

DEVELOPING OPTIMAL ROAD ALIGNMENT USING GEOSPATIAL TECHNOLOGIES: CASE OF GINCHI TO CHULLUTE OF WEST SHOA ZONE, OROMIA REGION



ASTER CHALCHISA EGGI

A Thesis Submitted to

The Department of Geomatics Engineering

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in
Geo-informatics Engineering

Office of Graduate Studies

Adama Science and Technology University

July, 2021

Adama, Ethiopia

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APPROVAL SHEET

We, the advisors of the thesis entitled “Developing Optimal Road Alignment Using Geospatial Technologies: Case of Ginchi to Chullute” and developed by Aster Chalchisa, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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DECLARATION

I hereby declare that this Master Thesis entitled “Developing Optimal Road Alignment Using Geospatial Technologies: Case of Ginchi to Chullute of West Shoa Zone, Oromia Region” is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation

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RECOMMENDATION

We, the advisor(s) of this thesis, hereby certify that we have read the revised version of the thesis entitled “Developing Optimal Road Alignment Using Geospatial Technologies: Case of Ginchi to Chullute of West Shoa Zone, Oromia Region” prepared under our guidance by Aster Chalchisa submitted in partial fulfillment of the requirements for the degree of Master’s of Science in Geo-informatics Engineering. Therefore, we recommend the submission of revised version of the thesis to the department following the applicable procedures.

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LIST OF ACRONYMY AND ABBRIVATIONS

AHP	Analytical Hierarchy Process
AI	Artificial Inelegancy
ANP	Analytical Network Process
ALOS	Advanced Land Observation Satellite
AOI	Area of Interest
ASTER	Advanced Space Borne Thermal Emission and Reflection Radiometer
AUC	Area under the Curve
CI	Consistency Index
CR	Consistency Ratio
CV	Consistency Vector
CSA	Central Statistical Agency
DEM	Digital Elevation Model
EIA	Environmental Impact Assessment
ERA	Ethiopian Road Authority
FAO	Food and Agriculture Organization
FR	Frequency Ratio
GA	Genetic Algorithm
GIS	Geographic Information System
GPS	Globally Positioning System
LCPA	Least Cos Path Analysis
LCP	Least Cost Path
LSI	Land Slide Suspect ability Index
PALSAR	Phased Array Type L-band Synthesis Aperture Radar
RS	Remote Sensing
ROC	Receiver Operating Characteristics
SMCDM	Spatial Multi-Criteria Decision Making
SRTM	Shuttle Radar Topography Mission
USGS	United State Geological Surveying

ABSTRACT

Route selection is a critical first step in the process of design and construction of a road. Especially, route planning analysis using geospatial technology provides strong decision support in searching for optimal routes. Even though optimal route selection has been the focus of several studies, only a few efforts have been made on optimal route selection in a landslide-prone area using geospatial technology, in Ethiopia. Therefore, this study aims to develop optimal road alignment connecting Ginchi to Chullute using geospatial technology. The study employed Sentinel 2A satellite image, ALOS DEM, geological map, population data, SPOT 5, and intensive field visit to drive the major factors for optimal road alignment. Analytical Hierarchy Process (AHP) multi-criteria decision-making was used to drive the weight for the factor. Thematic maps were prepared for four cost surfaces by using weight overlay in spatial analyst tools. Four cost surfaces generated from engineering, environmental, landslide, and hybrid factors were used for modeling alternate least-cost paths. The engineering cost surface was generated from five major factors; namely, slope, stream order, lithology, lineament, and soil. AHP was used to drive weight based on importance, and cost surface was generated by using weight overlay. Likewise, the environmental cost surface was generated from three major factors, LULC, slope, and proximity to the river, and the cost surface was generated by the same procedure with engineering one. The landslide cost surface was generated by using the frequency ratio method and the results were validated by using receiver operating characteristics (ROC) and Area under the curve (AUC). The result shows an AUC of 0.756, which indicated that the model has very good performance. The hybrid cost surface was generated by an equal weight of all the three generated cost surfaces. The least-cost path function in spatial analyst tools was used for modeling the most economical path. The first cost distance and cost backlink were created by using cost surface and origin (Ginchi). Afterward, cost paths were generated by using destination (Chullute), cost distance and cost backlink has been used as input for modeling the least-cost path. The generated least-cost path has been optimized by using integrated criteria of engineering, environmental, and social perspectives. The hybrid least-cost path was found to be the optimal route connecting Ginchi to chullute as it had overall advantages over the others. Besides, the selected and the remaining modeled least-cost paths were more feasible than the existing routes. The existing route is 122 km long and the proposed route is only 103.46 km. Moreover, the existing road is prone to landslides; however, the proposed route is relatively free from the landslide. The environmental, engineering and landslide-based setups (104.3, 105, and 98.3 km long, respectively) were also more feasible and less susceptible to landslide compared with the existing road. Therefore the study concludes that using integrated geospatial tools in route planning is useful. It is therefore recommended to include the technology as a planning tool for analysis of transportation and other linear structures, such as drainage, pipeline, and railway.

Keywords: Analytical hierarchy process (AHP), Geospatial technology, landslide, least-cost path analysis (LCPA), optimal road alignment,

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

A road can be defined as the passageway connecting two different locations within a spatial context (Muriki and Kari, 2019). The position or the plan of the centerline of the road on the ground is called alignment. Road alignment is the task associated with new as well as existing roads. It is an essential part of the road planning and design phase, which has significant effects on the surroundings (Zhao et al., 2019).

Road projects bring the economic and environmental change. It has both negative and positive impacts on the environment. On the positive side, roads provide the opportunity for mobility and transport for people and goods. Roads, on the other hand, deplete land resources and create barriers for animals. Effective route selection process is very important for minimizing economic cost(Ahmed and Asmael 2015). Therefore, critical analysis has been necessary while, planning the road.

Over the years, engineers and road planners have struggled to find the most efficient route between two locations (Muriki and Kari, 2019). The problem is arisen due to unskilled professionals, the absence of appropriate data, and the lack of a proper method. Identifying optimal routes while using traditional methods requires significant time, cost, and effort since it requires a comprehensive assessment of multiple factors, such as cost and environmental impacts (Zhao and Mbachu, 2019)

Now a day, the problem can be resolved effectively using Geospatial technologies and during the last decade, a few challenges have been made to automate the route planning process. The least-cost path analysis (LCPA) is a mainly important GIS-based spatial analysis approach to this purpose. Constructing a new road or railway, or aligning an old one can be very expensive, with costs depending on the alignment selected. Cost can be a function of time, distance, or other criteria such as forest land, water bodies, constructed structures, and hilly areas (Prakash et al., 2015). Costs are increased by long structures, by large volumes of cut and fill, and by unbalanced cut and fill where irregularity has to be dumped or borrowed. Based on terrain, socioeconomic variables, and environmental concerns, the basic highway design problem is to establish the best cost-effective alignment connecting two given

endpoints while satisfying a set of design and operating constraints (Suleiman et al., 2015). The first step in producing high-quality alignments depends on obtaining reliable data on geology, land use, slope, soil, and drainage. In addition, there are issues such as land value and ownership (Subramani and Pari, 2015).

Ethiopian Road Authority implements the choice of highway alignment mostly based on the topography of the land. Historical, economical, and geological data are not adequately considered. Sometimes these issues are considered visually based on the insight of the individual who does the reconnaissance on the selected route, environmental and social impacts are often neglected (Fiseha, 2005).

Physical elements of the area, such as terrain, ground conditions, and neighboring land use, are the most significant factors to be considered while choosing the optimal routes (Prakash, 2019). This requires a proper understanding of different aspects related to the environment it also requires a detailed analysis of the site characteristics on the area such as existing dry and perennial streams, river configuration, surface soil conditions, geology, physiographic conditions, groundwater, land use/ land cover and particularly the slope condition (Guo et al., 2020).

Landslide is one of the essential factors to be considered while route alignment selection. As many researchers explorer study-related road alignment selections using geospatial but no more study was carried out concerning optimal route selection along the road prone to landslide area. Though Early recognition of landslides and related slope instability enables decisions to be made regarding avoidance, reduction, or elimination of hazard (ERA, 2013), but , many efforts not invested in such kinds of issue.

In fact, the absence of systematic investigation and proper scientific approaches may lead to more time-consuming and expensive to overcome the problem. Moreover, the degree of complexities may rise to serious if the issues related to the environment, society, and cultures are not properly addressed in the public domain. However, with the development of geospatial technology in the last few decades, the alignment/realignment design of a new route and/or an old road in any area has grown easier and more realistic in resolving these challenges. Therefore, Least Cost Path Analysis (LCPA) would help to investigate effective routes.

However, geospatial technology enables the consultants to handle all factors including social, environmental, engineering, and obtain the feasible route over the study area. In Ethiopia Route option identification is usually commenced by consultants on behalf of the Ethiopian Road Authority and should take into account avoidance of environmentally protected areas and other sensitive habitats (ERA, 2016). However, all EIA reports show that all the damage is passed simply by compensation and rehabilitation agreements.

Dagnew, (2020), explored the socioeconomic impact of the corridor from Ginchi to Kachis, which is one segment of the road under study. The researcher concluded the road has a significant impact on the income of study area stakeholders, but the road has a geo-hazard problem which prevents the proper flows of goods and service. But no more study was carried out to solve the problem.

Hence, this study designed the methodology to develop optimal route from Ginchi to Chullute by integrating criteria set from engineering, environmental and social point of view by using integrated geospatial tools.

1.2 Statement of the Problem

Road projects typically involve both environmental and economic issues facing a community as it grows and changes (Wahdan et.al, 2020). Selecting the most appropriate road alignment is useful to reduce, construction costs, an accident occurred due to geometric alignment and traffic volume, and the environmental impact of the road on the surroundings. Effective route selection process is very important for minimizing economic cost, (Ahmed and Asmael, 2015). The road alignment process is a complicated one, due to the many variables that must be taken into consideration for achieving the best results. Geospatial technology can be a powerful tool to handle different variables.

From Ethiopia's regional roads, two-thirds of which are virtually impassable imposes significant penalties on agricultural activity through its effect on vehicle operating costs, delayed evacuation, and damage to land use (ERA, 2013). As a result, the cost to the economy has become enormous first; the problem is occurred due to poor alignment and less environmental consideration for factors that affect the alignment of the road. Secondly, the conventional way of Environmental Impact Assessment (EIA) for road alignment is a time-

consuming process because it has a large number of dependent and independent variables which have to be taken into account, which also have different significances. Thirdly, route selection through the use of remote sensing and GIS geoprocessing, although a traditional approach of aerial photo interpretation is used, has not been a common practice in Ethiopia. The reason being an insufficient appreciation of the technique as it is relatively new and recently introduced technology in the country and a lack of skilled professionals in the discipline (Arega and Belaw, 2014). So the mitigation measures should be taken for this issue.

On the other hand, the landslide is one of the major problems throughout route alignment selection. Effective route planning, capable of avoiding landslide-prone locations and embracing engineering design and other geological elements in terms of slope stability and safety, is greatly compulsory (Padmani and Sudath, 2016). Therefore, it needs a critical assessment of landslides throughout route alignment selection.

Numerous studies relevant to landslides susceptibility assessment can be found in the field of GIS (Geographical Information System) and RS (Remote Sensing) for example (Wubalem, 2021; Getachaw and Meten, 2021; Hearn and Hart, 2019; Hamza and Raghuvanshi, 2017). However, Studies related to road construction combining with GIS and RS in the landslide-prone area were limited in the country. This situation is the same for worldwide studies.

However, Ginchi to Chullute is one of the roads prone to landslides but there was no study carried out to find optimal route alignment-free from the landslide using geospatial technology. Dagnew, (2020) documented that route is gravel-surfaced and with numerous curves and passes through difficult topography. It is five percent in good condition, 35 percent in fair condition, and 60 percent in bad condition. There are no drainage canals along the whole route which results in unmanaged floods that contribute to wear and tear the study road very sloppy and full of curves (Dagnew, 2020). In this year the part of segment from Ginchi to shukute where upgraded to the asphalt and the segment from shukute to Chullute were under construction. However, only roadway upgrading was done without the alignment revision because of this the construction of segment take more than the contract period without starting actual road construction for the segment from shukute to chullute. one of the reason for these problem is the segment was in steep topography and hard lithology type for crushing and the problem of inspected landslide (Beyene, 2021)

ERA, technical experts and engineers inspect landslide affected- and instability-prone segments of the route corridor. Accordingly, about fourteen segments of the route corridor that are either affected by slides and/or prone to instabilities were inspected with minimum and maximum aerial coverage of about 60 and 600 m, respectively(ERA,2020). However, there was no study conducted for the problem. Geospatial tools handle all landslide governing factors and avoid the landslide-prone area and are used to investigate more stable corridors before actual road construction started. However, no, more study was carried out for this corridor and else ever in our country using geospatial technology. Therefore, it needs to find the most passage ways to reduce the problem. Consequently, the study aims to find the optimal route using integrated geospatial technology.

1.3 Research Objectives

1.3.1 General objective

The main objective of this study was to develop optimal road alignment that connects Ginchi to Chullute using geospatial technology.

1.3.2 Specific objectives

- To identify the factors affecting optimum road alignment.
- To model alternative road alignments from Ginchi to Chulute.
- To propose optimal road alignment from the alternative models.
- To verify the feasibility of an optimal route over an existing road.

1.4 Research Questions

The conducted research tried to answer the following questions.

1. What are different factors that contribute to select optimal routes?
2. What are a different alternative road alignment that connects Ginchi to Chullute?
3. Which route was the optimal route?
4. Is the proposed route is feasible over existing routes?

1.5 Significance of the Study

Route selection is a critical first step in the process of design and construction and has the potential to significantly impacting the construction cost and environment of the area(Ahmed and Asmael, 2015). In planning highways, engineers gather information about the terrain

types of the area, ground conditions, and possible adverse environmental impacts (Isah , 2008). Effective route selection process is very important for minimizing economic cost(Ahmed and Asmael 2015). Route planning analysis in Geographical Information System (GIS) provides strong decision support for users in searching for the optimal route. Therefore this study finding is expected to have the following significances to city/ rural road planer, Policymakers, designers, and stakeholder through providing the following:

- For road designers to know geospatial tools environmentally friendly tools for optimal route selection (Tae-Ho et al., 2008; Ahmed and Asmael 2015)
- for urban/rural planners to know how and which parameters affect environmental, engineering, and social were affect the road alignment(Fekerete and muse, 2014; Soycan, 2012).
- for engineers and high way designers to provide scientific techniques to select the route alignment around the landslide-prone area (Padmani and Sudath, 2016)
- For EIA experts providing scientific-based information for the development of environmental impact assessment of road alignment using geospatial tools to reduce disturbance of biomass.
- For policymakers provide scientific-based information to develop the strategic policy for optimum route selection (Asmael and Alkawaaz, 2015)
- For study area beneficiaries reduce the cost of transportation, travel time, and accident. (Muriki and Kari, 2019)

1.6 Scope of Study

This study is geographically bounded in the Ethiopia Oromia region in the west shoa zone the road traverse seven woredas. The content scope of this study was selecting the optimal routes for the road that connects Ginchi to chullute. The optimal route was selected by using geospatial tools. The remote sensing data were used for the extraction of the different factors used for optimal route selection. The GIS tools are used to analysis, and mapping of thematic layers for factor affect the route alignment. The least _cost path analysis is used to define the least cost routes and AHP spatial multi-criteria evaluations are used to derive weight for the factor and compare the defined routes and select the optimal routes.

1.7 Limitation of the Study

Bureaucracy and limited access to get data from different governmental organizations were the major limitations to get of population density up to the Keble level within the study area. The other is Lack of clear, standards for factors affecting the route alignment planning in the country. Absence of accurate rainfall data for research works. And unavailable high-resolution satellite image also limits the quality of the landslide inventory map. Furthermore, absence free automatic landslide susceptibility assessment (ALSA) extension in Arc GIS spatial extension tools for automatic landslide susceptibility assessment for landslide susceptibility mapping is the other limitation.

1.8 Organization of the Thesis

This study is organized into five chapters. The first chapter elaborates the background of the study, statement of the problem, general and specific objectives, significance, limitation, and scope of the study. The next section, chapter two, focuses on a theoretical and conceptual framework of literature review and related work for this study. The third chapter focuses on the general methodology followed, the data sets used in this study, and a detailed explanation of the study area. This chapter argues all the procedures and techniques applied for optimal route selection. The fourth chapter deals with the results and discussion which presents the quantified results for optimum route alignment. The last chapter presents conclusions and recommendations this chapter elaborates the key findings and critical points that need further treatment has been forwarded as a recommendation for future work and beneficiary.

CHAPTER TWO: LITERATURE REVIEW

2. General Overview

Transport is a key contributor to economic growth, prosperity, and societal well-being. The main task in road planning is to select an optimal alignment. This process is huge since it requires a comprehensive assessment of multiple factors, such as cost and environmental impact. Efficient roads are increasingly vital in facilitating the smooth flow of goods and services to people living in remote communities. Once highway alignment has been settled, other critical aspects and related costs, such as construction costs and user costs, are largely determined (Zhao and Mbachu, 2019). To obtain an optimum highway route alignment that is economical, suitable, and compatible with the environment, various types of data have to be considered simultaneously (Uleiman et al., 2015). For stable and economic societal advantages, relevant data such as topography, soil qualities, geology, and land use are integrated and assessed (Tae-Ho et al., 2008). Up-to-date and accurate information on the land use land cover topography and road network is of vital importance (Thanh, 2010 ; Arega and Belaw, 2014 ; Asmael and Alkawaz , 2015 ; Subamarani and Pari , 2015). Satellite remote sensing data is usually the most accurate and timely “map” available (Pieczynski , 2003). Remote sensing data and techniques and geographic information systems (GIS) provide efficient methods for the analysis of land use issues and tools for land use planning and modeling (MMS, 2016). The cost-effective and less environmental impact highway projects can be defined with Analytical Hierarchy Process (AHP). Likewise, the least-cost path analysis (LCPA) algorithm is used to define the alternative route for highways. The integration of geospatial technologies supports a methodology for evaluating the spatial compatibility or physical development along highway corridors (Tian et al., 2013).

Ethiopian Road Authority's 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, 2014). Although promising investments and positive outputs are registered in Ethiopia, what is striking is that how these infrastructure investment development efforts impact spatially and temporally upon society is under the

question of how is the state of quality of the roads constructed. What are the quantifiable socioeconomic changes that road development brought to bear on households in the study area? The cases of such large projects, i.e. road Corridors, have not yet been analyzed from a scientific point of view (Dagneu, 2020). Therefore, the study aimed to find the optimal routes by integrating engineering, environmental and social factors by using geospatial tools.

2.1 Route Alignment Selection Practice in Ethiopia

Route selection is a problematic planning process that involves the concern, analysis, and evaluation of socio-economic, engineering/technical, and environmental impacts of different alternatives (Arega and Belaw, 2007). The parameters which should be considered during route selection includes; the approximate construction costs, alignment and profile studies, typical section development, preliminary designs for geometric layout, drainage, right-of-way and utilities, location of interchanges, grade separations and intersections, preliminary bridge designs at critical locations, hazard evaluations, and other supplemental studies. The identification of the nodal points, that is the start and endpoints of the route to be studied are determined for political, economic, or social values through a letter from the regional administration (Shiferaw.et.al, 2012).

Ethiopian Roads Authority (ERA) usually marks the points on a small-scale road map and continues the conventional method of manual route selection process based on the request. Mostly the recommendation is posted from either a local consultant. The choice of a feasible corridor of a new highway is mostly based on the topography of the land. Economic and geological data are often not adequately considered and sometimes considered visually based on the perception of the individual who does the reconnaissance on the selected route. The Ethiopian Road Authority applies different criteria for the preliminary selection of new road projects that are proposed by regional states. As would be expected, priority in road placement is given to areas with high economic potential and surplus food production. ERA also takes into account population distribution as well as regional equity in economic development. Road projects that pass the preliminary selection will go through feasibility studies which would help ERA refine its selection of projects and the proposed budget.

Despite having a set of criteria for road placement, it is not clear what specific variables ERA uses to operational them. For instance, it is not clear how exactly the economic potentials of

different geographic locations are assessed or how regional inequality in economic development is evaluated (Shiferaw.et.al, 2012). There is also a lack of clarity about the process and criteria by which regional states prioritize their road projects before they submit to ERA (Shiferaw et al., 2012). Road infrastructural planning is concerned with preparing and supporting decisions about the development of the road network system in the country. The development of road transport in a nation has several issues either related to the economic point of view or opening access to the most remote areas. According to the Ethiopian Roads Authority (ERA) route selection manual, the engineering, environmental and economic parameters are given due attention. Integrated geospatial technology for preliminary route alignment selection where explanatory stage in the country(Arega and Belaw, 2014). Therefore, it should be improved.

2.2 Role of Geospatial Technology for Optimal Route Selection

2.2.1 What are geospatial technologies

Geospatial technology is a term used to describe the range of tools contributing to the geographic mapping and analysis of the Earth and human societies. It is an emerging field of study that includes Geographic Information System (GIS), Remote Sensing (RS), and Global Positioning System (GPS). Geospatial technology enables us to acquire data that is referenced to the earth and use it for analysis, modeling, simulations, and visualization. Geospatial technology allows us to make informed decisions based on the importance and priority of resources most of which are limited in nature. Geospatial technology may be used to create intelligent maps and models that may be interactively queried to get the desired results in other technology. Technology is related to the collection or processing of data that is associated with a location. These specialized information systems should adapt standardized modern technical and technological solutions arising from the operational requirements of their functionality. An integrated approach of geospatial technologies such as GPS data, remote sensing imagery, aerial photographs, Google Earth and GIS is valuable in the development of modern Geoformation.

The most known geospatial technologies are:

Remote Sensing is the process of detecting and monitoring the physical characteristics of an area by measuring it is reflected and emitted radiation at a distance (typically from satellite or

aircraft). Special cameras collect remotely sensed images, which help researchers to get up-to-date and historical-geographical information.

Geographic Information Systems (GIS): is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. It can be used as a tool in both problem solving and decision making processes, as well as for visualization of data in a spatial environment. can be used to analyze to determine (1) the location of features and relationships to other features, (2) where the most and/or least of some feature exists, (3) the density of features in a given space, (4) what is happening inside an area of interest (AOI), (5) what is happening nearby some feature or phenomenon, and (6) and how a specific area has changed over time (and in what way).

Global Positioning System (GPS): GPS is a satellite navigation system used to determine the ground position of an object.

Internet Mapping Technologies: software programs like Google Earth and web features like Microsoft Virtual Earth are changing the way geospatial data is viewed and shared. The developments in a user interface are also making such technologies available to a wider audience whereas traditional GIS have been reserved for specialists and those who invest time in learning complex software programs. Thus, using integrated geospatial tools is better for reliable results.

2.2.2 The role of geospatial technology for optimum route selection

RS and GIS techniques are becoming irreplaceable tools for resolving several issues associated with geoformation. RS observations provide data on Earth resources in spatial form, where geographic information systems link different types of spatial data and their characteristics data for use in various areas of geoformation related projects. GIS tool was used to manage and analyses network-based spatial data to solve routing problems including point-to-point routing and time-based delivery problems considering various spatial attributes. Following major steps have been adopted to solve the problems(Mawjoud and Jamel, 2016). Route planning analysis in Geographical Information System (GIS) provides a strong decision facility for users in examining optimal routes, finding the optimal path is an important advanced analysis function in GIS.

Various studies show the use of some of the geospatial technology in route planning some of the studies are Rajaduiry and Jonny, (2015) Use Geographic Information System (GIS) techniques, by applying the Least Cost Path Analysis method to achieve viable results that were useful in determining a feasible road corridor. The route analysis parameters contained different weighted overlay surfaces; each surface is influenced by various criteria (slope, geology, population, and land use-land cover). The least-cost route was then calculated based on the weighted overlay of each criterion. The study concluded GIS least-cost path analysis as a reliable tool for finding the least-cost path which is economical. The least-cost path analysis (LCPA) can reduce the overall cost of road construction and minimize the negative impacts of such projects on both the macro and microenvironments. It has long been known that remote sensing plays a vital role and have got a wide range of applications in transport planning and geotechnical investigations(Arega and Belaw, 2014).some of the researcher used remote sensing data for route planning are (Thanh, 2010 ; Arega and Belaw ,2014 ; Asmael and Alkawaz , 2015 ; Subamarani and Pari , 2015). Furthermore, google earth and global positioning system are playing a significant role in route planning. Google Earth uses as a reference for different remote sensing data, it uses as visual interpretation tools for LULC classification, also three-dimensional visualization of modeled routes. GPS uses for ground point collection for verification and georeferencing of a different map for route planning. Also for route tracking. Therefore, this study used the geospatial tools for route alignment selection in which DEM, geological map soil, and population density map, are parameters used for route alignment selection. Since Geospatial technology consists of tools and applications easily handle and analyze such kinds of data easily.

2.2.3 Local applications of geospatial technology in highway route planning

There are a limited number of studies regarding the use of GIS in transportation planning in Ethiopia. The one which can be mentioned as a pioneer study on the application of GIS and Remote Sensing on highway route selection was done by (Arega and Belaw, 2007)). The objective of the study was to introduce the application of remote sensing datasets and utilization of GIS geoprocessing techniques to highway route selection and present the resulting routes of a GIS analysis based on available data. Various engineering factors, as well as environmental constraints that influence the cost of construction, economic benefits,

environmental compatibility, and future viability of the proposed road project, were considered in the route selection analysis. Among the engineering constraints are the length of the road, slope/gradient of the terrain, water bodies (wetlands, rivers, streams, and lakes), soil types, lithology & geologic structures (faults, lineaments, and escarpments). The environmental constraints are land use/land cover which includes settlement areas (cities/towns/villages), distance from existing roads and railways, and other constraints, etc. Finally, the researchers selected two optimum alternate route alignments between Addis Ababa and Nazareth using different parameters and weights per their expected influence. The study showed the potential worth of applying geospatial technologies in highway route selections, particularly in reducing time, effort in the field, and hence cost of the reconnaissance stage. In addition, the method provides decision-makers with better quality of information and an opportunity to examine & evaluate various constraints cumulatively and interactively.

The other study was done by Fiseha, (2005) the researcher explored and evaluated the potential use of GIS, in the current practice of route alignment planning in the Ethiopian Roads Authority in comparison to the scientific and technological approach. The researcher found that problems are encountered on some of the started projects to which the manual method of route alignment planning has been deployed. The study underpinned most of the problem was derived from the lack of a modernized tool to visualize the consequence of the selected route. To reduce this and similar problems it recommended the authority to establish the technological input of GIS in ERA and adopt an integrated spatial decision-making approach for route alignment selection within the GIS framework.

Likewise, Derbachew, (2015) explored GIS-based route alignment selection between Hmuse to Estie road the main objectives of this study was to explore the potential application of GIS for route alignment selection and the researcher concluded GIS as a very important and efficient tool for road alignment selection and other engineering location to reduce the quantity of Engineering, environmental and social impacts and optimizing different linear and others infrastructures. However, no more study was carried out considering landslide-prone areas by using geospatial technology. Nevertheless, it needs more critical consideration as it affects the maintenance cost and safety of the road.

2.3 Road Alignment Optimization

Optimizing highway alignments is a complex combinatorial problem that finds the best alternatives (usually the most economical path) of a new highway connecting specified points or locations (Kang and Schonfeld, 2012).

Since 1970, many researchers have focused on how to simplify and support engineers in the highway alignment definition. After many preliminary attempts employing several traditional analytical methods were developed (Bosurgi et al., 2017). The road alignment design problem is traditionally a very complicated task in infrastructure engineering, due to the several and heterogeneous skills required to the engineers for the analysis (Bongiorno et al., 2019). Since traditional approaches are too slow and error-prone, in recent years many efforts have been made for developing original tools and algorithms that can support the designers in these tasks. The alignment optimization problem is normally formulated as a minimization problem, and its objective functions and constraints are non-differentiable, noisy, unsmooth, and implicit. Theoretically, there may be an infinite number of alternatives to be evaluated.

In previous decades the main results have been obtained using AI (artificial intelligence techniques (in particular, using GA and one SI approach, i.e. the PSO method – Particle Swarm Optimization method). Both GA and PSO represent iterative evolutionary approaches and start from some random initial solutions that, after each cycle, are improved and corrected to minimize specific cost functions and observe several constraints. Their main differences concern the analytical methods adopted for modifying and optimizing the various solutions (Bongiorno et al., 2019). Theoretically, there may be an infinite number of alternatives to be evaluated. Many mathematical models have been developed either for optimizing horizontal alignments or vertical alignments or for three-dimensional (3D) alignments (i.e., optimizing both horizontal and vertical alignments). These are the calculus of variations, network optimization; dynamic programming, enumeration, linear programming, Numerical search, distance transformation, neighborhood search heuristic with mixed-integer programming (MIP), and genetic algorithms (GAs) are the method for optimum route alignment selection the main target the methods and their limitation is shown in Table 2.1.

Table 2.1: A review of road optimization methods

Target for Optimizing	Optimization Approach	References
Horizontal alignment only	Calculus of variation Network optimization Dynamic programming Mixed-integer programming neighborhood search heuristic with mixed-integer programming	Howard et al., (1968) (Shaw and Howard, 1982), Turner and Miles , 1971; OECD, 1973), Athanasoulis and Calogero , 1973 ; Parker , 1977) Wan,1995; Trietsch, 1988; Nicholson et al.,1976) and Hogan, 1973 (Easa and Mehmood, 2008 and Lee et al., 2009)
Vertical alignment	only Enumeration Linear programming Numerical search	(Easa ,1988 ; Puy Huarte , 1973 ; Murchland 1973) Goh et al. , 1988 ; Fwa , 1989 ; Chapra and Canale , 2006) (Revelle et al., 1997; Robinson, 1973 and Hayman, 1970
Three Dimensional .	Numerical search Distance transform, alignment Neighborhood search heuristic with mixed-integer programming, Genetic algorithms	Chew et al., 1989; Mandow and Perez-de-la-Cruz 2004; Smith, 2006) Cheng and Lee, 2006; Jha, 2000), (Kim ,2001 ; Jong and Schonfeld , 2003 ; Tat and Tao , 2003) Jha and Schonfeld , 2004; Kim et al. , 2007 ; Kang ,2008 and Kang et al. , 2010

Among them, the genetic algorithm (GA) has been the most popularly adopted method for optimizing highway alignments since it was first used for this problem (Jong, 1998). It is an adaptive search method based on the principles of natural evolution and survival of the fittest

and can avoid getting trapped in local optima through a pool-based search rather than a single solution comparison as in other heuristics (e.g. simulated annealing and Tabu search).

A comprehensive review of the existing methods for alignment optimization has been conducted by the authors Yareg and Amin, (2006); Gao et al., (2016). They conclude that all considered methods other than the GA (Genetic algorithm) based approach have some flaws for alignment optimization.

Limitation of the conventional method of road optimization ((Yang, 2009)

- (i) cannot model discontinuous cost items (e.g., right-of-way cost and property areas affected by the alignment),
- (ii) cannot yield realistic highway alignments,
- (iii) use discrete solution sets rather than continuous search space,
- (iv) formulate too few cost components and constraints,
- (v) may produce multiple local optima, and
- (vi) do not jointly optimize horizontal

In general, among those convectional method GAs is considered especially suitable for problems with huge numbers of local zones. While they do not guarantee that the globally optimal solution for a large problem is found within a reasonable time, their population-based search is very helpful in preventing the search from getting trapped in local optima. The effectiveness of GA-based approaches for alignment optimization can be described in terms of the following key advantages(Tae-Ho et al., (2008):

- i. Can yield realistic alignments.
- ii. Can search in a continuous search space.
- iii. Can find globally or near globally optimal solutions.
- iv. Can deal with most of the important highway costs and constraints.
- v. Can jointly optimize horizontal and vertical alignments.
- vi. Can incorporate through customized operators much of the highway designers intuition and experience about efficient searches for alignments.

However, the method created a problem of inefficiency as it is time-consuming to manually populate the cost and elevation matrices used in the input file required for running the model. The elevation and land unit costs are filled manually into the input file and this is an impossible process for a geographic region containing many features. And vertical alignments

(i.e., use a conditional approach in which they sub-optimize a horizontal alignment first, and then sub-optimize the vertical alignment based on the horizontal alignment created.

In recent years many researchers use geospatial technology for the selection of optimal routes that combines all environmental and engineering factors for optimum route selection. The combination of remote sensing data with GIS tools used to handle all spatial and non-spatial data influences the proficiency of the routes. Remote sensing up-to-date spatial data for extract data for analysis GIS has a powerful tool for analyzing both spatial and non-spatial data. Some researcher used LCPA are(Mahavar et al., 2019; 2017; Padmani and Sudath, 2016)

Suleiman et al., (2015) Demonstrate advantages of GIS capabilities that offer the ability to perform spatial analysis on various layers of information. This study is aimed at locating an optimum, economic short path, this path is supposed to connect two towns a grid-based approach of a least-cost path analysis method using ArcGIS software was adopted, the cell size used was 30mx30m. The factors considered are land use, land slope, and soil. A model for route location was developed; this model was used in obtaining three optimum alignments. The shortest and most economic route was found to be 27.75km. The results of this study clearly showed the applicability and potential of using GIS as a tool in route location. But he hasn't used high-resolution images available like ALOS DEM and high-resolution satellite images. Correspondingly, he does not include the most important factor geology which is directly related to construction as well as slope stability.

Muriki and Kari, (2019) Practice Geographic Information System (GIS) techniques, the Least Cost Path Analysis method were applied to achieve viable results that were useful in determining a feasible road corridor. The route analysis parameters contained different weighted overlay surfaces; each surface is influenced by various criteria (slope, geology, population, and land use land cover. The researcher concluded least-cost path analysis (LCPA) can reduce the overall cost of road construction and minimize the negative impacts of such projects on both the macro and microenvironments. But the researcher does not include drainage densities which affect the cost of bridge construction and safety of the road .also he does not use high-resolution satellite images for LULC. Moreover, the researcher does not introduce the capability of other geospatial tools like google earth and GPS (global positioning system).

In Ethiopia, difficulties face on road construction sites during construction due to inadequate attention to the initial selection of the route (URS, 2010) . Route option identification is usually undertaken by consultants on behalf of the Ethiopian Road Authority and should take into account avoidance of environmentally protected areas and other sensitive habitats (ERA, 2013). However, all EIA report shows that all the damages pass simply by compensation and rehabilitation agreements. Planning a new road or highway is an expensive and time-consuming process. Since numerous environmental issues need to be addressed. The problem and challenges will depend upon the characteristics of the study area.

The issues need to addressed varies with time With the help of remote sensing and GIS, every challenge of the study area may be addressed because these are the powerful tool for the compilation, management and display data associated with geographic space, is used for the preparation of digital maps and analysis purposes rather than the conventional manual methods which are difficult, time-consuming and expensive. In this study The researcher proposed the optimum routes by using GIS least cost path with AHP SMCDM by using environmental parameters like geological data(lineament and lithology), drainage, (stream order and proximity to the river), DEM (slope and aspect) satellite images (LULC) was used to assess the impact of the road on the environment and the road alignment safety. Many scholars use different environmental and engineering parameters and select the most optimal routes. However, no more study carried out considering the optimal route selection around the landslide-prone area. In this study researcher was used the LCP with AHP SMCDM spatial multi-criteria evaluation for parameters .the method recommended for this research work were discussed in the next section

Multi-Criteria GIS Analysis

The utilization of GIS-MCDA choices gives the likelihood of prioritization joining spatial instruments from various areas and points of view is portrayed, and at last aides in settling on far-reaching choices (Mb and Maji, 2018; Erick et al., 2016). There are several characteristics of spatial decision problems that are evaluated based on multiple criteria. The spatial multi-criteria decision model (SMCDM) involves analysis of geographical events supported criterion values and therefore the decision maker's preferences to a group of analysis criteria. A large number of factors necessary causes difficulties in making spatial decisions, difficulties

in attempting to acquire and process data to obtain information for making decisions. Therefore, using GIS and MCDM techniques to support the decision-maker achieves greater effectiveness and efficiency in solving spatial decision problems. The combination of GIS capabilities with MCDM techniques provides the decision-maker with support in all stages of decision making, that is, in the intelligence, design, and choice phases of the decision-making process (Gyabeng, 2020). MCDM issues involve the determination of the relative importance of the criteria. This can be typically achieved by assigning a weight to each criterion. A weight may be defined as a value assigned to an evaluation criterion that indicates its importance relative to other criteria under consideration (Wahdan et al., 2019)

The overall framework for decision-making in route planning is based on the following steps:

- Intelligence: The identification of problems for decisions. According to defined problems to evaluate criteria and generate criteria maps based on GIS functions
- Design: Evaluate the relative importance of given criteria based on one of the MCDM methods.
- Choice: Evaluation of alternative options and making decisions of problems by applying the corresponding multi-criteria decision rules.

The analytic hierarchy (AHP) and analytic network process (ANP) are two multi-criteria decision methods (MCDM). Since the ANP is the general method of AHP, the study wished-for result using the AHP method in arc GIS.

2.4 Analytical Hierarchy Process for Optimum Route Selection (AHP)

Due to the negative effects of highway projects on the environment, the cost of the projects is getting increased. The environmental and cost priorities of the highway projects must be considered when examining the most suitable highway routes. AHP, which was proposed by Saaty in 1987, is a multi-criterion. Decision-making method for complicated and unstructured problems and also it is an approach that uses a hierarchical model having levels of goal, criteria, possible sub-criteria, and alternatives. Applications are used to determine the most suitable solution to the real problems by providing a selection from different data clusters. It develops pairwise comparisons to do the ranking. This approach is associated with a consistency ratio (CR) (Asadabadi et al., 2019). The general steps of the AHP method that is based on pairwise comparisons are as follows discussed by (Uleiman et al., 2015).

Step 1: Identifying the problem and establishing a hierarchy of goals, criteria, and alternatives.

Step 2: Pairwise comparisons between criteria and between alternatives according to each criterion

Step 3: Normalize the generated comparison matrices and find the eigenvectors

Step 4: Determine the weights of criteria and calculate a consistency value to determine the suitability of the decisions

Step 5: Matrix multiplication of the importance ratings of the alternatives found for each criterion with the weights of the criteria and find the significance levels of the alternatives.

Step 6: Order or selection of alternatives according to their importance

Assuming that there are several criteria and alternatives, the weights of the criteria are computed through pairwise comparisons using Saaty's scale shown in Table 2.2.

Table 2.2: Saaty's scale (1987)

Rank	Description
1	Equally importance
3	Moderate importance
5	Strong importance
7	significant importance
9	Extremely importance
2,4,6,8	Are intermediate between 1,3,5,7

The consistency level of the comparison matrix can be computed considering its maximum eigenvalue, namely $\lambda_{\max}$. Since $\lambda_{\max}$ is substituted for the order of the matrix (n), its difference from n is used to compute the Consistency Index (CI) and the closer to the more consistent the judgments.

$$CI = \frac{\lambda_{\max} - n}{n - 1} \dots \dots \dots (2. 1)$$

The principal eigenvalue of the matrix is divided by the average of the principal eigenvalue of a certain number of matrices filled in a random way (RI). If the result is smaller than 0.1 (the threshold), the comparisons are confirmed (perfect comparisons lead to (CR = 0)

$$CR = \frac{CI}{RI} \dots\dots\dots (2. 2)$$

Values for RI are as presented in Table 2.3 where the order of a matrix increases to more than three; their consistency issue arises and increases exponentially as the number of the criteria and alternatives grows. If CR is more than 0.1, the user is blamed for providing inconsistent comparisons and the tables are returned to them for improvement.

Table 2.3: Random consistent index (RI)

Matrix Order	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.32	1.41	1.45	1.49

For determining the most suitable highway locations, AHP includes flexible, effective, and adjustable structures to provide user-defined solutions. Thus, the results can be adjusted, evaluated, and measured in both environmental and cost-oriented approaches ((Usul and Kara , 2012). AHP provides cost surfaces to the LCPA such as environmental, economic, and social, thus, the routes can be determined with LCPA according to the desired parameter-oriented approach(Sarı and Sen, 2017).

2.5 GIS Least Cost Path Method for Optimum Route Selection (LCP)

LCPA(least-cost path analysis) provides users to find the cheapest route that connects two locations using a cost surface that is determined by considering multiple criteria (Effat and Hassan, 2013; Mawjoud and Jamel, 2016). The cost is multivariable, which real model of problems, such as the function of time, suitability, and risk reduction (Januadi & Nabila, 2019) The cost must be calculated in different ways, such as a measure of the distance from a terrestrial resource, alternative measures of physical ease of access, or using the cultural logic that people use to choose where they travel. Commonly employed least-cost path (LCP) analysis relies on the underlying cost matrix (Huck et al., 2011). To calculate least-cost routes

across a cost-surface, most GIS least-cost modeling approaches convert the raster cost-surface into a weighted lattice graph for processing. Many researchers used the LCP analysis to determine the least cost route for different linear structures by using remote sensing data and GIS. Feldman et al., 2015, used the LCP analysis to determine the least cost pipeline path using remote sensing data and GIS. Also recently many other researchers conclude that GIS least-cost path analysis is a reliable tool for optimal route selection and also another linear civil engineering project for example (Kukadapwar and Parbat, 2016; de Lima et al., 2016; Kang and Lee, 2017; Larbi and Boye, 2018). Therefore, the researcher preferred the GIS least-cost for modeling the optimum route connecting Ginchi to Chullute.

2.6 Analyzing the Factor Affecting the Optimum Route Selection

Before actual road construction highway designer reviews topographic, geologic, and soil maps as well as available aerial photographs of the area. Optimizing highway alignments (including assessing massive amounts of relevant data and evaluating multiple highway impacts), has posed major challenges to researchers because various tangible and intangible factors are associated with the problem (Kang et al., 2012). From the perspective of the environment, broadening of highways will create environmental pollution due to increased traffic on the road, land-use change, air and noise pollution, socio-economic changes, and loss of biomass (Banerjee and Ghose, 2016)

Understanding those environmental, engineering, and social impacts is essential for unbiased and environmentally appropriate decision-making by governmental agencies on the viability of such development projects. Environmental impact assessment (EIA) is the process of assessing the impacts of such development projects on the environment. However, conventional EIA is time-consuming, expensive, and sometimes suffers subjective bias in the assessment of the impacts of a project on the environment (Daigle, 2010 ; Takyl, 2012). (GIS) overcome the limitation of conventional EIA and provide an unbiased and easily interpretable EIA. GIS is a computer-based system for capturing, storing, querying, analyzing, and displaying geographical data (Chang, 2008). For sound management of environmentally sensitive development projects like construction and broadening of highways in mountainous areas, it is essential to predict the long-term impacts of such projects. GIS-based

environmental modeling provides prediction and simulation of likely impacts of projects on the environmental features (Banerjee and Ghose, 2016).

Various engineering factors, as well as environmental constraints that influence the cost of construction, economic benefits, environmental compatibility, and future viability of the proposed road project, were considered in the route selection analysis. Among the engineering, constraints are the length of the road, slope/gradient of the terrain, water bodies(wetlands, rivers, streams, and lakes), soil types, lithology and geologic structures(faults, lineaments, and escarpments), etc. the environmental constraints are land use/land cover which includes settlement areas(cities/towns/villages), distance from existing roads and railway and others constraint, etc. All these factors will be considered at the time and interactively to select the best alternative (Arega and Belaw, 2007).

Consequently, the literature reveals that there are numerous environmental, engineering, and social issues that need to be addressed either these are Physical, Political, Environmental, Economical, Ecological, social, institutional, etc. these issues need to be considered before starting the road construction or the parameters to address these issues must be included as an input for the preparation of the environment and engineering cost maps. And these must be used as the input for the road alignment optimization. The integration of GIS and remote sensing is used to reduce the time and effort spent on this problem. To assess the impact of the road on the environment different environmental, engineering, and social parameters are used for road optimization. Those data are collected from different sources and analyzed by using geospatial tools for analysis purposes. a parameter was discussed next section.

2.6.1 Land use - land cover (LULC)

Different land use/land cover types have their proportional importance depending on their suitability for the construction of transport infrastructures. The score values are assigned to each LULC category based on expert judgments, mainly consultants and highway engineers.

Many researchers conduct the optimal route alignment selection by using LULC as the main important factor (Arega and Belaw, 2007; Tahnah, 2010; Noor et al., 2015; Muriki and Kari, 2019)

(win and Kari, 2019) Conducts the study on determination of optimal route selection using least-cost path by using the parameter land use land cover, geology, and population and

conclude that the land use land cover has a high influence on the route selection from the parameter used. LULC with a higher value indicates more costly and therefore less suitable for road construction (Kiema et al., 2011). Land use land cover data is required to estimate the cost of land acquisition or compensation cost during route planning.

Land use land cover data is required to estimate the cost of land acquisition or compensation cost during route planning. To estimate the cost of land acquisition or compensation cost during route planning it is obligatory to have the types of land use land cover in the study area (Arora et al., 2005). The LULC criterion permitted the least cost path to take into account the type of surface that was most optimal and less hazardous (Kelly, 2014). Since land use land cover extracted from land sat an appropriate correction must be applied. Land use land cover mapping involves image preprocessing and land use types classification. This involves downloading satellite images from USGS and radiometric, spatial, and spectral correction of the image must be carried out to increase the data quality.

Land use land cover classification

Every pixel in a pre-processed satellite image is a unique entity and it has to be labeled to obtain the LU/LC classification maps using different classification techniques (Sung et al., 2020). Image classification is the process of categorizing 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 (Sung et al., 2020). Supervised classification is image classification in the field of remote sensing, which is the process of assigning pixels or the basic units of an image to classes. 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 other and those of known identity (Maheswarappa 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 and allows the image analyst to specify parameters that the computer uses as guidelines to uncover statistical patterns in the data. It is contrast to supervised classification, 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 will be five classes such as built-up, agricultural land, bare land, forest, and water body. It is used to identify the class of land covers that are more favorable for route planning according to cost and suitability.

Image preprocessing

Pre-processing is an essential technique used to improve the quality of raw satellite data (Agilandeewari, 2020 ; Nicuta et al. ,2017). Comparative analysis using different Landsat data (i.e., TM, ETM+, OLI (Operational Land Imager)) and sentinel 2A can be challenging due to the instrumental errors related to the sensor, noise from several sources, and uncertainty in scale and geometric conditions (Thau et al., 2015). Preprocessing satellite imagery before conducting image classification and change detection is very vital to minimize those errors and to build a more thorough association between the obtained data and biophysical features on the ground (Sung et al., 2020). This correction model involves the initial processing of raw data to correct geometric distortions, calibrate the data radiometrically, and eliminate the noise present in the data. All preprocessing methods are considered fewer than 3 heads, namely (i) geometric correction methods, (ii) radiometric correction methods. (iii) Atmospheric correction methods (Sharrath, 2012). ERDAS images 2015 was used for mosaicking, layer stacking of bands, and sub-setting of the images to cover the full coverage of the study area, and ERDAS images are the most knowingly used software for image preprocessing.

2.6.2 Digital elevation model (DEM)

The DEM was used to determine the contour, slope, aspects for the study area. The slope was used to represent the changes in elevation of the topography within the study area (Godwin et al., 2019). The choice of the cross-section for a new road in rolling, mountainous, and escarpment terrain can be of critical importance in terms of cost and impact on the landscape, and these considerations are therefore required at the route selection stage (ERA, 2013). The slope is crucial to the route selection process. Steeper slopes are hazardous and difficult to construct large linear features; therefore, the areas encompassing the steepest slopes were assigned the highest values in the output raster (Muriki and Kari, 2019).

Also, the DEM data are used to extract the drainage patterns of the study area. Many researchers used the DEM 30m resolution, but the new product of DEM ALOS has a high

resolution of about 12.5 have more reliable than 30m resolution DEM for drainage density extraction as well as slope degree (Maryam et al., 2020).

(Maryam et al., 2020) Conducted the study on the reliability of data extracted from different open source and ground truth height also, between the open truth each other. They evaluated four of the up-to-date and open-sources digital elevation models against accurate ground truth information in the M' Ground watershed using DEMs at different spatial resolutions: SRTM 3-arcsec, SRTMGL1 V003 1-arcsec, ASTER GDEM 1-arcsec, and ALOS PALSAR. The researcher used the same datum and coordinate system. DEM with the highest resolution (ALOS PALSAR 12.5 m) gave the best performances with lower uncertainty and their horizontal and vertical accuracies are excellent compared to DEMs with low resolution. As regards the DEMs with the same 30 m resolution, results show that SRTM 1-arcsec carry out better than ASTER GDEM 1-arcsec. At this higher spatial resolution, as well as SRTM 1-arcsec performs better as concluded by (Hirt , 2014 ; Punia , 2010). The SRTM 3-arcsec DEM gave the worst accuracy compared with the three other DEMs. The ALOS-PALSAR DEM is more accurate to evaluate water erosion vulnerability in a high elevation watershed, the increase of spatial resolution leads to the clarity of erosion factor and of the delimitation of vulnerable areas to water erosion risk conducted by (Maryam et al., 2020). Therefore ALOS DEM 12.5 resolution is used for this study.

2.6.3 Geology and soil

Geological data was used in the whole process of routing the alignment; the reason being that implementation of less hazardous routes needed a more comprehensible dataset for the area (Muriki et al., (2019) & Wahdan et al. , (2020)). Geological investigations play important role in the design, stability, and economic road construction and maintenance cost((Prakash et al., 2015; Conduat et al.,2017). geological factors on the route alignment and stability of roads were related with:

- Topography
- Lithology
- Geological character
- Lineament
- Groundwater condition

Variation in weathering and erosion resistance of rocks is commonly reflected in topographic features. Topographic maps would reveal the existence of various land features like valleys and the inflowing streams, the hills and their undulations, the plateaus and the plains with all their varying configuration from place to place. Knowledge of all such features is not only important but very essential for the right alignment. Weathering-resistant rocks such as high-grade metamorphic rocks, igneous intrusions, walls, and sills frequently form prominent features in the landscape (e.g., cliffs, scarps, ridges, plateau, etc.). Geological structures such as faults, folds, anticlines, and synclines, unconformities, contacts, horizontal and inclined bedding often produce characteristic topographic features (ERA, 2013). Soils that susceptible to erosion and unconsolidated materials cost more to construct a road. Poorly drained soils are also unfavorable for road construction. It is therefore relatively cheaper to construct a road on the earth with soil that is consolidated and well-drained. Rocky grounds should be deflecting as they increase construction costs due to heavy excavation of rocks. Geological surveys should invariably provide all possible details regarding the composition, texture, structure, and origin of rocks and sediments making the ground through which the proposed alignment of the highways has to pass. Broadly speaking, the ground may be divided into two types – consolidated, massive hard rock type and soft, unconsolidated type (<https://www.geographynotes.com/geological-investigations/geological-investigations-and-the-construction-of-roads-geology/5837>, 2020 ,10:17PM).

The Massive groups of rocks include all varieties of igneous, sedimentary, and metamorphic rocks which can stand even with vertical slopes. For making roads through them, however, these rocks require extensive blasting operations. They cannot be simply cut out or dugout. Once cut, especially if they are free from joints and fractures and unfavorably inclined bedding planes, these rocks stand erect for a year without much maintenance.

The Unconsolidated group presents the engineer with many complicated problems. Thorough soil investigations regarding their mode of origin, texture, structures, porosity, permeability, degree of compaction, consolidation characteristics or compressibility, etc. all are required to be known within broad limits to design safe and stable roads over them. Residual soils are generally homogeneous and properties evaluated from selective bore whole samples might prove sufficient. Due to the relative importance of geological data for optimum route selection

these studies used lithology, lineament as the factor for modeling optimum route. Also, the soil data are used as the soil determines the bearing capacity of the sub-base of the pavement material.

In Ethiopia, most of the time, only the selection of the route depends on the topography of the area. However, geology and soil have also a significant role. Soil is the ultimate point that supports the whole structure of the road. Since soil being a natural material has a very unpredictable behavior so it is important to study its response to the Load coming from the road or any structure (<https://www.quora.com/Why-soil-engineering-is-important-in-the-construction-of-road>, 2021,10:45pm). The necessary flat base provides crucial support for buildings, construction foundations, pavements, roads, and various other constructions. Constructing roads need to be on stable and strong soils. Soils range in strength. Some soils can support a skyscraper, while other soils are not able to support the weight of a human. If the soil under a building is not stable, the foundation of the building could crack, sink, or worse—the building could fall. The strength and stability of soil depend on its physical properties. Soil with a good structure is more stable. Clay textures are often more stable than sand textures because they have a better structure. However, a mix of particle sizes (and pore sizes) is best for engineering (just as it is best for growing crops). It is also important that soil is stable through wetting and drying cycles so that expanding soil does not crack roads or foundations. Some clay minerals, from a family, called spectate, are more likely to shrink and expand during wetting and drying cycles than minerals from other families, such as kaolinite. Good soil should also have the ability to capture precipitation, so that runoff and erosion do not damage structures. Finally, good soils for infrastructure have balanced chemistry so no building material corrosion occurs. Therefore we need to know the types of soil in the area before the actual construction of the road.

2.6.4 Drainage structure

Drainage densities are calculated by dividing the total stream length (km) by the total watershed area (km²). The drainage density layer has been used to estimate the cost of bridge construction. If the width of the river channel larger with increasing order of drainage or drainage density, which consequence of a corresponding increase in the cost of bridge construction. The primary purpose of a road drainage system is to remove the water from the

road and its surroundings ((<https://www.roadex.org/e-learning/lessons/drainage-of-low-volume-roads/components-of-road-drainage-system/>), 2021,08:46).

The influence of drainage considerations on route selection relates primarily to:

- The suggestions of routes located on ridge tops, valley floors (including flood plain routes), and valley sides and flat to rolling terrain
- The location of major bridges as potential fixed points in a route selection exercise
- Expected levels of flooding, scour, and sediment accretion where their factors control Feasibility and significantly influence route option cost comparison and watercourses, supplied by large catchments, with the requirement for bridges.

The cost of large watercourse crossings makes the selection between ridge and valley floor routes on drainage grounds an important issue for route selection (ERA, 2013). Drainage is an important factor for road construction since it is directly related to the cost of bridge construction as well as flood risk management for the road.

2.6.5 Geo-hazards problem

Geo-hazards can pose significant constraints to the construction and operation of road infrastructure; therefore it should be critical to route selection in all terrain types. In Ethiopia, geology and tectonic setting, combined with climate and hydrology, create conditions that encourage the occurrence of a range of geo-hazards ((ERA, 2013). the landslide is one of the geo-hazards related to road alignment selection. Cutting and filling, one of the main activities in the construction of the roads, especially in mountainous areas can directly trigger landslides. Therefore, it is needed to identify the most suitable corridor for road construction considering landslide distribution, the slope of the area, land use, drainage order, etc. If the map of the landslide-prone area is available, the route selection can be done by avoiding the area prone to landslide (Padmani and Sudath,2016). Landslides in Ethiopia are most common in steep terrain with high relative relief, they can also occur in more gentle terrain of low relief. For example, slopes formed in residual soils, colluvium and clay shales may fail if their angles exceed 30-40°, 10-20° and 8-15° respectively or if support is removed at their toe; both outcomes can be affected by natural processes in the long term and road construction in the short term((ERA, 2013).

(Hearn et al., 2011) describes how the cost of reinstating the 90 km Hirna -Kulubi road in 26 landslide areas amounted to 5% of the total cost of road widening and upgrading works between 1996 and 2005 low volume roads, the cost of landslide management can be a significant contribution to the overall cost of road construction and operation. Early recognition of landslides and related slope instability enables decisions to be made regarding avoidance, reduction, or elimination of the hazard. The second Geohazard problem effect on the road alignment is problematic rock. Problematic rocks range from expansive, soft, porous, deformable, susceptible through soluble, and highly fissile to those prone to softening, slaking, and rapid deterioration. Problematic rocks can be of igneous, sedimentary, or metamorphic origin (ERA, 2013). Another geo hazard problem is problematic soil. Problematic soils include expansive, dispersive, collapsible, compressible, and saline soils. Knowledge of local geology and terrain analysis can greatly assist in anticipating potentially collapsible, dispersive, compressible, and expansive soils. For example, soft ground (compressible conditions).therefore the geo-hazard problem must be considered critically while routing alignment.

2.6.6 Assessing landslide for route alignment

The planning and construction of a new road or highway necessitate a thorough hold of several environmental factors. It also requires a detailed analysis of the site characteristics on the area such as existing dry and perennial streams, river configuration, surface soil conditions, geology, physiographic conditions, groundwater, land use/ land cover, and particularly the slope condition. In absence of thorough investigation and proper scientific approaches, it may lead to more time-consuming and expensive than expected. Moreover, the degree of complexities may rise to significance if the issues related to the environment, social, and or cultures are not properly addressed in the public domain. However, in the last few decades with the advent of space technology and GIS, alignment/realignment planning of the new route and/or old roads in any area becomes easier and viable in resolving these issues extensively (Shanka, 2019). The mountainous areas of the world are frequently affected by the occurrences of the landslide because of high energy with variability and instability of masses (Gerrarad, 1994; Shanka, 2019).

Over the last decade, many studies relevant to landslides susceptibility assessment can be found in the field of GIS (Geographical Information System) and RS (Remote Sensing) (Abella, 2007). However, studies related to road construction combining GIS and RS are limited. This situation is the same for worldwide studies. The application of GIS and RS in the identification of the most suitable route alignment in landslide vulnerable areas has not been studied in our country. Many researchers focused on optimum route selection, but no one considers landslide distribution in the area of route selection. But a common mode of transport in hilly areas is road transport in developing countries like Ethiopia.

2.6.7 Methods for landslide susceptibility map

A variety of approaches and methods for landslide susceptibility assessment have been proposed since the 1970s, and they can be clustered into several groups, namely, classical statistical, index-based, and machine learning methods, among others (Reichenbach, 2018). However landslide problem is critical in Ethiopia, still, there is no adequate slope stability assessment applied in the different parts of the country (Wubalem, 2020). The mitigation measures of landslide incidence in the area, which is already failing or susceptible to fall, require identification of existing landslides, determination of the contribution of prevailing causal factors, and generation of landslide susceptibility map. Landslide vulnerability assessment has been used to assess the amount of hazard in threatened areas for landslide hazard evaluation. There are three most known methods for landslide mapping. Quantitative, qualitative, and semi-quantitative methods are most known (Xing et al, 2020 ; Mete, 2020 ; Goetz et al, 2015). Several researchers used qualitative and quantitative methods (Reichenbach et al., 2018). According to the qualitative method, the expert can evaluate the landslide susceptibility zones in his own opinion, which required field experience specialists (Xing et al, 2020 ; Mete, 2020 ; Goetz et al, 2015). Semi-quantitative methods are the combination of qualitative and quantitative methods, which introduce grading and weighting of the effects of landslide factors on landslide incidence (Indra et al., 2017; Bui, 2019; Xing et al., 2020). This method, both qualitative and quantitative methods can be applied to evaluate the effects of landslide governing factors on landslide occurrence (Geertsema et al., 2019). The quantitative methods can be divided into three categories such as statistical, machine learning/ data mining, and deterministic methods (Canoglu, 2017 and Ciurleo, 2019). Statistical methods are indirect susceptibility mapping methods widely or routinely used to

evaluate the correlation between landslide governing factors and landslides based on mathematical expression (Wang et al., 2011). The statistical methods can be further divided into multivariate and bivariate statistical methods, which are widely used throughout the world and provide reliable results (Xing et al., 2020 ; Mete, 2020 ; Goetz et al., 2015) the bivariate statistical methods are used to evaluate the relationship between landslide governing factors and past landslides. Certainty factor (CF) (Sharma, 2012 ; Kumaravel et al., 2012) frequency ratio (FR) (Pradhan, 2010 ; Meten, 2020) .information value (IV) (Sarkar et al., 2006 ; Meten, 2020) and weight of evidence (Wang et al., 2019 ; Meten, 2020). Are examples of bivariate statistical methods, are simple and easy, and produce a reliable result. It also helps to evaluate the effects of a landslide at a factor class level that is impossible in data mining or multivariate methods. Many studies of landslide susceptibility mapping have been conducted using GIS with a variety of approaches and methods, especially bivariate statistical analysis methods. The frequency ratio method is a type of bivariate statistical analysis method and is one of the most popular approaches for landslide susceptibility assessment (Korup and Stolle 2014 ; Kumar et al. 2019)). The simplicity of the principles and the ease of implementation in a GIS environment make this method a user-friendly and effective approach to landslide susceptibility assessment (Oh et al., 2011 ; Zhang et al. , 2015 ; Hong , 2017 ; Massonary, 2017 ; xing, 2021)). Therefore, frequency ratio has been used in this study for landslide suspect ability map to avoid the more hazardous area for route alignment selection.

2.6.8 Frequency ratio model for landslide mapping

The FR model is one of the bivariate probability methods, which is applicable to determine the correlation between landslide occurrence and landslide causative factor classes. The FR is the ratio of areas in which the landslide occurred to areas in which landslides not occurred. Many researchers used the FR model for landslide mapping (Roy and Saha, 2019 ; Meten, 2020 ; Li, 2020). Similar to other bivariate methods, the frequency ratio method not only produces landslide susceptibility maps but also encompasses the sensitivity of landslide failure to individual landslide-related factors (Oh et al., 2011 ; Zhang et al. , 2015 ; Hong , 2017 ; Massonary, 2017 ; xing, 2021)). When the ratio value is greater than one, it indicates the strong correlation between factor class and landslide occurrence in a given terrain; however, the ratio value less than one indicated a weak coloration between landslide occurrence and

landslide factors, which means a low probability of landslide occurrence. It can be calculated using equation (2.3)

$$FR = \frac{a}{b} = \frac{\frac{N_{slpix}}{N_{tspix}}}{\frac{N_{cpix}}{N_{tcpix}}} \dots\dots\dots \text{Equation (2. 3)}$$

Where: FR - frequency ratio, indicates how each factor affects the occurrence of the landslide,
 N_{slpix} - the landslide pixel in a landslide factor class,
 N_{tspix} - the total area of a landslide in the entire study area (a),
 N_{cpix} - the area of the class in the study area, and
 N_{tcpix} - is the total pixel area in the entire study area (b).

2.6.8 Model validation

Landslide susceptibility map without validation has no sense in the scientific world (Roy and Saha, 2019 ; Meten, 2020 ; Li, 2020). Therefore, validation of the landslide susceptibility model is very important to evaluate the degree of accuracy of modeling using different validation techniques. For this purpose, the landslide area is classified based on time, space, and random partition (Meten, 2015 ; Pradhan,2017). Most of the researchers use ROC and AUC for model validation for bivariate statically method like frequency ratio (Padmani and RA , 2017 ; Roy and Saha, 2019 ; Meten, 2020 ; Li, 2020, 2017). the study used the AUC for model validation. The ROC curve is drawn by the X and Y-axis. The X-axis represents the false positive rate (1-specificity) and the Y _ axis represents the true positive rate (sensitivity). (Mallick , 2018 ; Qureshi, 2018 ; Roya and Sah, 2019 ; Feizizadeh et.al, 2014)Applied ROC curve for the validation of the landslide susceptibility zone. The model validates the range of the AUC based on the input value. The area under the curve ranges between (0_1)

Table: 2.4: Characteristics of AUC of ROC curve (Yesilnacar, 2005)

AUC Values Characters	Character
0.6–0.5	Average
0.7–0.6	Good
0.7_0.8	Very good
0.8_0.9	Excellent
0.9_1	prefect

Table 2.4 shows that either the performance of the model used was good or not if the AUC value is less than 0.5 calculation of FR must be again.

2.7 Conceptually Framework

Traditional road design requires experienced engineers to repetitively evaluate various alternatives to determine the most favorable alternative which satisfies the needs, optimal in its location for minimizing the costs of its construction and avoiding any environmental constraints in the area. The conventional design method of alignment refers to the calculations and analysis of the elements of highways that are visible to the drivers. (Al-Hadad, 2010). Genetic algorithms (GAs) are skillfully applied for optimizing highway alignments. Genetic algorithms are very effective at finding good solutions in a complex search space with many local optima His representation of the area was in a matrix format. However, the method is time-consuming and inefficient in a geographically complex place. Recently, many researchers recommended the GIS as a power full tool for optimum route selection. Road construction projects highly depend on geographical information obtained from field surveys. Since, several costs of road alignments are sensitive to geography, using GIS as a tool to calculate these costs is very efficient and time-saving. Consequently, the researcher decided to use GIS least-cost path analysis for optimum route selection since the literature reveals the method is user-friendly and highly powerful fully to select the least-cost routes for connecting two locations. With GIS Least cost path because of its reliable and standardized processes allows the output to be shown quantitatively ((Muriki et al., (2019) & Wahdan et al. , (2020)). The concept behind the least-cost analysis is to determine a route that is cheap and would have a less negative impact on the surrounding environment (Nayana & Sudath, 2017). The researcher used the weight overlay analysis function to integrate the criteria. AHP spatial

multi-criteria evaluation pair comparison was used to evaluate the alternative defined. The remote sensing data are used to extract different factors used for selecting the least cost paths. Therefore, the researcher used integration of different geospatial technology for route optimization as one fills the gap of the others. While route alignment the engineers should have to understand the physical, social, and environmental nature of the environment. Specifically, route alignment should be done critically around the landslide area because it directly affects the safety and maintenance cost of the road. Therefore critical analysis was required.

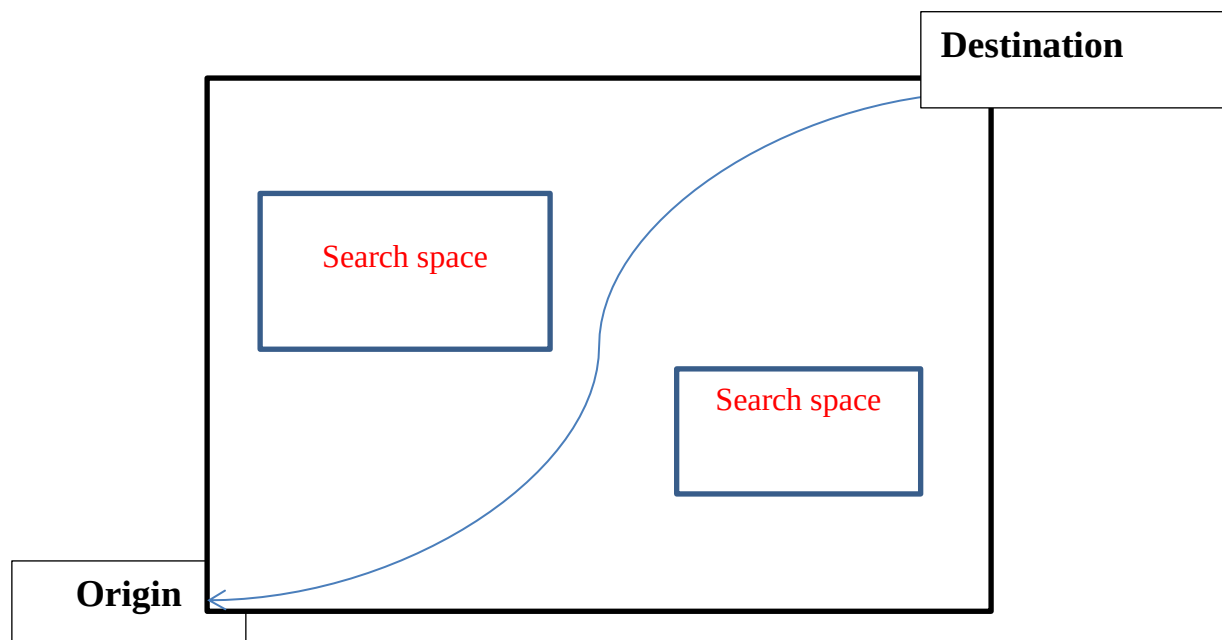


Figure 2.1: Conceptual framework

CHAPTER THREE: MATERIALS AND METHODS

This section explains the data used to achieve the objective of the study as well as how the process of analyzing it was carried out.

3.1 Study Area Description

3.1.1 Location

Ginchi-Shukute-Chullute road is located in the central part of Ethiopia in the West Shoa Zone of the Oromia Regional State. The road is 122 km and traverses four Woreda (Dendi, Jeledu, Abune Gendebere, and Gendebere). Recently, Jeldu woreda is divided into Chobi and Jeldu, and the previous Dendi woreda is split into Dendi, Elfita, and Ejersa lafo. The road mainly traverses through the previously mentioned woredas. The geographical location of Ginchi(origin) town is $09^{\circ}02'N$ and $38^{\circ}06'E$ and it is found 73 km from Addis Ababa. Whereas Chullute found in North West of Ginchi town and the geographical location of Chullute(end) , is latitude $9^{\circ}39' 21.22''N$ and longitude is $37^{\circ}45' 49.77'' E$.

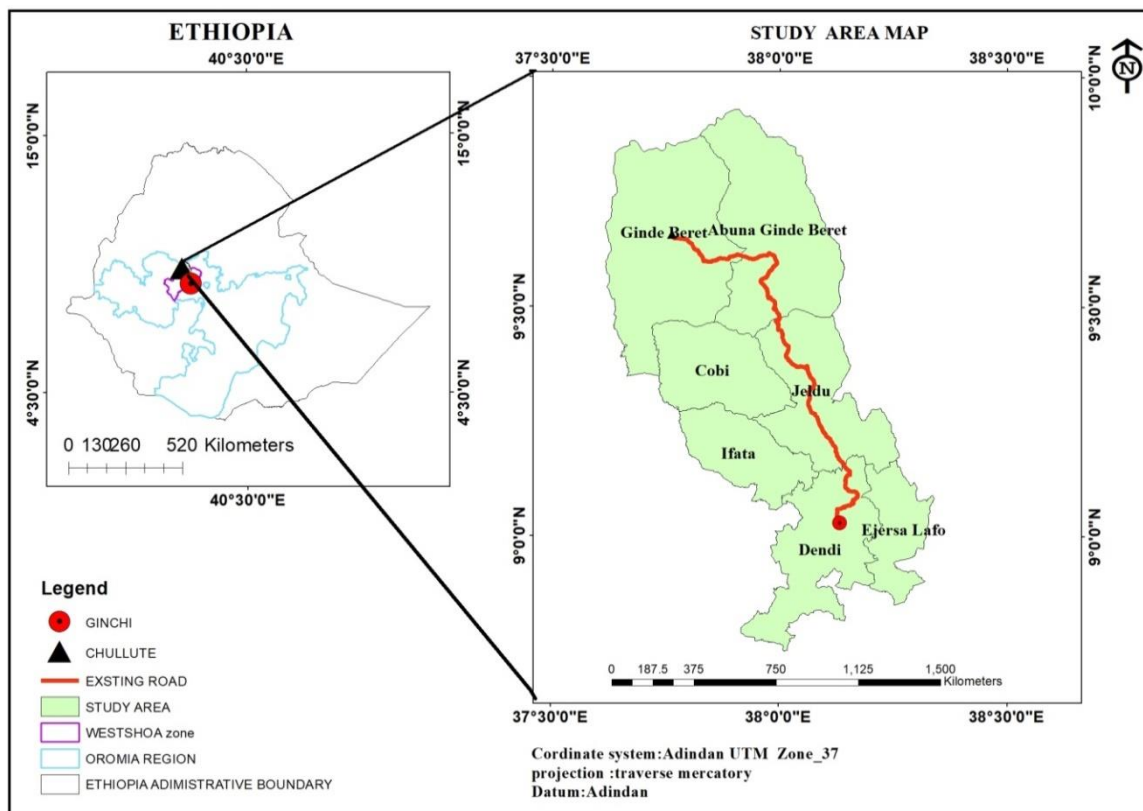


Figure 3.1: Location map of study area (source: BOFED, 2020)

3.1.2 Topography

The area under the study has different terrain. The relief features of Dendi woreda is plateaus, plains, and mountains Accordingly, the highest and lowest most points of the study area are 3270 and 1500 m above sea level, respectively (BOFED, 2020). On other hand, Jeldu Woreda has an undulating terrain nature with an altitude ranging from 2900-3200 m above sea level. The topography of Gindeberat and Abuna Gindeberat is almost the same. Topography is mainly made up of conspicuous rugged to undulating landscape in the lowland and with a flat plateau in the mid-highland. generally, the altitude of the study area falls under 920 to 3307 m. The topography of the study area is illustrated in Figure 3.2

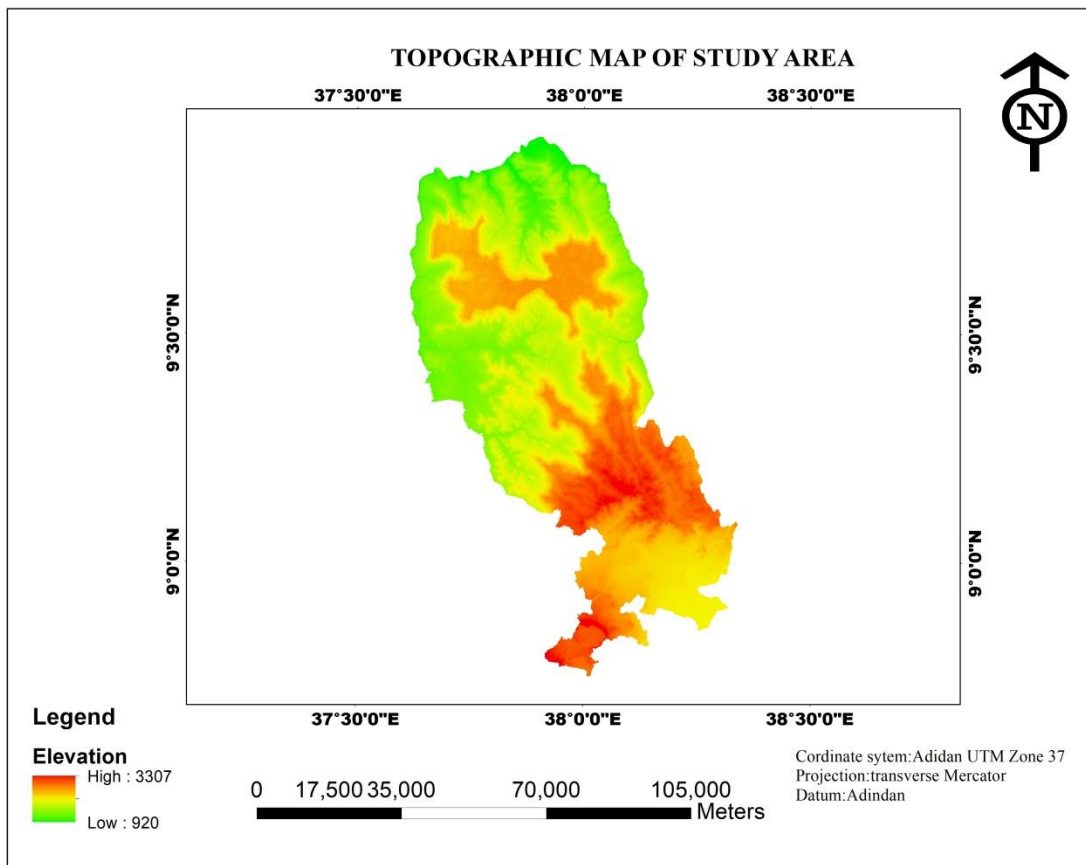


Figure 3.2: A Topography of study area(Source: ALOS DEM (2021))

3.1.3 Land use

The Study Area was mostly dominated by forest and cultivated agricultural land. Dendi woreda has very dense forest and vegetation in the past nowadays it is sparse due to increased

demand for farmland, deforestation, and increased population pressure. Now, major types of land use dominant in study area dense forest (include savannas and shrubland), built up, agriculture include (grassland and sparse vegetation), bare land are major land-use types in the study area and water body including lake, river and tributaries stream are found as mentioned above the study area dominated by agriculture land which covers 54% (284.99 km²) and next the dominant land use type is a dense forest which covers 21% (110.5 km²) of total area. Built-up, water body, and bare land cover 13 % (70 km²), 4% (21.6 km²) and 7% (35.1 km²) respectively. Chillimo forest, which is the one of dense Forest in Oromia, is presented in the study area and it covers 19.93 km² of the total area.

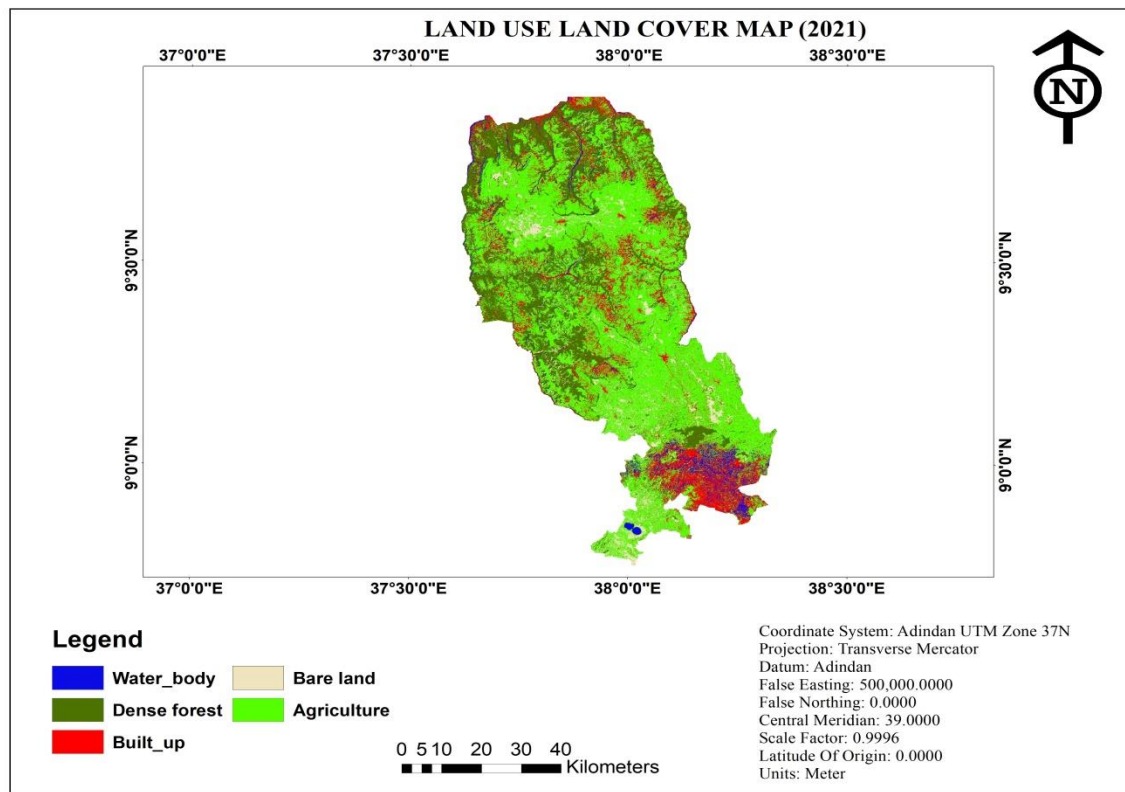


Figure 3.3: Land use land cover map of study Area (source: google earth and USGS, 2021)

3.1.4 Drainage structure

The study area is rich in water resources (both surface & underground). Drainage density is high, with the stream pattern mainly dendritic and deep-seated straight channels. The drainage pattern of the study area may a part of the north Abay basin in which major tributaries of the

north Abay basin start from here. a major part of study Area Drainage structure of where dendritic drainage with tributaries and the main river like Tutu, Kersa, Fele, and Litu Rivers, Qarasa saden, Oronisa,laga ula, Fino Gajo, river, , Dongage jawaro,laga Bala.a, mukadima, Calalaki ,Baara,Chulluxxe are stream tributaries of the Muger Riverin Muger and joint theAbay river . All these rivers ultimately joined the Abay River. also, Abay river starts from the lower parts of Abuna gindeberet worda. Moreover, the pond like Haro sema and other small streams are there in the area. Figure 3.4 shows the drainage pattern of the study area. The largest stream is Urgaha, with a length of 17.5 km, and it is a tributary of Mugehar River. Totals length of drainage in the research area was 1763.24 km.

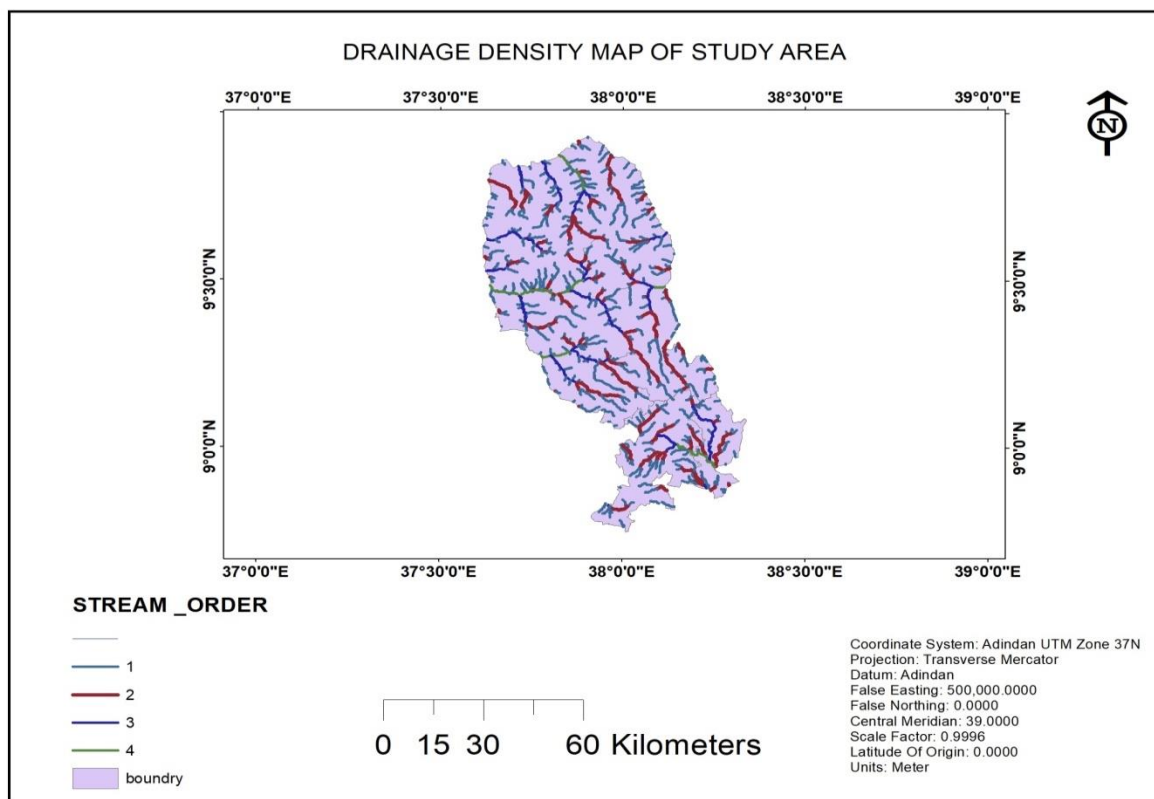


Figure 3.4: Drainage Map of Study area (source: ALOS DEM, (2021))

3.1.5 Climate and rainfall

The climatic zone of the road understudy is predominantly Woina-dega which accounts for 71 % and Dega agro-ecology accounts for 29 %. Dendi worda receives a moderate amount of rainfall ranging from 750 to 1170 mm annually. In this worda, the mean 18⁰c maximum and

minimum temperatures are 23.8 and 9.3 °C, respectively. Abuna gindeberet Woreda is divided into two agro-climatic zones, with mid highland and lowland accounting for 32 and 68 percent of the total area. it receives an average annual rainfall that ranges from 700 mm in the low land to 1400 mm in the highland, with an average temperature that ranges from 10 to 12°C ((Fikadu, 2013). Similarly, Gindeberat woreda is categorized into two agro-climatic zones, where mid-highland and lowland are 43 and 57 %, respectively. The average annual rainfall ranges from 800mm in the lowland to 1600mm in the highland, with an average temperature of 18.5 °C (Fikadu, 2013).

3.1.6 Geology

The sedimentary & volcanic rocks in the study area are formed within Mesozoic & Cenozoic time respectively. The nature of lithology, fossils dispersion and sedimentary structures are due to the complexity of depositional environments, such as coastal, fluvial, lacustrine, and partially arid lagoon. But the basalt is from fissure flow magma (Fentaw and Alemayehu, 2011). The major lithological units exposed in the study area are illustrated in Figure 3.5.

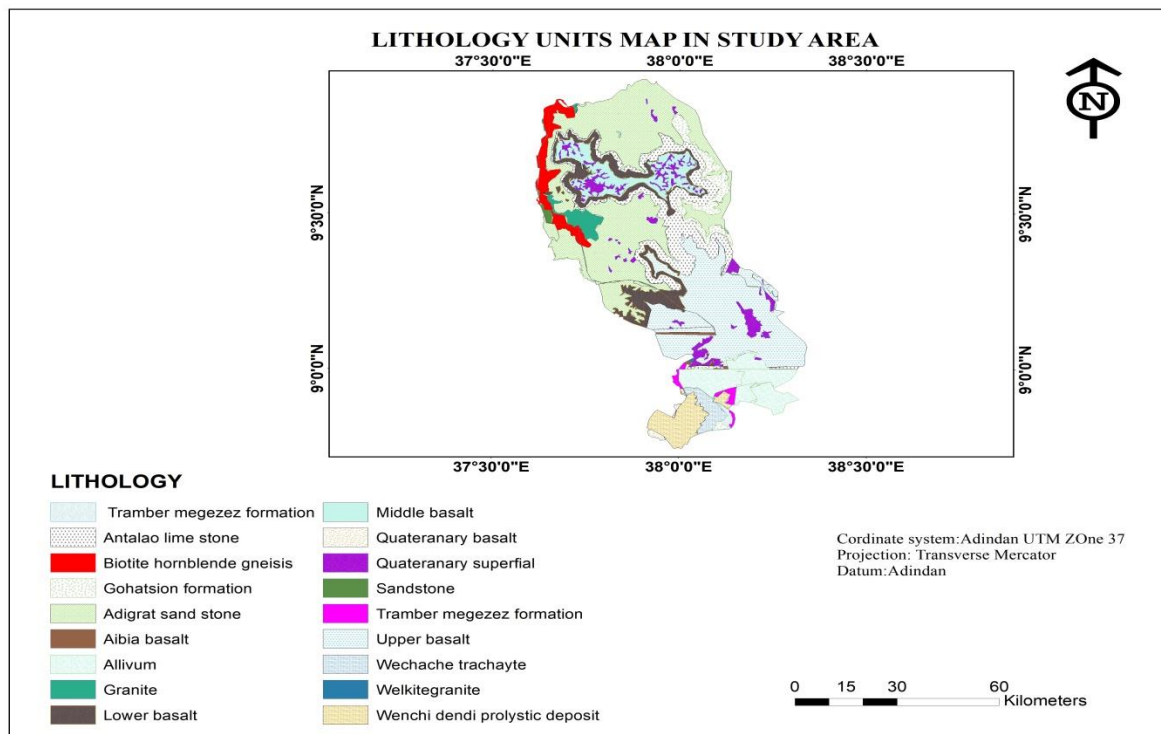


Figure 3.5: Lithology map of the study area (source: Ethiopia geological survey, (2019))

3.1.7 Soil types

Various soil types are found in the study area. This includes chromic cambisols, chromic luvisols, dystic nitisols, eutric cambisols, eutric nitisols, eutric regosols, pellic vertisols, leptols, phaezem, orthic luvisols, orthic solonchaks, ortoic acrisols, chromic vertisols. Figure 3.6 illustrates the soil map of the study area. Types of soil textures commonly found in the study area are loam, sandy loam, and clay.

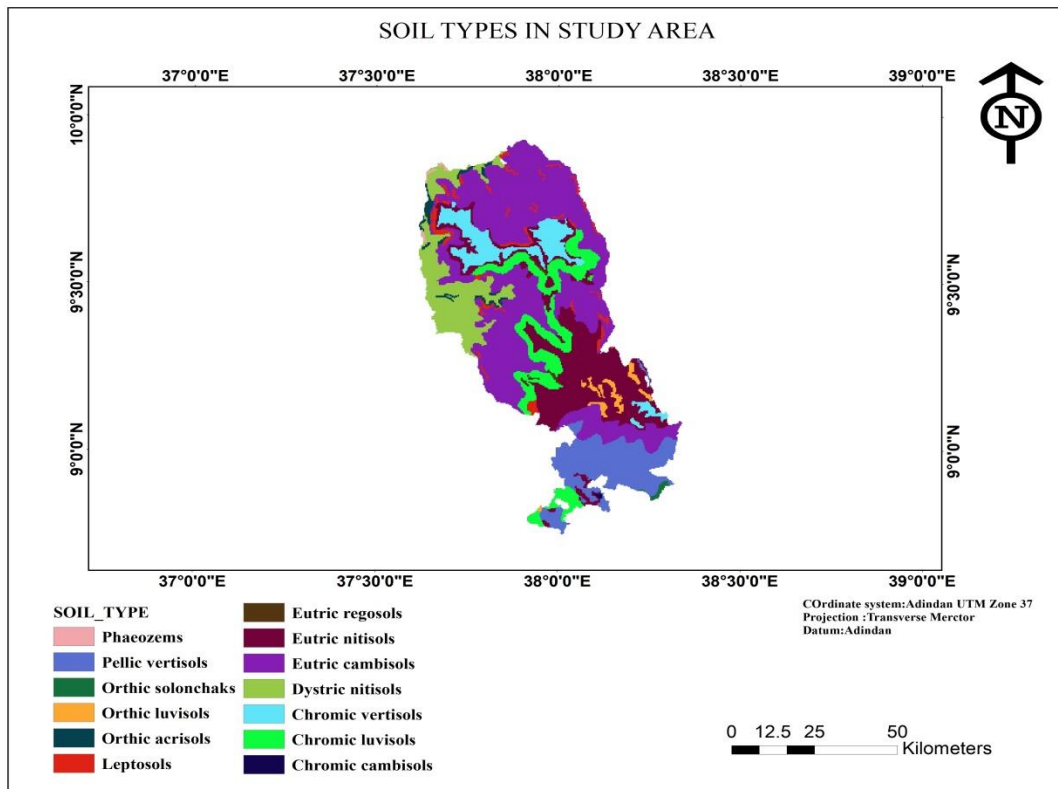


Figure 3.6: Soil types in the study area (source: MOWIE, (2020))

3.1.8 Population

The total population of the study is projected at the Keble level based on data collected from census 2007. Accordingly, the total population was 941,597, in which male accounts for 466,879, and female, 474,757. Jeldu woreda has the highest population density, whereas Cobi woreda has the least in the study area. The population density map was prepared from census, 2007 population data, and projected to 2020. ARC GIS 10.8 has been used for mapping population data. The population density map of the study area is shown in Figure 3.7.

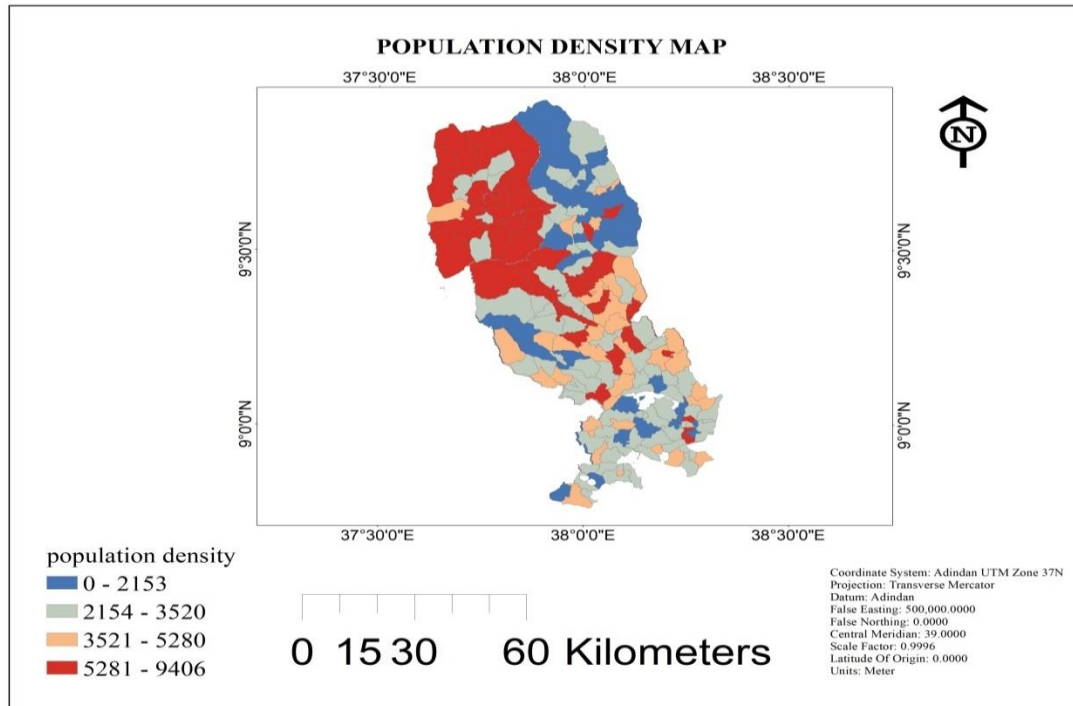


Figure 3.7: Population density map (source: CSA)

Total population data in each weroda was illustrated in appendix 6

3.2 Data Source and Material Used

This study incorporates the assembly of both spatial and non-spatial data from actual fieldwork and secondary data from different sources. Table 3.1 summarizes the types of data used in the study, formats, and where the data has been gathered from.

Table 3.1: Data source

S. No	Data	Source	Data Type	Cell Size/ Scale	Purpose
1	Sentinel 2A,(2021)	USGS	TIFF	10 m	Land use the land cover map
2	DEM, 2021	PLASAR https://search.asf.alaska.edu/#/USGS_ALOIS	Raster	12.5 m	preparation for extraction of drainage pattern, aspect, slope, and curvature
3	Soil map,2020	MOWIE,	Shapefile		For soil classification
4	Geological map	Ethiopian geological survey agency	JPEG	1:200,000	To extract a geological map of study Area
5	Road	ERA	Shapefile	-	For existing road extraction
6	Village and town boundary	BOFED,2020	Shapefile	-	For study area boundary delineation.
7	River	MOWIE	Shapefile	-	For extraction of the river for the study area
8	Population density	Ethiopian CSA	Excel data	-	Population density map
9	SPOT 5 ,2017	Geospatial information institute	Tiff	1.5cm	For visual interpretation and reference data Landslide inventory map and LULC classification

Materials used to conduct the research works are given under Table 3.2.

Table 3.2: Materials used

S.NO	Description	Purpose
1	ERDAS, IMAGINE 2015	For image preprocessing and land use land cover classification, Study area subset, and mosaicking. For land use land cover classification
2	ARC GIS 10.8	For the preparation of all thematic layer for the research works
3	Globally mapper	To calculate cut and fill for each proposed LCP
5	Google earth	Used for visual interpretation tools for LULC classification and landslide inventory map preparation
6	PCI geomantic	To extract lineament for study Area
7	Handheld GPS (accuracy 3 m)	To collect origin and destination coordinate

3.3 Methods

3.3.1 Data collection methods

The first step in producing high-quality alignments depends on obtaining suitable data on geology, land use, slope, soil, and drainage. In addition, there are issues such as land value and ownership (Subramani, 2012). To achieve the objectives, the study used different primary and secondary data. The study used GPS field data as primary data. The secondary data, like a satellite image, DEM, the boundary of the study area, geological map, topo map, soil map, village and town map, were collected from the relevant sources Table 3.1.

3.3.2 Data analysis method

The process for road alignment selection is a rational one that takes care, among others design, to provide balanced information about the effects that the proposed route has been on the road environment. The traditional road selection process is modified here to reflect the use of geospatial tools with an integrated model. This study comprises five basic stages, which are

interrelated. The information acquired in one stage of the process was used as input in the next step. Generally, the study data analysis has been conducted in five general stages listed below.

- Identification of major factor
- preparation of data set
- creation of criteria map for each factor
- defining possible route alternatives using LCPA
- Valuation and final selection of optimal route.

The major criteria for route alignment were identified through literature review, expert consultation, and ERA standard manual. A personal discussion was carried out with Different professions to identify which parameter has a major impact on optimum route alignment. Afterward, based on their idea, ERA standard manual, literature review, nature of study area, and researcher knowledge the major influential factors were included for analysis. Once the major criteria were identified, then the research was conducted by the procedure shown in Figure 3.8

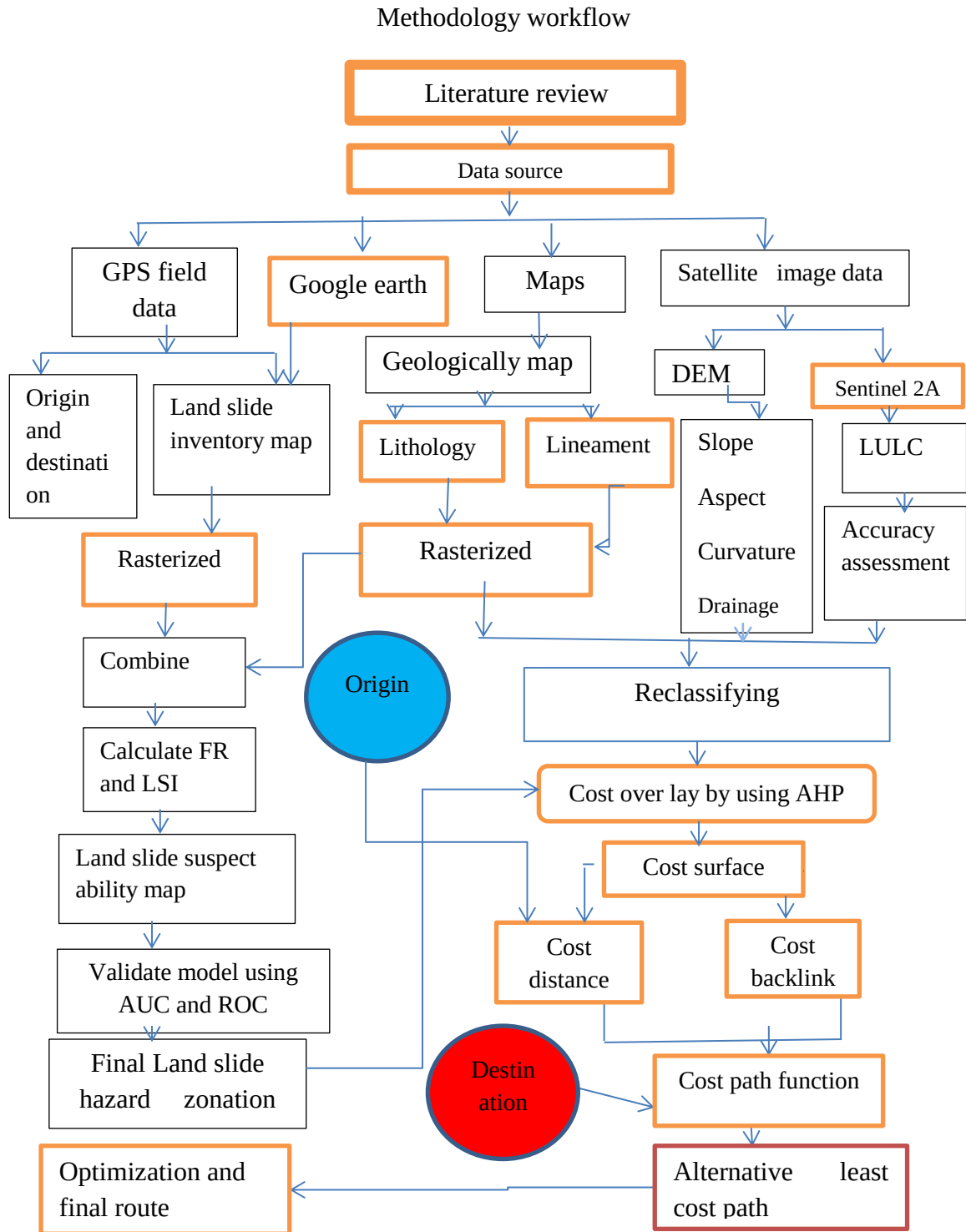


Figure 3.8: Technological scheme of the research works

3.3.3 Data set preparation

Considering the nature of the study area, literature review, and personal discussion after identifying the major engineering and environmental parameter affect the optimum route selection. Then the study prepared the data set for analysis work. The data set was prepared by using ARC GIS 10.8. The data set used for research work were shown in Table 3.3

Table 3.3: Data set

Input data	Software	Process	Output
Sentinel 2A, 2021	ERDAS IMAGINE 2015	Supervised classification	LULC map
DEM	ARC GIS 10.8	drainage extraction	Stream order
		Slope extraction	Slope
		Aspect extraction	Aspects
		car venture	Carventure
Geological map	ARCGIS 10.8	On-screen digitizing	Lineament
			Lithology
Soil map	ARCGIS 10.8	Clip	Soil map
Village and town map	ARCGIS 10.8	Clipping	Town and village boundary
Road	ARCGIS 10.8	clip	existing road
SPOT 5 2017	ARC GIS 10.8	Mosaic and clip	For visual interpretation of the LULC class and landslide inventory map

3.3.4 Data set properties

a) Slope

The slope is an important factor in road alignment location because steep slopes should be avoided as much as possible to prevent accidents and give driving comfort to the user. (Agrawal et al., 2015). The slope is crucial to the route selection process. Areas of the steep slope are supposed more expensive to modify than areas of the flat. The slope of the study area was derived from a PLASAR ALOS 12.5m resolution Digital Elevation Model (DEM)

using ArcGIS 10.8. Afterward, it was reclassified into 4 classes ranging between 0^0 – 79.89^0 using the reclassify spatial analyst tool in ARC GIS.

b) Land use land cover

Sentinel 2A acquired February 2, 2021 images of 10 m -meter spatial resolution has been used for land use land cover (LULC) classification. The two scene images were mosaicked to cover the study area. The mosaicked image was classified using supervised classification and compared to a satellite image retrieved from Google Earth that contained the research area. Since the Google earth image contained less percentage of cloud cover, it helped justify the accuracy when making an assessment. Moreover, SPOT 5, 2017, an image having 1.5 cm spatial resolution is also used for visual interpretation of land use land cover classification for the study area. The LULC criterion permitted the least cost path to take into account the type of surface that was most optimal and less hazardous (Austin, 2014).

c) Geology

Geological data was used in the whole process of routing the alignment; the reason being that implementation of less hazardous routes needed a more comprehensible dataset for the area (Muriki and Lewi, 2019). From geological parameters, the study considers lithology and lineaments as these two parameters are the most influential for optimal route selection. Since they are directly related to construction, cost .maintenance cost, and the safety of the road for road users. (Cut ability) of rocks is directly proportional to the hardness of the rock. Higher the Drillability, higher will be very hard and unsuitable for road construction (Engineering Vision)). Also, the area more prone to lineament results in an unstable slope prone to landslide. Consequently, the study classifies the rock type based on their crushing cost and also the degree of weathering considered for rock as the old igneous rocks are subjected to weathering. The lithology of the study area digitized from a 1:200,000 scale geological map of Addis Ababa sheet and Akake sheet by using ARC GIS 10.8 .the sheet taken from Ethiopia geological survey. The Study Area is more dominated by sedimentary rocks with the least coverage of igneous rock and metamorphic rocks.

d) Soil

Soil is a primary engineering material for road construction and maintenance. When it comes to road building and maintenance, the majority of road authorities are successful in identifying and managing the physical features of the soil. However, identifying and managing soil

chemical characteristics and soil-landscape dynamics, as well as how they may influence road building and maintenance today and in the future, is highly variable. Soil affects the relation between constructability and soft ground, and the condition of drainage, etc. Accordingly, the item of soil is judged to be a factor influencing the economic and technical aspects. Due to difficulties of foundation stability for the road bed, soil type categorization is a significant consideration in choosing a highway route alignment. To minimize both construction and maintenance costs, for example, stable soils such as loams are deemed more suitable than unstable soils such as coarse sands or clays (Agrawal et al., 2015). Soil type and distribution in Ethiopia during road design and construction soil engineering maps are very essential. However national or regional-based soil engineering maps do not exist in Ethiopia. Consequently, maps are often only available in association with specific road construction projects. In the absence of engineering soil maps it is common practice to use agricultural soil classification systems (ERA, 2013). In this study soil map is prepared from the shapefile data taken from the ministry of water irrigation and energy.

e) Drainage

Hydrologic factors are important considerations in the location, design, and construction of a road. The drainage for this study was derived from ALOS DEM 12.5 resolution and classified into four classes by using ARC GIS 10.8. The classification was done based on the number of streams in the Study Area.

f) Population Census Data

The population census data is one important factor for route alignment planning as ERA manually in rural area road planning dense populations must be served in 5 km buffer distance from the road. The census data contained the population statistics for the entire area showing the distribution and density in square kilometers. The study was carried out to establish a route connecting the two locations so that the majority of the population can have not restricted to access to goods and services. The major population should be served with the road. Therefore, it was compulsory to have population data. Population density map prepared by using ARC GIS 10.8 from population density taken from Ethiopian central statistics agency.

g) Existing road network

Existing Road patterns should also be analyzed before a new road alignment to ensure proper facilitation of road infrastructure to the population residing in the area. Hence, was done to

ensure adequate connectivity of the newly aligned route with the existing road. Similarly, it is one factory for mapping the landslide-prone area. The existing road network of the study area has been shown in Figure 3.9

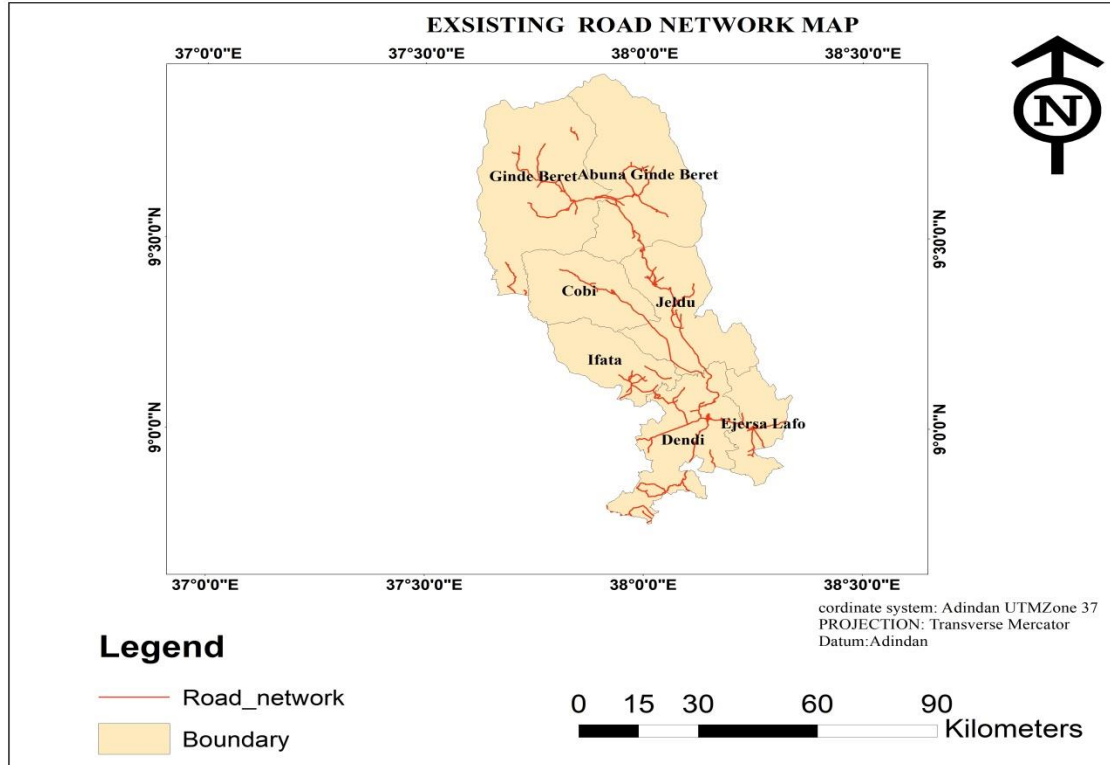


Figure 3.9: Study area existing road pattern(source: ERA,2020)

3.4 Preparation of Criteria Maps for Each Factor

Once the data set was prepared AHP spatial multi-criteria model was used for comparing the criteria in each criteria map and for the selection of different proposed route alternatives. Analytical Hierarchy Process (AHP) offers a structural basis for quantifying the comparison of decision elements and criteria in a pair-wise fashion. This kind of comparison greatly reduces complications and enriches the simplicity of decision-making. In the GIS database, the attribute factors are represented as thematic map layers and it contains attribute values for each pixel in raster data (Kiker, 2005). For analysis purposes, four alignments have been proposed and compared with each other. Suitability distance analysis relies on a Suitability Surface which is a raster dataset. The value of each cell represents the suitability level to align the road through that cell, the higher the value of the cell lesser will be the suitability and vice versa. According to the study area characteristics, the costs are based on one or several

variables such as slope, land cover, geology, soil, drainage, roads, aspect, etc. Every single raster has been created using an overlay function aggregates the suitability grids in a theme into one grid such as environmental cost surface.

3.4.1 Preparation of criteria weights for the factor

In criteria, mapping process weight was assigned for the factors to combine in the raster calculator. If the study area has very steep slopes, a high weight will be set to the slope raster value, giving it a higher weight, more attention is given to avoid a steep slope. To reduce the effect of different engineering and environmental parameters on the road prepared four suitable surfaces to define the least cost routes. All criteria were derived through literature review, expert consultation (personal discussion), and ERA design and route selection manually also used.

1. Engineering cost surface
2. Environmental cost surface
3. Landslide cost surface
4. Hybrid cost surface

3.4.2 Engineering cost surface

Optimal route alignment selection aims to reduce the cost and effect of engineering environmental and social parameters on the road and vice versa. Therefore engineering suitably (cost) surface was created to reduce the effect of the geological structure, slope, and drainage pattern on the road construction. To create the engineering suitability surface slope has been classified into four classes to avoid the steep area for road alignment and the geology of the study area has been classified based on the crushing cost of the rock to avoid high construction cost. Likewise, the drainage of the study area has been classified as per stream order to reduce the cost of bridge construction and avoid the flood risk area. In addition; lineament was classified as per lineament line density to ensure slope stability. The soil has been classified as per its texture since it controls the bearing capacity of sub-grade material. The AHP method was used for driving the weight for specified parameters. Figure 3.10 shows the parameter and procedures for preparing engineering cost surfaces.

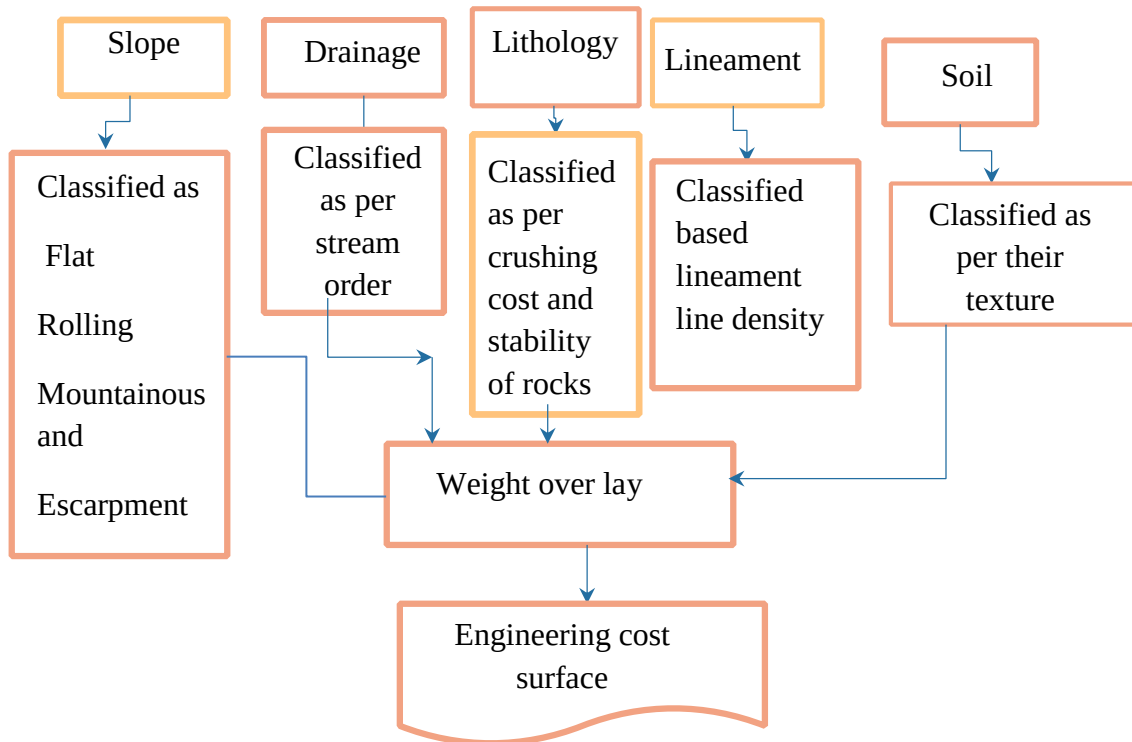


Figure 3.10: Technological Scheme of the Engineering cost surface

Table 3.4 shows the slope suitability level based on slope degree

Table 3.4: Weight of slope in engineering cost surface

Class	Slope(degree)	Suitability Level	Weight
Flat	0 – 2	Highly Suitable	1
Rolling	2 – 14	suitable	3
Mountainous	14 – 37	Less suitable	5
Escarpment	>37	unsuitable	7

Source (ERA Manual, 2013)

Here below also the drainage suitability level and the weights are given based on drainage density found in the study area. Table 3.5 illustrates the suitability level as per stream _order

Table 3.5: Weight of drainage in engineering cost surface (source: Effat, 2013)

Stream _Order	Suitability Level	Weights
1	Highly suitable	1
2	Suitable	3
3	Moderately suitable	5
4	Unsuitable	7

The weight for the geological data set was prepared based on the stability view and cut-ability (crushing) of rock by considering their blasting and excavation cost. Table 3.6 shows the suitability level of the geological surface based on crushing cost and stability of rock these properties and their stability of the rock was given through literature review and expert consultation.

Table 3.6: Weight of lithology in engineering cost surface (source: Expert consultation)

Rock Types	Suitability	Weights
Sandstone/limestone	Highly Suitable	1
Gypsum	Near to suitable	3
Basalt/trachyte	Moderate	5
Granite/gneiss	Less suitable	7
Quaternary superficial/alluvium/ pyroclastic deposit	Unsuitable	9

Lineament was classified based on lineament line density include (fault/structure/all other linear geologically formation like joint) also included under lineament line density. Line Density can be classified into four classes as shown in Table 3.7 lineament density is calculated by using line density spatial analyst tools in the Arc toolbox and classified as follow. Soil suitability based on their texture shown in Table 3.8

Table 3.7: Weight of lineament in engineering cost surface

Lineament	Suitability Level	Weights	Reference (Effat, 2013)
0-0.09316	Suitable	1	
0.09316_0.2544055	Moderate	3	
0.2544055_0.47655	Less suitable	5	
0.47655_0.913699	Unsuitable	7	

Table 3.8: Weight of soil in engineering cost surface

Soil Texture	Suitability	Weights	REFERENCE
Sandy loam	Suitable	1	(Jagabandhu , 2019)
Loam	Moderate	7	
Clay	unsuitable	9	

3.4.3 Environmental cost surface

Environmental suitability cost surface more attention was given to the gradient and land use land cover type. Here LULC is classified into five classes based on study Area characteristics (dense forest, agriculture, waterbody, built-up, and bare land to avoid high-cost land use land cover types. Similarly, 500 m buffer has been performed along the river to avoid the road passes over 500 m buffer from the river to reduce accidents as well as the cost of bridge construction. Likewise, the slope will be classified into flat, rolling, mountainous, and escarpments to avoid difficulties in topography in the road.

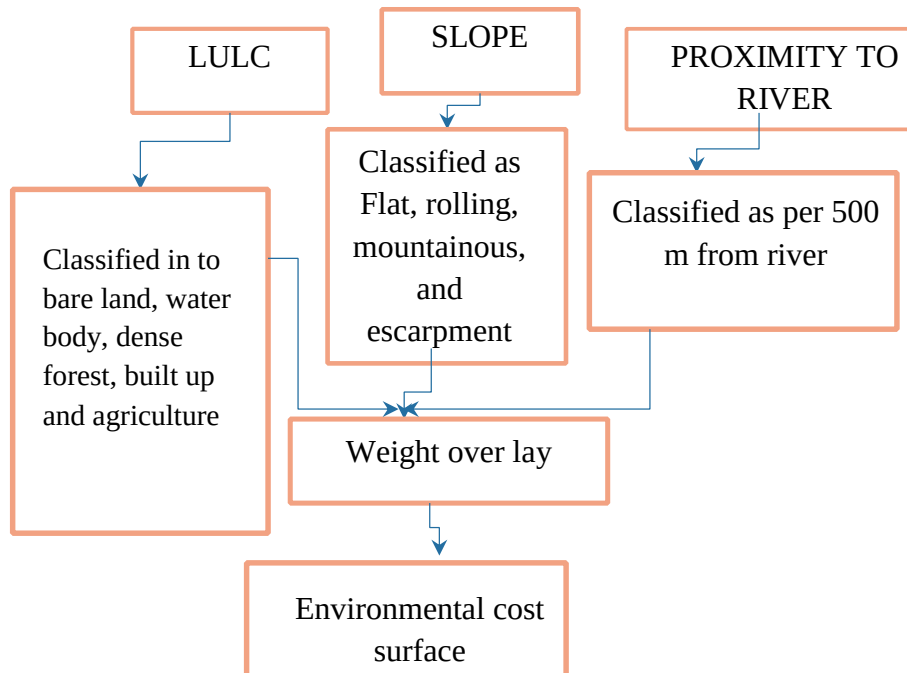


Figure 3.11: Technological Scheme of the Environmental cost surface

The weight is given as stated in Table 3.9 3.10 and 3.11 and also the data set used to prepare environmental cost surfaces is shown. The weight is proposed by using the ERA manual and related literature

Table 3.9: Weight of land use land cover in environmental cost surface (source: ERA)

LULC	Suitability Level	Weight
Waterbody	Unsuitable	9
Dense forest	Less suitable	7
Built-up	Moderate suitable	5
Agriculture	Near to highly suitable	3
bare land	Highly suitable	1

Proximity to the river for environmental suitability surface has been shown in Table 3.10

Table 3.10: Weight of proximity to the river in environmental costs surface (source: ERA).

Buffer from River	Suitability Level	Weight
<500	Unsuitable	9
>500	Suitable	1

Slope weight and suitability level in environmental suitability surface shown in Table 3.11

Table 3.11: Weight Of slope in environmental cost surface (source: ERA)

Class	Slope(degree)	Suitability Level	Weight
Flat	0 – 2	Highly Suitable	1
Rolling	2 – 14	Suitable	3
Mountainous	14 – 37	Less suitable	5
Escarpment	>37	Unsuitable	7

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

Using GIS and MCDM techniques to support the decision-maker achieves greater effectiveness and efficiency in solving spatial decision problems. (Wahdan et.al, 2020). After, all data layers are reclassified the pair-wise comparison was done to drive the environmental cost surface for the least cos path model .as mentioned previously the weight derived by using the AHP MCDM method. AHP extension tools were used to derive the weight.

A pairwise comparison matrix was formed by personal discussion conduct with several experts, knowledge of the researcher, and the Ethiopian Roads Authority's (ERA's) standard manual for optimal route alignments. The weight derived by using AHP extension tools in Arc GIS was shown in Appendix 7 and the procedure involved for calculation is discussed in the next section. Total no of a parameter (N) = 5, matrix A was the pairwise comparison matrix of 5 by 5 used to drive the weight. The steps followed were:

1. Form matrix A

$$A = \begin{bmatrix} R11 & R12 & R13 & R14 & R15 \\ R21 & R22 & R23 & R24 & R25 \\ R31 & R32 & R33 & R34 & R35 \\ R41 & R42 & R43 & R44 & R45 \\ R51 & R52 & R53 & R54 & R55 \end{bmatrix}$$

2. Then sum up all column in a pairwise comparison matrix

$$S = \sum_{l=1}^5 RIJ = B11 = R11 + R21 + R31 + R41 + R51$$

$$S = [B11 \ B12 \ B13 \ B14 \ B15]$$

Then the weight calculated by normalizing each rank of the parameter and weight is calculated the normalized matrix N created

3. derive the weight by using the formula below

$$N = \begin{bmatrix} R11/B11 & R12/B12 & R13/B13 & R14/B14 & R15/B15 \\ R21/B11 & R22/B12 & R23/B13 & R24/B14 & R25/B15 \\ R31/B11 & R32/B12 & R33/B13 & R34/B14 & R35/B15 \\ R41/B11 & R42/B12 & R43/B13 & R44/B14 & R45/B15 \\ R51/B11 & R52/B12 & R53/B13 & R54/B14 & R55/B15 \end{bmatrix}$$

Then,

$$W = \sum_{l=1}^5 Nij/5 \dots\dots\dots (3.1)$$

For example

$$W_{11} = N_{11} + N_{12} + N_{13} + N_{14} + N_{15}/5 \dots\dots\dots (3.2)$$

4. Check the consistency of weighted value

For this step first weighted sum is calculated by using the equation below (δ)

Then now we can calculate the consistency ratio first we should have formed a consistency vector

$$CV = \sum_{i=1}^5 \frac{\delta}{weight} / 5 \dots\dots\dots (3.3)$$

Where,

$$\delta = \sum a_{ij} * W_{ij} \dots\dots\dots (3.4)$$

δ =weighted sum.

a_{ij} : - is the rank of each criterion in a pairwise matrix

W_{ij} : - is the row average or the weight of factor

Now we can calculate the

$$\lambda_{max} = CV/N \dots\dots\dots (3.5)$$

Then calculate the consistency index by using

$$CI = \frac{\lambda_{max} - n}{n - 5} \dots\dots\dots (3.6)$$

Then,

$$CR = \frac{CI}{RI} \dots\dots\dots (3.7)$$

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 the comparison matrix. Table 2.3 shows random indexes of the matrices of order 1–10 (satty, 1987). Section 2.3 for environmentally cost surface the same procedure has been

repeated to drive the weight .while number of a parameter in environmental cost surface was three (LULC, slope, and proximity to river).

3.4.5 Landslide cost surface

Avoiding landslide-prone areas while route planning reduces the maintenance cost due to landslides. In the past, this was not possible due to a lack of information and technology. The advanced tools and extension in GIS and remote sensing now days enables to collect and analyze data to avoid sensitive areas and choose the most cost-effective road alignment (Padmani and RA , 2017 ; Roy and Saha, 2019 ; Meten, 2020 ; Li, 2020, 2017). In this study landslide, suitability surface will be created to compensate for the effect of landslide on road construction.to prepare the landslide suitability surface the land susceptibility map was prepared to map the landslide hazard zonation. To map landslide susceptibility map statically bivariate frequency ratio was used in this study. The frequency ratio method is a type of bivariate statistical analysis method and is one of the most popular approaches for landslide susceptibility assessment (Korup, 2014 ; Tehranah et al. , 2019). The simplicity of the principles and the ease of implementation in a GIS environment make this method a user-friendly and effective approach to landslide susceptibility assessment (Oh et al. , 2011 ; Lee, 2017). Notably, the frequency ratio method can have higher accuracies than other methods as mentioned by (Altural, 2013 ;Ramesh and S, 2014 ; zare, 2016, Hong, 2017; Saha, 2019 ; Mersha and Metiebea, 2020). Landslide susceptibility mapping for a certain area is a useful tool in landslide hazard management as it reveals the degree of susceptibility of an area to landslide occurrence. Landslide susceptibility maps can be prepared by assuming that future landslides would occur under the same conditions as previous ones. The landslide suspect ability map using frequency ratio method involves five basic steps:

1. Preparation of landslide inventory map
2. Thematic map preparation for governing factor for landslide suspect ability map
3. Calculate frequency ratio(FR) and landslide susceptibility index (LSI)
4. Validating the model using AUC and ROC
5. Final hazard zone map.

a) Preparation of landslide inventory map

The quality of the landslide inventories depends on the accuracy, type, and certainty of the information shown in the maps. In different physiographic, climatic, and land cover situations, the integration of satellite, airborne, and terrestrial remote sensing data is the preferred procedure for landslide detection and mapping. Mondt et al., 2012; Ye, (2019) able to detected landslides from hyperspectral remote sensing data using a deep learning technique.

In the current study, the landslide inventory dataset consists of a total of 578 landslides. Active landslide identified from Google Earth image interpretation and intensive field visit. For landslide susceptibility mapping landslide polygons can be divided into training and validation datasets. The training dataset is used for constructing the susceptibility map while the validation dataset is used for validating the model. In this study, the specific date of landslide occurrence is not well known. Hence, the landslide polygons were randomly split into two classes with 70% for training and 30% for validation by keeping their spatial distribution into account.

b) Database for landslide causative factors

To undertake landslide susceptibility analysis in the study area, a Geodatabase was first constructed for the causative factors within the spatial analysis tools of ArcGIS 10.8 software. The database consists of the landslide inventory datasets (training and validation) and the landslide causative factors (slope, aspect, curvature; lithology, and proximity to drainage, proximity to lineament line, proximity to road, elevation). These factors were subsequently evaluated by computing their weights from the relationship between the landslide and landslide causative factors and then these results were verified. There are no strict standards or guidelines for the triggering factors to be used in different statistical approaches for landslide susceptibility mapping. Instead, the factors should be chosen as it is operative and measurable depending on a particular study area's characteristics (Ayalew, 2020). One parameter may be an important controlling factor for landslide occurrence in a certain area. But in most cases, a combination of two or more landslide causative factors used for effective management of the landslide occurrence.

c) Frequency ratio (FR) model

For landslide susceptibility mapping, the frequency Ratio model is a well-known and commonly used bivariate statistical approach. The training landslide group was mixed with thematic data layers independently to evaluate the impact of each factor on landslide susceptibility, and then the frequency ratio of each factor's class was computed. To compute the frequency ratio first, the number of pixels for landslide occurrence and non-occurrence in each factor's class was calculated. Afterward, the percentage of each factor's class having landslide to the total pixels holding landslide of the factor was calculated. Then the percentage of each factor class's number of pixels to the total number of pixels in the research region was calculated. Finally, the frequency ratio of each factor class was obtained by dividing the percentage of landslide pixels by the percentage of area pixels in each factor class.

$$FR = \frac{\text{land slide frequency}}{\text{class frequency}} \dots\dots\dots (3.8)$$

$$\text{Land slide frequency} = \frac{\text{the number of land slide pixel in each class}}{\text{total landslide pixel in the parameter}} \dots\dots\dots (3.9)$$

$$\text{Class frequency} = \frac{\text{Area of the class}}{\text{total area of all class}} \dots\dots\dots (3.10)$$

Then after calculating the frequency ratio the LSI (landslide susceptibility index can be calculated by using the formula.

$$LSI = \sum_{i=1}^j FR \times Xi \dots\dots\dots (3.11)$$

Where: FR is the frequency ratio in the parameter and Xi= the raster data set of the parameter.

The higher the value of LSI indicates a high landslide zone and low LSI shows a low landslide zone. Then the landslide susceptibility model is validated by using AUC and ROC and finally, the land susceptibility zone can be produced. Then the land hazard map classified as shown in Table 3.12

Table 3.12: Weight for landslide hazard zone

Landslide Hazard Zonation	Suitability Level	Weight
Very low hazard	Suitable	1
Low hazard	Near to Suitable	3
Moderate hazard	Moderate suitable	7
High hazard	Not suitable	9

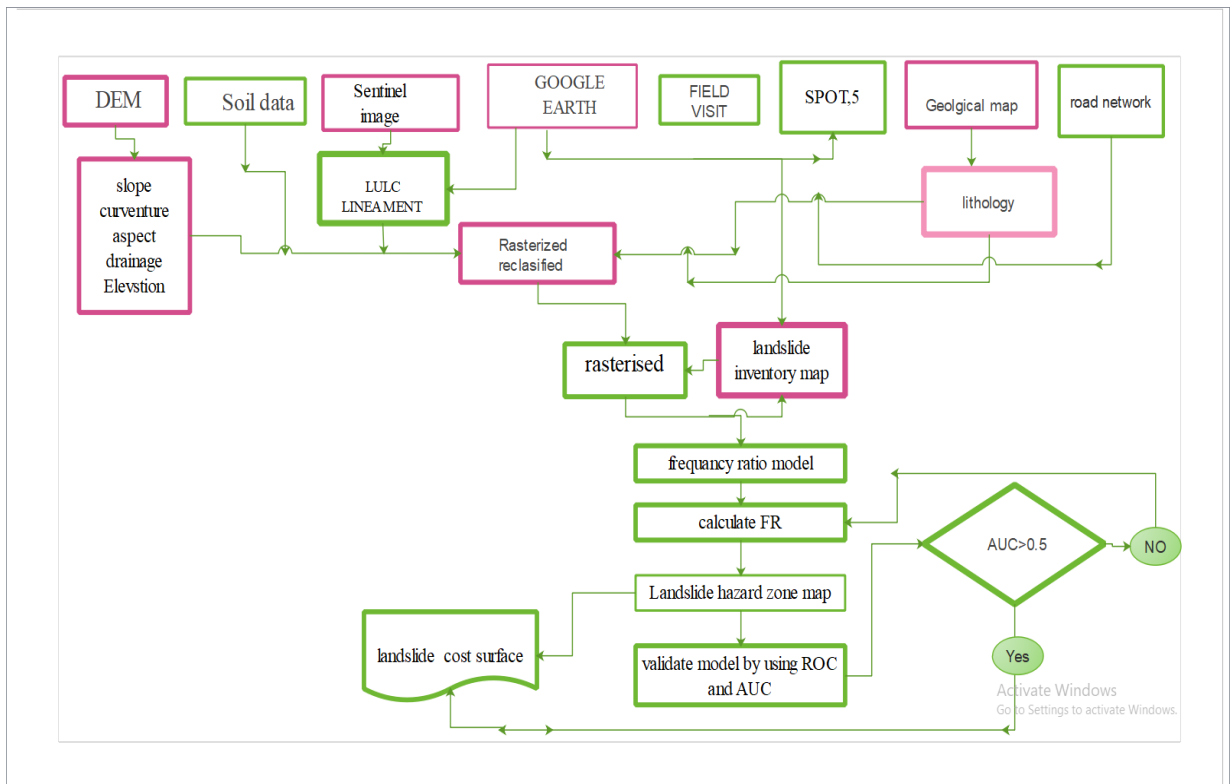


Figure 3.12: Technological Scheme of the landslide cost surface

3.4.6 Hybrid cost surface

A hybrid suitability surface was created by the weighted overlay of a previously created cost surface. Figure 3.13 shows a procedure of hybrid suitability surface. It is created from weight overlay (environmental suitability surface, engineering suitability surface, and landslide suitability surface by equal weight

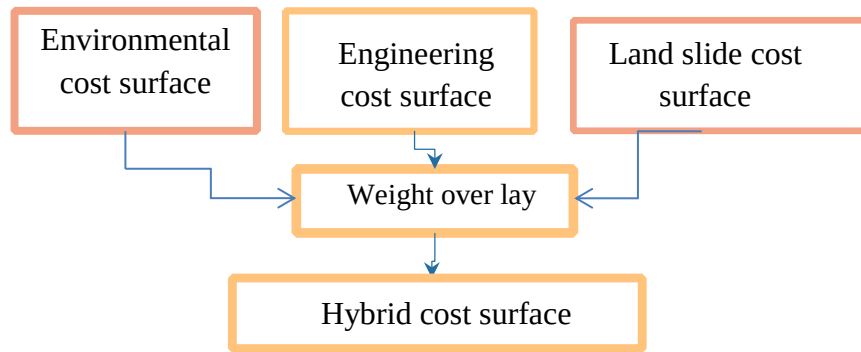


Figure 3.13: Technological scheme of the hybrid cost surface

3.5 Defining Possible Route Alternatives

Defining possible alternative routes allows getting the alternative that connects two locations. Similarly, the optimal routes connect two locations from alternative defined were selected. The task was performed in three simple steps.

1. creating the weighted cost distance and cost backlink
2. obtaining the alternate least-cost path and
3. obtain optimal route from alternative modeled

3.5.1 Creating the weighted cost distance and cost backlink

Cost distance and cost backlink Created from weighted cost raster and the origin of the road alignment. Cost-weighted distance analysis is to find out the accumulative cost of each cell to its nearest source. The weighted cost distance raster is created using the cost distance function. It uses the starting point (Start Point) of the proposed road created earlier and the (Cost Raster) and produces an output raster (Cost-Weighted Distance Raster). In the (Cost-Weighted Distance Raster), a value is calculated and assigned to each cell; this value is the least accumulative cost of getting back from that cell to the (Start Point) along the least cost path. In Cost distance analysis a source dataset and a cost raster are used as input to produce the least-cost path. Figure 3.14 shows an example of cost distance raster and origin.

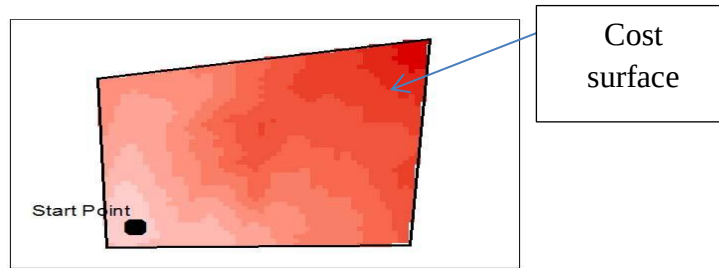
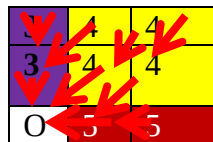


Figure 3.14: Example of a Cost Weighted Raster

When creating the weighted cost distance surface, the program prompts to create other layers which are the Direction Raster. The direction raster promotes a road map that shows how to get from any cell to the nearest source along the least-cost path and get back to the nearest source. The algorithm for computing the direction raster assigns a code to each cell that identifies which one of its neighboring cells is on the least-cost path back to the nearest source. The direction coding diagram of Figure 3.15 represents every cell in the accumulative cost raster. Each cell is assigned a value representing the direction of the nearest, cheapest cell on the route of the least costly path to the nearest source. This process is done for all cells in the (Weighted cost Distance Raster), producing the direction raster, telling the direction to travel from every cell in the Weighted surface Distance Raster and back to the Start Point.

5	7	10
2.5	5	6
0	1.5	3



Cost weight

direction

coding

Figure3.15: Example showing how Codes are assigned and the direction coding used

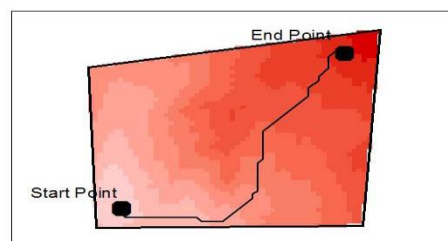


Figure3.16: Example of the route found by using least_ cost paths

The procedure for defining the least-cost path has been illustrated in Figure 3.

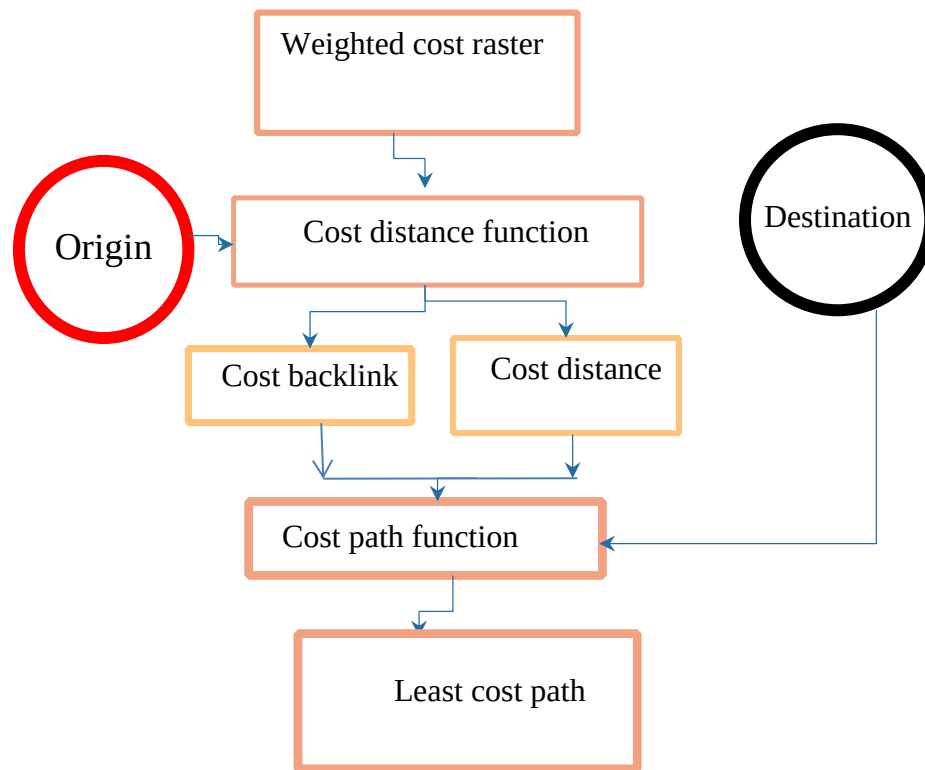


Figure 3.17: Methodology Workflow for Least-Cost Path Analysis

AHP is used to get the most efficient route from the alternative we defined in the cost raster surface. All the steps defined so far, end up in the formulation of an optimal alignment connecting two points is to be located based on various factors represented in the raster, for which environmental factors were taken into consideration by giving them high unit cost and topography which is represented by the slope raster and the aim is to avoid traversing steep slopes as it constitutes to higher construction cost and reduces the geo-hazard problem on the road.

3.5.2 Optimization of least-cost path for final selection

Now, the study defined four least-cost paths and the optimal routes were selected by integrated different parameters to evaluate each alternative. The evaluation criteria were compiled from ERA route selection, and design manual with different literature. Here the parameter used for the evaluation is discussed in the next section.

1. Number of the population to be served within five-kilometer

To analyses, this parameter a village (Keble) and town layer which constitutes a village wise population are considered. A five 5 km buffer was created around each alternative and intersect function was used and the population-wise list of the village has resulted.

2. Number of Keble to be served within five-kilometer

To analyses, this parameter a village (Keble) layer that constitutes a village-wise Keble boundary is considered. A five km buffer has been created around each alternative and intersects function was used to get the number of Keble to be served in five kilometers.

3. Number of connecting nodes with existing road network

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

4. Area of Forest covered to be disturbed

Firstly, forest layer extracted from the land use land cover layer and secondly 15 m has been created around each alternative to get its right of way. And then intersect function has been performed to get an area of forest covered to be disturbed.

5. Length of a road passing through the distance of 500 m from rivers

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

6. Area of agriculture land to be disturbed

Firstly, the agriculture layer was extracted from the land use land cover layer and secondly, a 15 m buffer has been created around each alternative to get its right of way. Then intersect function has been performed to get the area of agricultural land to be disturbed.

7. No of bridges/culvert required

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

8. Volumetric analysis

Continuous points created at a regular interval of 30 m using ARC GIS 10.8 on each alternative. An elevation of these points was extracted from DEM. Globally mapper has been used for slope calculation between consecutive points. Then by using extracted slope cut and fill volume has been calculated by taking the same height along the right of ways of each

alignment and for the centerline. Analysis was done basis on the calculated slope as illustrated in Table 3.13.

Table 3.13: Volumetric analysis for optimal route selection

S. No	Slope	Volumetric required
1	Less than – 15	Bridge
2	-15 to 0	Fill is required
3	0	No change
4	0-15	Cut
5	>15	Tunnel is required

Source (Nicuta and Andrei, 2017)

9. Quantity of buildable land available along each alignment

A slope map was converted into the vector format and a buffer of 2 km was created along the right of way of each alignment then intersection function was performed between the slope and 2 km of each alternative separately and the type of land available for future development was analyzed and compared.

10. Type of land use available for future widening

Land use layers converted into the vector format and a ring buffer of a right of way of the two-lane road. A ring creates of future widening with Erase function and intersects function between ring and land-use layer performed to analyze the type of land available for future widening.

3.5.3 Final optimal route selection

In the final selection, weight has been given to each parameter. The hybrid least-cost path has been scored the highest and selected as the optimal route between two locations. The parameter is weighted based on ERA manually and literature review. Table 3.14 illustrates the weight of different parameters used for the valuation of the alternate routes.

Table 3.14: Weight for a parameter for optimal route selection

S.NO	Parameter	Weight
1	Number of Keble to be served within five-kilometer (km)	5
2	Number of the population to be served within five kilometers (km)	5
3	No. of connecting nodes with existing road network	5
4	Area of Forest covered to be disturbed in 15 m buffer from the road	15
5	Length of a road passing through the distance of 500 m from the river	10
6	Area of agriculture land to be disturbed in 15 m buffer	10
7	No of bridges or culvert required.	10
8	Volumetric analysis	20
9	Quantity of buildable land available along each alignment in 2 km	15
10	Type of land available for future widening in 15 m buffer from the road	5
	Total	100

CHAPTER FOUR: RESULTS AND DISCUSSIONS

In this chapter, the data has been analyzed and the result was presented. Likewise, discuss how data has been analyzed. The analyzed data was presented in the form of table maps and graphs to show the results first all criteria maps have been prepared based on methodology discussed in chapter three, then cost raster surface, cost distance, and cost backlink was generated. Afterward, the alternative least-cost path was modeled by using cost distance cost backlink and destination dataset. Next, the least-cost paths generated were compared by using different engineering, environmental and social parameters, and optimal routes has been selected.

4.1. Preparation Criteria Map for Each Factor

4.1.1 Reclassified Slope layer

The slope of the study area was extracted from the PLASAR ALOS DEM having a resolution of 12.5 by using ARC GIS 10.8. The slope degree indicates the rates at which elevation changes over time, as lower slope values indicate flatter terrain and greater values indicating steeper terrain. In the current study, According to ERA (2013) standard, the slope angle is divided into four classes, i.e. gentle(flat) slope (0° - 2°), rolling slope (2° - 14°), mountainous slope 14° - 37° , and escarpment ($>37^{\circ}$). The gentle slopes (below 2°) only 5% (28.8 km^2) of the total area. The moderately steep or rolling and steep slopes and mountainous accounts for 64.213% (334.8 km^2) and 27% (145.7 km^2) of the total area of the road corridor respectively, the remaining 4 % (12 km^2) of the total area possesses very steep to precipitous (escarpments (above 37°) slopes. The highest landslide densities occur in a class along rolling and mountainous slope areas and the density and distribution of the landslide decreases along areas having a slope of below 2° and areas having greater than 37° . The steepest slope involves deep cutting during the construction. This makes worse the existing landslide problems for two reasons. The cut surface promotes the percolation of water which ultimately lubricates and increases the load, this results in sliding. The second is vibration during construction and maintenance. Vibration during maintenance accelerates removing the loose materials and cracking at the weak points. During the operational stage of the road, heavy trucks stay long on road due to the steepness of the slope. Particularly during the wet season, the road becomes slippery. As result trucks and trailers move slowly aggravates the sliding

problems. The riding quality was immensely also reduced. Therefore, in the course of optimal route selection, it was an effort to avoid the steep slope. Figure 4.1 shows the reclassified slope layers.

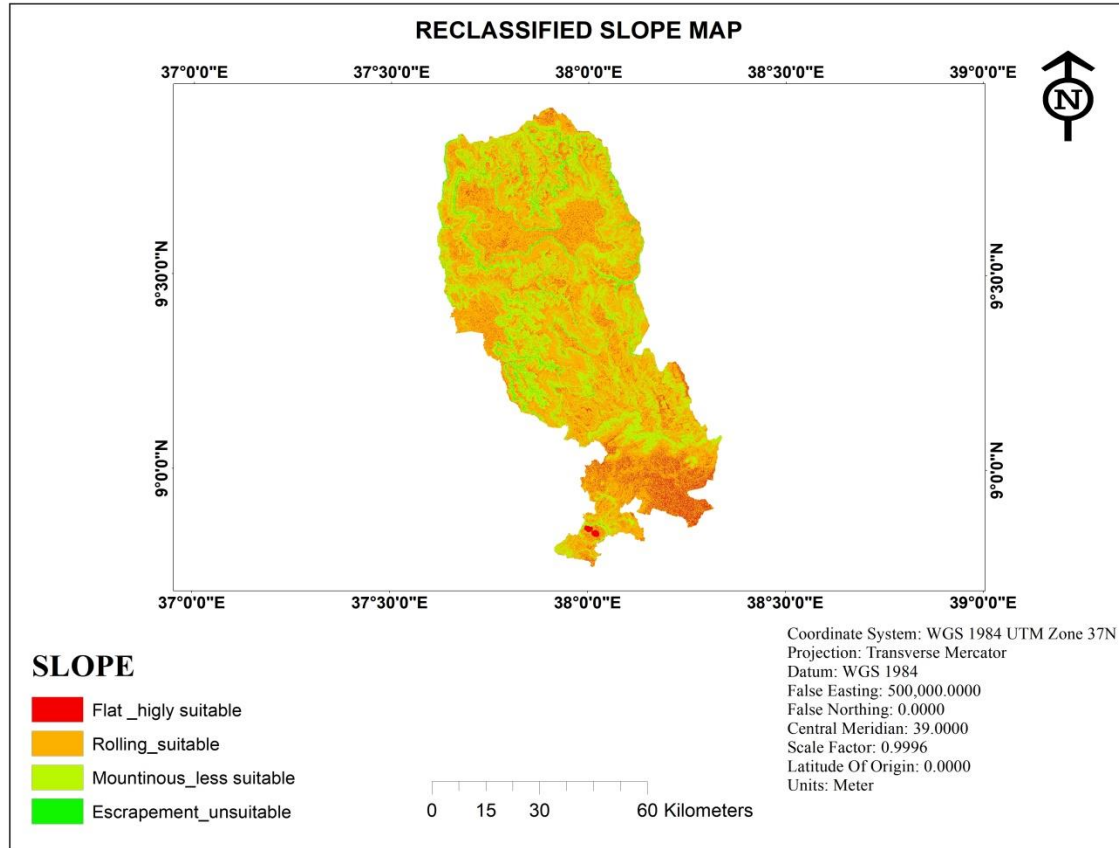


Figure 4.1: Reclassified slope layers map

The flat slope is more preferable for route alignment. Mountainous and escarpment are unsuitable due to high construction cost were required for slope stabilization ((Noor Moutaz Asmael.et al, 2015)

4.1.2 Reclassified Land use land cover layers

Land use/ land cover an essential parameter for road alignment. The construction cost, the safety of the road and the compensation cost for landholder is directly related to the types of land use type available in the study routes. The LULC with a higher value indicates more costly and therefore less suitable for road construction (Muriki et al., (2019) & Wahdan et al. , (2020)) Concluded Land use land cover data is required to estimate the cost of land

acquisition or compensation cost during route planning. The route should pass 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 inference. The following rankings are estimated to identify the suitability, and cost of compensation and clearing.

Table: 4.1: Descriptions of land use land cover

LULC	Suitability	Rank	Description
Waterbody	Unsuitable	9	It needs bridge construction, it leads to landslide in a wetland area
Forest	less suitable	7	High Clearing cost, leads to the unsafe road and disturbs the biomass system when cleared.
Built _up	moderate	5	Needs high compensation cost for the holder.
Agriculture	Near to highly suitable	3	Compensation for landholder
Bare land	Highly suitable	1	Needs only simple clearing.

(Source: compiled from ERA, 2013)

The above Table 4.1 shows Bare land (score=1) is relatively favorable for route planning since, such areas are under government control, involve no compensation cost, and are devoid of environmental problems like cutting of trees also it is most probable in stable slope that may reduce accident and increase efficiency safety of the road for the road users. Agricultural land (score=3) is relatively suitable since the compensation cost less than the building cost. Built-up (score=5) is relatively favorable when comparing with forest and water bodies. Forest (score=7) is not suitable for route selection because it contains loss of biodiversity including wild animals. Roads passing through the forest will increase the death of wildlife. Similarly, the cost of cutting dense trees is expensive. Water bodies (score=9) are not suitable for route selection. Because constructing roads across the waterbodies involves heavy investment such

as overpass bridge construction and underwater tunnels. Reclassified LULC map of study area illustrated in Figure 4.2.

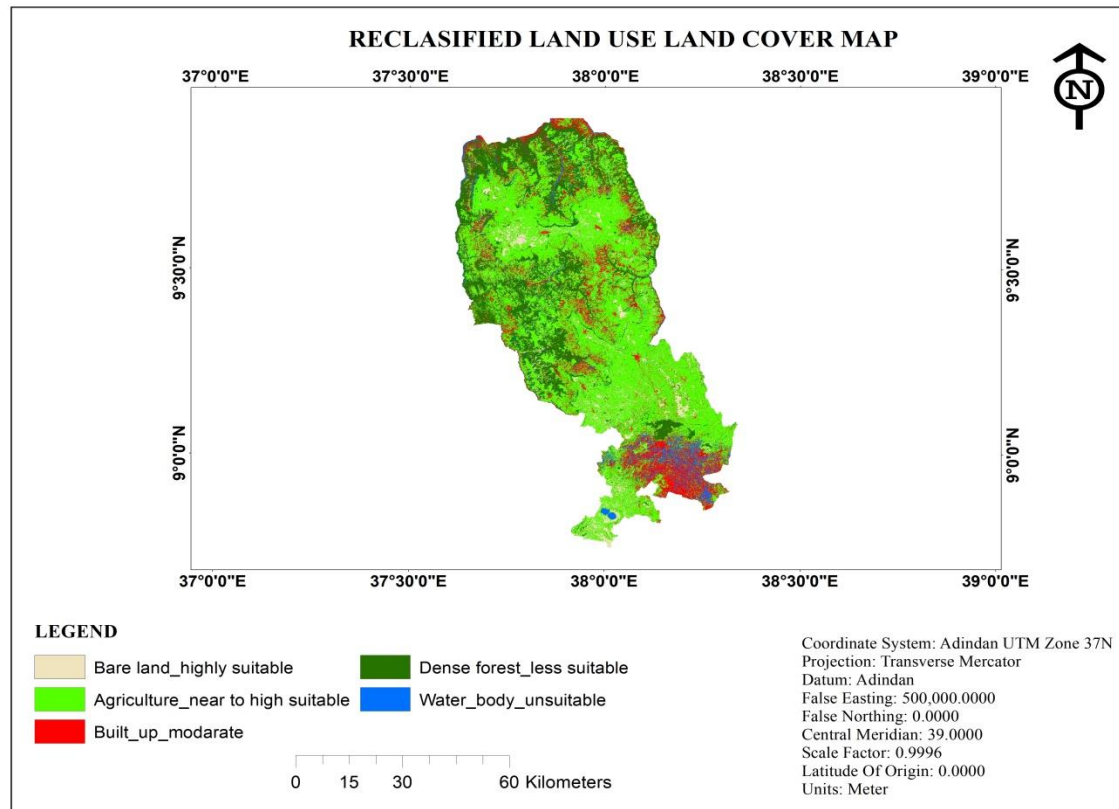


Figure 4.2: Reclassified land use land cover Map

Accuracy assessment of supervised classification

Accuracy evaluation or validation is an important step in the processing of remote sensing data (Rwanga and Ndambuki, 2017). The accuracy is typically used to express the degree of “correctness” of a classification result. The classification accuracy of a remote sensing image should be assessed before the classification result is used in data analysis and scientific investigation (Jingqi et al., 2017). The key emphasis for accuracy assessment pixel selection was on areas that could be identified on Landsat high-resolution image, Google Earth and Google Map. In this study google earth is used as reference data and visual image interpretation instrument. The study classifies the study Area into five major classless. The result indicates that the user's accuracy is maximum (95.16%) for dense forest. The minimum accuracy was obtained for the built-up class which is 78.55%. Agriculture, water body, and

bare land have an accuracy of 94.8%, 95.03%, and 87.79 %, respectively, Table 4.2 shows the accuracy assessment result for LULC classification results. 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.)

Table 4:2: Accuracy assessment for land use land cover

Classified map	REFERENCE DATA								
	Classified data	Bare land	Dense forest	Built-up	Agriculture	Water body	Total row	Commission error	User accuracy
	bare land	2751	0	0	380	0	3131	0.12	87.79%
	dense forest	21	4451	0	105	103	4680	0.04	95.16%
	Built-up	34	4	60	3	16	117	0.048	78.55%
	Agriculture	126	94	1	4336	13	4570	0.051	94.88%
	water body	0	55	0	14	1319	1388	0.049	95.03%
	Column Total	2932	4604	61	4838	1451	13886		
	Omission Error	0.062	0.033	0.0212	0.1	0.091			
	Producer accuracy	93.82%	96.68%	98.3%	89.67%	90.9%			
	Overall accuracy	93.02% allowable							
	Kappa coefficient	0.902 allowable							

Overall Accuracy (93.02%) 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 4.2 shows the 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 93.02% obtained in this research is acceptable. To have looked at non-diagonal elements in the matrix the 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 a strong agreement, values between 0.4 and 0.8 (40%-80%) represent moderate agreement and less than 0.4 (40%) values represent poor agreement and reclassification must be again (MMS, 2016). higher the kappa coefficient, then more accurate the classification. In the current study, the result of the kappa coefficient was 0.902. Therefore, it is acceptable.

4.1.3 Reclassified drainage densities layers

The drainage patterns in the area are an outcome of long-time interaction between the geological structure, topography, and slope. In this study, the drainage density of the study area was Generated from ALOS DEM and reclassified as shown in Figure 4.3. Less drainage order is more preferred than dense drainage for route alignment selection. If drainage density is high it needs to bridge construction. Also, it leads to unsafe vehicle operation. In this research, the drainage order is one or no drainage is more preferable for road construction as the drainage order increases no of bridge construction increase and these leads to high construction cost. Figure 4.3 shows drainage densities classified as per the number of stream orders. The length of streams order in the study area are 1029.83 km and 427.27 km of first, and second-order which is suitable and moderately suitable for road construction as they are narrow and the cost of bridge construction is less. Likewise, the third and fourth-order 218.20 km and 87.93 km are not suitable for road construction. as they are wide and need large bridge construction.

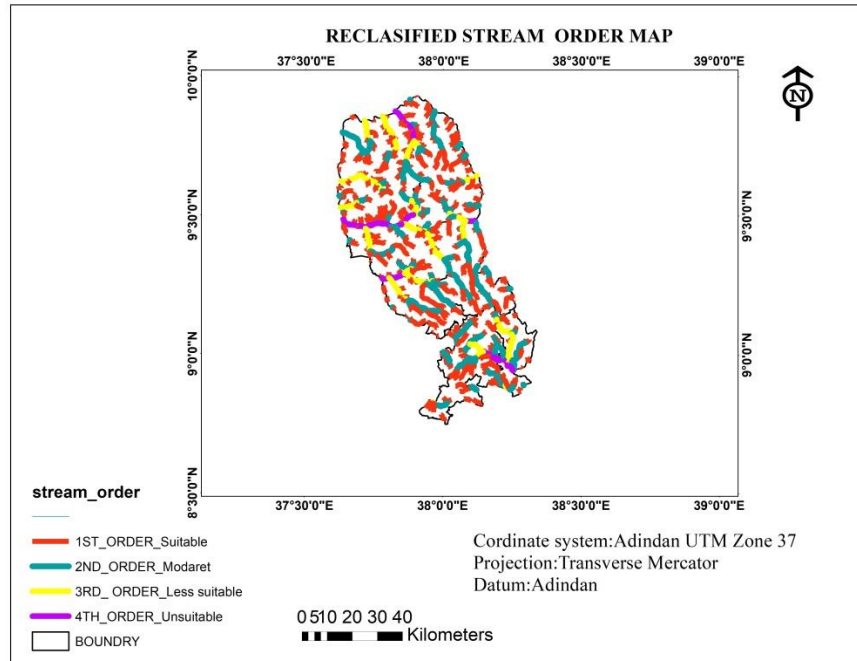


Figure 4.3: Reclassified stream order map

4.1.4 Reclassified lithology layers

The lithology of the study area is the most important parameter for route alignment selection. Since the types of rocks in the study road may affect the construction cost (excavation cost).in this study the lithology of the study area was digitized from 1:200, 000 geologically map.in different types of rocks are there in the Study Area. The lithology grouped in the study area classified into five classes based on their crushing cost and stability the rank was given as shown in Table 4.3.in the study area sandstone and gypsum (Gahtsion formation) is dominant rock types. In which 45.545 % (200 km²) of the study area was covered by sandstone with medium to high bearing capacity and easily crushed. And the second abundant rock types the study are is basalt which covers 22.93971% (150 km²) of the total Area, limestone covered 10.28821% (25.5 km²), basalt 5% (35.2 km²) and trachyte cover 1.460006% (6 km²) quaternary superficial, 10.1121%, (23 km²) , gneiss cover 3.251401%(5 km²) from the total area, pyroclastic deposit alluvium and granite are 3.6255%(4.31 km²), 7.16% (6.01 km²) , 0.038%/(1.33 km²) , 3.25% (3 km²) , covers, respectively.

Table 4.3: Valuation of different lithology units in the study area (source: expert consultation)

Rock Types	Terrain Types	Crushing Cost	Stability	Suitability Level
Basalt	Rolling	High to medium	Moderate	Moderate
Limestone	Rolling	Low to medium	Medium	highly Suitable
Sandstone	Flat to rolling	Low to medium	Medium	highly suitable
Granite	Rolling	High	Medium	Less suitable
Gypsum	Rolling	Low	Stable	Near to suitable
Gneiss	Near to mountainous	Extremely high	Stable	Less suitable
Trachyte	Rolling	Medium to low	Medium	Moderate
Alluviums/superbill sediment /pyroclastic deposit	Flat to rolling	Low	Unstable	Unsuitable

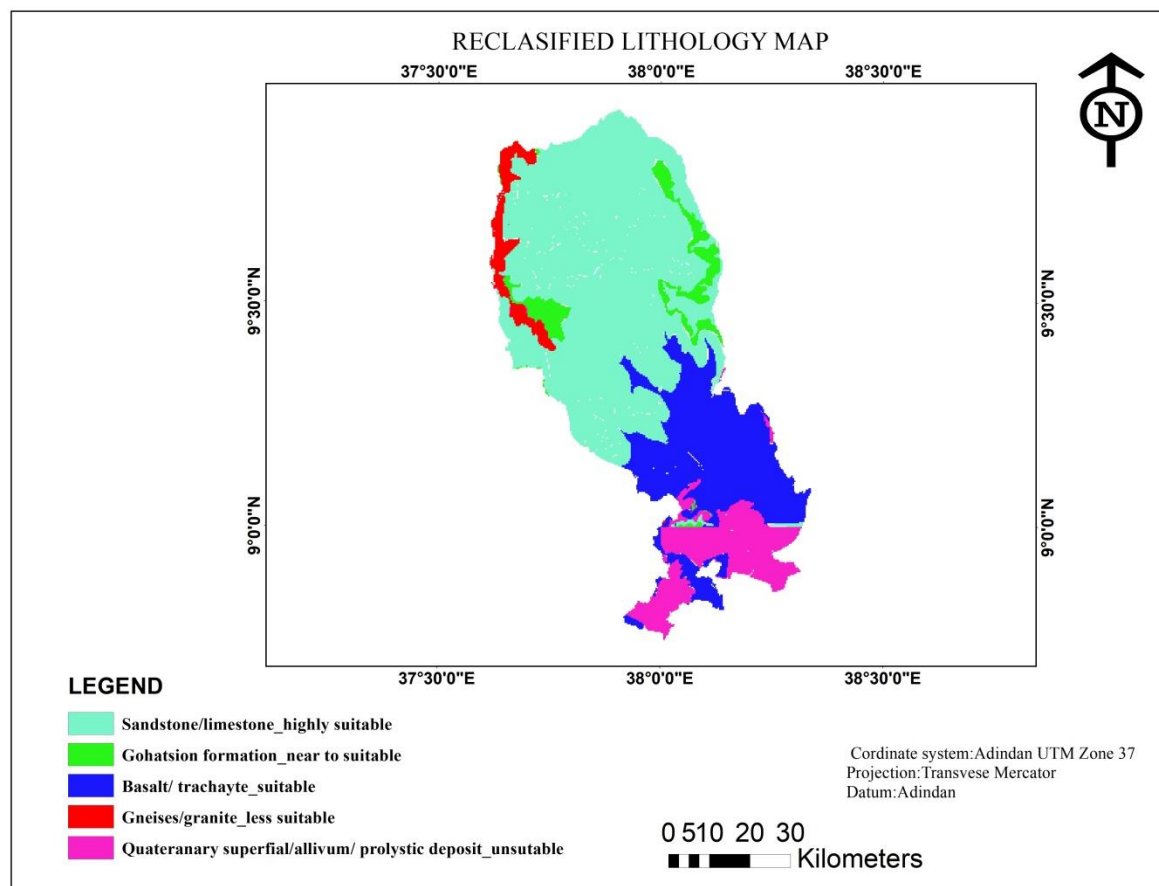


Figure 4.4: Reclassified lithology map

Limestone and sandstone are the most suitable rock types for road construction because of relative low crushing cost as results the less construction cost of the road and medium to high stable based their mineral content and the terrain which they are found in the study area .in this study the sandstone with quartz cementing agent is dominant over the study area (Meten and Yonas, 2006) which suitable for road construction. Most of the sandstone in the study area found in rolling and moderate flat slopes and has medium to high bearing capacity. Correspondingly, the limestone available in the study area is insoluble and has moderate strength with less amount of calcite which prevents solubility (Meten and Yonas, 2006). Therefore, they are the most suitable rock types for road alignment. Similarly, gypsum was selected as a moderately suitable rock type since it is relatively stable and has less crushing cost comparing with the other types of rock types available in the study area. Rather, the basalt and trachyte are taken as relatively near to moderate suitability for route alignment due to their stability high bearing capacity when compared with the left rock types in the study area. Granite and gneiss are not suitable because of their high crushing cost and also are found relatively in steep terrain. Pyroclastic quaternary superficial and alluvium are not suitable for route alignment because of their low bearing capacity and solubility and they are not stable.

4.1.5 Reclassified lineament density

Lineaments are very important from the stability point of view of soil as they control the movement and storage of groundwater (Wahdan et al., 2019). Wherever the ground is high; the area is not suitable for road construction. In the study area, there is a total of 0.935 km lineament exists. High lineament density was unsuitable for route alignment it needs slope stabilization whereas low lineament density or no structure (faults, joints, etc.) Suitable for route alignments. In this study, lineament density is classified into four classes as shown in Figure 4.5. Lineament density has been extracted by using PCI GEOMATIC and digitized from 1:2000, 000 geologically map of Addis Ababa and Akaka sheet then the result was compared and the lineament line density map produced using ARC GIS 10.8 from the result of Sentinel 2A images using PCI Geomatic. The suitability level and values of lineament density are shown in Table 3.7.

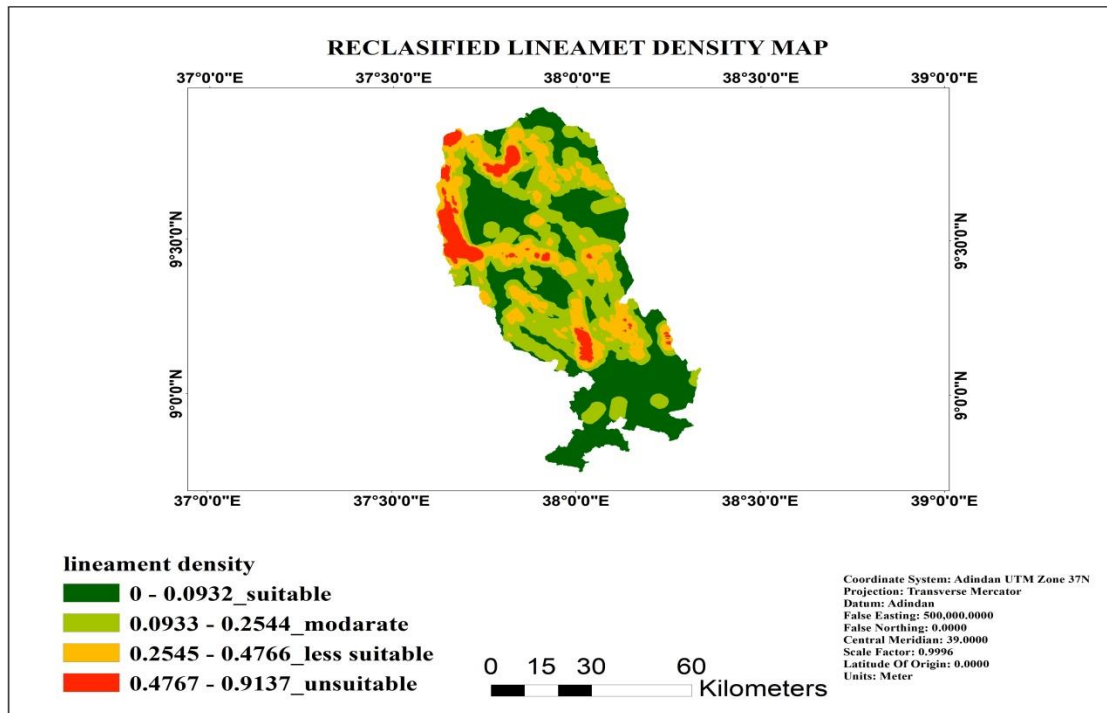


Figure 4.5: Reclassified lineament density map

4.1.6 Soil layer

Soil texture defines the bearing capacity of construction material for road construction. Access to good sub-grade soil is very important for construction roads and other infrastructure. Water losses from seepage will be small in good soil. To meet the road asset's intended design life and cause minimal damage, it may be necessary to remove biological properties, change chemical properties, and reduce or remove some physical properties when using soil as a road engineering material(or vice versa) on the immediate and surrounding landscapes. The main properties required of a road embankment are minimal potential for movement and erosion. The main properties of a road pavement are strength, durability, impermeability, volume stability, wear resistance, and workability during construction. The study area is dominated by the sandy loam texture of soil cover out of which 43.04% (233.07 km²) of the surface is having good strength to hold the road when compared with the left soil texture available in the study area. Then, followed by the loam texture which covers 41.003% (202.23 km²) and the clay soil texture have the least percentage of 15.95 % (85.77 km²) from the total study area. Figure 4.6 shows the reclassified soil texture as per suitability for road construction.

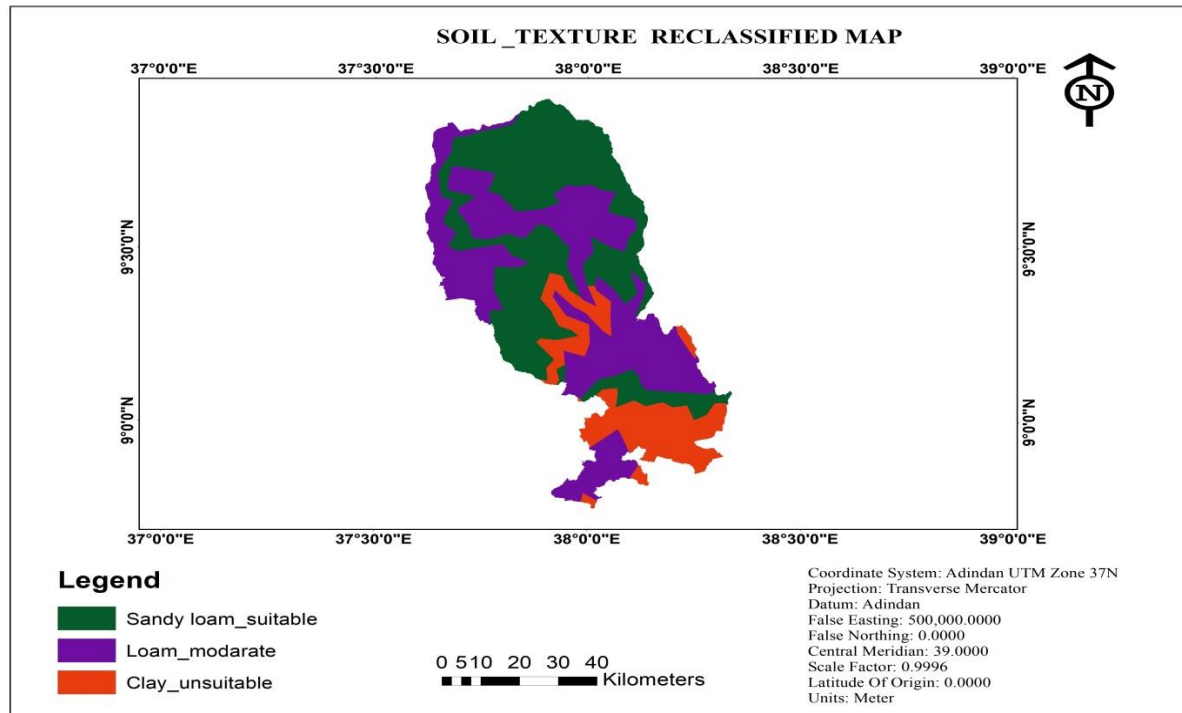


Figure 4.6: Reclassified soil map

The good soil must have less preamable porosity have a high bearing capacity with less organic content that leads to reduce solubility. 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 determines the porosity and permeability of soils. Sub-grade soil types suitable for construction require 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 excellent for road construction. While clayey soils have higher porosity, and so can hold more water than sandy soils, they also have high permeability because the pores (opening) are so small. Clay soils are characterized by a small pore size and therefore not suitable for sub-grade soil for road construction. Large pore size, and thus poor water-holding capacity, is a problem only in very sandy soils (Biggs, 2012). 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, are drained, and are less probable to compact. The particle size of fine-textured soils (sandy clays, clays, and silty clays) is small they can trap water and nutrients, take a long time to dry, and compress readily when wet, and are frequently associated with

poor drainage, limiting field use during wet weather. Sandy loam is a suitable coarse-textured soil; 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 moderate soils are a type of soil that is midway between sand and clay. It usually contains a combination of organic material, sand, and clay. This is advised by builders to be capable of 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 is unsuitable for road construction. It is a type of fine-textured soil that has a small particle size, it is unfavorable. Because of this happens flood by soil erosion and less bearing needs excavation to remove the top soils which affected by the erosion

4.2. Preparation of Cost Map

As explained in the methodology part preparation of criteria maps involves the identification of the factors (criteria) required for cost map preparation. The environmental and cost priorities of the road projects must be considered when examining the most suitable road. The environmental or cost-oriented road projects can be defined with Analytical Hierarchy Process (AHP) (Sen, 2017). Besides AHP, the least-cost path analysis (LCPA) algorithm is used to determine the route alternatives of the road. LCPA provides users to find the cheapest route that connects two locations using a cost surface that is determined by considering multiple criteria (Effat, 2013). In this study the AHP is used to determine the cost surface for modeling different types of alternative by considering the factor for each cost surface. The pair-wise comparison was done for the factor used to determine the cost surface. The procedure is explained in the methodology part was applied to derive the cost surface for modeling LCP (least-cost path). Here below the thematic cost surface created for modeling the least-cost path alternative is explained.

4.2.1 Engineering cost surface

The preparation of cost maps involves a weighting of related factors that affect road alignment. 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, 2013). In this study AHP is used to derive the

weight for the factor .the factor is identified by a personal discussion with different professions, Researcher knowledge, and literature review. A total parameter used here is five, slope Figure 4.1, drainage, Figure 4.3 liniment densities, Figure 4.5, soil, Figure 4.6, and, lithology Figure 4.4. 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 carried out. First, rasterization was done for the vector data layers to produce similar data layers with 10m resolution, for further data analysis. Then the data has been reclassified into subclass using Arc GIS 10.8 software package. Before merging the elements, weights must be assigned using the Analytic Hierarchy Process based on (satty, 1987) Analytic Hierarchy Process (AHP), which involves creating a pairwise comparison matrix for each map using a nine-point priority scale. Weighting is used to express the relative importance of each factor compared to the other. The larger the weight, the more important is the factor. Table 4.4 shows the pairwise comparison matrix of engineering cost surface. The weight is derived by using AHP extension tools in ARC GIS. The result of the AHP extension is shown in Appendix 6 and the procedure involved and all step calculations were expressed here below.

Table 4.4: Pairwise comparison matrix in engineering cost surface

Pairwise Comparison Matrix						
S/N	Factor	Slope	Drainage	lithology	Soil	Lineament
1	Slope	1	3	5	7	9
2	Drainage	0.333	1	3	5	7
3	Lithology	0.2	0.333	1	3	2
4	Soil	0.143	0.2	0.333	1	2
5	Lineament	0.111	0.143	0.333	0.333	1
6	Sum	1.787	4.676	9.666	16.333	23

Then to calculate the weight for the parameter first normalized matrix is obtained by divided each matrix element by it is total column. For example to get $N_{11}=1/1.787=0.559$ Table 4.5 illustrated normalized matrix and weight. The weight is calculated by summing the rows of normalized function and dividing by a number of a parameter used. The number of a parameter is five for the engineering cost surface.

Table 4.5: Engineering cost surface normalized matrix and weight

Normalized Pairwise Matrix and Weight							
Criteria	Slope	Drainage	Lithology	Soil	Lineament	Sum	Weight
Slope	0.5596	0.6416	0.5173	0.4286	0.3913	2.5383	0.5077
Drainage	0.1863	0.2139	0.3103	0.3061	0.3044	1.3210	0.2642
Lithology	0.1119	0.0712	0.1034	0.1837	0.1304	0.6007	0.1201
Soil	0.0800	0.0427	0.0344	0.0612	0.1304	0.3486	0.0697
Lineament	0.0621	0.0306	0.0344	0.0204	0.0435	0.19101	0.0382
Sum							1

$$W_{11} = N_{11} + N_{12} + N_{13} + N_{14} + N_{15}/5 = 0.5077$$

Afterward, the consistency ratio was calculated as the first consistency vector was calculated by using the formula

$$CV = \sum_{i=1}^5 \frac{\delta}{weight} / 5 \quad , \quad \text{Then the CV vector is obtained,}$$

Table 4.6: Engineering cost surface consistency matrix

Consistency Matrix								
criteria	Slope	Drainage	Lithology	Soil	Lineament	Sum	weight	Ratio
Slope	0.5084	1.5229	0.6007	0.4884	0.3438	3.4636	0.6927	5
Drainage	0.16943	0.2643	0.3604	0.3489	0.2674	1.4100	0.2820	5
Lithology	0.10153	0.0879	0.1201	0.2093	0.1146	0.6336	0.1267	5
Soil	0.07245	0.0528	0.0400	0.0697	0.1146	0.3498	0.0699	5
Lineament	0.05633	0.0204	0.0400	0.0232	0.0382	0.1782	0.0356	5
Sum								25

From Table 4.6 the value of, CV= 25 using the formula given above, then the λ_{max} calculated as follow.

$$\lambda_{max} = CV/N=25/5 = 5$$

Therefore, the consistency index obtained from calculated λ_{max}

$$CI = \lambda_{max} - n/n - 1 = 0 \quad , \quad \text{then the random index (RI) for 5 x 5 matrix is for n=5, RI =1.11}$$

So, $CR = CI/RI, = 0/1.11 = 0$ which is acceptable, then the cost map was prepared by using the calculated weighted in the ARC GIS package

Therefore, $Cost\ map = SL * 0.50766 + DR * 0.26420932 + LTH * 0.12014031 + LD * 0.038202 + SOL * 0.069781$

Where, SL=slope, DR=Drainage density, LTH=Lithology, LD= Lineament density, SOL=Soil texture.

subsequently, the engineering cost map was generated and classified into four class .in which From total area under study 33.62% (170.5 km²) falls under very less cost, which highly suitable for road construction 30.40 %(154.153 Km²), falls under less cost, moderately suitable for road construction, 23.07% (116.99 km²) and 12.95% (72.7 km²) are falls under moderate and high cost which relatively near to unsuitable and unsuitable for the route alignment. The same procedure is followed for environmentally cost surfaces for driving the weight for the parameter. Figures 4.7a and 4.7 b show the weight of the parameter using a pie chart and engineering cost surface generated.

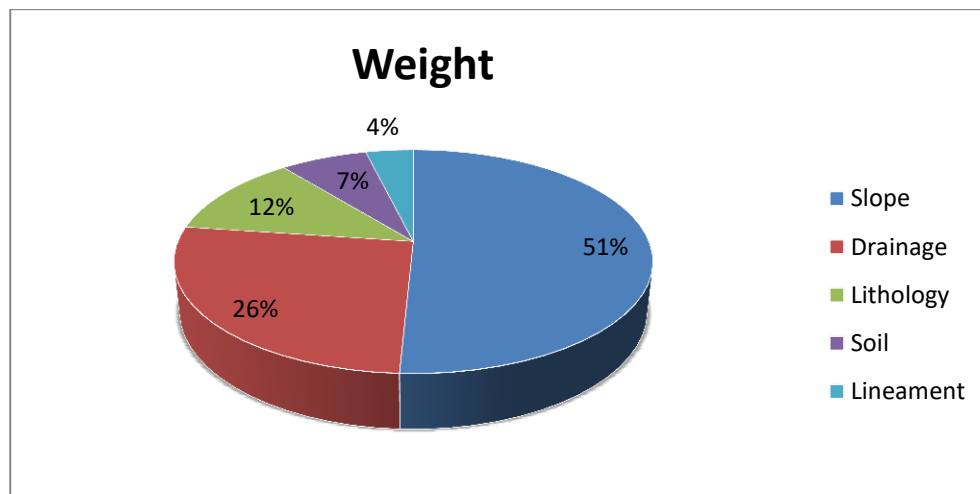


Figure 4.7 (a): Pie chart shows the weight of parameter for engineering cost surface

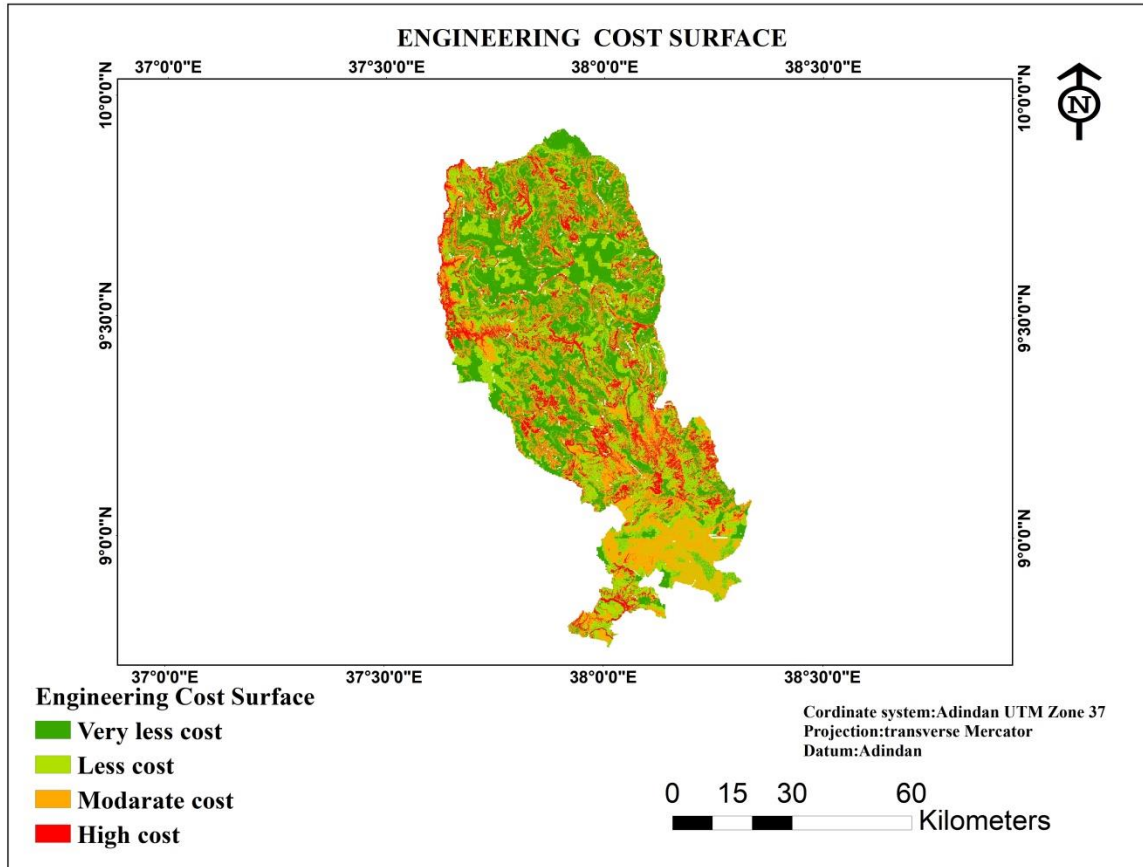


Figure 4.7 (b): Engineering Cost surface

4.2.2 Environmental cost surface

Environmental data is necessary to specify the impacts of the recommended road on the surrounding environment where the road has been laid (Suleiman et al., 2015). The procedure is the same with engineering cost surface. for preparation of environmental cost surfaces three parameters have been used to reduce the effect of the road construction on the environment and to increase road safety by decreeing construction cost as well as properties damage biomass and compensation cost. The parameter used was slopes, land use land cover and proximity to the river considered as environmentally parameter .the parameter selected by expert consultant ERA manual and literature review as mentioned in the methodology chapter. The weight for parameter derived by using the AHP method the same procedure is followed as engineering cost surface. From the total area, 21.75% (113 km²) under very less cost i.e. suitable for road alignment, 48% (250 km²) under less cost which relatively good for route alignment, and

14.45% (75 km²) and 15% (82 km²) falls under the moderate and unsuitable area which is not preferred for road alignment. By using the same procedure with engineering cost surface the weight was derived for all three parameters. Table 4.7, 4.8 & 4.9 shows the pairwise comparison, normalized and consistency vector matrix's for environmental cost surface.

Table 4.7: Environmental cost surface pairwise comparison matrix

Pairwise Comparison Matrix			
Parameter	LULC	Slope	Proximity to river
LULC	1	3	5
Slope	0.333	1	2
Proximity to river	0.2	0.5	1
Sum	1.533	4.5	8

Table 4.8: Environmental cost surface normalized matrix and weight

Normalized Matrix					
Parameter	LULC	Slope	Proximity to river	Sum	Weight
LULC	0.652316	0.666667	0.625	1.943982	0.647994
Slope	0.217221	0.222222	0.25	0.689443	0.229814
Proximity to river	0.130463	0.111111	0.125	0.366574	0.122191
Sum					1

Table 4.9: Environmental cost surface consistency matrix

Consistency Matrix						
	LULC	Slope	Proximity to river	Sum	weight	Ratio
LULC	0.647994	0.076605	0.04073	0.765329	0.25511	3
Slope	1.945928	0.229814	0.122191	2.297934	0.765978	3
Proximity to river	3.239971	0.459629	0.244383	3.943982	1.314661	3
Sum						9

By using the same procedure in section 4.3.1, then $CR = 0.004 < 0.1$, therefore, it is acceptable. Then cost map is prepared by using derived weight.

*enviromental cost map = cost map = Land use land cover * 0.647994 + Slope * 0.229814 + proximity to river * 0.122191*

Land use land covers weigh more to avoid the land use types that have high costs and to reduce the biomass reduction. Figure 4.9 shows proximity to the river map. The weight of the parameters is shown in Figure 4.8 using pie charts.

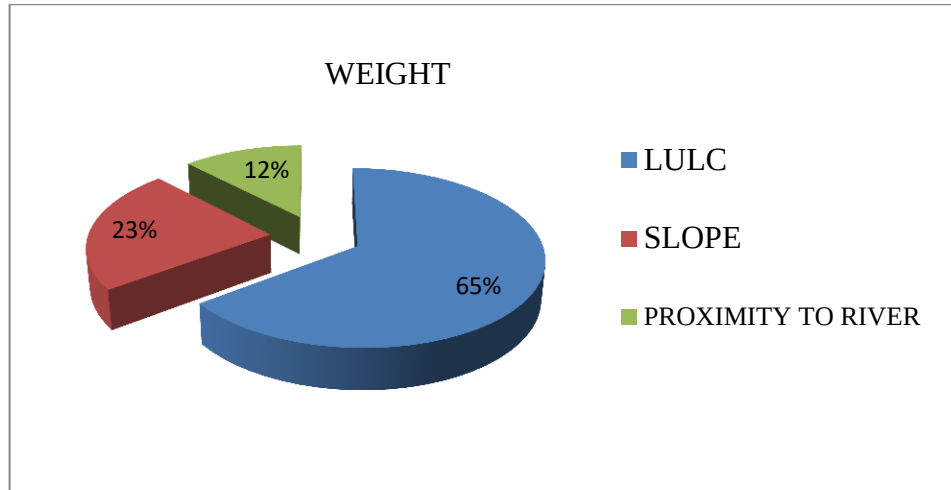


Figure 4.8: Pie chart showing the weight of parameter for environmental cost surface

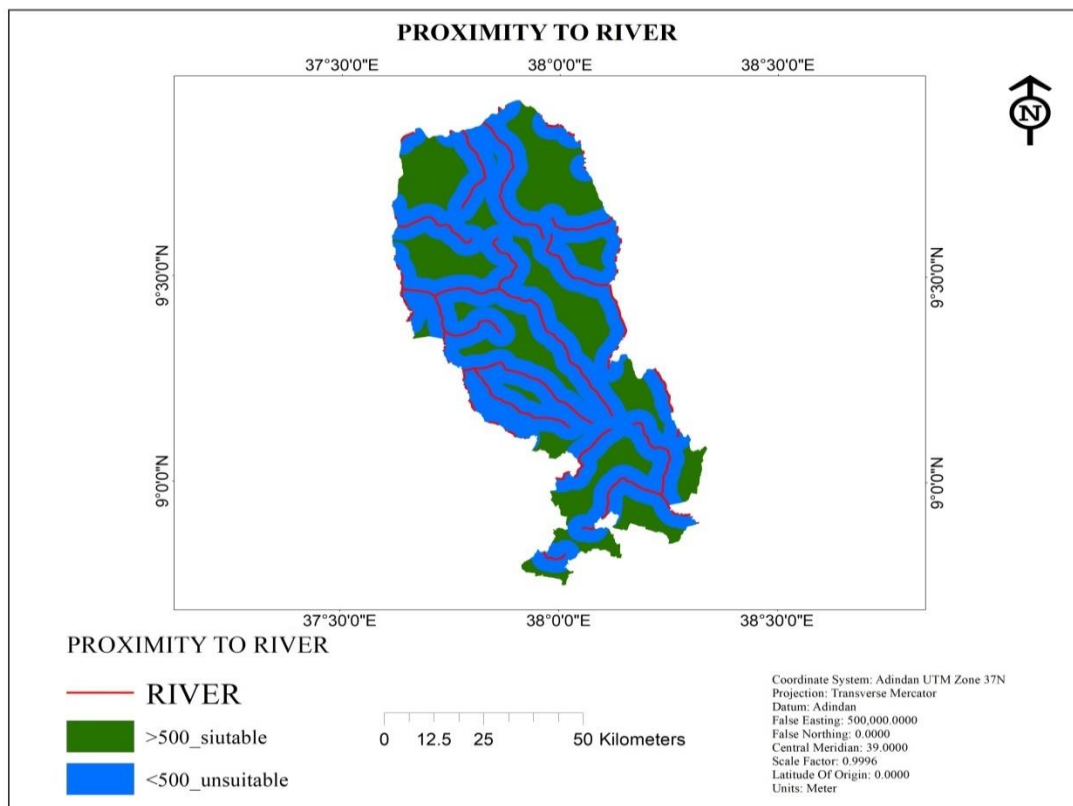


Figure 4.9: Reclassified proximity to river map

The result shows from the total area of 466.3 km² is under a distance greater than 500 m from the river which is suitable for route alignment and the 57.86 km² area under the distance less than 500 m from the river which is unsuitable for route alignment. The reclassified land use land cover was shown in Figure 4.2 in section 4.1.2 Likewise, slope layers were shown and classified as discussed in section 4.1.1 in Figure 4.1. Environmental cost surface was shown in Figure 4.10.

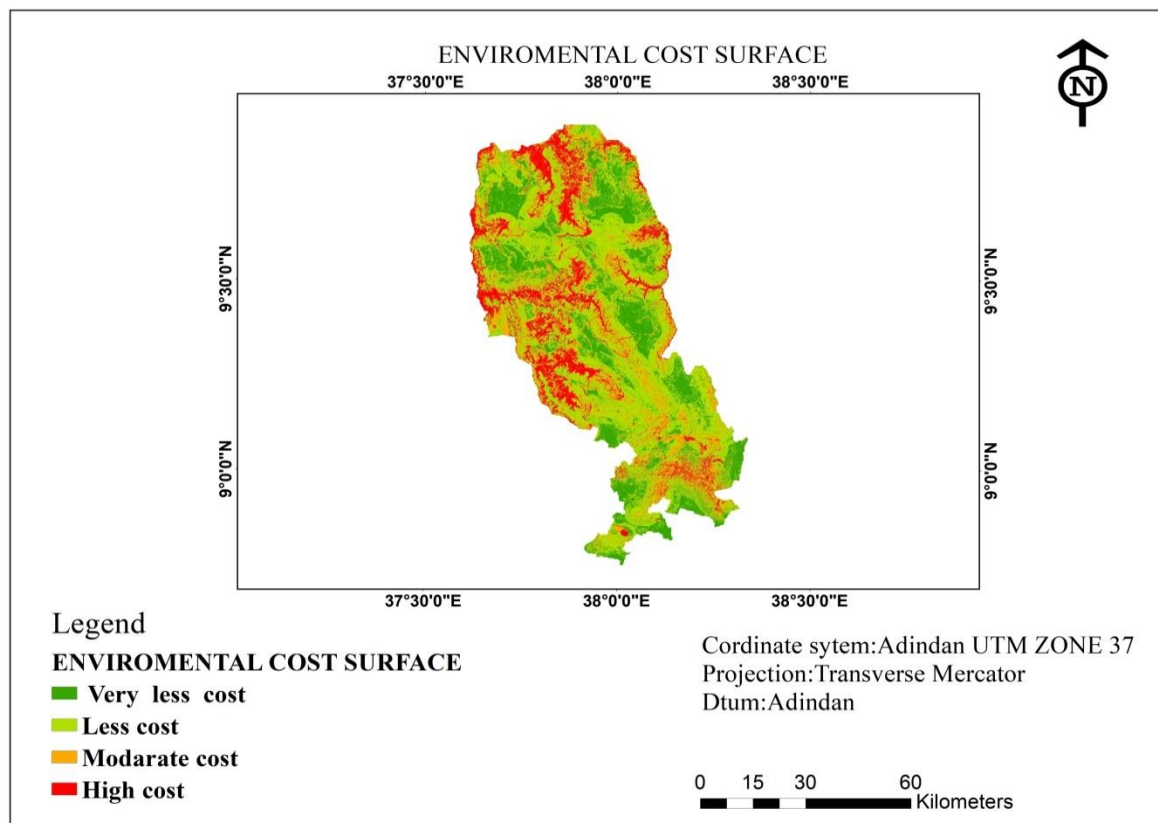


Figure 4.10: Environmentally cost surface map

4.2.3 Landslide cost surface

Landslide cost surface created by using frequency ratio model. To prepare the landslide cost surface first landslide inventory map has been prepared. The cost surface was prepared from ten causative factors depending on the availability of the data and literature review. curvature, slope aspect, slope degree, land use land cover, distance to lineament, distance to the drainage, proximity to road, lithology, elevation, soil, were used .in this study the location of the

existing landslide were identified by using google earth imagery and SPOT 5 satellite image with an intensive field visit.

a) Landslide inventory map

The identification and mapping of existing landslides is a prerequisite for performing statistical analysis of the relation between the distribution of landslides and its influencing parameters as well as to select an optimal route that is free from landslide hazard. Landslide inventory map is the basis for mapping the landslide suspect ability map of the landslide-prone area. Landslide inventory mapping is one of the important aspects of landslide susceptibility mapping, and it can be generated using a variety of methodologies, including an aerial photograph or Google Earth imagery interpretation and fieldwork coupled with GIS tools (Meten , 2020). Landslide inventory maps can also be prepared using Google Earth imagery (Mansou et al. , 2019 ; Azemeraw, 2020). In this study, 578 landslides were identified by using google earth imagery; historical record, spot 5, 2017, satellite images, and intensive field visit around the road under study were conducted. From the identified landslide data 70% (405) samples were used for the landslide susceptibility map whereas 30% (173) is used for testing to validate the model. Figure 4.11 a, b, c & d shows the landslide in different periods for existing roads using google earth image. Figure 4.12 illustrates the landslide inventory map of the study area.



Figure 4.11 (a): Google earth image part of road affected by landslide in 2020



Figure 4.11(b): Google earth image part of the road affected by landslide in 2016



Figure 4.11(c): Google earth image part of the road affected landslide in 2014



Figure 4.11(d): Google earth image part of the road affected by landslide in 2021

The photo of an active landslide in the corridor under study is also shown in Appendix 2 .the photo was taken by the researcher around the corridor and some of the susceptibly areas to the corridor. The types of the landslide in identified from these field visiting are lateral spread and rockfalls. The field survey was conducted for verification of the landslide inventory map prepared. The result was acceptable as several researchers conducted and obtained the comparable result for example (Cantarino et al. 2019; Sarda and Pandey, 2019)

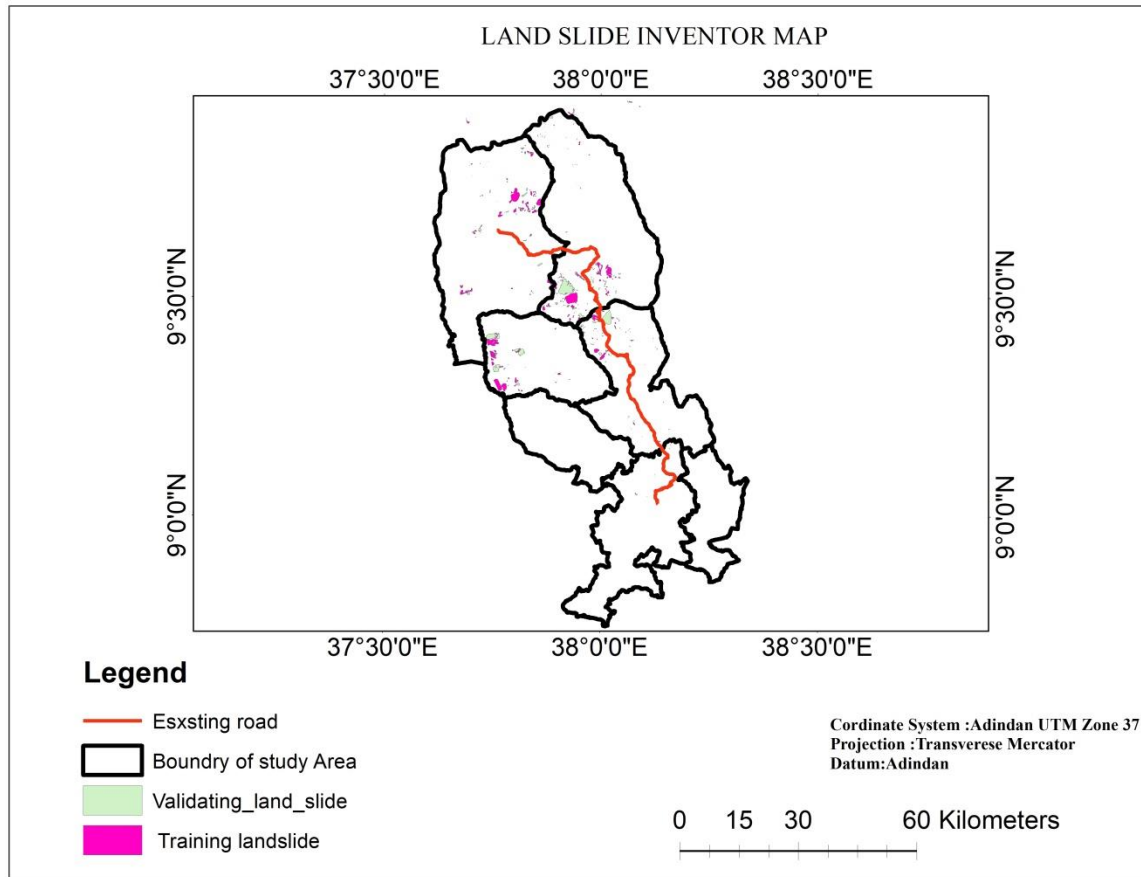


Figure 4.12: Landslide inventory map (from field visit, spot, 5, 2017, and Google earth)

b) Landslide governing factor

For landslide hazard zone mapping, ten governing factors were used in this study. In landslide susceptibility mapping, the selection of landslide factors is one of the most important elements. However, there are no well-defined standards to select the most significant landslide factors (Azemaraw et al., 2020). The factors that initiate the landslide incidence in the study

area are selected based on the data availability, local environmental conditions, and literature review. In this study, ten governing factors were selected for land susceptibility mapping. The parameters are explained in the next parts.

1. Aspect: Aspect refers to the slope orientation which is generally expressed in terms of a degree from 0° – 360° . It regulates the slope's exposure to sunshine, wind direction, rainfall (degree of saturation), and discontinuity conditions, making it a crucial component in landslide investigations (Mersha and Meten, 2020). In This study, the aspect was derived from ALOS DEM with 12.5 resolution data and it was divided into nine classes, namely; north, northeast, east, southeast, south, southwest, west, and northwest as shown in Figure 4.13. The most landslide occurs along the south, southeast and southwest which account 13% and 14%, respectively and low landslide occurred in flat and north which counts 8% and 9% and the respectively. Other aspect class score between 11_13 percent as shown in Appendix 3

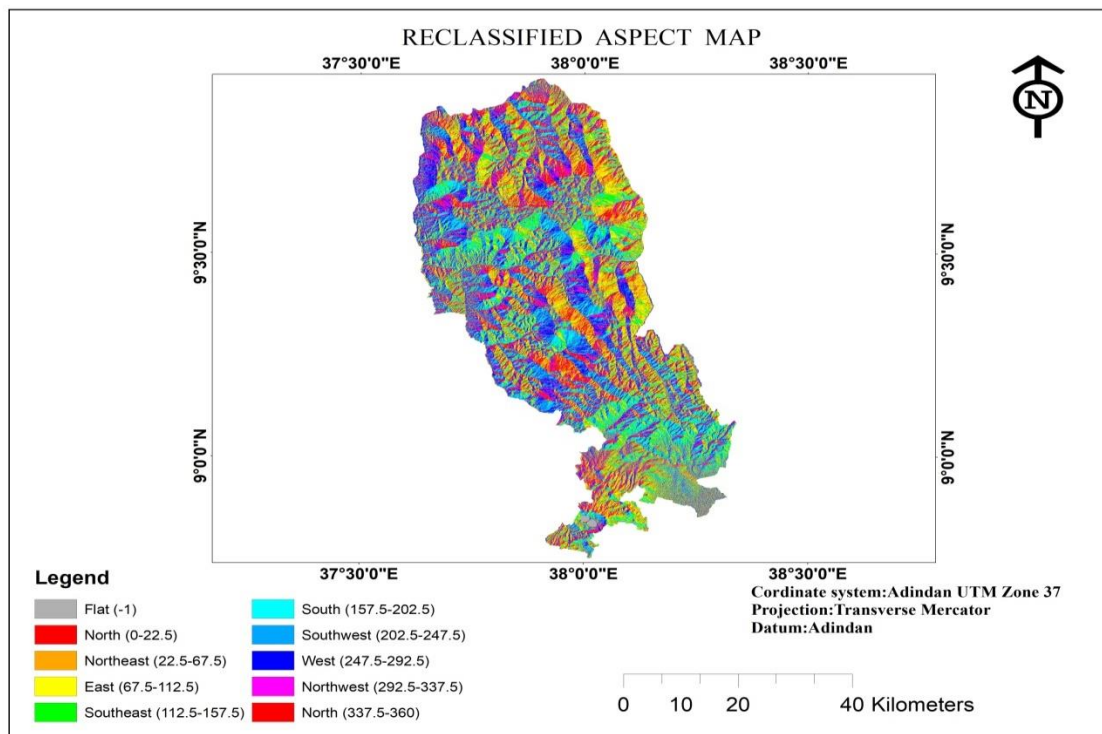


Figure 4.13: Reclassified aspect map

2. Slope Curvature: - Curvature is defined as the rate of change of slope gradient in a particular direction and controls the hydraulic condition and gravity. Curvature may refer to

the convex, concave, and flatness of a slope. As studied (Pradhan et al., 2010 ; Dahal, 2017) Based on Meter et al., (2015) in the flat area, the probability of landslide occurrence is very low. A positive curvature indicates that the surface was upwardly convex at that grid. A negative value of curvature indicates that the surface was upwardly concave at that grid, whereas a value of 0 indicates that the surface was flat (Roy and Saha, 2019). The curvature map of the study area was generated from DEM data and it was classified into 4 classes based on the value as shown in Figure 4.14. The more positive or negative values indicate the higher landslide occurrence. The landslide occurred in concave and convex areas which counts 26% (-29.33_-1.44), 23% (-1.43_-0.13), 24% (-0.12 _-0.97) and 25% (0.98_26.67) from a total landslide in the curvature class. The result shows as the value near to positive or negative the probability of occurrence of landslide increases and near to zero, it decreases.

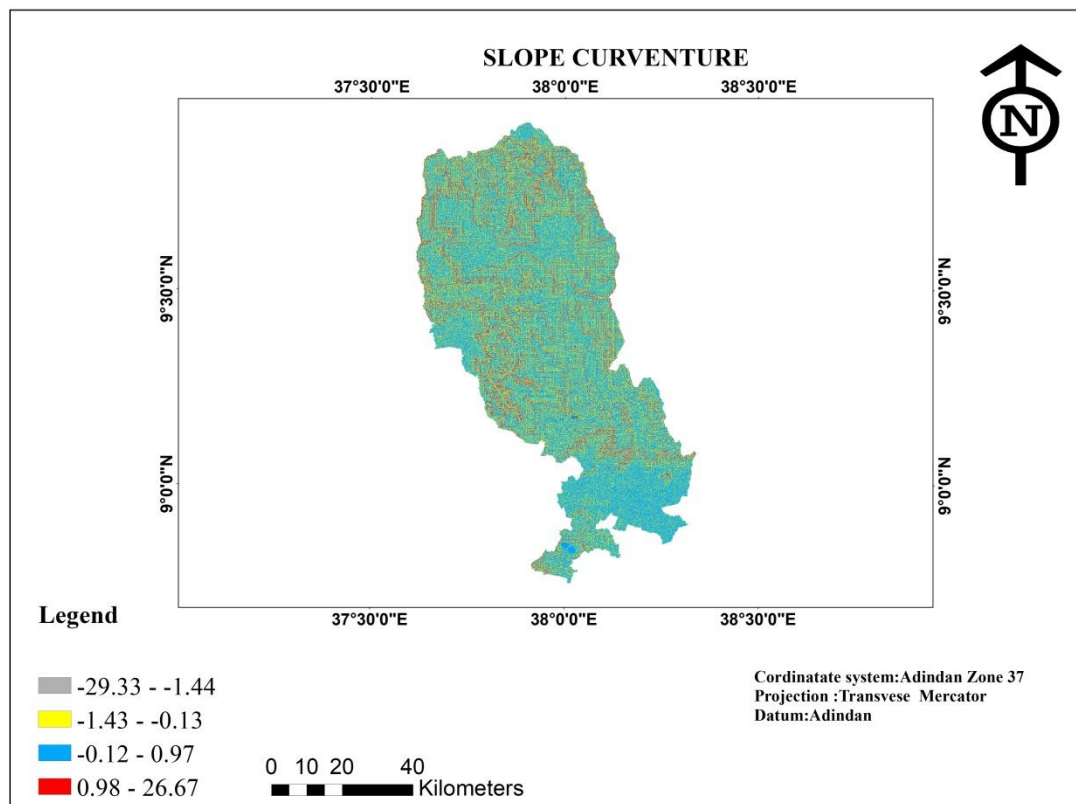


Figure 4.14: Reclassified curvature map

3. Elevation: _The elevation is another factor that plays an important role in landslide susceptibility assessments considered by several researchers (Zhang et al., 2001 ; Ye , 2019 ; Dou, 2015). The variation in elevation may be related to different environmental settings such

as vegetation types and rainfall (Dou, 2015). The elevation map of the study area has been prepared from 12.5m DEM using the spatial analyst of ARC GIS 10.8 and categorized into 5 - class ranges as shown in Figure 4:15. The minimum elevation is 920m, while the maximum is 3307 m. No major landslides were recorded at elevation class greater than 2643 m because this portion of the study area is sound rock mass which eventually reduced the potential land sliding process. About 52% of the landslides occurred at an elevation range between 1539_1912 m, 24 % of landslides probably occurred in the elevation range between 920_1538 m, 18 % of landslides probably occurred in elevation ranges between 1913_2277 m & 3% of, a landslide occurred at elevation range between 2278_2642 m.

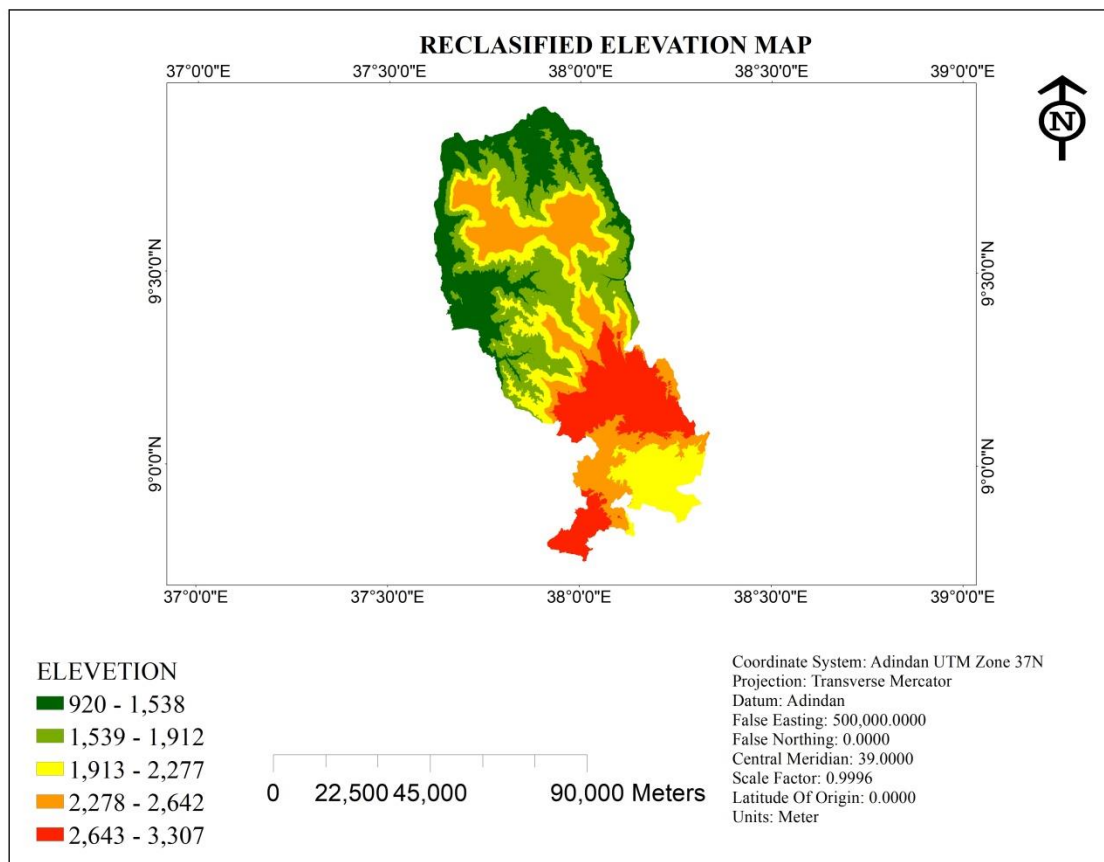


Figure 4.15: Reclassified elevation map (from DEM)

4. Distance to lineament

Tectonic structures and a linear arrangement of geomorphological features that may be continuous or interrupted without any clear evidence of displacement such as topographic break considered as lineament. (Getachew and Meten, 2020). The term lineament includes

faults, fractures, and escarpments. The more prone to lineament, the more likely the slope will fail. Lineament is a crucial controlling feature in determining landslide susceptibility. (Yilmaz, 2009 ; Pascale, 2014). The result shows 52 % of landslides occurred at distance 0_200 m from the lineament and low landslides occurred at distance > 800 m which is 1% only, and other class contributes 200_400 m (37%), 400_600 m (7%). Figure 4.16 shows the proximity lineament maps.

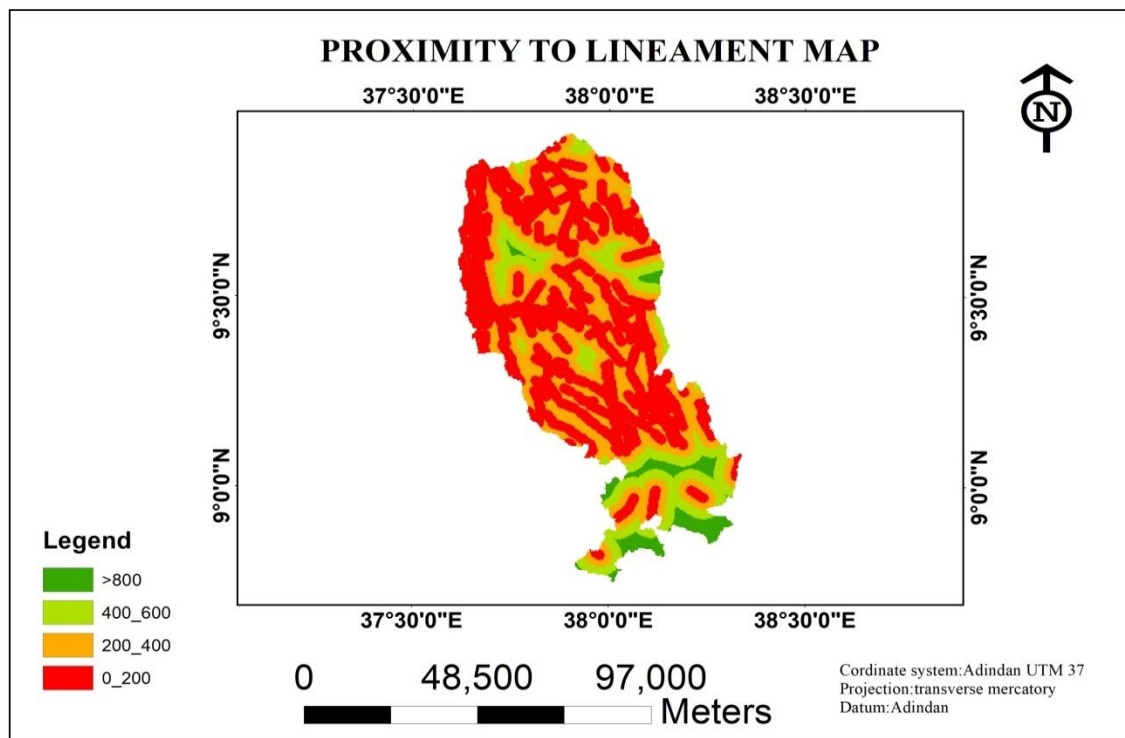


Figure 4.16: Reclassified proximity to lineament map

5. Distance to a road: _in this study road 5 km buffer has been created and classified for the preparation of the landslide hazard zonation map. A map is divided into four classes based on the natural breaks. Areas which are near to road are more prone to landslide hazard and areas which are far from the road are less prone to landslide hazard. Based on this, the area is divided into four classes. Highly near to road, near to the road, moderately near to road, far from the road. as discussed by (Djukem et al., 2020) the presence of roads is supposed to trigger landslides through the undercutting of slopes. The spatial distribution of distance from the road is shown in Figure 4.17. The result of this study shows as an area prone to the road is

more affected than an area far from the road. The high percentage of landslide occurred at distance near to the road which accounts for 54 % and low as far from the road which accounts for around 3 , 23 % of landslide occurred at a moderate distance, 17% of landslide occurred when the area highly near to the road.

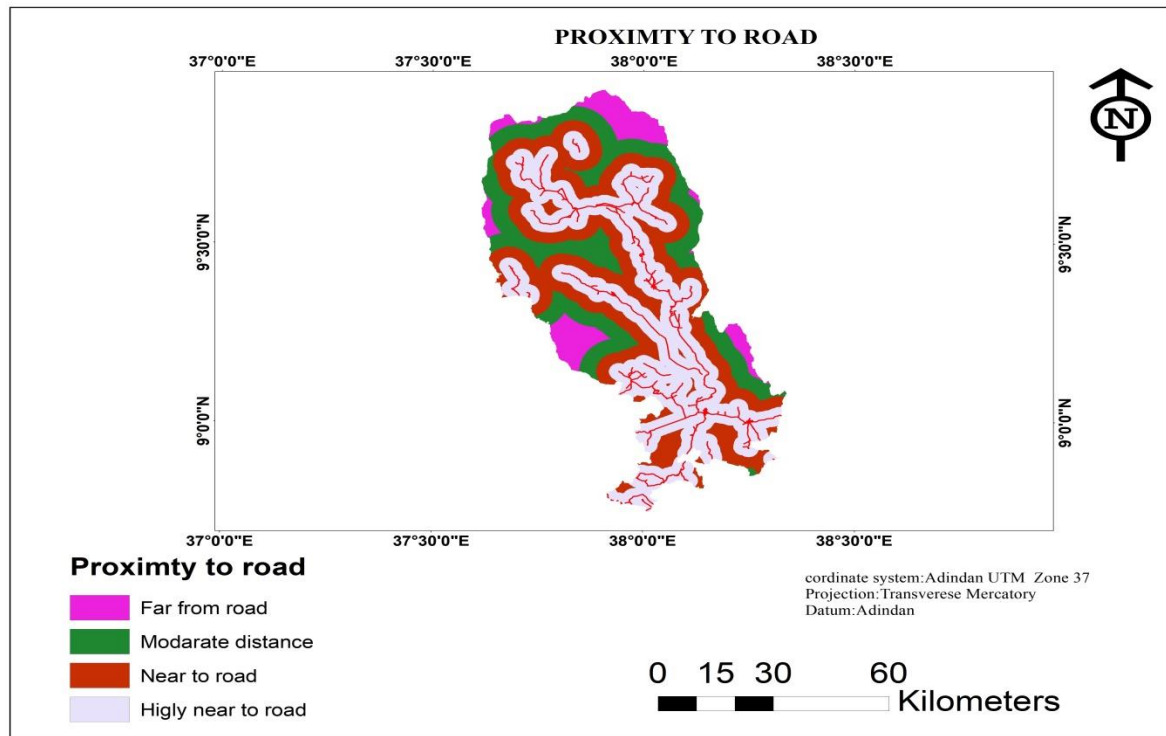


Figure 4.17: Reclassified proximity to Road map

6. Distance to drainage: _ Streams may adversely affect slope stability by eroding steep slopes or by saturating the lower part of it (Zhang et al., 2001). Distance to stream is one of the important factors for slope stability of a (Yalcin, 2011). The drainage map has been prepared from the 12.5m resolution ALOS DEM, using ArcGIS 10.8. Figure 4.18 illustrates the Proximity to the drainage map. The classification is done as (0_100 m, 100_200 m, 200_300 m, and > 500 m). The result indicates that landslides increase as the distance nearest to the high drainage density area. The high landslide occurred at distance from 0_300 m which accounts for 64% and low when distance >500 m from drainage and accounts for 9%, only. the result was comparable with the other researcher for example(Getachew and Meten 2021; Hamza and Raghuvanshi, 2017; Shano, Raghuvanshi, and Meten,2021; Sharma et al., 2012)

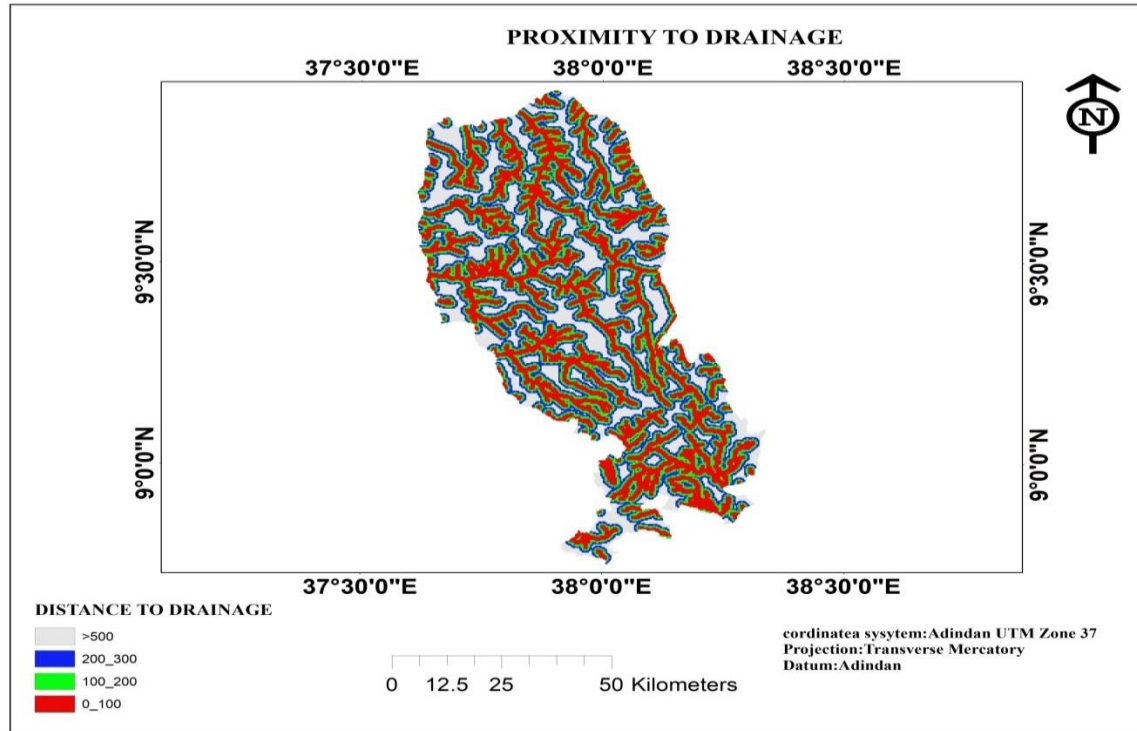


Figure 4.18: Reclassified proximity to a drainage map

7. Land use land cover: _ Land use is also one of the key factors that initiate landslides (Getachew and Meten, 2020). In this study Land use/land cover map of the area was prepared from Google Earth image and spot satellite image with researcher experience in the study area. It can be grouped into five classes including forest, agriculture bare land, water body, and settlements mentioned previously. The distribution of landslides within different land use land cover is water body and barren land accounts (28%) and 36% of the total landslides in the study area, respectively. The lower distribution of landslides was encountered in the land use classes of settlement (8%) and dense forest (7%). medium landslide encountered in agriculture which counts around 18% of a landslide from the total landslide in the class. The result was comparable with the result achieved by (Getachew and Meten, 2021) which shows bare land has scored a high percentage of landslide density

8. Lithology: _ Lithological changes frequently result in differences in rock strength and permeability, and thus play a crucial influence in the occurrence of landslides. (Getachew and Meten,2021). The hazard analysis indicates that gneiss and granite have more probability for landslide occurrence, as they are subjected to weathering in the study area. Around 51% of

landslides occurred in gneiss and granite in the study area whereas low landslides probably occurred in basalt and trachyte which is 5 %. Also, sandstone and limestone show relatively high landslide probability around 41 % of the landslide occurred in the study area. In this study, the pyroclastic deposit; colluvium has not shown the landslide occurrence as they are relatively found in flat slopes.

9. Soil texture: _ soil texture is one of the major factors for landslide occurrence .these study shows the major landslide occurred in the area covered by sandy loam texture which shows around 64 % and low landslide occurred in clay around 1.5%, and moderate in loam which is 35 %. the result of the finding done by (Sharma et al., 2012) shows how soil with more sand, high slope, and intensive rainfall, which constitute as most factors for landslide, occurrence and cause severe damage to the land

10) Slope: _ the slope is the most important factor for a landslide susceptibility map. The nature of the terrain highly affects slope stability. The slope is considered a key factor for GIS-based landslide susceptibility mapping (Ayalew, 2005). It is one of the most controlling factors of a landslide that affects the concentration of moisture and the level of pore pressure at a local scale and it controls regional hydraulic continuity at larger scales(Getachew and Meten,2021). The high landslide probability occurrence is high along with mountainous and rolling slope class which is 34% and 25% and low in flat which is 15% and escarpment accounts 24%. The low FR Value indicates a low probability of landslide occurrence for each parameter class and high FR indicates a high probability of landslide occurrence. The frequency ratio for each parameter is shown in Appendix 3 and graphically represented in Appendix 3A

c) Landslide susceptibility map

After the calculation of the landslide susceptibility index, it is important to classify the LSI into different susceptibility classes based on the LSI value (Meten , 2020).in this study the landslide susceptibility was calculated automatically by using ARC GIS software in spatial analyst tools. First, all parameter was reclassified according to their suitability for road alignment selection. Then combined with landslide inventory map using ARC GIS by using tabulated spatial analyst tools then the total area of landslide in each class for a parameter was obtained then from a total area of the landslide affected no of the pixel in each class has been

calculated. Then frequency ratio that shows the probability of landslide occurrence in each class for each parameter was calculated by using equation 3.8 in Chapter three (3). Then previous classes were reclassified by using the RFR (relative frequency ratio) calculated from FR then the landslide susceptibility map was produced by using reclassified parameter and FR calculated by using raster calculator. The calculated frequency ratio for each parameter was shown in Appendix 3 and land slide hazard map has been produced

$$\text{Land slide cost map} = \text{Slope} * 0.010373 + \text{elevation} * 0.01300 + \text{proximity to road} * 0.055039 + \text{lithology} * 6.03 + \text{LULC} * 0.009537 + \text{drainage} * 0.0554895 + \text{curvature} * 1 + \text{soil} * 0.0391 + \text{aspect} * 0.144895 + \text{Linemeant} * 0.040526$$

Then the result was classified into four susceptibility zones according to LSI obtained from the above result then the result of susceptibility will be validated by using validating/testing landslide by using ROC and AUC in ARCSDM tools in the ARC toolbox. The result of the analysis shows landslide susceptibility map shows 30.87 % (156.27 km²) of the total area under very low hazard zone, 21.94 % (111.04 km²) under low hazard whereas 35.8% (180.13 km²) and 11.6062% (58.75 km²) of the study area under moderate and high hazard zone, respectively. The result shows that lithology was the most causative factor for landslide occurrence. Accordingly, it has a 6.03 frequency ratio(FR) ratio which is the largest FR ratio and slope have less effect for landslide thus because the steepest area in the study area have a stable rock like basalt and trachyte, but they are not suitable for road alignment in case they required advanced machine for crushing and slope stabilization. the result was comparable with the finding obtained by(, Raghuvanshi, and Meten,2021). Table 4.10 shows the hazard zone and suitability level for route alignment.

Table 4.10: Landslide Slide Susceptibility Index Value and Suitability Level

Class of Land Slide Susceptibility Index.	Landslide Hazard Zone	Suitability Level	Area (km²)
11.00_18.6596	Very low hazard	suitable	156.27
18.659_21.26	Low hazard	Near to Suitable	111.04
21.26_23.86	Medium hazard	Moderate	180.13
23.86_28.93	High hazard	Not suitable	58.75

d) Model validation

Model validation is the last step in landslide susceptibility mapping, which helps to evaluate the accuracy of the model, generated using different statistical methods. Success and prediction rate curves, landslide relative density index (R index), receiver operating characteristic curve (ROC), and area under the curve (AUC) are some of the model validation techniques accessible (Meten, 2020). However, in the present research work, the receiver operating characteristics curve and area under the curve were used to evaluate the accuracy of the landslide susceptibility model generated by frequency ratio. The curve was generated by using arc toolbox extension in ARCSDEM by using ARC GIS 10.8. The result was showed the AUC value is 0.756 which shows the models have very good performance. Figure 4.19 illustrates receiver operating characteristics and AUC graphs. Landslide susceptibility map and 30% of landslide data are used as input for model validation.

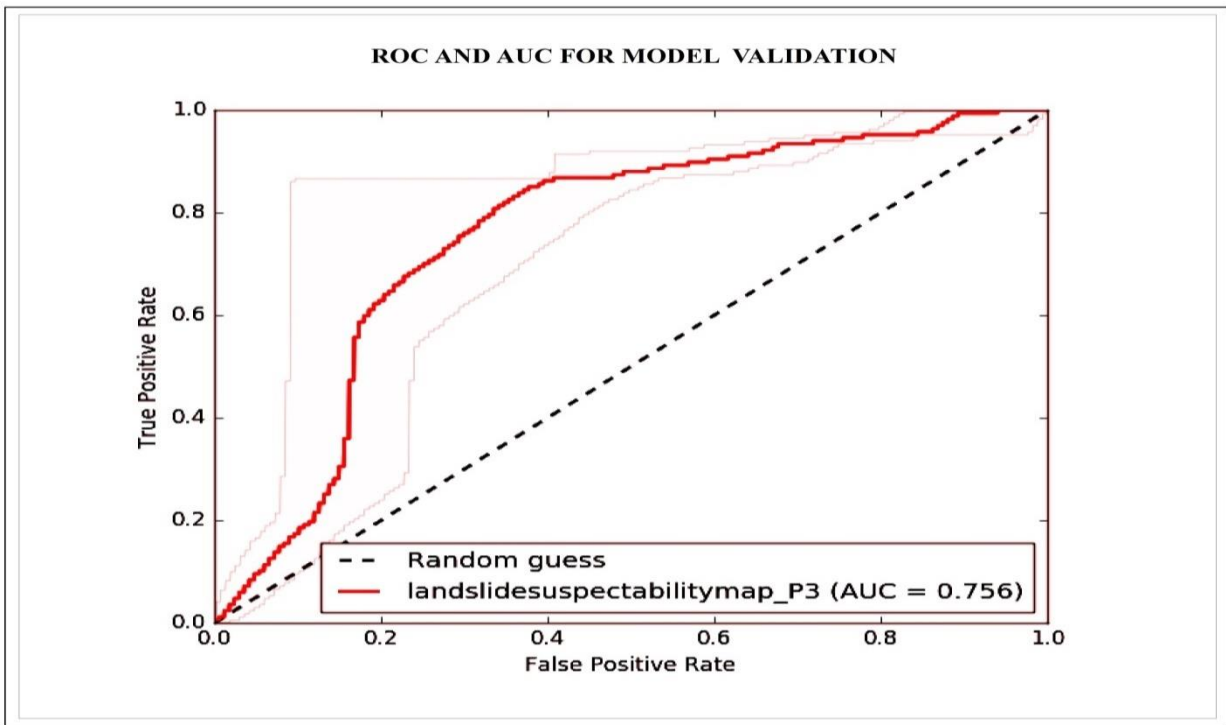


Figure 4.19: AUC and ROC graph for FR model validation

Figure 4.20 & 4.21 shows the landslide hazard zone map and probability of occurrence of each hazard zone using pie charts. The area with very high hazard is highly unsuitable for

route alignment and the area with very low hazard (no hazard) was suitable for route alignment. The result shows the area under rolling slope moderate elevation, near to drainage and covered by granite and gneiss show a high probability of landslide. The result was comparable with the result obtained by (Getachew and Meten, 2021)

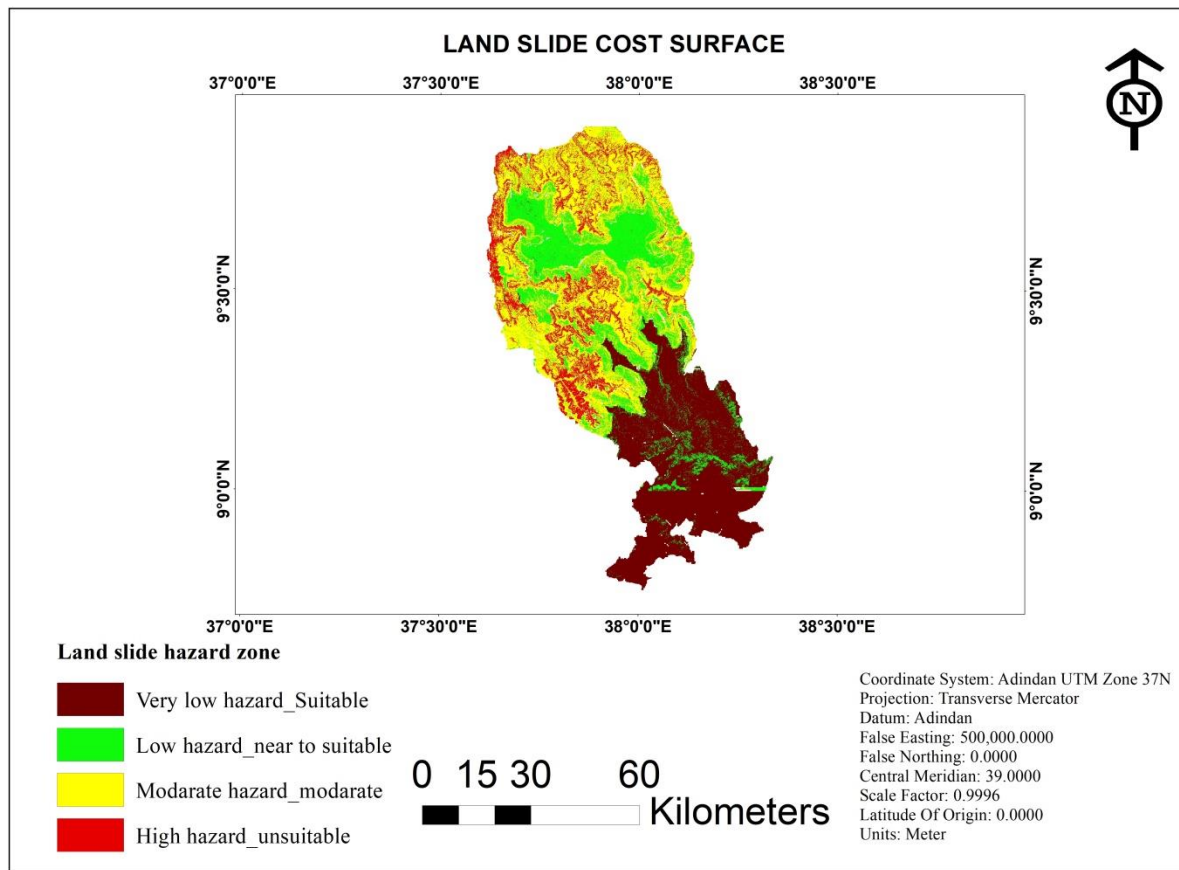


Figure 4.20: Land Slide Cost Surface

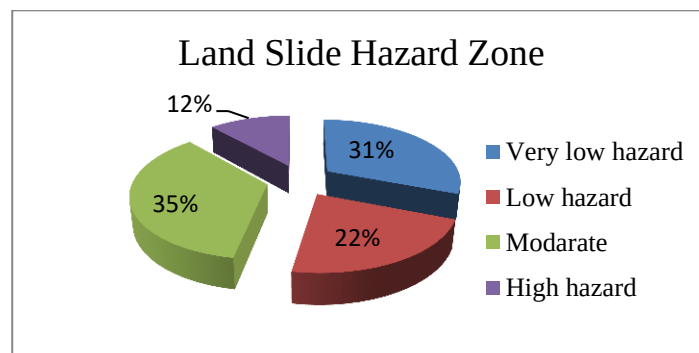


Figure 4.21: Pie Chart for Land Slide Hazard Zone;

4.2.4 Hybrid Cost surface

All three previously created cost surface has been overlaid by equal weight. The hybrid suitability surface is also divided into four levels of suitability. The four classifications were highly suitable, suitable, less suitable, and unsuitable. Out of the total study area, 38.633 % (195.6 km²) of the area is under highly suitable, 23.4 % (118.41 km²) under suitable, 23.6% (119.41 km²) is less suitable, and the remaining 14 % (72.7 km²) area is under unsuitable for road construction. The spatial distribution of all their suitability as per the hybrid suitability surface was is shown in Figure 4.22

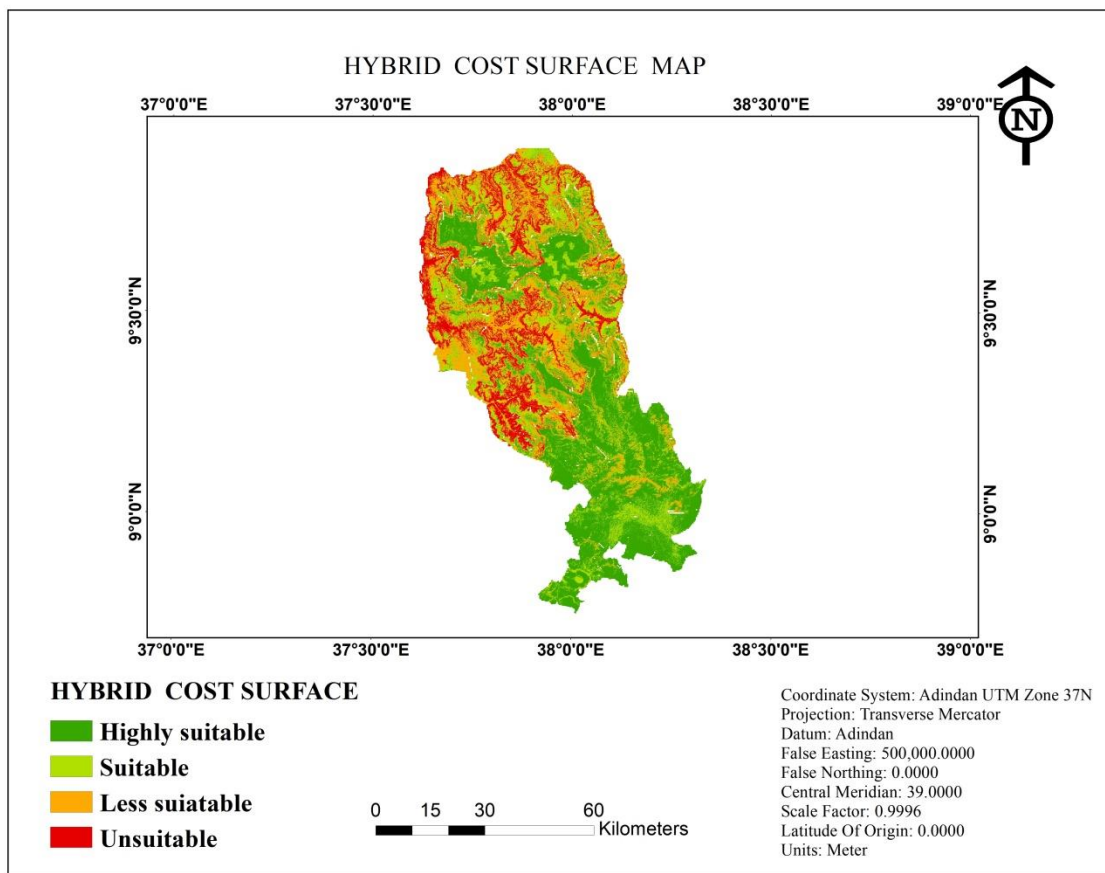


Figure 4.22: Hybrid Cost Surface

4.3 Alternative modeling for optimal road alignment

The least-cost model that uses cost surfaces and cost accumulation provides paths that are considered realistic(Gonçalves,2010). This is Due to additional constraints or functions,

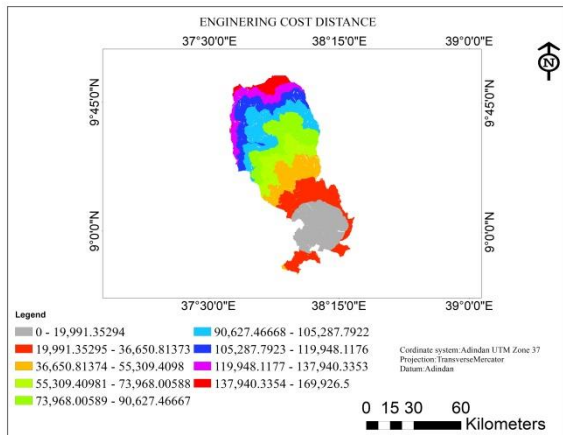
domain-specific properties, primarily linked to the cost of transit across space, can be represented. The Least Cost Path Algorithm is one of the applications of ArcGIS software in spatial analyst extension. In this study total, four alternate least-cost paths were generated by using the least_ cost path algorithm (LCPA). Cost distance and cost backlinks are generated by using origin point (Ginchi) and the four cost surfaces generated above i.e. environmental cost surface, engineering cost surface, landslide cost surface, and hybrid cost surface has been used for generating the least-cost path and the generated cost path as the polyline. The spatial analyst tools ARCGIS 10.8 were used for performing the task. The cost path function uses destination (Chullute) a cost distance, and cost backlink as input.

4.3.1 Cost distance analysis

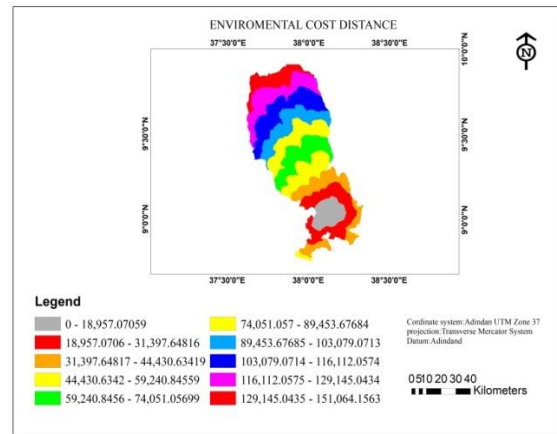
The objective of the cost tools is to determine the least-cost path to reach a source for each cell location in the Analysis window. The least-accumulative cost to a source, the source that allows for the least-cost path and the least-cost path itself must be determined for each cell (Agrawal et al., 2015).

4.3.2 Cost distance

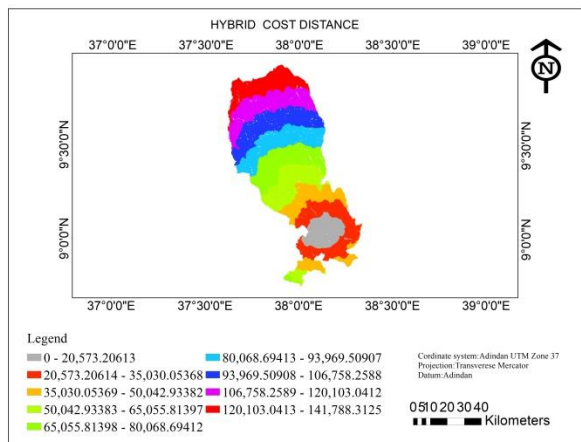
Based on the least-accumulative cost over a cost surface, cost distance calculates the distance to the nearest source for each cell in the cost raster. Input data for cost distance were origin (starting point) and cost raster like environmental cost surface, engineering, landslide, and hybrid cost distance. In this study, four cost distances were generated from four weighted cost raster's. Cost weighted raster provides the cost of each cell based on the criteria provided during the cost raster preparation. Cost raster was prepared by providing the weight to each parameter to classify each cell cost to reduce the higher cost while routing alignment. Then by using the cost of each cell cost distance calculate the least distance from each cell to the starting point. Figure 4.23 illustrate cost distance for all generated cost surface.



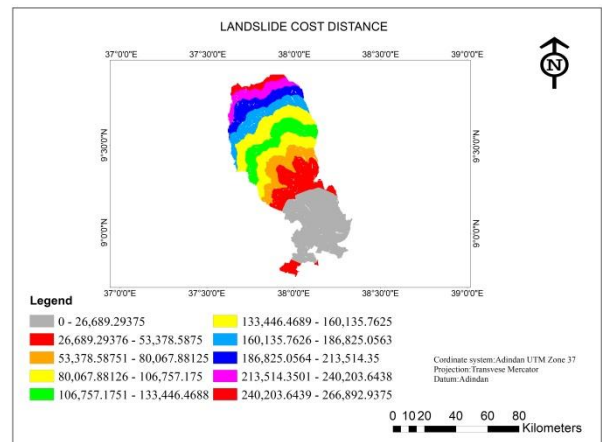
(a) Engineering cost distance



(b) Environmental cost distance



(c) Hybrid cost distance;



(d) Landslide cost distance

Figure 4.23: Cost distance

4.3.3 Cost backlink

Cost backlink Gives neighbor that is the next cell on the least-accumulative cost path to the nearest source. The cost raster and start (origin) is obligatory input data. Figure 4.24 shows the cost backlink for four cost raster. The back-link raster comprises values 0 through 8, indicating the direction to go from each cell in the cost distance raster back to the source point along the accumulative cost path. The algorithm is each cell is assigned a value representing the direction of the nearest and cheapest cell.

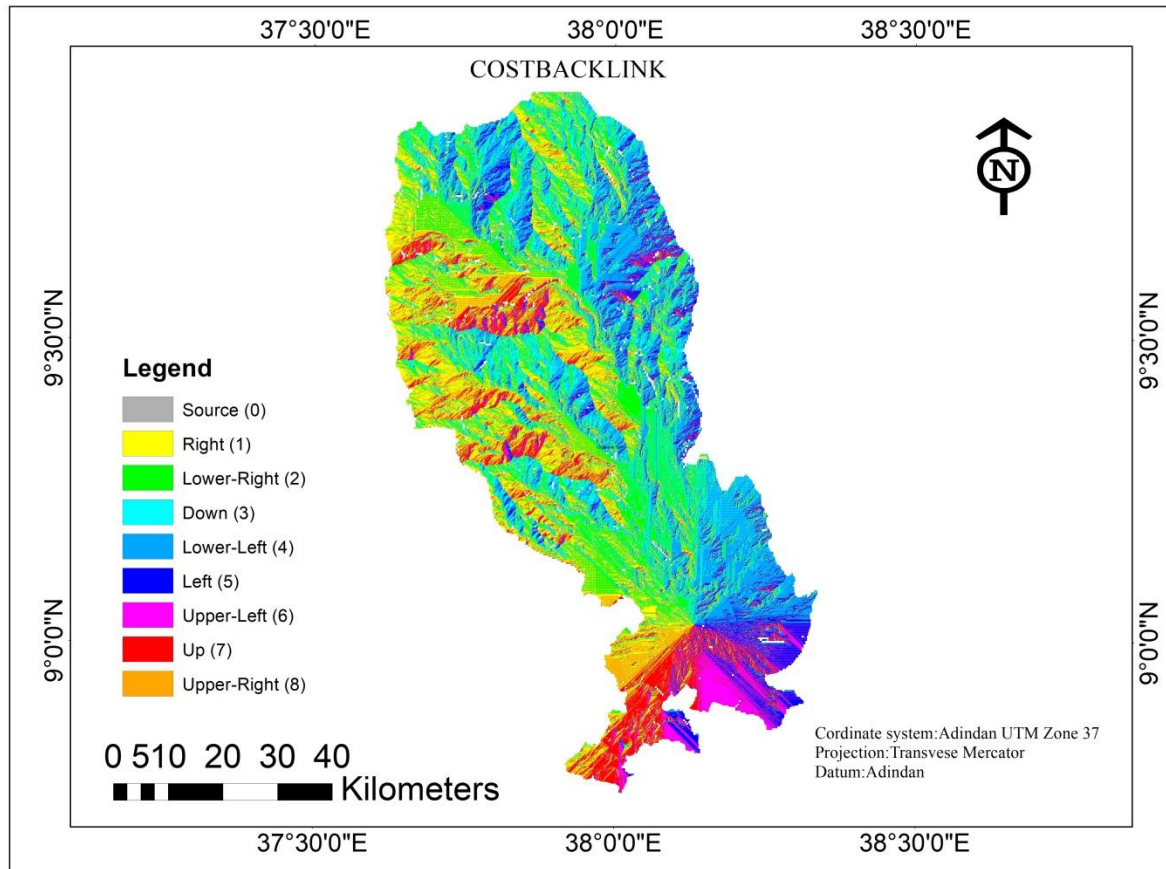


Figure 4.24: Cost backlink

4.3.4 Least cost paths

The least-cost path gives the path with the least cost from a source to a destination. Input data are a destination, cost backlink, and cost distance. Figure 4.25 shows modeled least-cost path for all surface and existing roads. All least-cost paths have less length less than that of the existing road which shows the result is comparable with the other researcher conduct by using the least cost path. For example (Murik and Kari , 2019 ; Beczkowaz , 2019 ; Albattah , 2017 ; Asmale and Akawazi, , 2015).

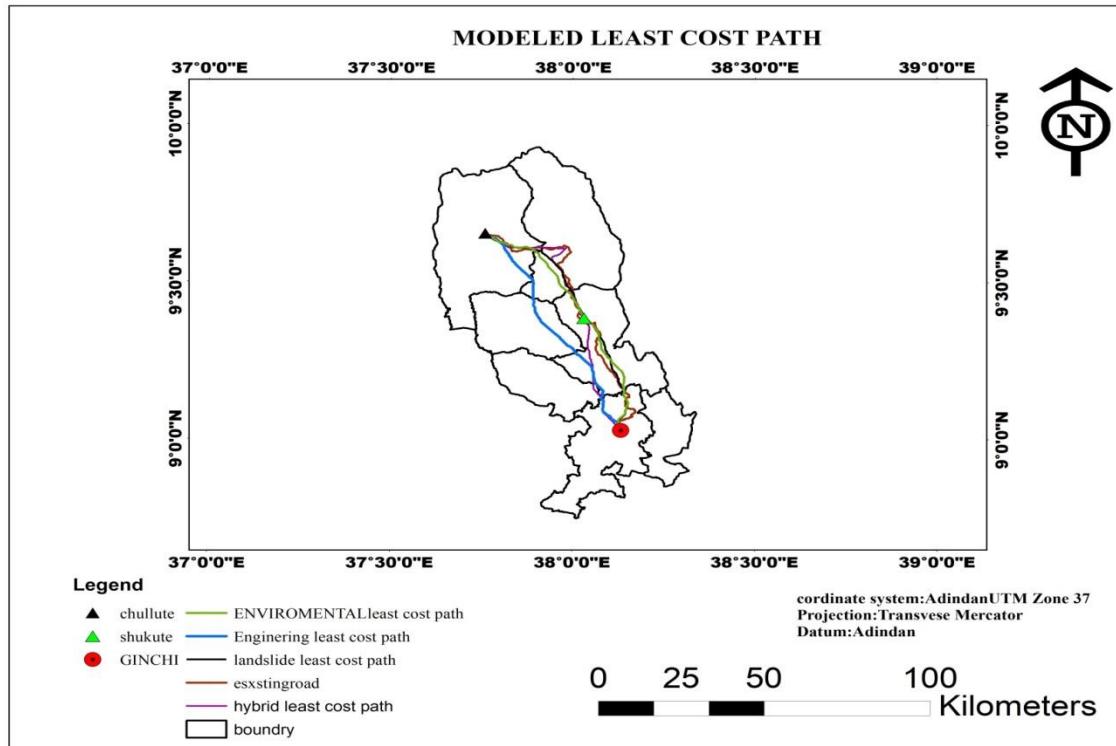


Figure 4.25: Modeled Least-Cost Path

4.4 Final Optimization of the Routes and Obtain Optimal Route

According to ERA route alignment selection, the route should be full fill the following general criteria

- safe
- Easy
- Economically
- Short

While optimum route selection the following point must be considered either directly or indirectly (ERA, 2013)

- Ease of topography
- The practicality of designing an alignment according to geometric standard within the topography
- Avoidance of areas of known geo-hazard, including landslides, flooding, and problematic soils
- Avoidance of environmentally protected areas and other sensitive habitats
- Avoidance of location or areas of cultural heritage value

- Need to maximize connectivity of villages and towns and improve rural mobility
- Need to maximize traffic connectivity and access to economic resources and markets
- Need to select the shortest distance alignment.

Based on this researcher evaluated each modeled least_ cost path by using the parameter discussed in the methodology chapter.

4.4.1 Final evaluation

The final evaluation result was illustrated in Table 4.11. The data analyzed basis on the procedure discussed in chapter three (3) of section 3.6. The graphical interpretation of the evaluation result was shown in Appendix 7. In Table 4.11 the least cost path are represented as follows

- ENVLCP_ Environmental least-cost path
- ENGLCP_ Engineering least-cost path
- LSLCP_ Landslide least-cost path
- HYBRDLCP_ Hybrid least-cost paths

Table 4.11: The result from the data analysis for route optimization

Parameter	Units	ENGLCP	ENVLCP	LSLCP	HYBRDLCP
No of Keble served within five km	number	80	72	83	90
No of the population served in five km	number	37123	56511	35740	36609
Area of forest affected by alignment in 15 m buffer	km ²	9.2403	5.623	5.755	7.382
Area of agricultural land affected by alignment in 15 m buffer	km ²	1.84	1.7	1.80	1.715
No. of connecting nodes with existing network	number	7	6	6	8
Length of a road passing within the buffer distance of 500 m from the river	km	5.6839	2.88144	9.94720	10.0306
No of bridges/culverts required.	number	5	6	8	7
Cut volume	M ³	16601436.	2840154.6	91997584.4	3132891.6
Fill volume	M ³	10647908.	50996006	10843867.4	1072318.2
Total length	km	104.27	105.39	98.4399	103.4607
Quantity of buildable land available along each alignment within 2 km buffer	km ²	2.741	2.933	2.66	2.84
Quantity of land use type available for within 15 m buffer	km ²	2.92	2.96	2.478	2.97

4.4.2 Final route selection results

The final selection result shows hybrid least-cost path scores the highest and selected as optimal routes. The evaluation result was shown in Table 4.12.

Table 4.12: Final route selection result

Parameter	Weight of ENGLCP	Weight of ENVILCP	Weight of LSLCP	Weight of HYBRDLCP
No of Keble served with five km	2.5	1.5	3.5	5
No of population served in five km	3	5	2.5	4
Area of forest affected by alignment	7.5	7	12.5	12
Area of agricultural land affected by alignment	6	10	8	9
No. of connecting nodes with existing network	3	3	2	5
Length of the road passing within the buffer distance of 500 m from the river	8	8.5	7.5	6.5
No bridges/culverts are required.	8	7.5	6	7
Cut volume	6	8	7	8
Fill volume	8	7	8	8.5
Total length	2	2.5	4.5	4
Quantity of buildable land available along each alignment	3.5	3	2	3
Quantity of land use type available for future widening	3	3.5	3	5
Total	60.5	66.5	66.5	77

Based on the evaluation result advantages and disadvantages of each modeled least_ cost path have been discussed in the next parts. The modeled engineering least cost has an advantage over the left three modeled least-cost path in which it crosses less drainage order, as a result, no need of bridge construction .moreover the model relatively passed through the flat area. The disadvantage of this model was it affects more agricultural land, it not susceptible to or passes through the town in the study area. Have maximum lengths relative to other modeled least-cost paths excluding environmental least-cost path. Whereas the environmental least-cost path the advantage over the other in which it serves a large number of people, less agricultural affected and less length is pass through the buffer less than 500 m from the river. The disadvantage of this model is less buildable land and a high volume of fill is the major disadvantage relatives to the others. Landslide's least-cost path has an advantage in which it has a less total length, and it is a disadvantage is less quantity of buildable land related to others. A hybrid least-cost path has the advantage in overall engineering and environmentally impact overall modeled least-cost path. The disadvantage of this model is passed through more drainage in less than 500 m but it is the first and second drainage order subsequently, it is relatively cheap for bridge construction or it possible to construct a culvert only. By considering both engineering and environmental perspective and the weight given to each parameter the hybrid least_ cost path was the optimal route connecting Ginchi to Chullute. The selected routes have a length of 103.461 km .from the total length 72% (74.6 km) were laid on highly suitable Areas for route alignment 12% (11.86 km) laid on suitable and 14.83% (17 km) lay on moderate. The result was comparable with other researchers uses the technology for example (Singh et al., 2019; Larbi and Boye,2018).

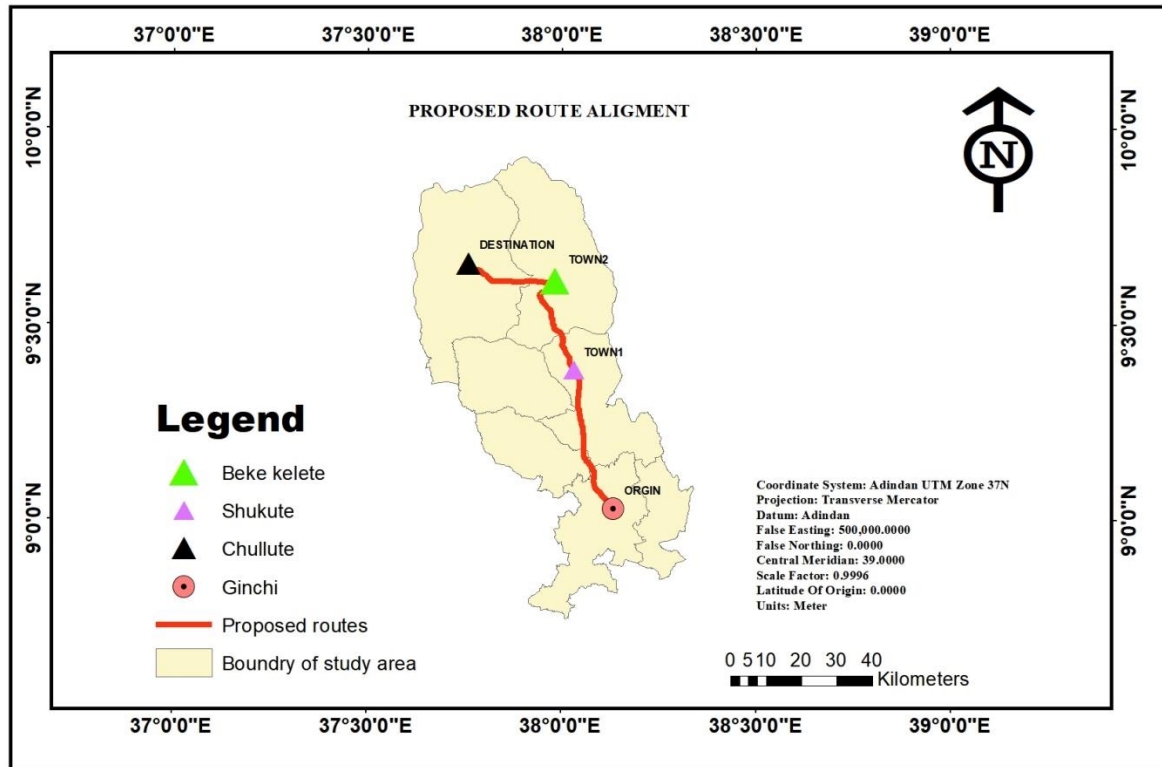


Figure 4.26: Propose optimal route

4.5 Comparison between Existing Routes and Optimal Route

The comparison result between existing and optimal routes present in Table 4.13

Table 4.13: proposed versus existing route alignment routes

Existing routes				Proposed routes			
Area of forest (15 m) buffer distance (km ²)	Length of the road(km)	Total Length of the road affected by a landslide(km)	Available land types for future widening within 2 km (km ²)	Area of forest affected within 15 m buffer distance (km ²)	Length of the road (km)	Length of the road affected by a landslide (km)	Available land use types for future widening within 2 km buffer (km ²)
1.98	122	4.41. km	1.776	1.77	103.46	0.016	2.84

The proposed route is generated by the multi-criteria approach implementing from hybrid factors of engineering and environmental perspectives. Factors are compared to the existing road alignment for validation for the achievement of research objectives. Figure 4.27 shows

the proposed route versus the existing road map. The result of the proposed route shows that it has the shortest length of the existed route, which is 103.46 km. whereas from the total length of 122 km of the existing road 4.6 km length of the road was affected by the landslide. Also, the proposed road has relatively has more buildable land than the existing road which is 2.84 km²

On other hand, the proposed route also has less cost land-use types through a 15 m buffer for future widening, less agriculture and forest area through widening 15 m buffer which is shown in Table 4.13. So, the proposed route was feasibly over the existing road as short length reduces traveling time, transportation cost, construction cost. Likewise, a high percentage (area) of the buildable area around the proposed route results in less cost for slope stabilization .in addition less area agriculture and forest affected reduce compensation, clearing cost, and reduce the biomass disturbance. Moreover, the proposed routes pass through the slope from (0_14) degree was (96.05 km) from the total length of the road 103.46 similarly, the existing road passes through 0_14 degree from is 90 km from the total length of 122 km and the length of the existing road passes through the slope between 14_37 to the degree is 18.6023 km whereas, the length of the proposed route passes through this slope is 7.09 consequently, the proposed route is more stable than existing routes. Accordingly, the result shows that the proposed route was feasible over existing routes. Figure 4.27 shows the graphical representation of comparison results. And the result was comparable with the result obtained by (Sekulic et al.,2020; Beczkowska ,2019) show the road designed by using geospatial technology are cost-effective and safer than those designed by the conventional method.

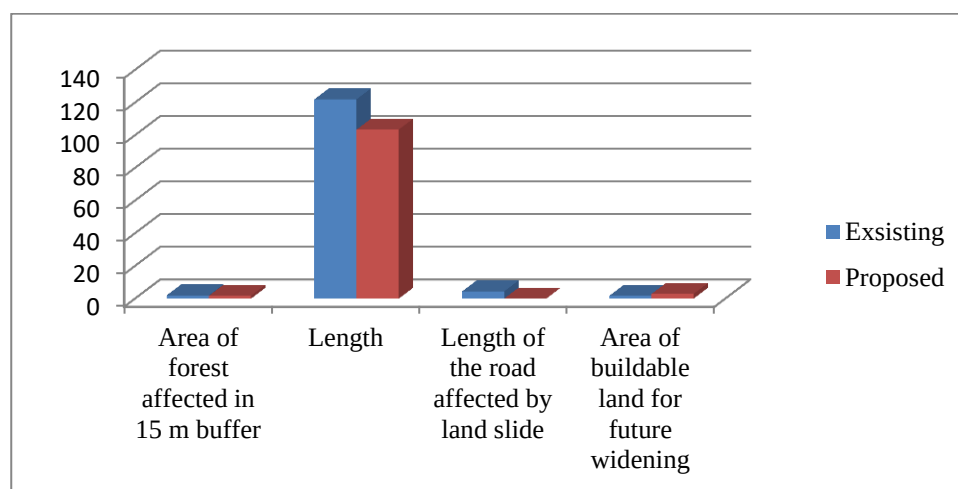


Figure 4.27: Graphical representation of existing road versus proposed route result

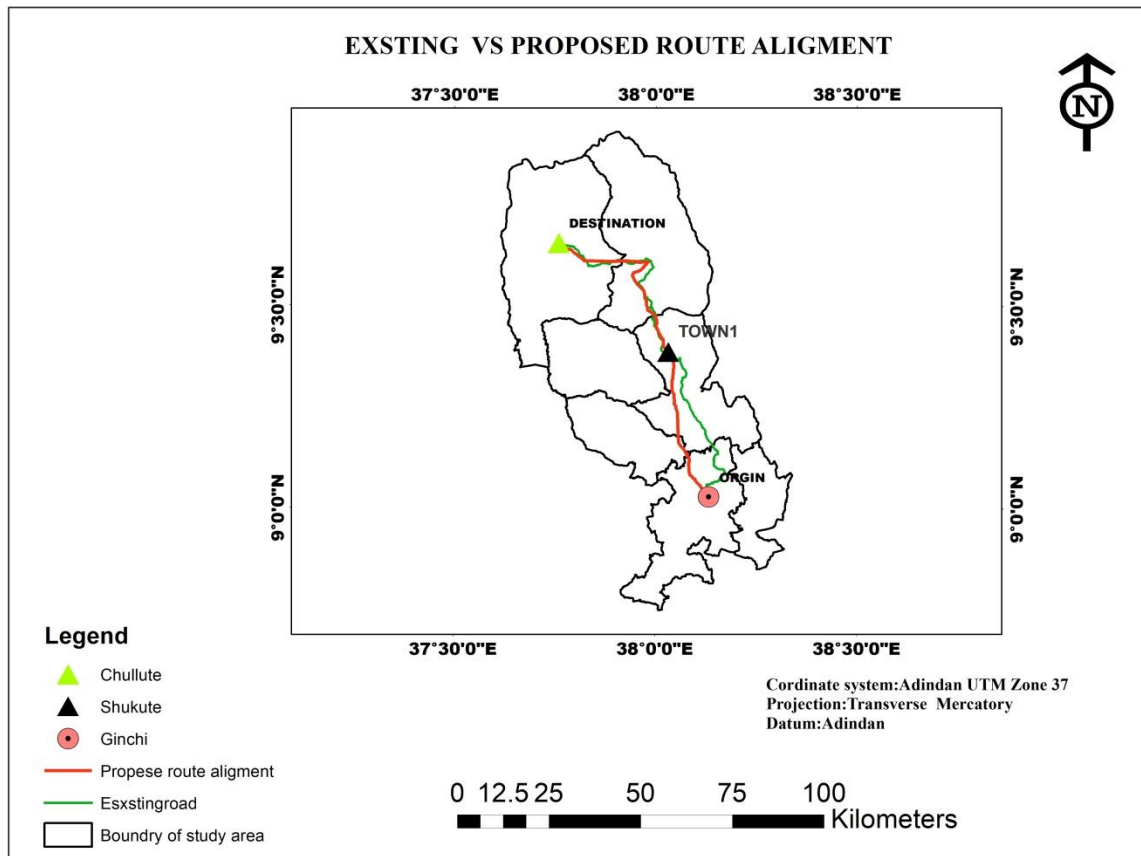


Figure 4.27a: Existing road versus proposed route alignment map

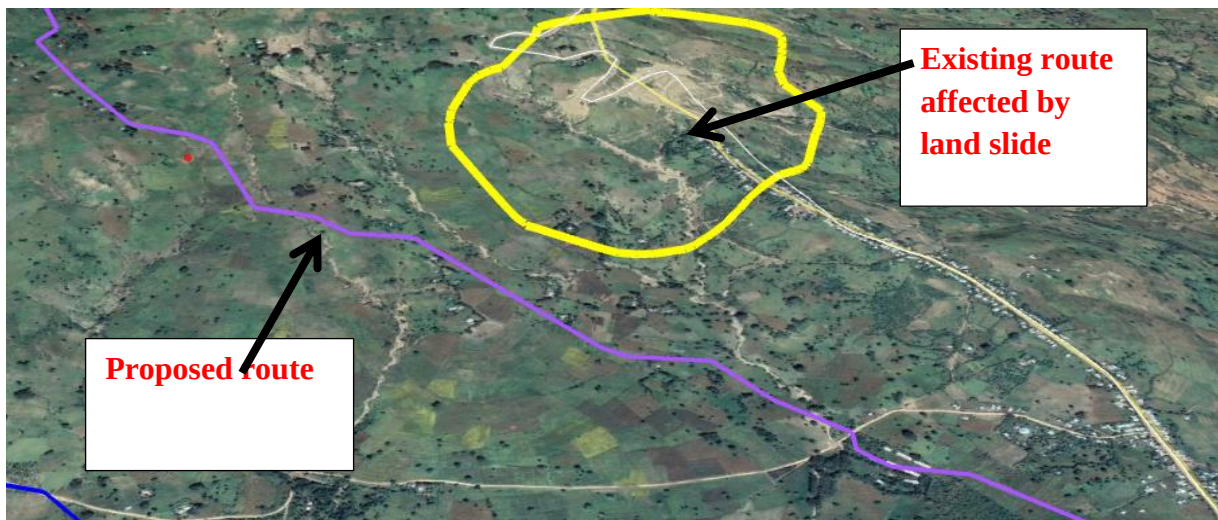


Figure 4.28: Existing road versus proposed route on google earth image

4.6 Discussion

The current study explored developing optimal route by using geospatial technology provides the answer to the research question how to select or develop the optimal road between two town or village or two urban center by using different engineering, environmentally and social parameter .formerly four different cost surface were generated based on different parameters explained in previous section then least cost path has been modeled basis on produced surface afterward, route were optimized by using additional social and environmental parameter and optimal route has been selected.

4.6.1 Least cost path

In current study four different cost surface were generated for modeling least cost path by using different parameter .Engineering cost surface were generated from five data set namely slope, lineament, lithology, soil and drainage was used to reduce the cost of road construction and also increase the safety of the road for road users the slope is given the highest rank to avoid the steep slope for route alignment as it increase accident and the cost of construction. these is acceptable with the other finding that the slope were the most important parameter for route alignments for example(Muriki and Kari ,2019). shows the slope has the most important parameter in steep area for routing high ways .then these cost surface used as input for modeling the engineering least cost path produced in the previous section .second the environmental cost surface was created from three parameter to reduce the effect or the road on surrounding and also reduce the cost of the road construction.in this cost surface the land use land cover , slope and proximity to river were used for producing this weighted cost surface the LULC parameter given the highest rank as it effect the cost of construction and the reduction of biomass thus several researcher was studied the LULC as the major important parameter for optimal route selection for example (Condurat and Andrei , 2017; Fekerete and Below , 2014). Thirdly the land slide cost surface was generated by using ten causative factor discussed so far previous section and land slide inventory map. The land slide inventory maps were prepared from google earth image result were acceptable as the other researcher used the method and got the comparable result(Januadi and Nabila , 2020; Pourghasemi, and Pradhan 2012; Shano, Raghuvanshi, and Meten 2021; Sharma et al., 2012) are uses Google earth for land slide inventory map and got the reliable result for land slide hazard map. Also Intensive

field visit were conducted by researcher for validation of inventor map to prepare landslide susceptibility map. Afterward, land slide susceptibility map was prepared by using causative factory combined with inventory map produced. The created land slide cost surface shows the area covered by gneiss and granite, bare land river bed (near to wet land area near to fault line and the area with rolling and mountainous area were show high land slide occurrence which shows comparable with other researcher finding for example(Getachew and Meten ,2021)which shows the area near to the fault line, river bed and bare land and shows high land slide .the hybrid cost surface was generated by using equal weight of three previously generated cost surface.to reduce overall impact of the road on the environment, reduce construction cost, and increase the safety of the road for the road users .then based on these the least cost path were generated on basis of the generated cost surface and hybrid least cost path was the optimal route connecting two locations similar finding reported the least cost path generated by different parameter the most optimal routes for example (Godwin Muriki, Lewi Kari , 2019; Booto et al. , 2019; Elatif and Bakry, 2016 ; Januadi and Nabila , 2020; Kang and Lee , 2017; Suleiman et al. , 2015; Wahdan et al. , 2019) their result shows that the route selected by using integrated parameter from environmental, social and engineering perspective using geospatial technology is more feasibly than the route propose by small number of parameter .similarly the study explored the feasibility of route proposed by geospatial technology over convectional planned routes and the proposed route were feasibly over the existing routes by it tis length , slope stability the environmental impact on biomass are major advantage of proposed routes over existing routes .similar finding reports that the route proposed by using GIS are more safer , and cost effective than that of proposed by other convectional method for example(Balogun et al. ,2012; Paper et al., 2020; Sarı and Sen, 2017; Singh et al. , 2019).therefore the finding of the study has agreed with the previous finding in which geospatial technology tools are useful for the optimal route selection. The proposed optimal route in this study was 103.46 km in length and also relatively free from land slide. Consequently, study employed that the geospatial tools was use full for effective route alignment.

5. CONCLUSIONS AND RECOMMENDATIONS

The current study aimed to develop an optimal road from Ginchi to Chullute using geospatial tools. With modeling LCP that has less construction cost and impact on the environment by identifying the major important factors that affect road construction. Specifically, the study focused to avoid the landslide while routing alignment. Different Geospatial tools with AHP SMCDCA were used for developing the optimal routes. The study concludes with the following stopping points and recommendations.

5.1 Conclusion

The current study explored is developing optimal road alignment connecting Ginchi and Chullute. Selecting the optimal route has different consequences on construction cost, maintenance cost, and impact on the environment like pollution and accident occurred. Using geospatial tools can avoid many location problems; in addition, the ability of the technique to provide several alternatives and to compare such alternatives is a benefit for designers and planners. The use of remotely sensed data integrated with spatial multi-criteria evaluation in this research proved the high ability to image a very large area within less time consuming and less cost. The capability of the tool to extract an updated land use map used in many environmental, spatial, planning, and spatial modeling issues. Likewise, RS and GIS-based MCDA make the alignment most appropriate avoiding vulnerable high-risk zones such as landslide area, stream crossing, and fault zones. It needs less manpower, less time consuming and less cost. The Possibility of applying this methodology to any linear infrastructure after some minor, adjustments is the other benefit of this tool. Based on the objectives of the study four least-cost paths have been proposed for alternatives based on four cost surfaces created from the factors identified. Afterward, the four cost surfaces are created on basis of different parameters. Engineering cost surface created based on five parameters (slope, lithology, drainage order, soil, and liniments) were used to model engineering least _cost paths. Environmental cost surface (slope, proximity to the river, land use land cover where used for environmental cost surface and used as input for modeling environmentally least_ cost path. The Landslide cost surface was created from a slope, proximity to drainage, proximity to the road, soil texture, lithology, lineament, elevation, slope aspect, carventure. Were used and a landslide least-cost path has been developed. Hybrid cost surface created from mentioned

three cost surface and hybrid least _cost path where developed basis on this cost surface. The hybrid least-cost path will be recommended as the least_ cost path between two places in which have less length 103.46 km whereas the existing road has 122 km. also the proposed route relatively frees from the landslide as compared with the existing road. Consequently, results show that the route which was designed applying geospatial tools (GIS, remote sensing, and google earth) in mountainous and land hazard-prone areas are a more cost effective and safe route.

5.2 Recommendation

The finding of this study shows that geospatial technology (GIS, RS, google earth) are use full to select the optimal route by considering environmental, engineering, social, factor. Therefore, when undertaking environmental and economic planning involving linear features, Least Cost Path Analysis should be seriously considered.

1. One of the results of the finding shows that the GIS least cost path was the effective tool for selecting cost-effective routes and has less impact on environments. Therefore road designers should have to use the least cost path at the initial stage of road planning.
2. The factor affecting route alignment and their degree of influence for different classes of the road should be put clearly in ERA standard manual.
3. While route alignment selection, the designers should have to identify the landslide-prone Area.
4. The policymakers should have to know the actual cost and impact of the linear project on the environment. At the initial stage of project works.
5. Since numerous studies and ERA reports show that the use of Geospatial technology is an explanatory stage in the country it is better to include the technology as one of the planning tools while transportation planning and other linear structure.
6. Other researchers should use the optimized frequency ratio method for landslide susceptibility map that was not used in this study due to the absence of free available automatic landslide susceptibility assessment (ALSA) extension tools for ARC GIS software
7. Also, geospatial technology should be applied for landslide hazard zoning maps.

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APPENDICES

Appendix 1: Personal discussion for Criteria identification and Weighting

S. No	Name	Profession	Educational level	Working place
1	Mrs. Kefalaw	Highway engineers	MSc	ASTU
2	Mrs. Tola	Engineering geologist	MSc	ASTU
3	Engineer Hika	Urban planning and housing development	PhD Candidate	ASTU
4	Olana Atomsa	Surveyor	B.Sc.	site surveyors in Ginchi to chullute road project
5	Fikadu Dirriba		BSc	CBE Oromia
6	Falmata	Transportation planning	MSc	Highway design Expert in ERA
7	Marta Gonfa	Transportation	BSc	Expert in Oromia transportation planning
8	Kuma Abera	High way designers	MSc.	planning team manager in Oromia region transportation planning
9	Tariku w/mekael	Chief surveyors	BSc	chief surveyors in Ginchi to Chullute road project
10	DR Leta	Engineering geologist	PHD	ASTU

Appendix 2: Photography for some of the active landslide area







Active land slide photography for existing road

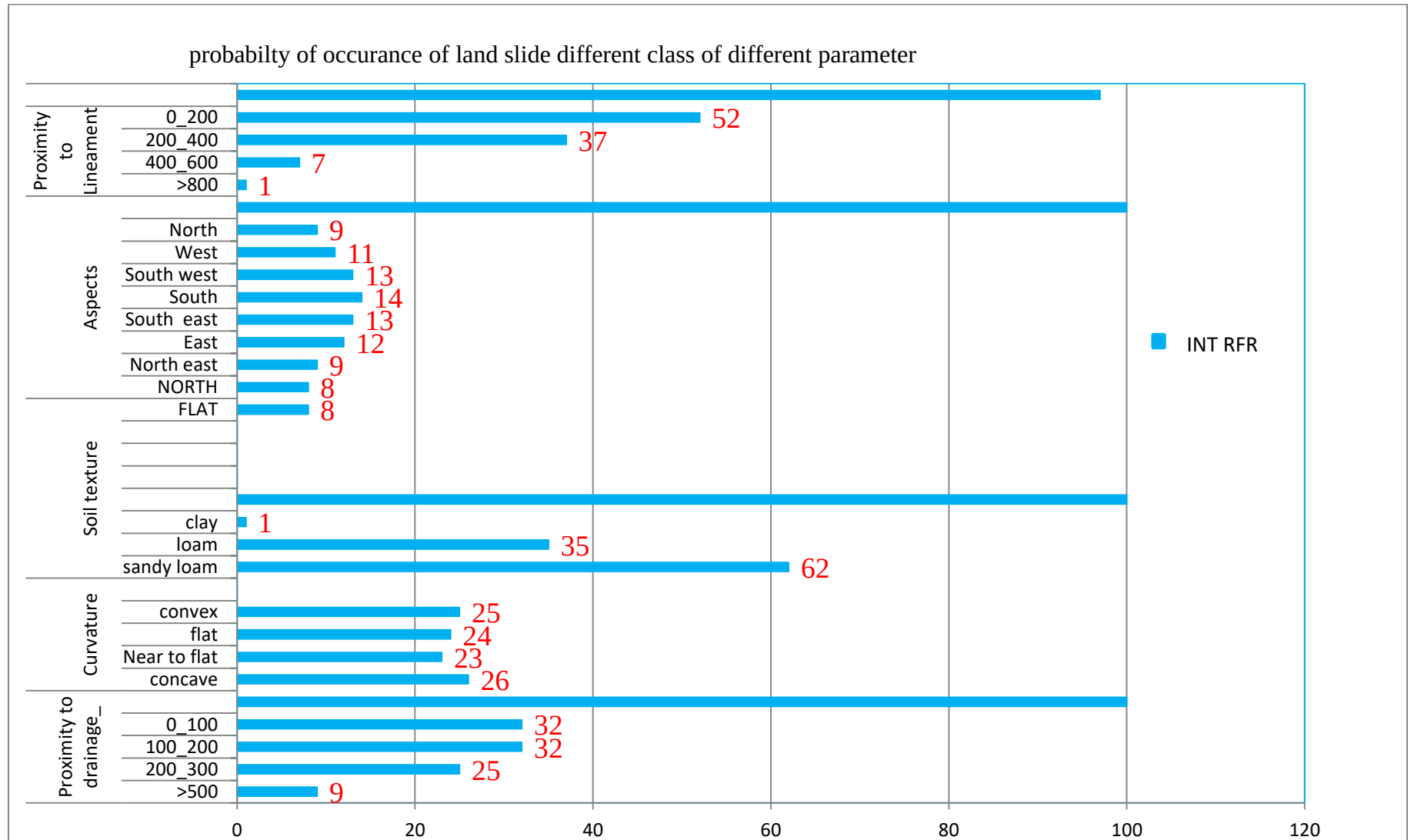
Appendix 3: Calculated frequency ratio for landslide governing factor

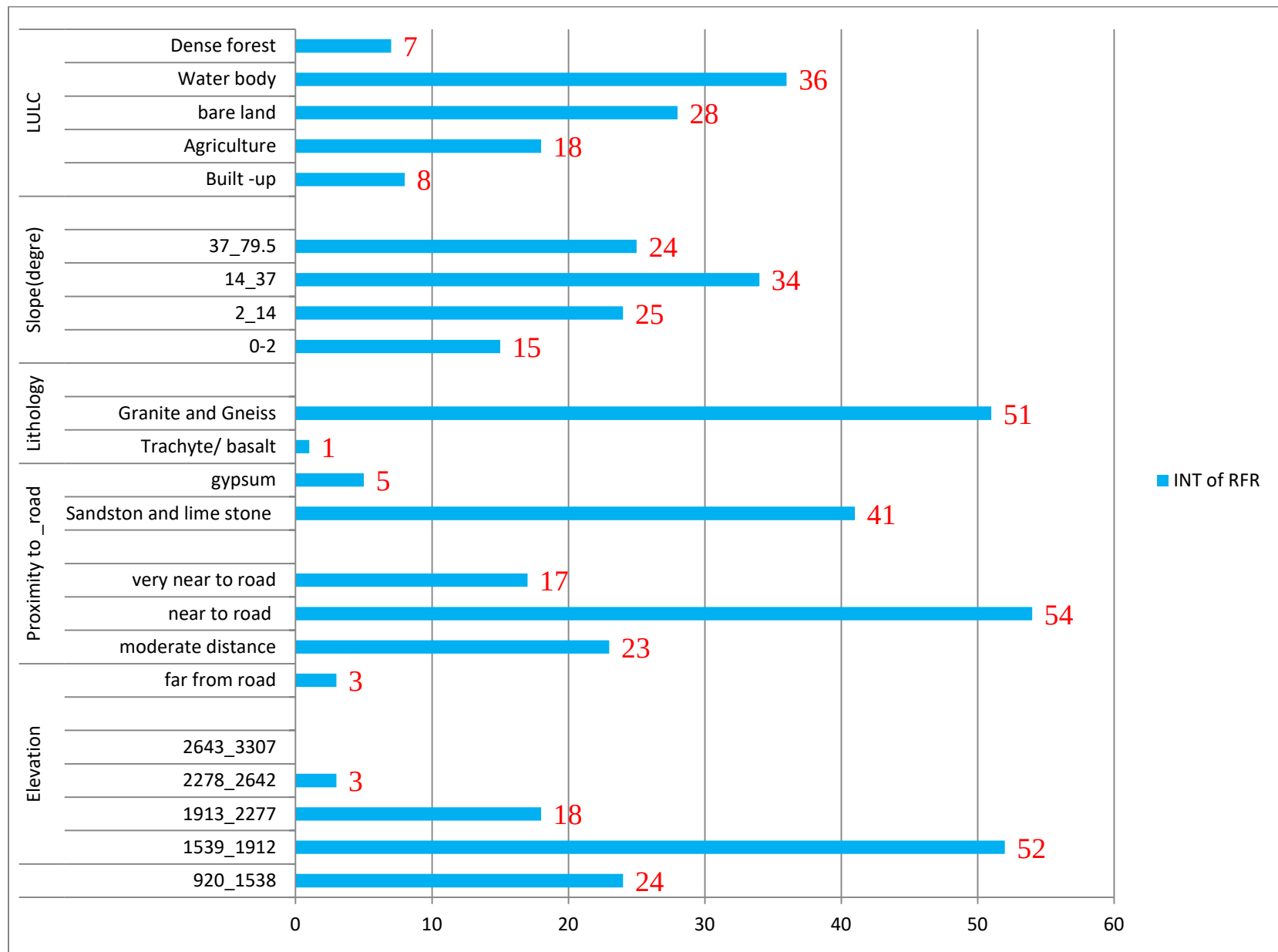
S/N	Parameter	Class	Rank	Class area	Land Slide area	No land Slide pixel	Frequency ratio	Relative frequency ratio(RFR)	RFR (%)	INT of RFR
		920_1538	1	6302772	18279000	20310	0.003222	0.247866	24.78655	24
	Elevation	1539_1912	3	7610757	46559700	51733	0.006797	0.522851	52.28506	52
1		1913_2277	5	6886867	14582700	16203	0.002353	0.180972	18.0972	18
		2278_2642	7	7023070	3203100	3559	0.000507	0.03898	3.897972	3
		2643_3307	9	5324604	581400	646	0.000121	0.009332	0.933218	0
				33148070	83205900		0.013001			0
		far from road	1	476766	905400	1006	0.00211	0.038337	3.833716	3
2	Proximity to _road	moderate distance	3	1168250	13638600	15154	0.012972	0.235678	23.56778	23
		near to road	5	1733483	46965600	52184	0.030104	0.546947	54.69468	54
		very near to road	7	2444253	21677400	24086	0.009854	0.179038	17.90382	17
							0.055039			0
		Sandston and lime stone	1	29133	75398400	83776	2.875639	0.419374	41.93735	41
		gypsum	3	2451	898200	998	0.407181	0.059382	5.938187	5
3	Lithology	Trachyte/ basalt	5	11324	780300	867	0.076563	0.011166	1.11657	1
		Granite and Gneiss	7	1670	5256900	5841	3.497605	0.510079	51.00789	51
							6.856988			0
	Slope	0 ⁰ -2 ⁰	1	1838773	2689200	2988	0.001625	0.156652	15.66524	15
		2 ⁰ _14 ⁰	3	21286912	48720600	54134	0.002543	0.255156	25.51556	25
4		14 ⁰ _37 ⁰	5	9258944	29979000	33310	0.003598	0.346815	34.68148	34

		37 ⁰ _79.5 ⁰	7	765454	1796400	1996	0.002608	0.241377	24.13772	24
							0.010373			0
	LULC	Built -up	3	394635	2090700	2323	0.005886	0.084652	8.465239	8
5		Agriculture	5	3165990	37641600	41824	0.01321	0.189977	18.99773	18
		bare land	9	785445	13975200	15528	0.01977	0.284306	28.43055	28
		Water body	7	1224130	27945000	31050	0.025365	0.36477	36.47705	36
		Dense forest	1	239762	1144800	1272	0.005305	0.076294	7.629435	7
							0.069537			0
6	Proximity to drainage	>500	1	577122	2723400	3026	0.005243	0.094496	9.449571	9
		200_300	3	1363413	17259300	19177	0.014065	0.253492	25.34919	25
		100_200	5	1902697	30942900	34381	0.01807	0.325656	32.56564	32
		0_100	7	1979520	32261400	35846	0.018108	0.326356	32.6356	32
							0.055487		100	100
7	Curvature	concave		336073	5188500	5765	0.017154	0.261764	26.17645	26
		Concave to flat		2857367	40288500	44765	0.015667	0.239066	23.90659	23
		Flat to convex		2356750	33556500	37285	0.015821	0.241416	24.14158	24
		convex		273101	4151700	4613	0.016891	0.257754	25.77539	25
						0	0.065532	1		0
8	Soil texture	sandy loam	1	2505938	53420400	59356	0.023686	0.624782	62.47825	62
		loam	3	2387307	29295900	32551	0.013635	0.359659	35.96587	35
		clay	5	929048	493200	548	0.00059	0.015559	1.555883	1
						0	0.037911		100	100
9										0
		FLAT	1	785214	8239500	9155	0.011659	0.080467	8.046694	8
	Aspects	NORTH	2	716191	8180100	9089	0.012691	0.087586	8.758595	8
		North east	3	658054	8091900	8991	0.013663	0.094296	9.429608	9
		East	4	585414	9264600	10294	0.017584	0.121358	12.1358	12
		South east	5	579384	10380600	11534	0.019907	0.137392	13.73917	13

		South	6	655188	12117600	13464	0.02055	0.141826	14.18258	14
		South west	7	665151	11574000	12860	0.019334	0.133434	13.34344	13
		West	8	614901	8918100	9909	0.016115	0.111217	11.12172	11
		North	9	533015	6424200	7138	0.013392	0.092424	9.24239	9
							0.144895		100	100
10	Proximity to Lineament	>800	1	292572	144900	161	0.00055	0.013579	1.357884	1
		400_600	3	846039	2452500	2725	0.003221	0.079478	7.947778	7
		200_400	5	1785348	24573600	27304	0.015293	0.377375	37.73749	37
		0_200	7	2899615	56006100	62229	0.021461	0.529568	52.95685	52
							0.040526			97

Appendix 3A: Graphically representation of degree of occurrence landslide in different class of each parameter





Appendix 4: Weight derived for engineering cost surface

Set weights

Criteria hierarchy

- Objective
 - slope+reclass [51.939]
 - rstm_ecu_r [26.638]
 - lithology.tif [11.048]
 - soil [6.028]
 - limnt_density [4.346]

Preference matrix

Set values between 1 and 9 (equal (1) to strong (9) preference). Compared is row against column. Transpose values are set automatically.

	ope+reclass	rstm_ecu_r	lithology.tif	soil	limnt_density
slope+reclass	1	3	5	7	9
rstm_ecu_r	.333	1	3	5	7
lithology.tif	.2	.333	1	3	2
soil	.143	.2	.333	1	2
limnt_density	.111	.143	.5	.5	1

Ahp results

slope+reclass: 51.939
rstm_ecu_r: 26.638
lithology.tif: 11.048
soil: 6.028
limnt_density: 4.346

Compute
CR: 0.037

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Appendix 5: Weight derived for environmentally cost surface

Set weights

Criteria hierarchy

- Objective
 - lulc_rcls.tif [64.833]
 - ptoriver.tif [22.965]
 - slope+rcls.tif [12.202]

Preference matrix

Set values between 1 and 9 (equal (1) to strong (9) preference). Compared is row against column. Transpose values are set automatically.

	lulc_rcls.tif	ptoriver.tif	slope+rcls.tif
lulc_rcls.tif	1	3	5
ptoriver.tif	.333	1	2
slope+rcls.tif	.2	.5	1

Ahp results

lulc_rcls.tif: 64.833
ptoriver.tif: 22.965
slope+rcls.tif: 12.202

Compute
CR: 0.004

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Appendix6: Population data

District(woreda)	Total Area(hectare) ,2020(author computation)	Total projected (population(2020)census(CSA)		
		Total	Male	Female
Dendi	120889.237	187372	94208	93164
Jeldu	12760.499	218564	107338	111226
Abuna gindeberat	103071.844260	153111	74394	78716
Gindeberat	12735.7803	150174	75628	74546
Elfita	44511.69487	80597	39973	40624
Ejersa lafo	3455.20	82268	41585	40683
Cobi	56363.94	69511	33753	35798

Appendix7: Graphically representations of evaluation result for route optimization

