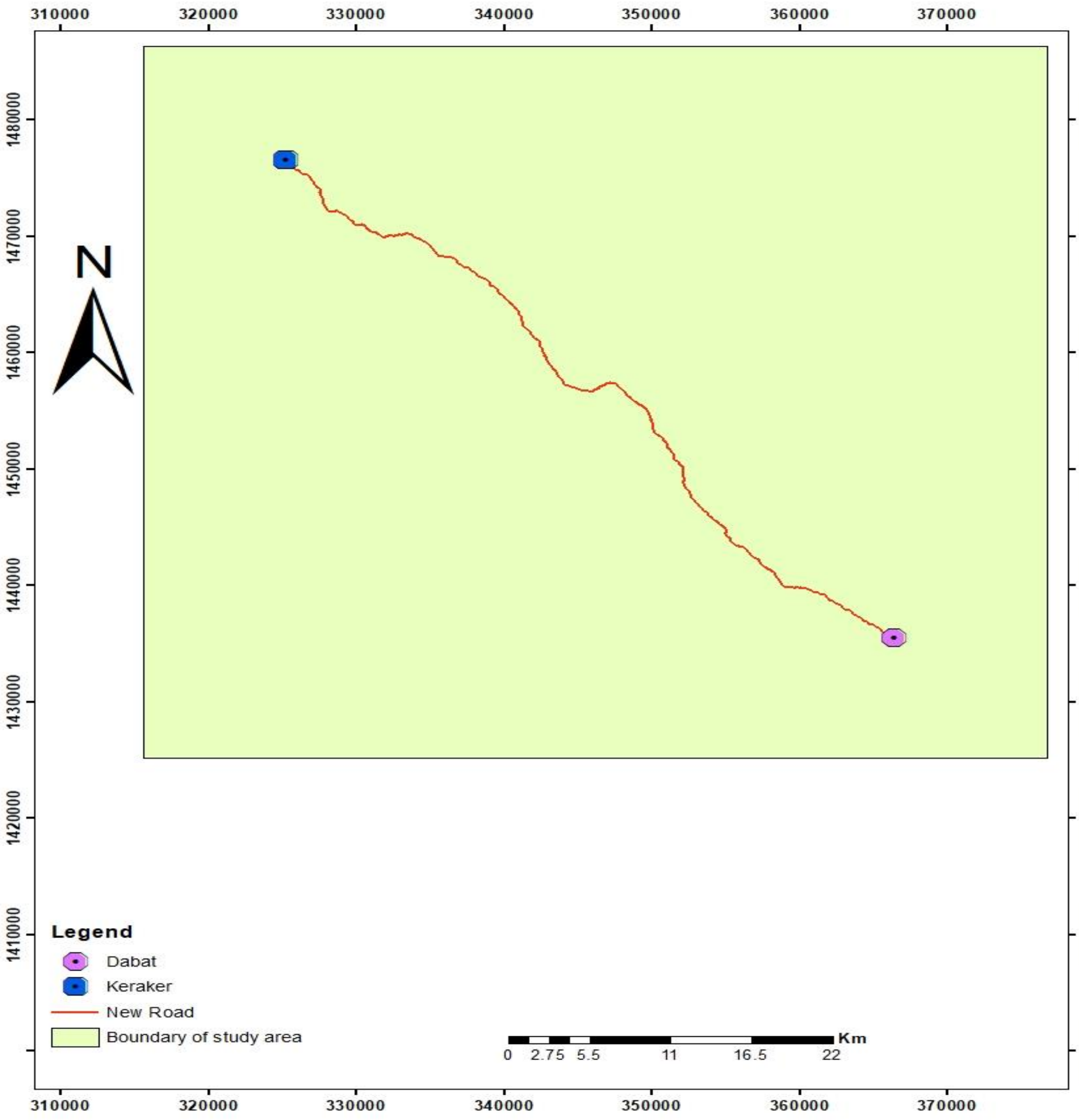

Figure 5.11: The result of the least-cost path route

5.13 Comparison of the existing road and proposed route

The proposed route generated by the multi-criteria approach implementing seven factors is compared to the existing old road alignment for the purpose of experimental validation (Figure 5.13). The result of the proposed route shows that it has the shortest length than the existed route, which is 65 km. In addition, it passes through the low elevation that varies from 1118m to 2831m above mean sea level. The new route alignment is characterized by slopes ranging between 0 to 73.33%. Most segments of the new alignment are characterized by rolling terrain (slope2.22% - 15.55% and 36 km) and flat terrain (slope 0 - 2.22% and 26.69 km length). While small portion of the new alignment is characterized by mountainous terrain (slope 15.55% - 41.1% and 2.17 km length) and escarpment terrain (slope 41.1% - 73.33% and 1.14 km length). The new route alignment segment that are characterized by larger slope values are, unsuitable for route selection due to the fact that it requires higher investment cost related to the earth work involving cut and fill.

Geometric analysis showed that the existing old road has a total length of 90 km. It also passes through low elevation varying from 1134m to 2833m. Overall, the existing road has wider ranges of slope (0 to 56.66%). In general, the road alignment is characterized by rolling terrain (slope: 2.22% – 15.55% and 62.53km length). On top of this, about 16.89km of the road is characterized flat terrain. While 9.98km road passes through mountainous terrain also some section of the road passes through escarpment (slope: 41.1% to 56.66%; 0.18 km). In most cases higher slopes are not economical for road construction.

Table 5.14: Comparison of the existed and proposed road

No	Proposed road slope(%)	Length (km)	Existing road slope (%)	Length (km)
1	0 – 2.22	26.69	0-2.22	16.89
2	2.22-15.55	36.0	2.22-15.55	62.52
3	15.55-41.1	2.17	15.55-41.1	9.98
4	41.1-66	0.14	41.1-56.66	0.18
Total		65		89.57

Therefore, the proposed route is relatively least cost than the existed route. Because the new alignment has the shortest route as well as characterized by flat and rolling terrain. The shortest path reduces fuel consumption, time, saving as well as minimize construction cost. On the other hand, the route passes though on the other six factors such as Land use land cover, soil texture, geology, fault, and drainage, certainly suitable both the two (proposed route and existed road).

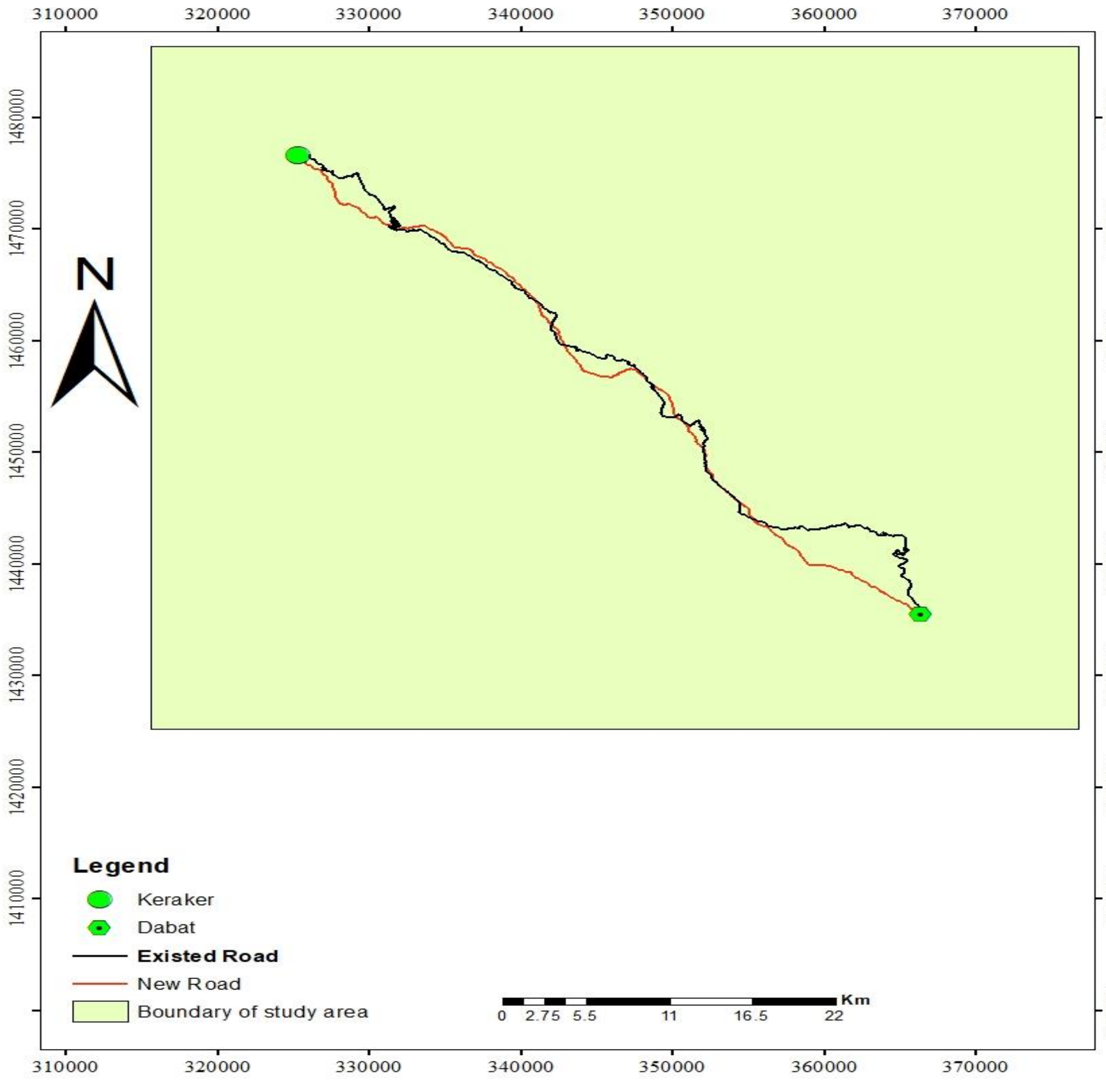

Figure 5.12: The existed road and proposed road display on the slope

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

GIS-based route planning a determination of least cost route within the route corridor in order to select the preferred route by using a multi-criteria approach. In this study, a least cost route is determined along the geographic corridor connecting Dabat and Keraker towns. Route planning highly depends on the importance level of factors governing the selection of appropriate route that maximize the socio- economic benefits while minimizing the physical distance between the origin and destination. In practice, each factor affecting the route selection will be assigned an optimal value (weight) on basis of the above condition. Each layer is reclassified to make an easy way to special analysis.

The weighted overlay (thematic cost map) indicating the net effect of all factors governing the selection of the best route should to statistically vary between 9.16 and 35.7. Lower values indicate suitable pixel sites for route planning, whereas higher values indicate relatively unsuitable or less favorable sites.

The new route alignment has a length of 65 km. this new route is by far shortest compared to the existing road (90 km in length). It is concluded that the multi criteria overlay is proved to be well suited method for best route selection.

6.2 Recommendations

This study didn’t use potential tourist sites as a factor to determine the least cost route due to lack of information. However, it is highly recommended to use information related to tourist site while planning new road alignments.

It highly recommended to use rural household cadastral map for the route selection in order to maximize the socio – economic benefits of the local residents while minimizing the physical length of the new route.

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