

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY
SCHOOL OF CIVIL AND ARCHITECTURE ENGINEERING
DEPARTMENT OF GEOMATICS ENGINEERING



**GIS BASED ROAD ALIGNMENT SELECTION USING MULTI CRITERIA DECISION
ANALYSIS**
(CASE STUDY OF HMUSITE TO ESTIE ROAD UPGRADING)

**A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF ADAMA
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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in the thesis entitled " *GIS based Road Alignment selection Using Multicriteria Decision Analysis from Hamusite- Estie* "impartial fulfillment of the requirements for the award of the degree of Master of science in Geodesy and Geomatics Engineering is an authentic record of my own work carried out from June 2015 to June, 2016 Under supervision of Dr. Tilahun Erduno, Mr. Endawok Assegid. Department of Geomatics Engineering, Adama University, Ethiopia.

The subject embodied in this thesis has not been submitted by me for the award of any other Degree or diploma. All relevant resources of information used in this thesis have been duly

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CERTIFICATE

This is to certify that the study entitled “GIS based road alignment selection: A Case of Hamusit - Estie” is carried out by Derbachew Getahun under our guidance and supervision. This is the actual work done by Derbachew Getahun for the partial fulfillment of the award of the Degree of Master of Science in Geodesy and Geomatics Engineering from Adama Science and Technology University, Adama, Ethiopia.

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ACRONOMYS

AHP	Analytical Hierarchical Process
CSA	Central Statistical Agency
DEM	Digital Elevation Model
ERA	Ethiopian Road Authority
ERDAS	Earth Recording Data Analysis System
GIS	Geographical Information System
GIS-T	Geographic Information Systems for Transportation
GPS	Global Positioning System
LCPA	Least Cost Path Analysis
MCA	Multi Criteria Analysis
MCDM	Multi Criteria Decision Making
MOA	Ministry Of Agriculture

ABSTRACT

The main objective of this study is to describe the application of geographical information system (GIS) and multicriteria decision making for optimal road alignment selection analysis. The important factors for the optimal alignment selection analysis were identified and selected based on literature and expertise discussion and categorized as engineering (Geology, Fault Lines, Soil type, Drainage density, Topography (Slope and Elevation), social and environmental factors(Land use, Forest Area, Sparse vegetation, Agriculture Area, Settlement, Open land and Rivers).

Raster map layers were prepared and reclassified to meet the factor and constraint requirements. In this study two stages of criteria weights were computed as phase1 criteria weights for criteria classes and phase2 relative weights of criteria for two designed alternative decision making scenarios (Engineering, social and environmental decision making scenarios) using analytical hierarchical process (AHP) based on literature and expertise discussion. Then the factors have been combined to give cost layer. By combination of the origin and criteria of cost layer the weighted cost distance and cost direction layers were generated. Using weighted cost distance and cost direction (Back link) criteria layers in the least cost path analysis function from origin (Hamusit to Estia) destination two alternative route alignments were generated.

The alternative alignments have been compared with the existing route and also each other by route alignment requirement criteria and the new alignment reduced the road length by about 10 kilometer and about 92. % area of route alignment passed through flat to rolling terrain which is less cost of earth work.

On the other hand less environmental and social impact has been for instance from 67.5 up to 75.24 % area of route location was lied in agricultural and open areas .From which the most optimal one was engineering scenario alignment.

Generally GIS is very important and efficient tool for road alignment selection and other engineering location in order to reduce the quantity of Engineering, environmental and social impacts and optimizing different linear and others infrastructures.

1. INTRODUCTION

1.1 Background of the study

From the development of the wheel through the industrial revolution to current times economic growth has always needed to go hand in hand with transportation growth. Thus transportation systems particularly highways play a key role in the development of any country. The country's economic and social wellbeing depends to a large extent on the performance of the highway systems. Not only does the highway system provide opportunities for the mobility of people and goods but also over the long term it influences patterns of growth. Land use and the level of economic activity through the accessibility it provides to land (Baniziste, 2002).

In Ethiopia Road infrastructure is one of the key impute to improve the economic and social welfare of people. Availability of sufficient road infrastructure and improved pavement conditions reduces travel times and costs of vehicle operation. While increase access to markets, jobs, education and health services with reducing transport costs for both freight and passengers. The Ethiopia Government and the development partners invest much of their resources and efforts for the planning, designing, construction, supervision and monitoring of the performances of road infrastructure computerizing the working procedure and facilitate the decision-making process in the day to day activities (ERA, 2004).

In transport development construction and maintenance costs of a highway as well as its operation performance and environmental effects are mostly dependent on its alignment. For this reason the most important step in the highway planning activity is the alignment selection (Ferit Yakar and Fazil Celik). 2014)

It is often reported that early transportation planning practice does not take environmental considerations into account. Originally, transportation plans were generated exclusively on economic, physical and technical constraints. It is sometimes even questionable if a corridor selected in this way is really the optimal one (Jankowski and Richard 1994, Guimarães Pereira, 1996).

In recent years transportation operations have become an environmental issue mainly in the highly developed countries. Air and noise pollution, biodiversity loss, and human health

deterioration are some of the urgent problems brought about by increased transportation needs (Kamila Małgorzata, 2005).

Traditional highway design were done by evaluating various alternatives in order to determine the most promising one which satisfies the needs and optimal in its location minimizing the costs of its construction and avoiding any environmental constraints in the area. Since the number of alternatives joining two highway end points is unlimited a manual design may arrive at a merely satisfactory solution rather than a near optimal design (Rasem Awwad, 2005).

Consequently traditional road alignment selection affect ecosystems and their values and functions through the following stress or processes: Alteration of topography, deforestation, erosion, sedimentation, and soil compaction, dehydration and inundation, acidification, salinization, and warming, contaminant toxicity, noise and visual disturbance, Introduction of exotic species and direct mortality from road (US EPA ,1994).

In Ethiopia due to the problem of selection of highway alignment difficulties are being encountered on road construction sites during construction due to inadequate attention to the initial selection of the route. The problems are particularly acute in the mountainous terrains of the Ethiopian highlands, where very high road construction costs have resulted from unnecessarily and large quantities of earthworks (URS, 2012).

On the other hand transportation development when done heedlessly can hopelessly damage and fragment the natural environment human kind's quest for development has led us to a point where any further development threatens the last remaining natural reserves. Thus in these times finding the optimal balance between infrastructure creation and nature conservation is achieving much greater importance than ever before (World Bank, 1 993 &World Bank, 1995).

Route proper planning is essential in order to maximize the benefits derivable from the use of routes. With the scientific planning of a route cost, time, and operating expenses can be saved ensuring longer operational life and minimizing environmental fallouts (Nasir and Hyder, 2000).

However the lack of using technologies and cooperation between the different local authorities and ministries involved complicates the process of data acquisition, integration and analysis for

the route planning. Therefore, historical, economical and geological issues are not accurately considered. Environmental and social impacts are also often neglected.

To overcome these deficiencies the use of Geographic Information Systems (GIS) is mandatory to manage the variety of data sets from different sources required for the planning process. Geographic Information Systems (GIS) is increasingly used in civil engineering applications. Transportation and highway engineering is the field which has been benefited by developments in GIS aspects, as spatial variables, including environmental, topography, built-up areas, and geology related variables, can be easily modeled. Such criteria are taken into consideration in the selection of route location and the design of highway alignment processes that are usually perceived as rather complicated. Therefore, this complexity motivates highway engineers to give more attention to GIS applications in route location and highway alignment, due to their ability to consider many spatial variables simultaneously (Bailey et al., 2001).

Multicriteria analysis can effectively be used for optimal route selection in GIS environment. Multi-Criteria evaluation procedure includes: criteria establishment, standardization of factors, establishment of factor weights and finally weighted linear combination. With the advent of GIS and personal computers capability alternative route selection analysis can be explicitly carried out because of its enormous capacity to store, handle and retrieve of huge volume of various spatial and non-spatial data. GIS software for analyzing raster data for criterion weighting in the Multi-Criteria evaluation process the analytical hierarchy process(AHP) is the most preferred method and widely used in the decision making process. Analytical hierarchy process uses a pair wise comparison method developed by (Saaty, 1980).

This study attempts to modernize and computerize the phase in the highway design process in which a preliminary location study is done using Geographic Information Systems (GIS) software. The case study was takes place in a geographic region with highly irregular land features and various existing constrains such as river, topography and forests.

1.2 Statement of the problem

Highway development can be said to affect ecosystems and their values and functions, through the following stress or processes: Alteration of topography, Vegetation removal, Erosion, Sedimentation, and soil compaction, Dehydration and inundation, Acidification, Salinization, and Warming, Contaminant toxicity, Noise and Visual disturbance, Introduction of exotic species and direct mortality from road (US EPA, 1994).

The conventional route planning has solely been based on topographical considerations gradient and curvature in developing countries.

Usual practice involves manually marking segments of permissible gradients for route alignment on large-scale topographical maps. Such an approach is cumbersome and tedious and it may not be feasible when variety of factors such as landslides, geology, soil type, vegetation, land use, and land cover are considered (Saha et al., 2005).

Due to inadequate data at the planning phase some additional engineering structures like bridges retaining walls etc. may be needed during construction phase and this increases the construction, maintenance costs and lengthens the construction period. Since a concrete procedure is not determined some irrational changes can be made in the alignment due to local and political pressures (Ferit Yakar and Fazil Celik, 2014).

Ethiopian Road Authority implements the choice of the 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 perception of the individual who do the reconnaissance on the selected route, environmental and social impacts often neglected (Yohannes Fisiha, 2005).

As a result the following are the major problems in road infrastructure development:

- ❖ Reduction of available wildlife habitats due to land acquisition for expansion of the road width and use of construction materials.
- ❖ Disturbance of wild animals in the road corridors, disruption of habitat use or migration patterns, and increased rate of accidental killing of animals while crossing the road

- ❖ Loss of farm and grazing land
- ❖ Resource loss/ecological damage
- ❖ Environmental loss and deterioration
- ❖ Social disruption
- ❖ Community dissatisfaction
- ❖ Resource-use conflict

Feedback from local experts during the route selection manuals preparation project has indicated that significant difficulties are being encountered in Ethiopia on road construction sites during construction due to inadequate attention to the initial selection of the route (URS, 2012).

Route option identification is usually undertaken by consultants on behalf of Ethiopian Road Authority and should take into account avoidance of environmentally protected areas and other sensitive habitats (ERA, 2013) but as all EIA report shows that all the damage are passed simply by compensation and rehabilitation agreements.

This study will show how GIS based multicriteria decision analysis improved the methods of road alignment selection.

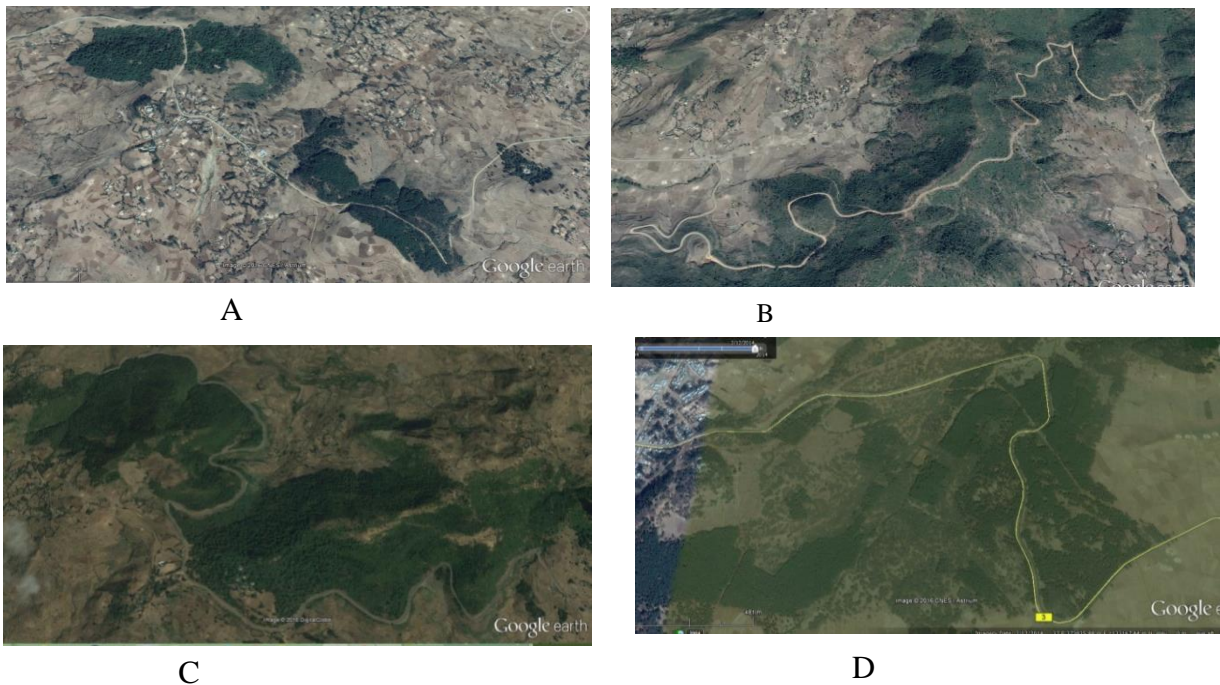


Figure 1: Road affecting nature conservation

1.3 Objective of the study

The study has a general and specific objectives.

1.3.1 General Objective

The general objective of this study is to demonstrate the capabilities and functions of GIS and remote sensing technology that offers an opportunity to overlay maps, merge and perform various spatial analyses on various layers of information to select an optimal route alignment location.

1.3.2 Specific objective

The specific objectives of the study are;

- ❖ Identify constraint and benefit factors for the alignment selection
- ❖ To use remote sensing imagery to obtain relevant special information.
- ❖ to modernize and computerize the road alignment selection for Humusit to Estia road
- ❖ To determine and quantify the impact of the route on social and environmental features
- ❖ To compare and evaluate the alternative route based on the criteria set up
- ❖ To select the optimal route alignment.
- ❖ To show the contribution of GIS in alignment selection

1.4 Research question

The study must answer the following research questions.

- ❖ What are the constraint and benefits factors for alignment selection?
- ❖ What is the information obtained for remote sensing image
- ❖ How the alignment selection is can be computerized?
- ❖ What are the impact of route in social, environmental and economic issues?
- ❖ is it possible to obtain relevant information using remote sensing imagery
- ❖ How GIS is used for least cost path route selection
- ❖ Which route is optimum having minimal environmental effect?

1.5 Significance of the study

The study output will have considerable significance to:

- ❖ Minimize the construction cost of the road for the Hamusite to Estia
- ❖ Support both the client and the contractor by reducing the delay of the construction
- ❖ Aspiring bond for professionals working in road corridor selection and road Planning
- ❖ Reducing environmental, social and economic disturbance of the ecosystem of Estia and Dera wereda
- ❖ Minimize the vehicle operation and user cost

1.6 Scope of the study

This study focuses mainly on the demonstration of the advantages of geographical information technology and remote sensing on optimal high way road alignment selection in the study area. This study mainly limited to the selection of the optimal road alignment and comparing each alternative alignments and to the governmental defined alignment.

1.7 Limitation of the study

This study has the following some limitations;

- ❖ Lack of organized and standardized spatial and a spatial (attribute) data related to engineering, social and environmental for the road alignment selection. For instance engineering properties of soil. However this was solved by transforming the format and by correlating their characters from different data source.

2. LITERATURE REVIEW

2.1. Theoretical view of GIS Technology

A Geographic Information System (GIS) is an organized collection of computer hardware and software people money and organizational infrastructure that makes possible collection and storage of geographic and attribute data for purposes of retrieval, analysis synthesis and display to promote understanding and assist decision-making (Taylor & Francis,2003).

GIS is a computer-based system that provides a full suite of tools for the creation, management, analysis and display of spatial data Categories of features (example roads, water bodies, (jurisdictional boundaries) are grouped into layers and can be combined in order to create a reference base map. Specific business data features such as poles, signs, culverts, and guardrails are also categorized and displayed on top of a referential base map. GIS provides the typical data query functionality such as select data features/records by type, length, value, inspection date, and ownership.

GIS support the acquisition, management, analysis, and visualization of spatial referenced data. GIS integrates location information with conventional tabular data to create data sets organized by spatial coordinates and these end results are represented by maps. Visualization helps people approach problems in the dimensions of space and time with intuitive maps instead of dimensionally restricted data tables and graphs.

The distinguishing feature of GIS over other database management systems is that it allows spatial analysis mainly on the form of overlaying and buffering and referencing layers of data by their attributes. And the results of the analysis could be in the form of tables or maps, or a combination of both (Miles & Ho, 1999).

GIS can also query point, line, and polygon data features/records based on spatial relationships such as within an area, along a route, overlapping within a given distance or intersecting. Tabular queries and spatial queries can be combined in order to perform more complex analysis and the results can be displayed on a map in order to illustrate patterns and spatial relationships. Data features can be displayed differently (color, size, pattern, width) based on various

attributes (type, length, value, inspection date, ownership) in order to represent query/analysis results (John A, 2012).

The innovation of GIS lies in the possibility of manipulation of spatial features together with its database attributes. In comparison to the traditional analogue overlay GIS wins with the easiness of retrieval of spatial data from the geodatabase and displaying it on the screen. Furthermore the technology supports unlimited number of ways of combining different thematic layers and presenting them to an audience. Ability to integrate data from different sources is one of the most valuable functions of GIS (Insyirah BT.and Mohd yunus, 2012).

2.2 Function of GIS in transportation planning

Among the wide range of potential applications GIS can be used for transportation issues have received a lot of attention. A specific branch of GIS applied to transportation issues commonly labeled as GIS-T has emerged. Geographic information systems for transportation (GIS-T) refers to the principles and applications of applying geographic information technologies to transportation problems. (Jean Paul, 1998)

An effective system management is required in planning development in order to achieve the desired goals and objectives evaluate alternative as well as control development programs that are in line with the current and future prospects. GIS technology has long been applied in planning activities which essentially include plans formulation as well as development control. The design of public transportation system operation and networks is complex and can include conflicting objectives. The design may not fulfill all the requirements in different perspectives. GIS can combine pieces of data for every object put it through the model process and get back a new piece of information. This allows spatial data to be processed in mass quantities using powerful complex formulas.

GIS is not only for mapping but it also can analyses, process data and display output. Besides of that the costing is much cheaper by using GIS because of GIS's effective way to integrate information needed to support the many facets of transportation there had been growing interest in employing GIS in transportation projects called GIS-T applications based on their

capabilities and adaptability. The GIS-T is employed to refer to the application and adaptation of GIS to research, planning and management in transportation (Thill, 2000).

Furthermore the ability of most GIS software to provide many basic transportation models and algorithms may also be useful in specific situations. The ability to link up to external procedures and software also provides flexibility as these procedures can access data within the GIS and present the results of analysis to the GIS for viewing and analysis.

The geographic information system (GIS) could be used as a tool for highway infrastructure management in a way similar to its current application in land-based information. GIS procedures provide a coordinated methodology for drawing together a wide variety of information sources under a single visually oriented umbrella to make them available to a diverse user audience. GIS tools can be applied to aid technical and administrative specialists both in managing costly and intensively used resources and in supplying information to decision makers.

Potential applications of GIS in transportation planning include the following:

- ❖ Executive information system.
- ❖ Pavement management system.
- ❖ Bridge management.
- ❖ Maintenance management.
- ❖ Safety management.
- ❖ Transportation system management (TSM)
- ❖ Travel demand forecasting
- ❖ Corridor preservation and right-of-way
- ❖ Construction management
- ❖ Hazardous cargo routing
- ❖ Overweight/oversize vehicles permit routing.
- ❖ Accident analysis
- ❖ Environment impact
- ❖ Land side economic impact and value-capture analysis and others.

GIS applications can be expected in pavement management, traffic engineering, planning and research, bridge maintenance and field office support, Other planning applications include

evacuation planning, planning for hazardous material release incidents, development of new traffic analysis zones from census tracts, and development of new urban highway networks. GIS is a powerful tool in the analysis and design of transport routing networks. Its graphical display capabilities allow not only visualization of the different routes but also the sequence in which they are built, which allows the understanding of the logic behind the routing network design. The interaction between the transportation system and its surrounding environment makes the GIS technology ideally suited for hazardous material, routing design, risk analysis, and decision making. GIS can also be integrated with sophisticated mathematical models and search procedures to analyze different management options and policies (Gupta *et al.*, 2003).

2.3. GIS for Environmental assessment of transportation projects

GIS can be used to analyze the spatial relationships between species ranges and land use patterns and to identify adequate buffer areas and potential habitat corridors for the maintenance of ecosystem integrity. For ecological evaluation mapping of individual habitat areas is essential. Only through GIS or other graphical methods can the areas of habitat impacted and the changes in landscape patterns be quantified. Current GIS approaches to assessing the impacts of highway development use photographic imagery (usually low level aerial) to delineate vegetation using classification techniques. In addition to accurate measures of habitat area this imagery provides perimeter to area ratios and other measures of habitat fragmentation and isolation). Even more promising is the use of GIS in highway planning that has grown advocated map overlay methods to determine the suitability of land for highway development. The anticipated rapid growth of highway systems in North Carolina has prompted the State to create a Center for Geographic Information and Analysis to provide the locational data on natural resources needed for effective highway planning (US EPA, 1994).

2.4. GIS for Highway network planning.

GIS plays an important role in transportation planning. This is due to the fact that the objective of transportation planning is to guide development of a land use/transportation system to achieve economic, social and environmental benefits, and GIS greatly contributes to this process through its powerful features in database management, geographic visualizations of

possible scenarios and tools for processing geographic data into geographic information (Shaw & Xin, 2003).

Furthermore GIS is widely used to improve existing road networks or plan roads for the future. The GIS network capabilities and its ability to represent road networks is a great benefit to transportation engineering and planning. GIS allows searching along a line, such as a route, or throughout a network of linear features, such as a road network. Network analysis can be used to define or identify route corridors and determine optimum travel paths, travel distances, and response times. For example network analysis may be used to assess the traffic volume impact of a road closure on adjacent roadways (Adams et al., 1997).

2.5. Review of GIS Application for route alignment selection

GIS play a main role in transportation application planning. It is useful to address complex tasks in policymaking, planning, analysis, evaluation, design, construction, and maintenance of different types of transportation facilities. In addition it provides database management for extending human memory spatial analysis for rigorous computation and map display for visualization of large amounts of information about transportation networks (Emad Basheer, 2005).

In the field of highway design various optimization techniques have been applied to locate a path between two known locations. Most of them employ GIS due to its powerful functionality representing and analyzing geographic features.

Geographic Information Systems based Methodology was prepared to evaluate socioeconomic data concerning impacts of Highway Bypasses in Oklahoma. GIS technology was used in this study to develop a comprehensive modeling framework that will allow the users to assess quantitatively the potential economic impacts bypasses may cause. Within this framework bypass alternatives were selected and evaluated via five primary factors: total cost, ability to serve traffic, number of residential and commercial displacements effect on the local businesses and environmental considerations along the route.

Alternative routes can be easily derived and compared to find the best one including the possibility of not constructing a new bypass but widening and improving the existing route

instead. This aspect of the project set it apart from other studies of highway impacts analyses. This study automatically updated GIS database for Oklahoma highway network was constructed to keep the planners and engineers well informed to the activities and needs of communities throughout Oklahoma. By properly developing and maintaining the GIS database and using the developed model users would be able to identify a proposed new bypass route graphically on a map identify the bypassed highway section and quickly calculate estimates of affected businesses and other economic activities within a specified distance of these routes. This identification combined with the impact models developed by using past bypass experiences in Oklahoma provides the users with a reasonable estimate of changes that could be expected for the proposed bypass route and replaced highway section. An impact buffer was created using Arc View around the selected street or proposed highway at a distance defined by the user (Jonathan, et al., 2000).

Alignment analysis and design for transportation facilities have traditionally been limited to the geometric design and cost estimate where the design process consists of several steps starting with the conceptual design that is done on large scale maps to identify broad design constraints and overall cost estimates then functional and preliminary designs while the final design is done based on a field survey to identify property and utility impacts and to refine the cost estimate in addition to cost estimates and engineering considerations in alignments design and evaluation an increasing emphasis on environmental aspects of transportation has been placed since the 1980s and has been paralleled with a focus on the essential role of community involvement (Bailey et al., 2001).

In order to optimize the right-of way cost for highways. A GIS-based model was developed. The model tries to overcome some weaknesses in the similar earlier model created which were not considering the value of damage to a property due to the partial taking by the proposed alignment not considering other geographic entities such as lakes and rivers unrealistic and incomprehensive formulation for geographically sensitive costs. Computing the right of way cost is very complex as it depends on before and after values of affected properties and structure appraisal temporary easement areas damage just compensation and relocation. A genetic algorithm (GA) optimization model is used to generate random control points at the start of each alignment solution and then passed to the GIS.

Other GIS-based algorithm was formulated using the script in Avenue programming language which is associated with Arc View GIS. This algorithm is used to calculate the right-of-way costs considering: parcel costs, appraisal costs (obtained through regression analysis), damage to properties, just compensation and transportation cost associated with relocation (Jha and Schonfeld, 2001).

Highway construction projects are highly depend on geographical information obtained from field surveys such as topographical features, property parcels and environmental features such as floodplains and wetlands. Since several costs of highway alignments are sensitive to geography using GIS as a tool to calculate these costs is very efficient and time saving. Geographic information can be extracted from GIS to calculate costs and/or costs can be calculated by exploiting GIS spatial analysis tools in algorithms to calculate some of the costs (Jha, 2001).

Route location and highway alignment presents a highly complex decision environment in which a variety of social, environmental, and economic factors must be defined, analyzed, and evaluated. There are several studies that benefit from the GIS for this purpose one of these studies was prepared by (Bailey, 2003)

Another study related to use of GIS in route location was prepared as integrated GIS framework. The model was developed as a decision aid tool for a multi-criteria evaluation of route alignments. The framework integrated specialized slope stability and roadway design packages within the Arc View user friendly environment. The objective was to allow for multi-criteria analysis and evaluation of route alignments based on the integration of topographic, geometric design, geologic, geotechnical slope stability analyses, environmental impact, and community disruption evaluation. The developed layout assessment approach worked within an integrated GIS platform. It had three basic elements a digital model of the study area, an integrated computer based module and an assessment framework.

Different types of data layers were required to create a geographically referenced database or model for a given region depending on the type of analyses and anticipated applications. The GIS model could be thought of as a geographically referenced base consisting of data layers of various types. The required layers of information relate to the application being implemented.

The more the data layers the more complete the model is however for developed application the following layers were needed Political and administrative existing roads, existing structures, land cover, land use, topography, rivers/streams, geology, soil, and depth to water table

The proposed framework provided the decision-maker with a set of evaluation criteria associated with any given route layout. The developed tool would call upon and use the various platforms and customized scripts and computer codes, moving sequentially through all the steps without intervention by the user. A report characterizing the specified route alignment based on the assessment criteria is automatically generated the final report that the engineer can use to evaluate a given alignment includes factual information resulting from the analyses. Possible alignments are evaluated based on two sets of criteria. First, traditional evaluation criteria focusing on geometric design factors and impact on man-made features are considered. Second, the developed assessment framework builds on the GIS platform to generate specific environmental and geotechnical criteria for route layout evaluation (Sadek et al., 1998).

Planning a road path requires an extensive evaluation process in order to identify the best possible path the road can follow. This path must comply with the requirements of the government regulations and at the same time must minimize economic, environmental, health and social cost. The road path selection procedure using multicriteria analysis and GIS make maximum use of the available information in trying to arrive at an outcome acceptable by most stakeholders and as such requires the processing of a variety of spatial data (Isah O. and Anavberokhai, 2008).

Route location and highway alignment presents a highly complex decision environment in which a variety of social, environmental, and economic factors must be defined, analyzed, and evaluated. There are several studies that benefit from the GIS for this purpose; one of these studies was. The design and development a GIS-based corridor route planning methodology called Analytic Minimum Impedance Surface (AMIS). This methodology facilitated choice of a route corridor for a section of a proposed interstate highway connector in the southeastern United State. Also it would both provide comparative information about pre-selected corridors and/or aid in the selection of corridors based on user-defined path inputs or endpoint location specifications. Five classes of data were defined as

- ❖ Environmental: Unique habitat, archaeological feature and streams
- ❖ • Man made public Features: Hospital, water tank, school and airport
- ❖ Dirt and rock: Oil and gas wells, mine, quarry and 15-25% Slope
- ❖ Socioeconomic: Land value, poverty rate and Population growth rate
- ❖ Picnic area: Picnic area, national properties register, state park

AMIS combined system priorities such as economic development, wetlands, schools, median incomes or areas where endangered species were located. Both the system priorities and features could be user specified. Input was in both written and electronic data format while the output was displayed on standard GIS software. AMIS was therefore built using iterative process that incorporated input from engineers, planners and environmental specialists.

The other study called highway Alignment Optimization (HAO) model is an intelligent optimization tool developed to assist planners and designers in finding the preferable highway alignment alternatives (usually the most cost-effective paths) connecting specified endpoints or zones. It integrates genetic algorithms with a geographic information system (GIS) for optimizing highway alignments and processes massive amounts of relevant data associated with highway design and alternative evaluation and has been applied to an actual highway construction project in Maryland (Schonfeld et al.,2004).

The recent study called Analytical hierarchical process and least cost path analysis method for the design and evaluation of alternative highway route the study have been used AHP to produce cost surface grids and to combine them in to single cost surface grid for the engineering and environmental themes. For each single cost surface raster was created and overlay function have been used to aggregate the cost grids in to one cost grid such as environmental cost grid and engineering cost grid and also the cost factor for each was identified. Finally the themes were combined. Then the combined cost surfaces were used in least cost path analysis using Arc GIS spatial analyst extension tool and from origin to destination three alternative paths have been produced finally by comparing and ranking each path the optimal was selected (Hala .A et al., 2013).

The other study termed as Three Stage Highway Alignment Determination Model. In this study a raster GIS based multicriteria decision making model is recommended for highway alignment determination process. The first stage of the model includes the application of constraints, the

second stage includes the generation of alignment alternatives and the third stage includes the comparison of the alignment alternatives and selection (Ferit Yakar and Fazil Celik, 2014).

A method developed using GIS and multicriteria decision making to determine a forest road network. In this study multicriteria decision making was used to evaluate the construction costs of the candidate networks in the study the Analytical hierarchical process (AHP) was used to determine the weights of map layers. Then weights and factors were entered into the multi criteria evolution module to create a final suitability map. The total cost of each alternative was extracted from the suitability map and the unit cost of each alternative was calculated (Abdi et al., 2009).

Generally Geographic Information Systems (GIS) is increasingly used in civil engineering applications. Transportation and highway engineering is one field which has been affected by developments in GIS aspects, as spatial variables, including environmental, topography, built-up areas, and geology related variables, can be easily modeled. Such criteria are taken into consideration in the selection of route location and the design of highway alignment processes that are usually perceived as rather complicated (Emad Basheer, 2005).

Therefore, this complexity motivates highway engineers to give more attention to GIS applications in route location and highway alignment due to their ability to consider many spatial variables simultaneously.

2.6. GIS for least cost path

The least-cost path algorithm is commonly included in commercial GIS. It determines the Shortest weighted distance from origin to a destination through a cost surface. The cost is defined by its neighboring cells relations and can be represented in monetary or other nonmonetary units. Therefore the weighted distance is not measured in geographic units but in cost units (Miller and Shaw, 2001)

The least-cost path performed in raster GIS is based on the regular square grid which is conceptualized to vectorized representation (Figure 2). The algorithm perceives each cell as a point placed in the center of it. The centric point of each raster cell is connected with adjacent cells

through links. Therefore this representation of raster is called node/link representation. (Miller and Shaw 2001, ESRI Desktop Help).

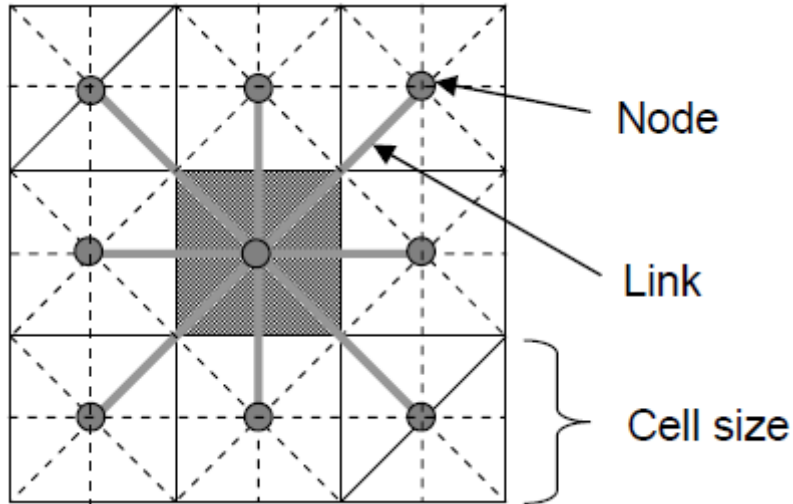


Figure 2: Node/ link representation

In GIS a process of generating the least cost path is performed in two steps. All calculations are based on a cost surface raster and a source raster (Figure 4a). Using a node/link representation, every node is assigned a value from the cell and every link is assigned a resistance value representing cost of travel between the two neighboring cells. When moving from a cell to one of its four directly connected neighbors the cost to move across the links to the neighboring node is calculated using the formula:

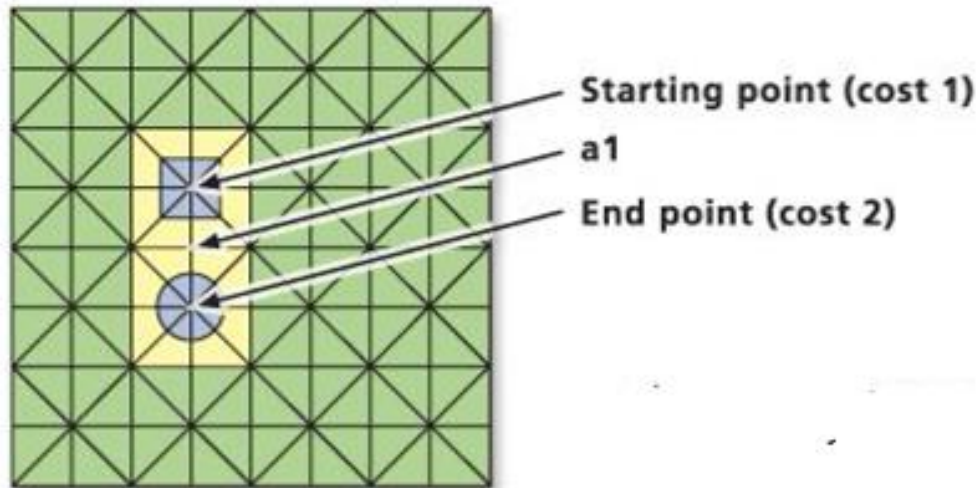
$$a1 = (cost1 + cost2)/2 \dots\dots\dots 1$$

Where:

cost1=the cost of cell 1

cost2=the cost of cell 2

a1=the total cost of the link from cell 1 to cell 2



If the movement is diagonal, the cost to travel over the link is 1.414214 (or the square root of 2) multiplied the cost of cell 1 plus the cost of cell 2 divided by 2: the formula is $a2 = 1.4142 \frac{(cost1 + cost2)}{2}$2

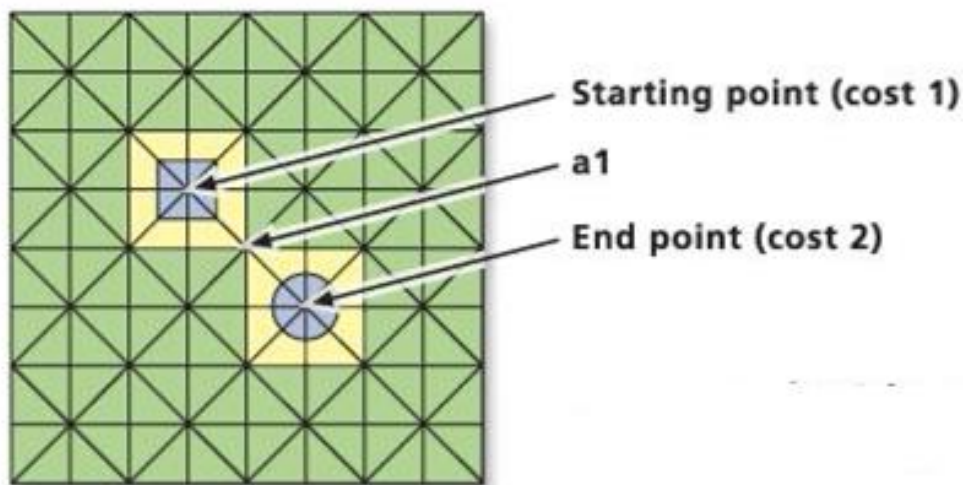


Figure 3: Horizontal and vertical movement

Calculation of the least accumulative costs for each cell is an iterative process which leads to the creation of a weighted distance raster (Figure 5b). Firstly the source cells are located and assigned zero value because there is no cost to travel to them. Next all of the immediate neighbors are assigned cost of travel from them to the source and the least cost cell is selected and assigned to the output raster. Simultaneously the direction of movement from the selected cell is coded as a back link raster. Again the accumulative cost of travel is recalculated for all the immediate neighbors of the selected cell. If the cost is higher than that previously calculated

it is ignored. However if the cost value is lower the old accumulative cost is replaced. The cells that are already assigned to the output raster are not recalculated and treated as permanent. The process is repeated until the least accumulative cost is assigned to all cells and the back link raster is completed. Generation of the weighted-distance raster is based on graph theory and the shortest path is based on the Dijkstra algorithm (ESRI Desktop Help).

On such defined accumulative cost surface it is possible to perform a least cost path to any location from the origin point (source cell) (Figure 4). If the origin is to change a new weighted distance raster needs to be calculated. The procedure described ensures that the lowest accumulative cost is guaranteed for each cell. Furthermore the cost calculation formula guaranties that the cost distance is adjusted to the distance to travel because every link value is multiplied by the cell size. Therefore cost assigned to every link reflects a resistance value of moving over one geographic distance unit (ESRI Desktop Help)

The accumulative cost is a sum of all costs from the source to the destination cell and determined by the following formula:

$$\text{Accumulative cost} = a1 + (\text{cost2} + \text{cost3}) / 2 \dots\dots\dots 3$$

Where:

cost2=the cost of cell 2

cost3=the cost of cell 3

a2=the cost of moving from cell 2 to cell 3

The accumulative cost = cost to move into cell 3 from cell2

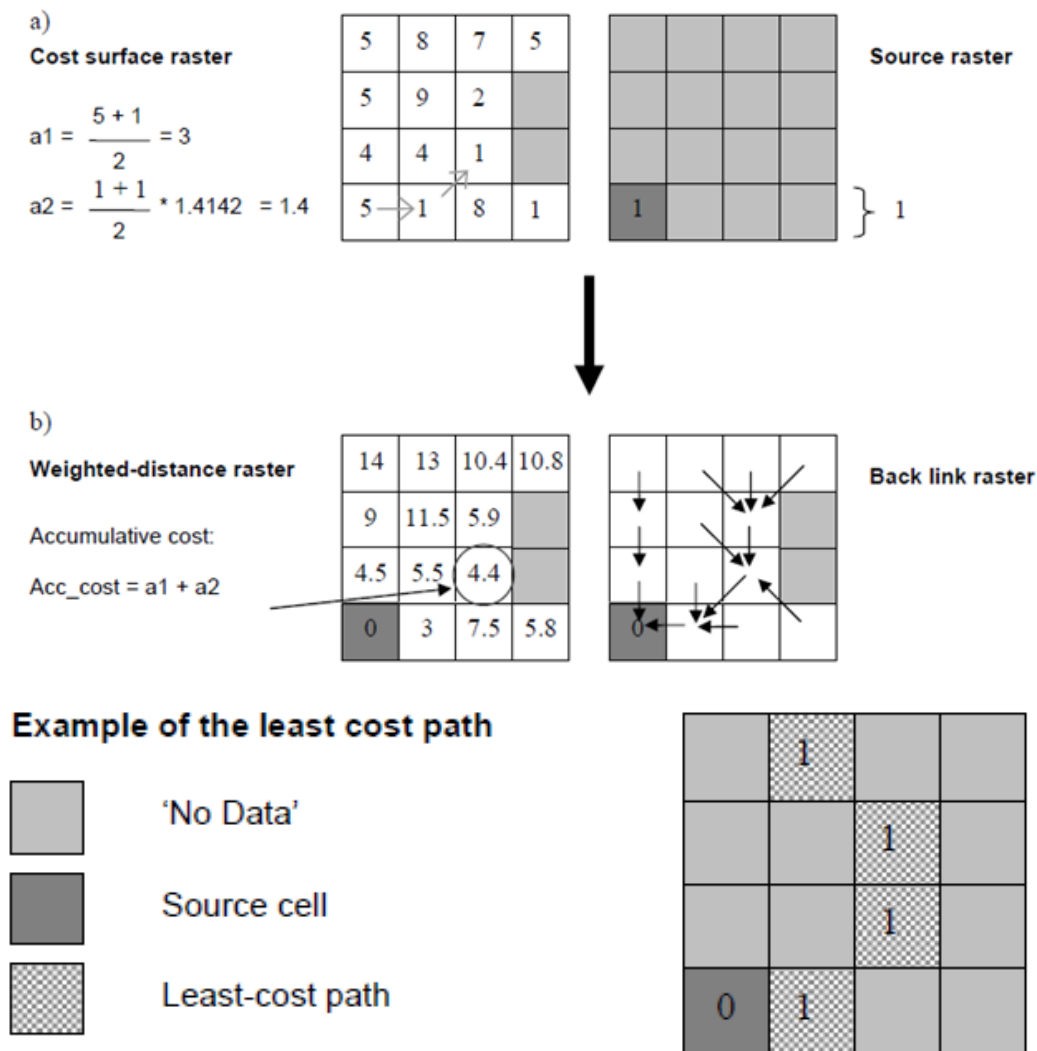


Figure 4: Procedure to calculate LCP in raster GIS based (Kamila Małgorzata, 2005)

2.7. Arc GIS 10 soft ware

Arc GIS is used by many GIS professionals all over the world. It is the most updated GIS software package released by the Environmental Systems Research Institute (ESRI).and the Arc GIS contains four components: Arc Map, Arc Catalog, Arc Toolbox and Arc Scene. While working separately to meet different levels of user requirements these applications are also designed to work together. It allows users to visualize geo data in a straightforward way to create map to spatially display data to analyze the spatial relationships of geo data. Arc Catalog helps to organize and manage user's GIS data. It allows locating previewing and manipulating the GIS data files in GIS databases (Ormsby et al., 2000).

2.8. Multi-Criteria decision making (MCDM)

Multi-Criteria Decision Analysis (MCDA) is a process that combines and transforms geographical data into a decision (Malczewski, 1999). Multicriteria decision making, combined with GIS data, is a powerful approach to systematically and comprehensively analyze a problem. The fundamental components of a multi-criteria problem are human value judgment and assessments of the importance of criteria. The main purpose of the multi-criteria evaluation techniques is to investigate a number of alternatives using multiple criteria and conflicting objectives (Voogd, 1983).

Multicriteria decision making (MCDM) is a term including multiple attribute decision making (MADM) and multiple objective decision making (MODM). MADM is applied when a choice out of a set of discrete actions is to be made. In MODM it is assumed that the best solution can be found anywhere in the feasible alternatives space and therefore is perceived as continuous decision problem. Whereas multi attribute decision making is often referred as multicriteria analysis or multicriteria evaluation (MCE). The main objective of MCDM is to assist the decision maker in selecting the best alternative from the number of feasible choice alternatives under the presence of multiple decision criteria and diverse criterion priorities. Every MCDM technique has common procedure steps which are called a general model (after Jankowski 1995). This procedure includes following actions

- ❖ Deriving a set of alternatives
- ❖ Deriving a set of criteria
- ❖ Estimating impact of each alternative on every criterion to get criterion scores
- ❖ Formulating the decision table with use of the discrete alternatives criteria and criterion scores
- ❖ Specifying decision maker's (DM) preferences in the form of criterion weights
- ❖ Aggregating the data from the decision table in order to rank the alternatives
- ❖ Making the final recommendation in the form of either one alternative reduced number of several good alternatives or a ranking of alternatives from best to worst

2.8.1. Multi-criteria decision making and GIS

GIS has good capabilities of handling spatial problems, and as such can be used to support spatial decision making. Solving a complex multiple criteria problem without spatial analytical and visualization tools would be computationally difficult. If not impossible (Jones, 1997).

Multiple criteria overlay was proposed by mainly for the purpose of identifying physical, economic and environmental criteria in order to assure social and economic feasibility of the projects. The complexity of the decision problem determines whether binary or multiple values overlay technique is used (McHarg, 1969).

Multi-criteria decision making and highway design are automatic procedures that involve many evaluation steps and take into account the relevant geometric, environmental, social, and geotechnical factors. Moreover, this approach is flexible and can include criteria for adjusting, evaluating and measuring stability from an environmental perspective (Fatih Kara and Nurünnisa Usul, 2012).

And also GIS and MCDM can be incorporated in alignment determination studies. At the most basic level GIS-MCDM can be thought of as a process that transforms and combines geographical data and value judgments to obtain information for decision making (Malczewski, 2006).

GIS and multi criteria decision making method was developed to determine a forest road network. In this method MCDM was used to evaluate the construction costs of the candidate alignments. AHP was used to determine the weights of map layers. Then weights and factors were entered into the MCE module to create a final suitability map. The total cost of each alternative was extracted from the suitability map and the unit cost of each alternative was calculated (Abdi et al. 2009).

2.8.2. Analytic Hierarchy Process (AHP)

Analytical Hierarchy Process (AHP) provides a structural basis for quantifying the comparison of decision elements and criteria in a pair wise fashion. This kind of comparison greatly reduces complexity and enhances simplicity of decision making. In the GIS database the attribute factors are represented as map layers and it contains attribute values for each pixel in raster data (Kiker et al. 2005).

Analytic Hierarchy Process (AHP) is a widely used method in MCDM and was introduced by Saaty (Saaty, 1977). It is easily implemented as one of the MCDM techniques. AHP is a decision support tool, which can be used to solve complex decision problems. It uses a multilevel hierarchical structure of objectives, criteria, sub criteria and alternatives. AHP uses a fundamental

scale of absolute numbers to express individual preferences or judgment (Table 1). This scale consists of nine points. In general, nine objects are the most which an individual can simultaneously compare and consistently rank. The score of differential scoring assumes that the row criterion is of equal or greater importance than the column criterion. The reciprocal values (1/3, 1/5, 1/7, 1/9) have been used where the row criterion is less important than the column criterion. AHP also provides measures to determine inconsistency of judgments mathematically. Based on the properties of reciprocal matrices the consistency ratio (CR) can be calculated. Where $CR < 0.1$ indicates that level of consistency in the pair wise comparison is acceptable. Saaty (1980). But if it is larger than 0.10, then there are inconsistencies in the evaluation process, and AHP method may not yield meaningful result

Table 1: Preference scale pair wise comparison in AHP (Saaty, 1980)

Intensity of importance	description
1 Equally important	Two factors contribute equally to the objective
3 Moderately more important	Experience and judgment slightly favor one over the other
5 Strongly more important	Experience and judgment strongly favor one over the other
7 Very strongly more important	Experience and judgment very strongly favor one over the other. Its importance is demonstrated in practice
9 Extremely more important	The evidence favoring one over the other is of the highest possible validity
2,4,6 and 8 Intermediate values	When compromise is needed
1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9	Reciprocal values of the previous appreciation

A decision matrix is always constructed by using Saaty's scale and factor attributes are compared in pair wise in terms of importance of each criterion/decision element to that of the next level. Weights are calculated by the following equations (Sadasivuni et al., 2009).

For a pair wise matrix of elements

$$\begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix}$$

1. Add the values in each column of the pair wise matrix and divide each criteria value by its column total to generate a normalized pair wise matrix

$$\begin{bmatrix} X_{11} & X_{12} & X_{13} \\ X_{21} & X_{22} & X_{23} \\ X_{31} & X_{32} & X_{33} \end{bmatrix} \quad X_{ij} = \frac{C_{ij}}{\sum_{i=1}^n C_{ij}}$$

2. Divide the sum of the normalized column of the matrix by the number of criteria (n) to generate a weighted matrix

$$\begin{bmatrix} W_{11} \\ W_{21} \\ W_{31} \end{bmatrix} \quad W_{ij} = \frac{\sum_{j=1}^n X_{ij}}{n}$$

3. Consistency Ratio (Cr) should be attained such that $Cr < 0.10$ and is calculated as follows

$$\begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix} * \begin{bmatrix} W_{11} \\ W_{21} \\ W_{31} \end{bmatrix} = \begin{bmatrix} C_{v11} \\ C_{v21} \\ C_{v31} \end{bmatrix}$$

Calculation of Consistency Vector is accomplished by dividing the weighted sum vector with the criterion weight as follows

$$C_{v_{11}} = \frac{1}{W_{11}} [C_{11} W_{11} + C_{12} W_{21} + C_{13} W_{31}]$$

$$C_{v_{21}} = \frac{1}{W_{21}} [C_{21} W_{11} + C_{22} W_{21} + C_{23} W_{31}]$$

$$C_{v_{31}} = \frac{1}{W_{31}} [C_{31} W_{11} + C_{32} W_{21} + C_{33} W_{31}]$$

Once the Consistency Vector is calculated, Lambda (λ) is calculated by averaging the value of the Consistency Vector. The Consistency Index (CI) provides a measure of deviation from consistency of criteria weight and computed as

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

Where n= number of criteria used

CR= CI/RI

Random inconsistency indices (RI) for N= 10

Table 2: Random inconsistency (Saaty, 2000).

N	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.46	1.49

3. MATARIALS AND METHOD

3.1. Description of Study Area

The study area is located in southern part of the Amhara region south Goander zone the study area cover two wered as Dera and Estie and it contains around 45 kebels. The geographical location of the study area is in between $37^{\circ} 0' 0''$ and $38^{\circ} 10' 0''$ Easting and $11^{\circ} 0' 0''$ and $12^{\circ} 0' 0''$ Northing and it's average elevation is 2057m above the MSL and the average annual rain fall and temperature is 1200mm and 19 degree cent grade respectively. According to the central statistical agency the population is estimated around 509 319. The total area is about 38772.881785sqkm the study area is more productive in agricultural products and domestic animal. The main reasons behind selecting this area for the application of this study is .First the variety of land use and topography of the study area that extends from Hamusite to Estie.

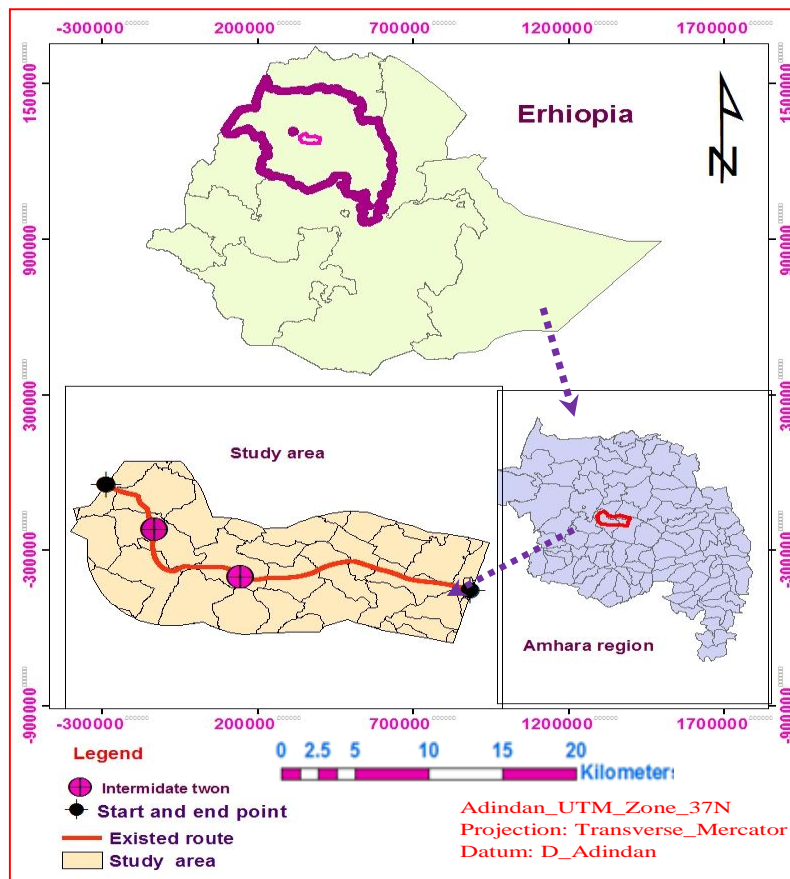


Figure 5 Location map of study area

3.2. Data Collection

This study focuses highway alignment optimization using GIS based multi-criteria analysis techniques. Data collecting included field surveys and secondary data collection from various organizations as shown in (Table 3). Firstly, the factors (data) were identified by personal discussion with experienced experts in road planning, engineering work and high level of educational professions.

The data were gathered from Ministry of Water and energy(MOWE)Ethiopian central statistical agency(CSA) ,Ethiopian map authority, and Amhara National Regional State transport bureau which includes boundary maps and land use land cover map of the study area the demographic figures of 2015 which was based on the population census of 2007. In addition Ethiopian Geological Survey and online searching (i.e. <http://landsat.usgs.gov>) was also used to download DEM data with 30m resolution. Moreover Table 3 clarifies sources of data with their format

Table 3: List of data and source

Data type	Format	Scale/Resolution	Source	Purpose
Land sat TM	Raster	30m	USGS,2015	For land use land cover extraction
DEM	Raster	30m	USGS, 2015	For contour/slope generating ,drainage order delineation
Soil	Shape file	1:250,000	FAO, 2007	Agricultural soil classification
Topographi c map	jpeg	1:50,000	EMA, 2014	Different features digitizing and verification
Geology	Raster	1:250,000	ARRA, 2012	Extracting fault lines and geology types
Rivers	Shap file	1:250,000	MOW,2007	Identifying stream

3.3. Discussion

As I mentioned above the factors (data) collection was accomplished by using field surveys and by collecting from various organizations (Table 3).in addition to the literature resource the discussions were held with experts of highway engineers, geotechnical engineers, socioeconomic engineers and environmental engineers and who are working in road design and Some academician those are PhD and MSC holders in related to the study problem. Starting from factors selection and latterly factors weight estimation.

3.4. Software used

The data collected for the study were edited, classified, weighted and overlaid and visualized on the basis of the selection of optimal route alignment analysis for the case study area using Arc GIS software. The application of GIS for overlaying thematic layers to establish criteria databases requires that all the layer maps need to be converted into a common coordinate system. Arc GIS 10 advanced (Arc Info) with spatial analyst extension was used for georeferencing both raster and vector data sets. In addition ERDAS Imagine 2013 software was used to layer stack different bands, subset images, and classify land use/cover map of the study area. Other soft-wares used in this research include Microsoft Internet, word, Excel. During field work Global Positioning System (GPS) hand held, and digital Camera were used to collect field data.

. Table 4: Material list

No	Hardware/software	Remark	Purpose
1	Handheld GPS	Garmin	For collecting spatial data (x, y)
2	Computer	Laptop	For general activities
	Scanner	A1-scanner	Converting hard copy to soft copy
	Printer	Laser-Jet	For printing
3	Arc GIS Software	Version 10	For data analysis
	MS-office word	Version 2007	For report writing

3.5. Methods

3.5.1 Multi-Criteria Decision Making (MCDM)

The main goal of this study is using Geographic Information System (GIS) integrated with Multi-Criteria Decision Making (MCDM) approach for determining the optimal road alignment from Hamusit to Esita.

Analytic Hierarchy Process (AHP) is a widely used method in MCDM and was introduced by (Saaty, 1977). It is easily implemented as one of the MCDM techniques. AHP is a decision support tool, which can be used to solve complex decision problems. It uses a multilevel hierarchical structure of objectives, criteria, sub criteria and alternatives. AHP uses a fundamental scale of absolute numbers to express individual preferences or judgment (Table 1).

Analytical Hierarchy Process (AHP) provides a structural basis for quantifying the comparison of decision elements and criteria in a pair wise fashion. This kind of comparison greatly reduces complexity and enhances simplicity of decision making. “In the GIS database, the attribute-factors are represented as map layers and it contains attribute values for each pixel in raster data (Kiker et al., 2005).

In this study Arc GIS 10 software and the analytical hierarchical process (AHP) method was used for:

- ❖ classification of factor (criteria),
- ❖ Standardization of criteria map
- ❖ Determination of criteria and sub criteria weights.
- ❖ assignning of weight values for criteria (factors) that is preparing of criteria (factors) cost map
- ❖ Combination of all factors using map algebra function in order to create weighted cost surface

After creation of weighted cost surface Cost Distance and Back link direction rasters were created and finally the Cost Distance and Back link direction raster have been employed to cost path module in ARC GIS spatial extension tool for the determination of least cost path road alignment

3.5.2. Conceptual Framework and Flowchart of the Analysis

There were eight important steps to select the optimal highway route location for the selected case study area these are:

1. Defining(Selecting) the cost criteria,
2. Standardization of the criteria maps,
3. Weighting Criteria
4. Creating scenarios and determine the relative weights
5. Weighted Overlay of the cost maps(map algebra function),
6. Using the Least Cost Path Algorithm generating alternative routes
7. Comparing scenario routes
8. Selecting the best one

The details of the conceptual framework and each processing step are discussed below and the conceptual work follow of the study shown in Figures 6

3.5.2.1 Step 1: Selecting factors

Cost distance analysis relies on a cost surface which is a raster dataset. The value of each cell represents the cost per unit distance of crossing that cell which does not include the physical distance travelled as a measurement. According to the study area characteristics the factors were selected in the contribution of expertise and literature review as slope, soil, drainage, land cover/use class, and geology type that is passing through with least damage to the area or passing with least monetary value (ESRI, 1996).

For each of the identified factors (benefits or costs) according to their source format all the vectors data were converted to raster Cost factors for this study were identified and classified into two themes, Engineering cost theme, and environmental and social values cost theme(Ferit Yakar and Fazil Celik, 2014)

Engineering Group: **G**eology, **F**ault Lines, **S**oil type, **D**rainage order, **S**lope **R**ivers, **E**levation

Environmental and social Group: **L**and use, **F**orest Area, **S**parsе vegetation, **O**pen land, **A**griculture Area, **S**ettlement and **R**ivers

3.5.2.2. Step 2: Standardization of factors map

Scores from the various map attributes can only be compared if the measurement units are the same. Through the standardization procedure the measurement units are made uniform, and the scores lose their dimension along with their measurement unit (Janssen and Herwijnen, 1994).

Standardization of the attributes was performed for each of the cost maps in ESRI Spatial Analyst reclassification module. Linear transformation was used to transform the criteria attributes into a cost scale that ranges from 1 to 9 where the value 1 is the least cost and 9 is the highest cost (Salem Jamal Uddeen, 2014).

3.5.2.3. Step 3: weighting of factors

A weight is a value assigned to an evaluation criterion that indicates its importance relative to the other criteria under consideration. From the perspective of GIS-MCDA there have been a number of methods suggested for assessing criterion weights (Hobbs and Meier 2000).

The methods can be classified as ranking, rating, pair wise comparison, and entropy approaches. They are based on the assumption of spatial homogeneity of preferences. Consequently they assign a single weight to each criterion. A vast majority of the GIS-MCDA applications have used one of the three global weighting methods: ranking, rating, and pair wise comparison (Malczewski 2006).

In this study the relative importance of the decision elements or factors weight is determined based on analytical hierarchical method developed by Saaty (1980) on a scale of 1 to 9 by to give relative rating of two criteria. The scale of differential scoring presumes that the row criterion is of equal or greater importance than the column criterion. The reciprocal values ($1/3$, $1/5$, $1/7$, or $1/9$) have been used where the row criterion is less important than the column criterion.

3.5.2.4. Step 4: Weighted Overlay of the cost maps

Using the Weighted Overlay function, the cost maps within each scenarios (engineering and environment) were combined to give a combined cost (friction) surface. Two combined cost friction surfaces have been produced by engineering decision makers scenarios and by environmental decision makers scenarios

3.5.2.5. Step 5: Using the Least Cost Path Algorithm

The combined cost (friction) surfaces were then used in a Least Cost Path Algorithm using ESRI Spatial Analyst. Since the case study area has two intermediate towns Anbesama and Arbgebeya between the starting (Humusit) and ending point (Estaie)

The route starts from origin (Hamusite) and ends at the first intermediate town1 (Anbesama) and again the route started from town1 (Anbesama) and ends at intermediate town2 (Arbgebeya)

Lastly it starts from town2 (Arbgebeya) and arrived to the destination point (Estia) since there are two scenario surface costs the process is repeated two times. And finally two alternative road alignments were created.

3.5.2.6. Step 6: Comparing alternative alignments

The comparison and ranking of the alternative alignments were conducted by means of a set of additional criteria. Criteria included in the evaluation step were from those previously employed to generate the cost surface map and some other additional criteria were used. To rank the alternative routes using Arc GIS special analysis tool an impact buffer analysis within 30 meter radii from center of the route both sides have been created and the social and environmental impacts were quantified from the center line of the alignment and also the engineering impact up on the routes determined.

The following are comparison criteria selected

- ❖ Number of the faults crossing the highway route.
- ❖ Number of each stream Order crossings.
- ❖ Length of the routes
- ❖ Topographic(slope) coverage
- ❖ Route affect the forest
- ❖ Areas of settlement affected by the routes
- ❖ Area of Agricultural land affected by the route
- ❖ Number of kebele crossed by the route
- ❖ Number of population served

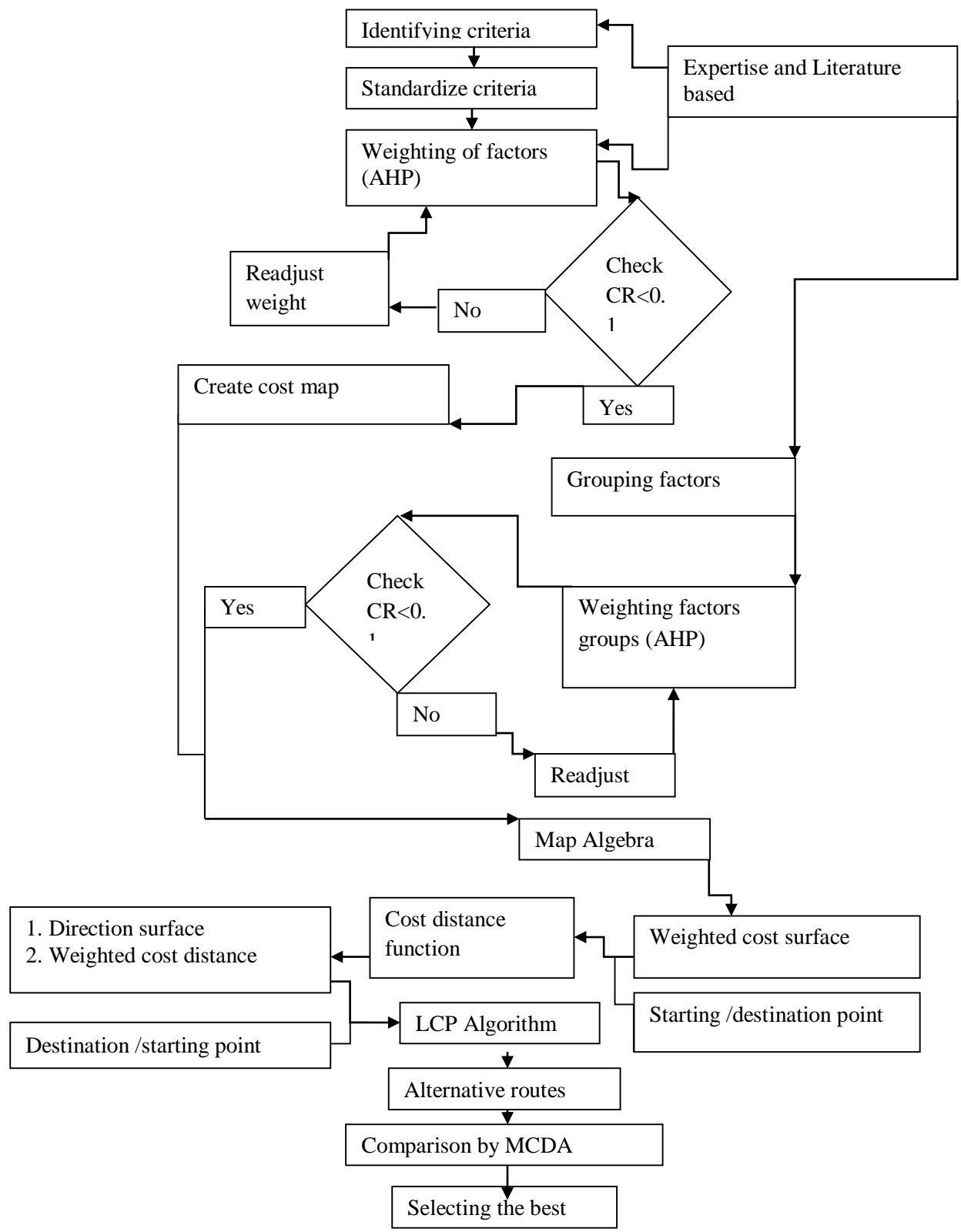


Figure 6: Schematic work flow of the study

3.6 Data analysis and processing

This part discusses the description of factors and their classification for the selection of optimal highway route alignment. The selection of optimal highway route alignment is influenced by the various characteristics of the site. The set of factors for selection of optimal highway route have been identified. Are geographic in nature so that they reference a particular location.

The following are the cost factors identified for the selected case study area

Table 5: Identified cost factors

Engineering Group	Environmental and social Group
Geology	Land use:
Fault Lines	Forest Area
Soil type	Sparse vegetation
Drainage density	Agriculture Area
Topography:	Settlement
❖ Slope	Open land
❖ Elevation	Rivers

3.6.1 Preparing factors maps

For the study the factors identified were obtained from different sources in different file.

In order to perform the objective analysis factors have been converted to the same file format in this study to raster format and the same projection and the data sets are described and prepared as follows.

3.6.1.1 Digital Elevation Model (DEM) factor map

Elevation data is commonly starting point of road, railway and pipe line design. Because elevation data is essential since the suitability of the terrain can be substantially determined by the elevation data and slope layer generated by elevation data. In addition to route selection, the profile of the terrain can be generated from the elevation data. For representing terrain surfaces digital elevation model has been frequently used digital elevation models generally produced by using remote sensing techniques such as LIDAR, photogrammetric, satellites etc. It consists of continuous raster cells or triangulated irregular networks (TIN) created by elevation data. Here the raster based DEM Figure. 4 was used for highway alignment selection analyses for generation of slope layer and slope classification. The DEM has been downloaded from USGS web site with 30m m resolution in WGS84 and projected to Adindan_UTM_Zone_37N

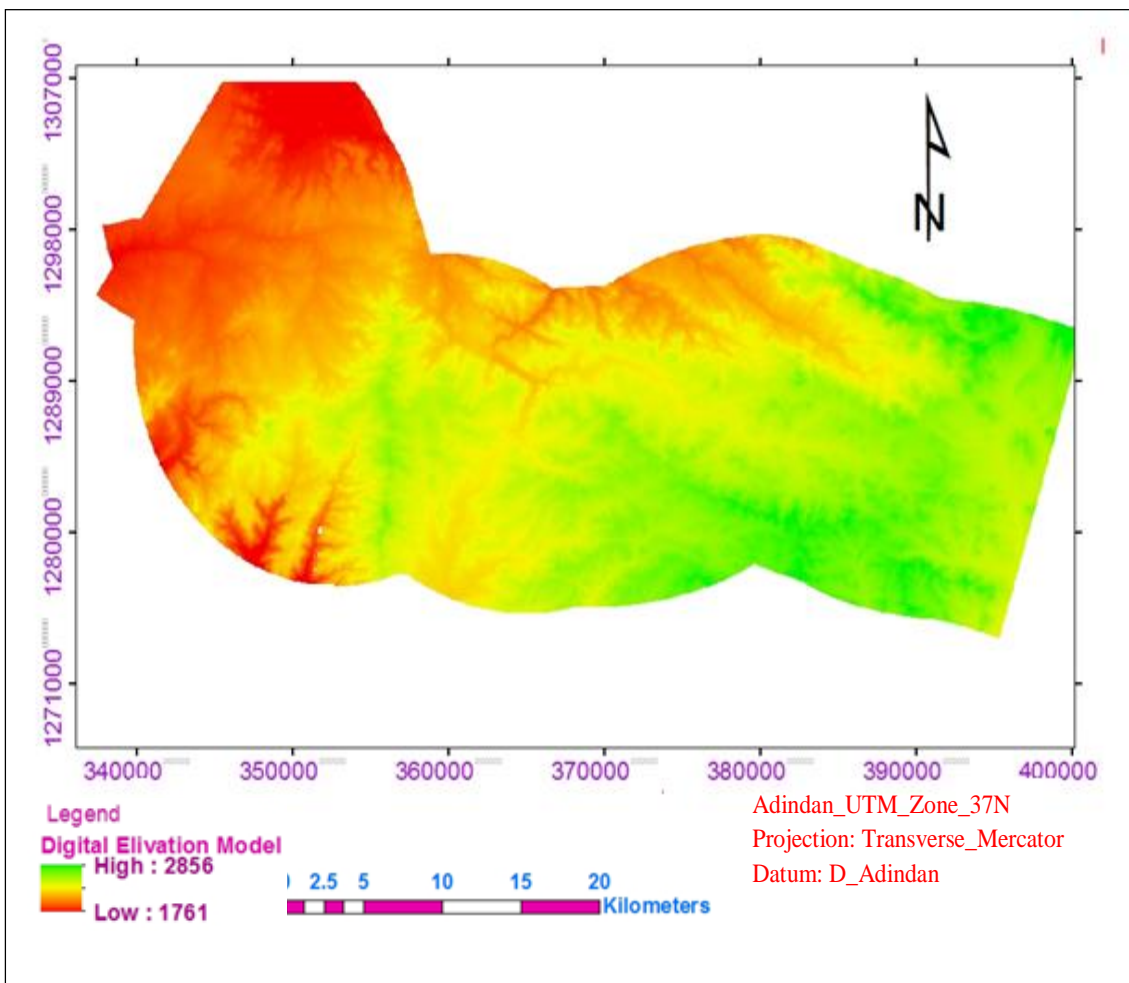


Figure 7: Digital elevation model of the study area (USGS)

3.6.1.2. Creating contour factor map.

Usually contour maps are prepared for the study area which is very useful to examine the topography. The contour map is very useful in selecting the rough corridor of the highway because the user can see the topography of the study area as it is in reality. On the other hand, it is very important from economic point of view to estimate the earthwork cut and fill volumes and to reduce the operational cost of the proposed highway by reducing the grades of proposed highway alignment. The topography and natural contour of the terrain have a critical impact on the suitability and desirability of any proposed road alignment. They affect volumes of cut and fill and vertical slopes among other evaluation criteria. For the work described in this thesis contour intervals of 25m were used

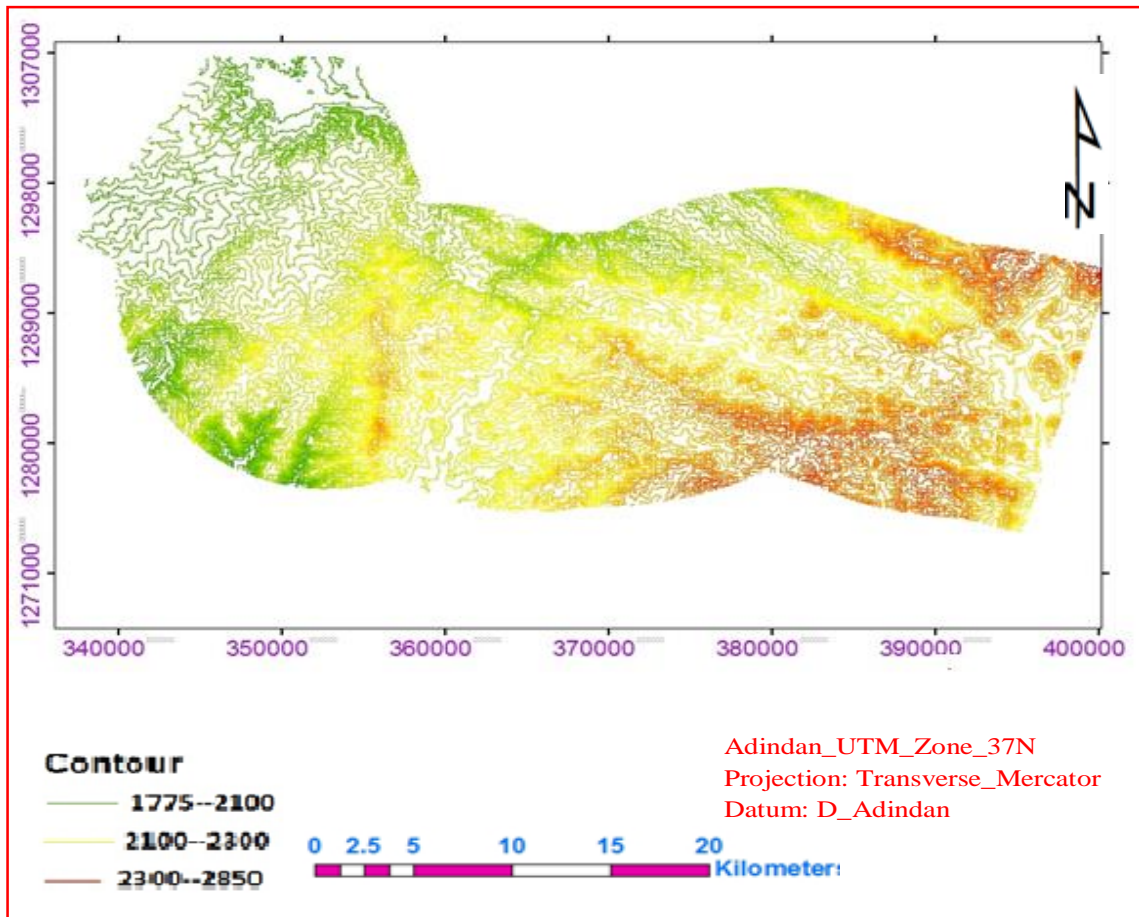


Figure 8: Elevation class map

3.6.1.3 Creating a slope factor map

From the DEM a slope raster can be created using the Slope function in the Spatial Analyst extension. The slope function calculates the maximum rate of change between each cell and its neighbors. The lower the slope value the flatter the terrain and the higher the slope value, the steeper the terrain. The slope was calculated in degree as:

0--2

2--14

14--37

and >37 degree based on Ethiopian route selection manual (ERA, 20013) Figure 9

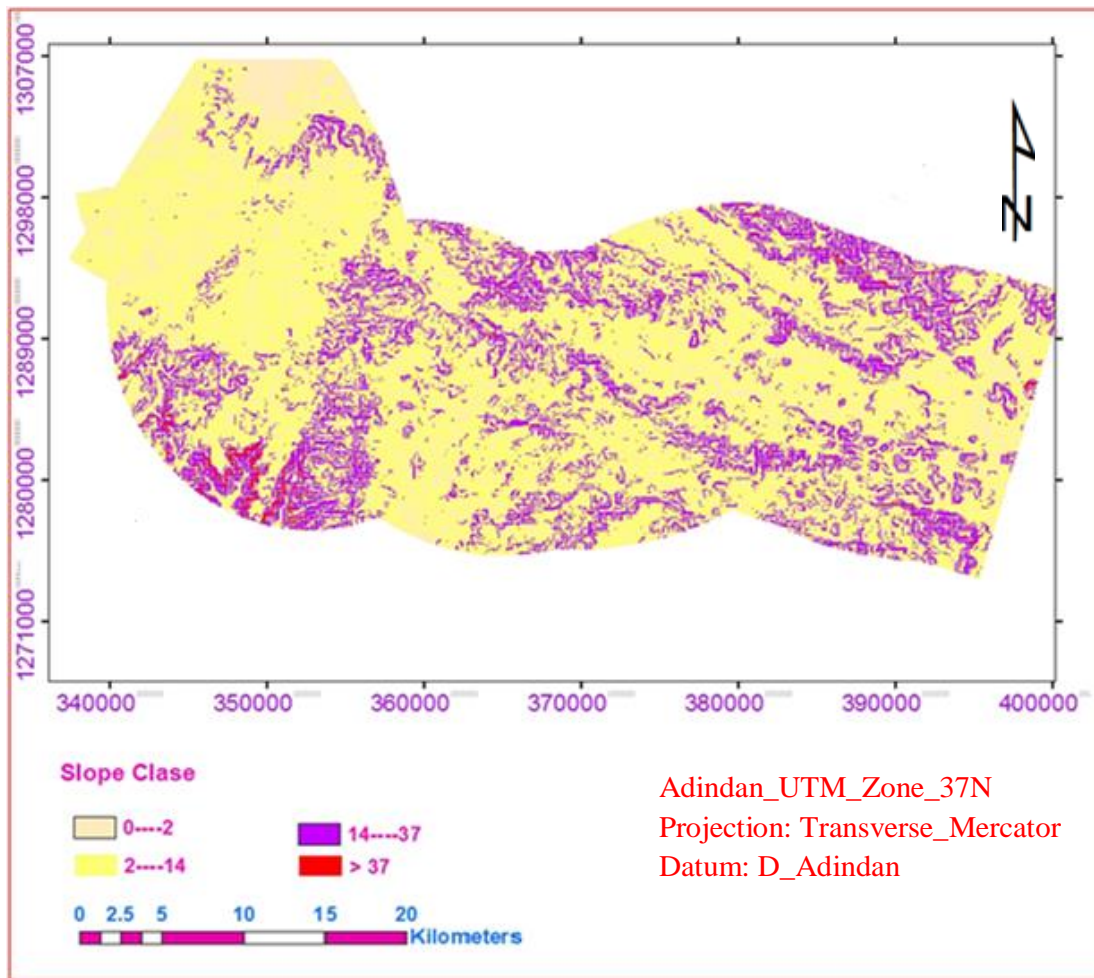


Figure 9: slope class map

3.6.1.4. Land use/land cover factor map

Environmental data: is necessary to specify the impacts of the suggested highway on the surrounding environment where the highway will be laid down. This data is to be divided into several classes and each class of them is to be represented as cost or benefit layer.

Agriculture Lands: Constructing new highway will result in the direct and indirect loss of agricultural lands...

Natural Reserves: Biodiversity areas and Forests: Data about these lands is very important due to their environmental role and due to its recreational role as well.

Water Resources: It is very important to collect data about water resources either ground or surface resources. These resources should be avoided by any highway project as much as possible because any serious source of pollution in the road will affect the water resources in the project area. Polluting these resources will on one hand and destroy a main domestic water resource. On the other hand it will destroy a major agricultural supply of water in the region. Therefore the highway should be laid down without causing any significant harm to the exits water resources. And will increase the cost of the road construction since it requires culverts and bridges construction.

Built-up Areas: To avoid demolishing of built up areas. Also constructing a new highway could cause residential and commercial relocations and significantly disrupts the people activities. Remote sensing data are particularly useful in mapping land use land cover. The land use of the study area was classified using "LANDSAT_8" DATE_ACQUIRED = 2015-03-01 with "GEOTIFF" format and having WRS_PATH = 169, WRS_ROW = 52

Layer stacking was done using ERDASE IMAGINE 2013 band1 to band 7 excluding band 6 which is spatially used for thermal. The image was geo-referenced to a Projection: Universal Transverse Mercator, Grid: UTM 37 N, Datum: Adindan. The study area was subsetting from the full scene. Then the subsetting image was undertaken supervised classification with the aid of 22 different ground control points collected during field survey (Appendix1). Classified pixels were clustered into the following six more general categories: as built up, agricultural lands, forest lands, sparse vegetation, and bare lands/open land and water surface. (Anderson et al., 1976)

Then each of the land use/cover types was reclassified into 6 classes based on their importance to determine the cost for each cell of land use type. These are built-up area, Rivers, open areas, forest, sparse vegetation and agricultural areas. According to Ethiopian road Authority route selection manual (ERA 2013) open areas and agricultural lands are more preferable for the location of the alignment but built up area, forest lands and rivers are the most unsuitable. This is mainly due to the low and high cost of acquisitions respectively and social and environmental disruption as general. The result of the reclassified land use/cover map is shown in Figure 10.

Accuracy Assessment

The accuracy assessment technique was made through a confusion or error matrix. A confusion matrix contains information about actual and predicted classifications done by a classification system.

The result of an accuracy assessment typically provides the users with an overall accuracy of the map and the accuracy for each class in the map. The percentage of overall accuracy was calculated using following formula ((Anderson et al., 1976).

$$accuracy = \frac{total\ number\ of\ correct\ sample}{total\ number\ of\ sample} \times 100 \dots\dots\dots 4$$

Table 6: Land cover classification error matrix

Classified data	Water	Built up	Dense vegetation	Agriculture	Sparse vegetation	Open area	Row total
Water	622	20	1	76	3	83	805
Built up	0	4911	0	253	186	114	5464
Dense vegetation	0	4	1226	0	30	0	1260
Agriculture	15	247	0	7051	13	26	7352
Sparse vegetation	5	349	35	25	1294	191	1899
Open area	9	240	0	18	273	3260	3800

Column total	651	5771	1262	7423	1799	3674	20580
Over all accuracy=	622+4911+1226+7051+1294+191=					183645	
	$183645/20580*100=89.23$						
	The sum of rows should equal to the sum of column total=2058						
	Over all accuracy =the sum of diagonal value divided by the sum of row total						
	Multiplied by 100 and the result was 89.23 it indicates that						
	The classification was accurate						

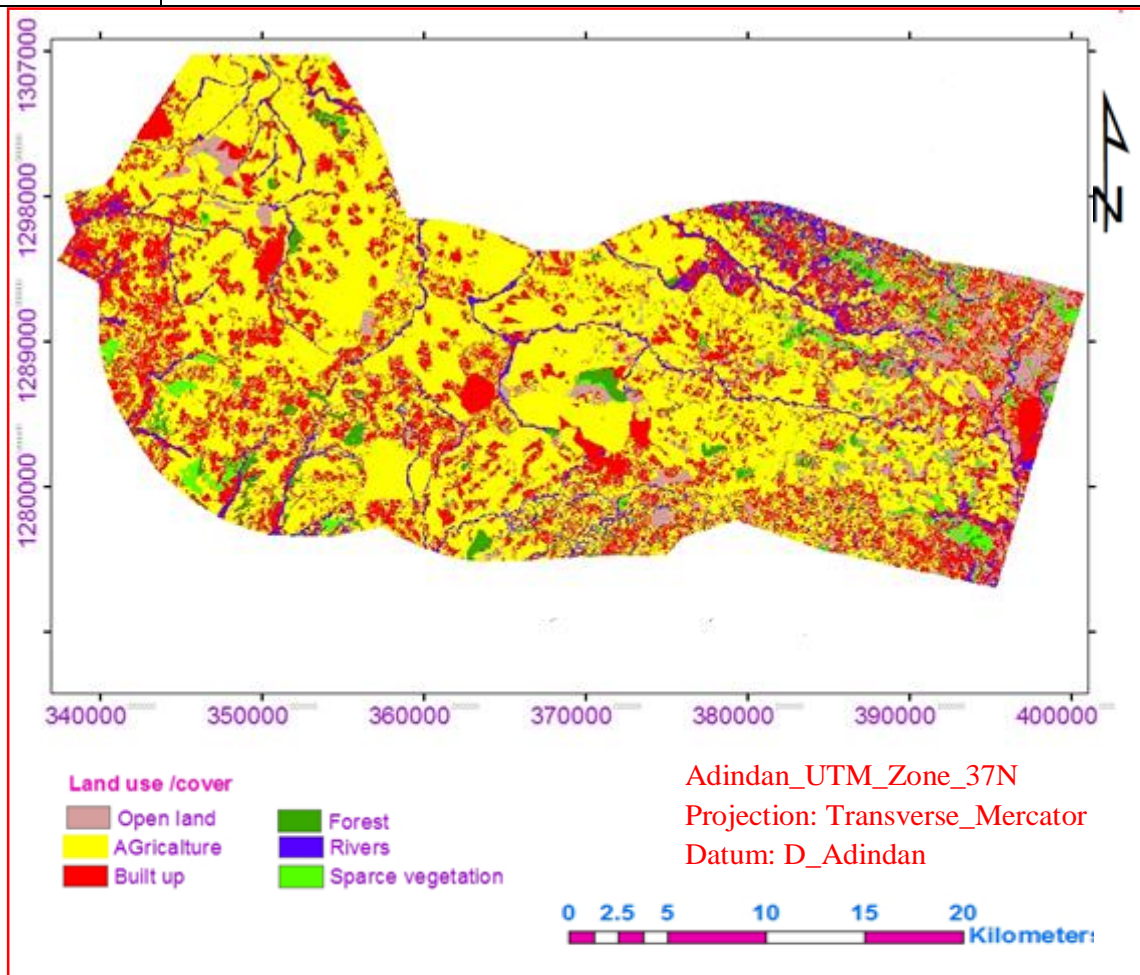


Figure 10: land use/cover factor map

Table 7: Land use factors suitability level (ERA, 2013)

Land use type	Rank	Level of Suitability
Open land	1	Highly Suitable
Agriculture	2	suitable
Sparse vegetation	3	Moderately Suitable
Forest	4	Unsuitable
Rivers	5	Highly Unsuitable
Built up	6	Extremely Unsuitable

3.6.1.5 Drainage density factor map:

The drainage density map has been used here to consider the cost of a possible bridge and culvert construction. Generally the width of the river channel increases with increasing order of drainage density which results in a corresponding increase in the cost of bridge construction. The drainage density map has been classified in to five class. The first and second drainages density classes have been assigned very low ratings as these are generally quite narrow and in most cases the water may be drained using underground pipes or by providing small culverts. For higher-order drainages there may be requirements for bridge construction the construction cost increases with the width of the channel. Therefore higher ratings have been assigned to higher drainage density (Strahler, 1964)

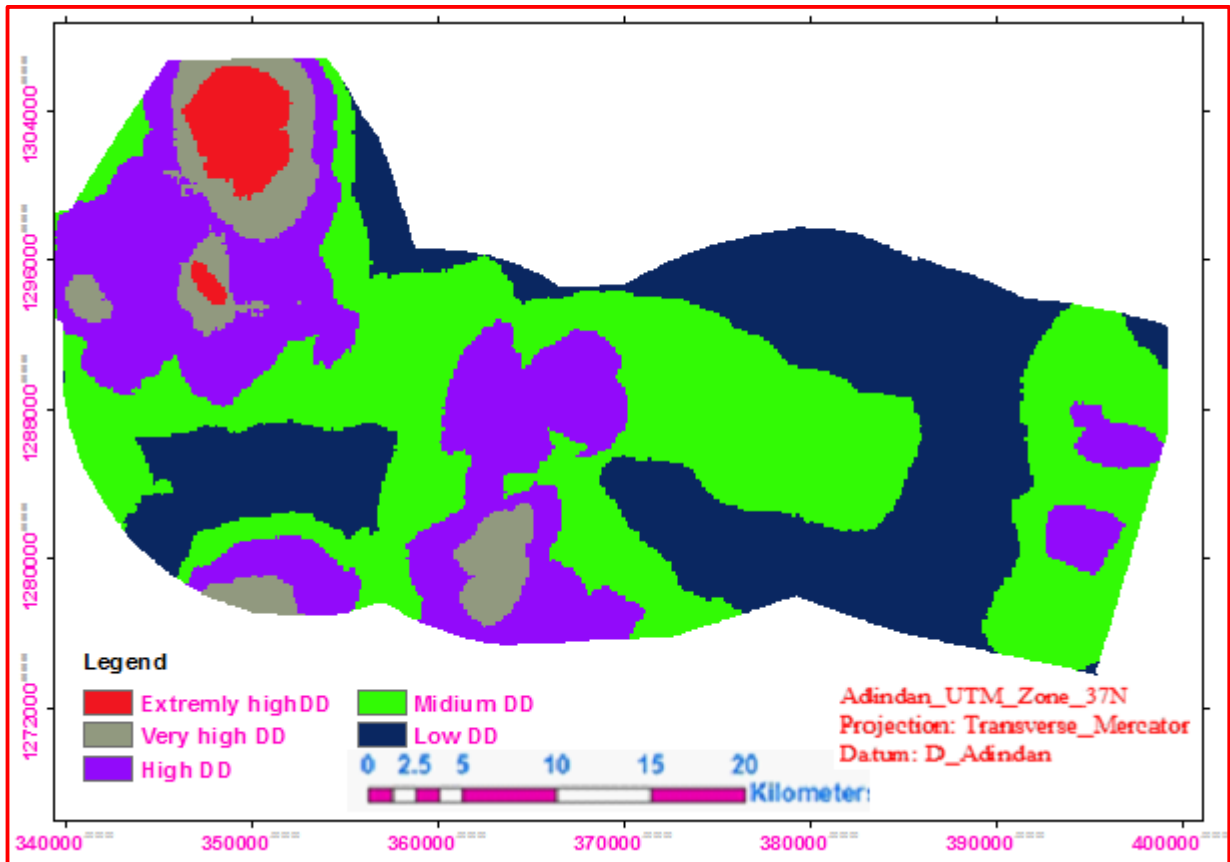


Figure 11: Drainage density criteria map.

Table 8: Drainage density suitability level adopted from (Raviraj Sadasivuni, 2009)

Drainage order type	Rank	Level of Suitability
1	1	Suitable
2	2	Moderate suitable
3	3	Slightly suitable
4	4	Unsuitable
5	5	Highly Unsuitable

3.6.1.6. Geological factor map

This coverage is needed in order to provide guidance as to the materials that are to be excavated or filled over. This is an important aspect of the evaluation of road alignments that has important cost implications. The traditional practice is to address this aspect of the design only after a preliminary alignment is selected. The attributes necessary for this coverage are the name and

the geological reference of the various polygons along with an engineering evaluation as to their ease/difficulty of excavation and ability to support embankments (fill). For this study the geology map prepared by Ethiopian geological survey at scale of 1:250,000 was used. Since it contains both polygon features (the geology boundaries) and line features (the fault lines) this map was digitized using ARC GIS 10 software and the following are the geological types digitized from the map.

1. *Trachyte*: It is a type of fine grained volcanic rock characterized by the presence of alkaline feldspar minerals.

It is an igneous volcanic rock with an aphanitic to porphyritic texture. Trachyte is an important very good and stable dimension stone which has been used as intersection material in historical buildings. Famous historical buildings where have been used mainly as intersection material (Stephanie et al., 2008).

2. *Sedimentary*: Sedimentary rocks are those that have formed when eroded particles of other rocks have been deposited (on the ocean floor, stream/lake beds etc) and compacted or by the precipitation of minerals. They are derived from pre existing source rocks. They are composed by sediments. This is material that has been weathered transported and deposited by processes such as running water (rivers) wind glaciation (glaciers) etc.<http://www.comparerocks.com/en/sedimentary-rocks/style-4>

3. *Volcanicrocks*: formed of magma erupted and cooled at the Earth's surface volcanic rocks are usually fine grained or aphanitic to glassy in texture. They often contain clast (small piece of rock): a fragment of rock produced by the breaking down of larger rocks). Volcanic rocks are named according to their chemical composition. Basalt is a very common volcanic rock with low silica content. Rhyolite is a volcanic rock with high silica content. Volcanic rocks often have a vesicular texture which is the result voids left by volatiles escaping from the molten lava. Pumice is a rock which is an example of explosive volcanic eruption. It is so vesicular that it floats in water.

<http://www.volcanodiscovery.com/706.html>. (Luis I .G et al., 2007)

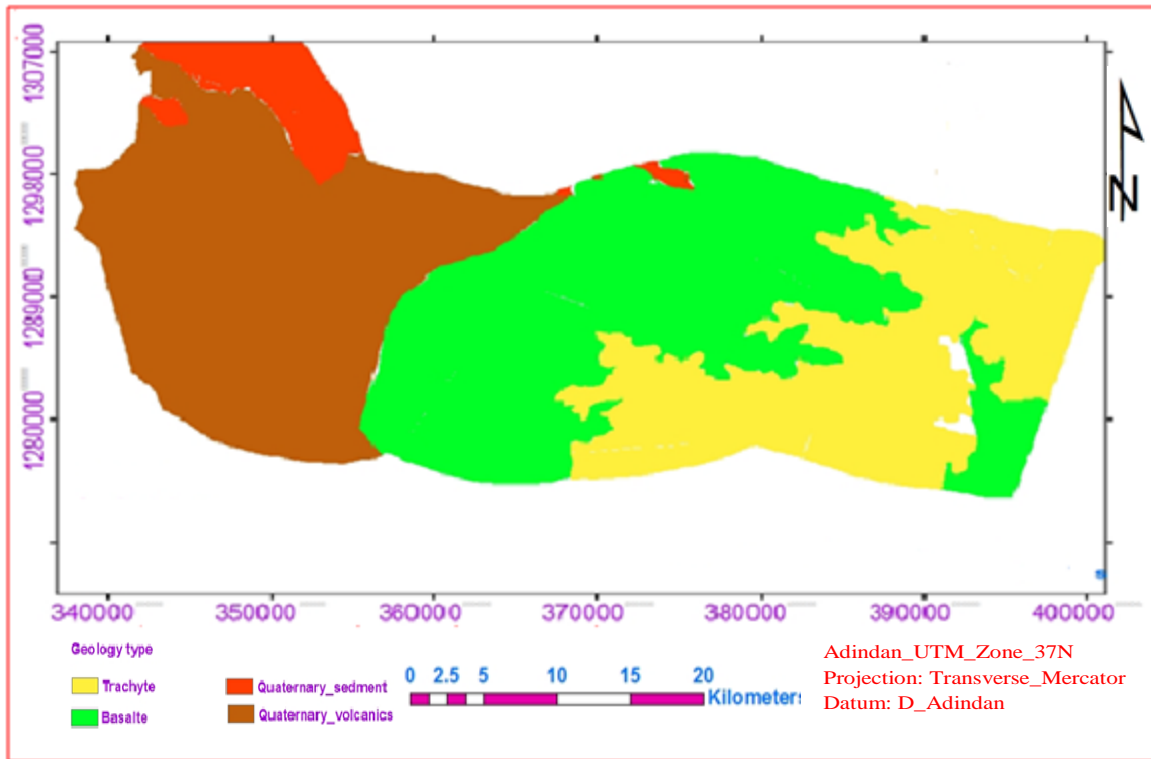


Figure 12: Geology type criteria map

3.6.1.7. Fault line:

Line of rock displacement: a linear feature on the Earth's surface occurring where displaced rock layers have broken through the Earth's surface

In geology fault is a planar fracture or discontinuity in a volume of rock across which there has been significant displacement as a result of rock mass movement.

Energy release associated with rapid movement on active faults is the cause of most earthquakes. Impacts on structures and people in geotechnical engineering a fault often forms a discontinuity that may have a large influence on the mechanical behavior (strength, deformation etc.) of soil and rock mass in for example tunnel foundation or slope construction.

The level of a fault's activity can be critical for locating buildings, pipelines, roads, dams etc.

[https://en.wikipedia.org/wiki/Fault_\(geology\)](https://en.wikipedia.org/wiki/Fault_(geology))

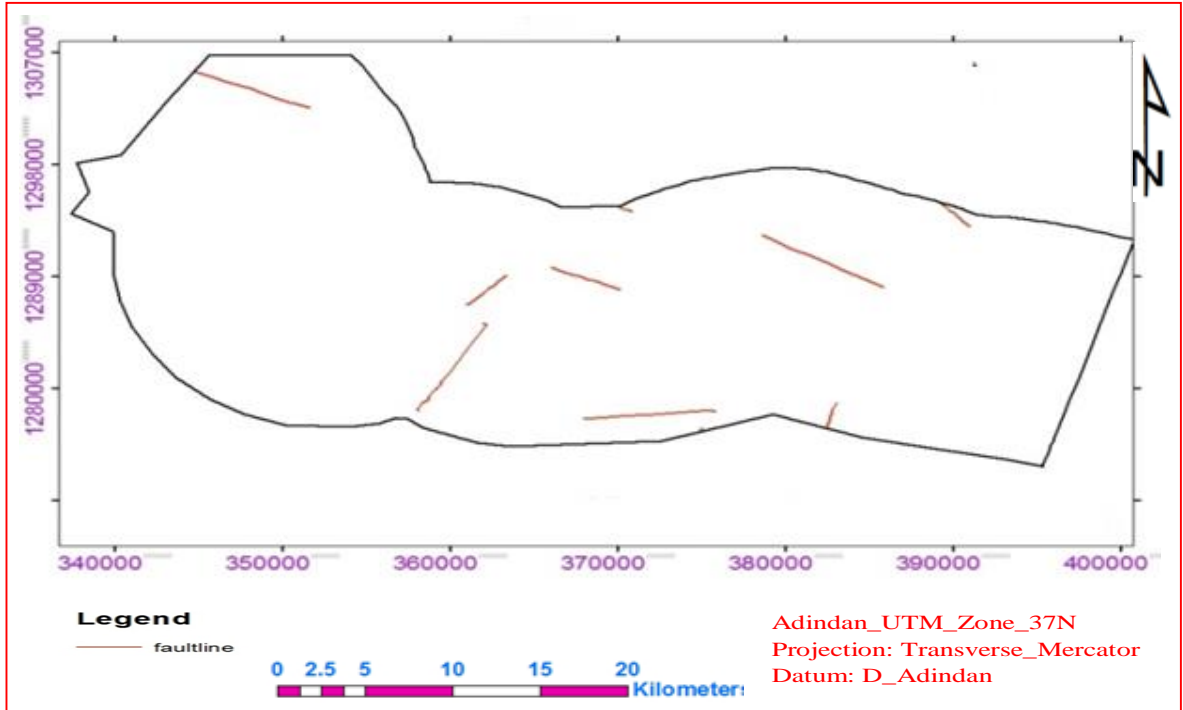


Figure 13: Fault line criteria map

3.6.1.8. Soil type factor map:

Soil type and distribution in Ethiopia during road design and construction soil engineering maps are very essential. These maps show the distribution of soils and describe their origin. The physical characteristics and engineering properties. 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).

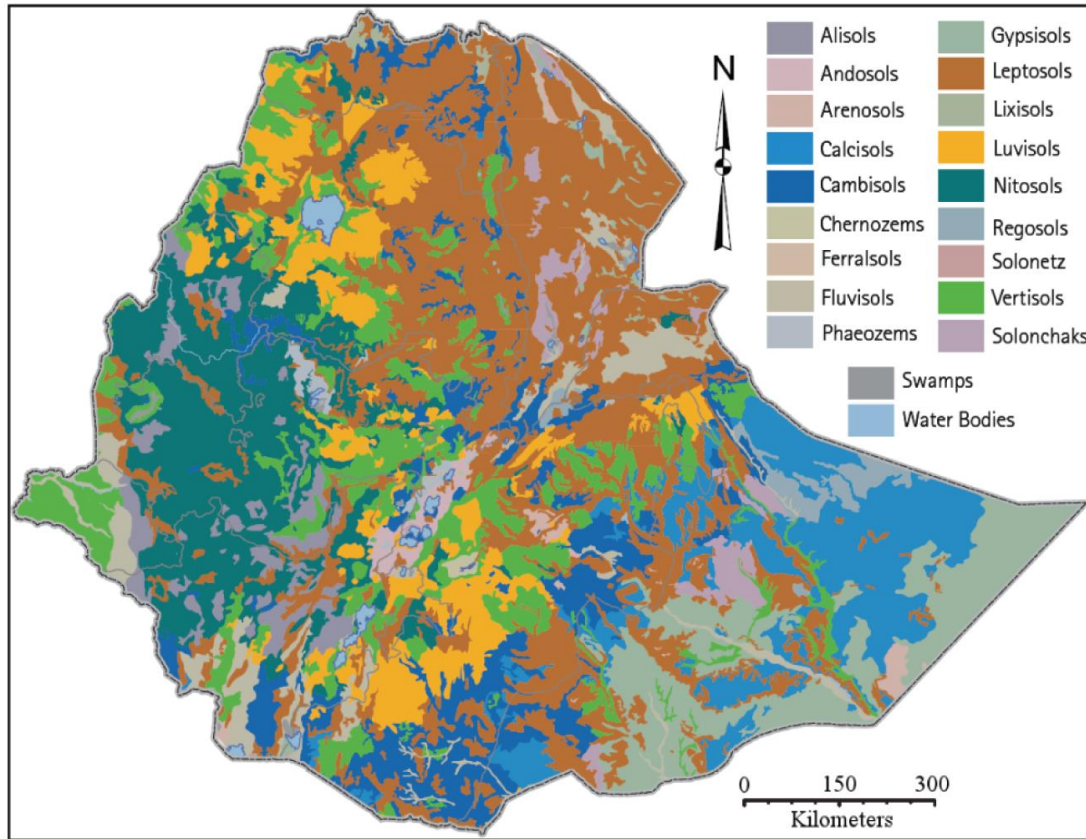


Figure 14 Soil map of Ethiopia (ERA, 2013)

Soil construction suitability has been assessed on the basis of the soil textures the soil dataset was produced in an agricultural classification. As result terminology and classes had to be adjusted to a geotechnical classification. Assignment of suitability classes was done with use of textural properties of soil. The literature review and expert’s consultations gave idea about textural properties of soil the main difficulty was encountered when agricultural and geotechnical soil classifications use different terminology for soils and fractions as well as soil groups. Delimitation in agricultural classification fractions are defined as follows: stones more than 25mm, gravel form 25 to 1 mm, sand from 1 to 0.1 mm, silt from 0.1 to 0.02 mm, and clay less than 0.02 mm (Gruszczyński 2005).

The geotechnical soil classification defines gravel as mineral grains of 40 -2 mm diameter sand of 2 to 0.05 mm silt of 0.05 to 0.002 mm, and clay less than 0.002 mm in grain size. The main difference is within sand and clay fractions.

This should be taken into account in the translation of agricultural names into geotechnical names.

Secondly every geotechnical soil type can be assigned approximate technical characteristics used in engineering. It is assumed that low support capacity requires more construction expenses for example in terms of pavement thickness. Generally mineral soils can be used as road sub grades, whereas organic grounds like peat and other highly organic soils should be replaced (Kraszewski 2005).

Generally the site contains the following soil type.

1. *Vertisols*: Dark montmorillonite rich clays with characteristic shrinking/swelling properties. Vertisols develop with in depressions in level to undulating landscapes mainly in tropical semi-arid to sub humid with an alternation of distinct wet and dry seasons. Sediments that contain a high proportion of smectitic. Deep wide cracks form when the soil dries out and swelling in the wet season and creates polished and grooved ped surfaces. Dry Vertisols can be very hard, while wet Vertisols are very plastic and sticky. Vertisols of the world are also known as black cotton soil (USA, 2008).
2. *Luvisols*: soils with high base saturation (>50%) and a pedogene increase of clay amount in the subsoil (Arenosols excluded Soils with a pedogenetic clay differentiation (especially clay migration) between a topsoil with a lower and a subsoil with a higher clay content high activity clays and a high base saturation at some depth.
3. *Luvisols*: show marked textural differences within the profile. The surface horizon is depleted in clay while the subsurface argic horizon has accumulated clay. Most Luvisols have favorable physical properties these are porous and well aerated. Soils with subsurface accumulation of high activity clays and high base saturation
4. *Nitisols*: are deep well-drained, red, tropical soils with a clayey nitic subsurface horizon boundaries and subsurface horizon with more than 30 percent clay. Red or reddish brown clayey soils with a nitic subsurface horizon of high aggregate stability. Nitisols have little water dispersible clay and a base saturation of less than 50 per cent. They are found on almost flat to sloping terrain in high rainfall areas. Their moisture storage capacity is high
5. *Leptosols*: Soils 20 cm deep or very stony unconsolidated material. This unit refers excessively drained, very shallow (0-10cm) stony and gravelly soils that occur mainly on steep ridge side slopes, and brown *in* color. The texture is sandy loam with moderate medium sub angular blocky structure. They are soft when dry, friable when moist and slightly sticky and non plastic when wet.

6. *Regool*: This mapping unit refers stone what excessively drained, very shallow to shallow (0-50 cm) gravelly and stony and dark brown soils that occur on strongly sloping to extremely steep physiographic units. The texture class is sandy clay loam with weak moderate sub angular structure. They are soft when dry friable when moist and slight sticky and non plastic when wet (gebeyehu belay January, 2004).
7. *Gleysols*: are wetland soils that unless drained they are saturated with groundwater for long enough periods to develop a characteristic gleyic colour pattern. This pattern is essentially made up of reddish brownish or yellowish colors at ped surfaces and/or in the upper soil layer or layers in combination with grayish/bluish colors inside the peds and/or deeper in the soil Conditioned by excessive wetness at shallow depth. This type of soil develops gleyic color patterns made up of reddish brownish or yellowish colours on ped surfaces or in the upper soil layers. (EUR, 2008).

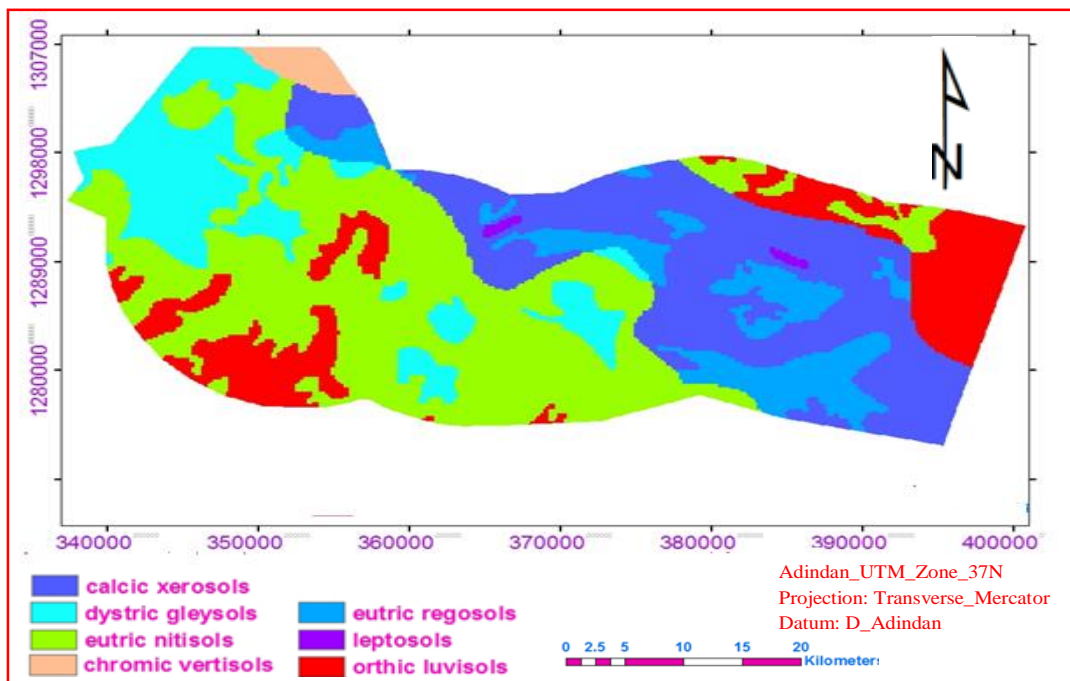


Figure 15: Soil type criteria map

3.6.2. Computing factors' weights

In order to generate the optimal highway route alignment factors hierarchy was developed under the Goal of the Optimizing highway alignment and totally twelve cost factors were selected as input data sets (factors). The selected input datasets were land use, faults, elevation, slope, drainage density, geology and soil. Each of the factor maps were produced from remote sensing image, topographic maps. Before combining the factors together first all the vector data were changed to raster form in order to produce similar data layers that suitable for GIS analysis and secondly standardization of each data set to a common scale of 1 to 9 was done in Arc GIS spatial analyst. Then prior to combining the factors criteria weights were calculated based on Satty's Analytic Hierarchy Process (AHP) (Saaty, 1980).

In this study two stage of factors weights were computed the first stage is factors weight for sub class of factors for instance slope classes' weight and in the second stage relative weights of factors group. These were done by professional decision making factors formed as Environmental and social and engineering factors. The weights for all criteria classes were computed first and then the relative weights of the factors group

Table 9: Sample pair wise matrix for slope criteria class

Normalized matrix=Each Matrix element divided by the sum of the column matrix									
Slope Class in degree	Step1				Step2				
	>37	14-37	2-14	0-2	Class	>37	14-37	2-14	0-2
>37	1	3	7	9	>37	0.63	0.662	0.618	0.500
14-37	0.333	1	3	5	14-37	0.21	0.221	0.265	0.278
2-14	0.143	0.333	1	3	2-14	0.09	0.073	0.088	0.167
0-2	0.111	0.2	0.33	1	0-2	0.07	0.044	0.029	0.056
Sum	1.587	4.533	11.33	18	SUM	1.00	1.000	1.000	1.000
Step3 Sum up Rows and divide by number of matrix to generate weighted matrix									

Slope Class	>37	14-37	2-14	0-2	SUM	Weight
>37	0.630	0.662	0.618	0.500	2.410	0.602
14-37	0.210	0.221	0.265	0.278	0.973	0.243
2-14	0.090	0.073	0.088	0.167	0.418	0.105
0-2	0.070	0.044	0.029	0.056	0.199	0.050

Step4 Determine consistency ratio								
First the Consistency Vector is calculated by the following steps								
Multiply the criteria matrix by weighted matrix								
Dividing the weighted sum vector with criterion weight								
Slope classes	>37	14-37	2-14	0-2	weights	WSV	CV=WSV/weight	
>37	1	3	7	9	0.603	2.52	CV1=	4.174
14-37	0.33	1	3	5	0.243	1.01	CV2=	4.151
2-14	0.14	0.333	1	3	0.105	0.42	CV3=	4.020
0-2	0.11	0.2	0.333	1	0.05	0.20	CV4=	4.010

Average=16.356/4
 Lamda=4.09
 CI= Λ -N/(N-1)
 CI=4.09-4/3 =0.03
 Cr=0.03/0.9= 0.033
 Since Cr (0.033) is < 0.1 the values are consistent

Where, WSV=weighted sum vector and CV=consistency vector

After the factors weight are computed for each of the factors type and within the factors classes the weights have been assigned for the factor's layers using ARC GIS spatial analyst tool and finally the layer were classified by the weighted values assigned and each cell of the factors contains the assigned weight value and the results of the weighted layers were used as cost layer for the next relative weighting steps and the cost layers for each of factors class were prepared as follows

Table 10: Slope classes weight

Slope classes	>37	14-37	2-14	0-2	weights
>37	1	3	7	9	0.603
14-37	0.333	1	3	5	0.243
2-14	0.143	0.333	1	3	0.105
0-2	0.111	0.2	0.333	1	0.05

$\lambda =4.09$
 CI= λ -N/(N-1)
 CI=4.09-4/3 =0.03
 RI=0.9
 Cr=CI/RI=0.03/0.9= 0.033
 Since Cr (0.033) is < 0.1 the values are consistent

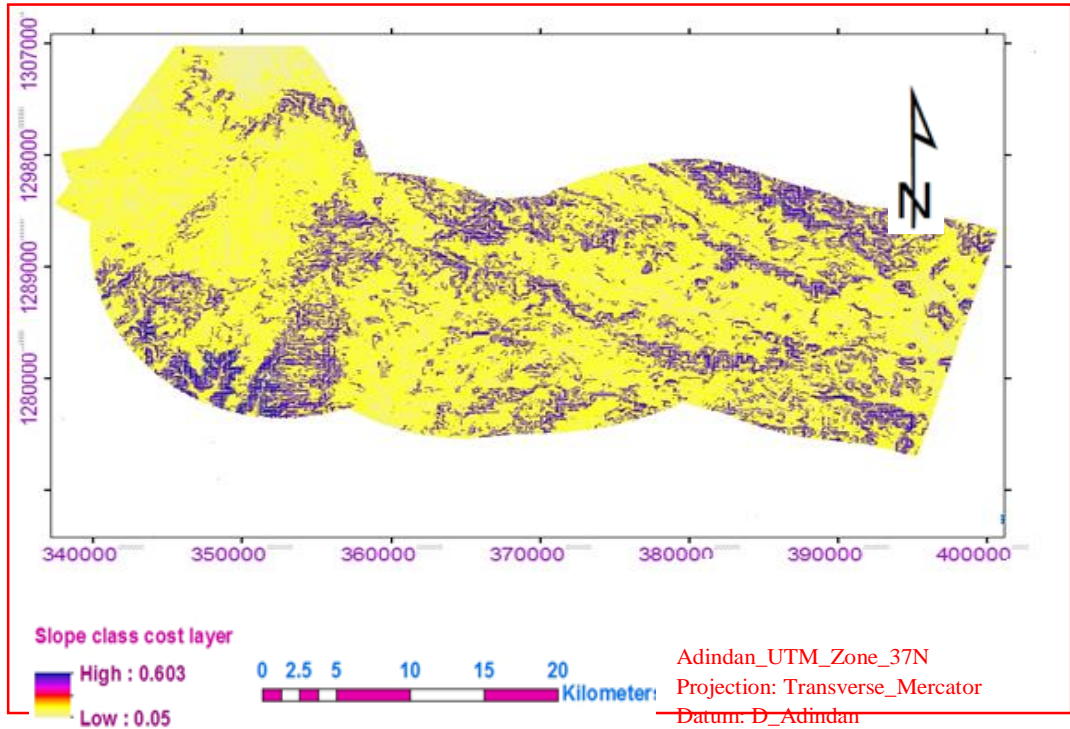
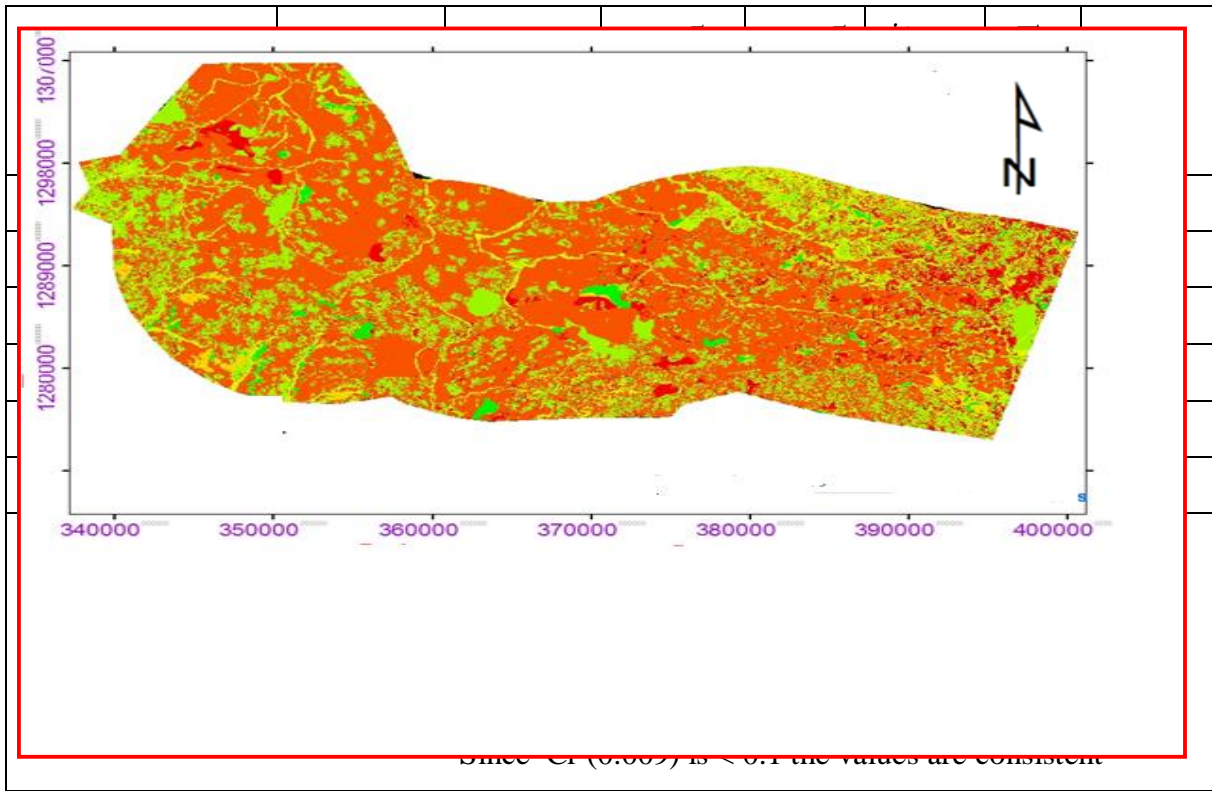


Figure 16 Slope class factor map

Table 11: Land cover weight



Adindan_UTM_Zone_37N
 Projection: Transverse_Mercator
 Datum: D_Adindan



Figure 17: Land cover/use cost map

Table 12: Drainage density class weight

Drain age density class	DD5	DD4	DD3	DD2	DD1	Weight
DD5	1.000	3.000	5.000	7	9	0.478
DD4	0.333	1.000	5.000	7	7	0.300
DD3	0.167	0.200	1.000	3	5	0.121
DD2	0.143	0.250	0.333	1	3	0.068
DD1	0.111	0.111	0.143	0.333	1	0.034

$\lambda=5.373$
 $CI=5.373-5/4 =0.093$
 $RI=1.12$
 $Cr=0.093/1.12= 0.083$
 Since $Cr (0.083)$ is < 0.1 the values are consistent

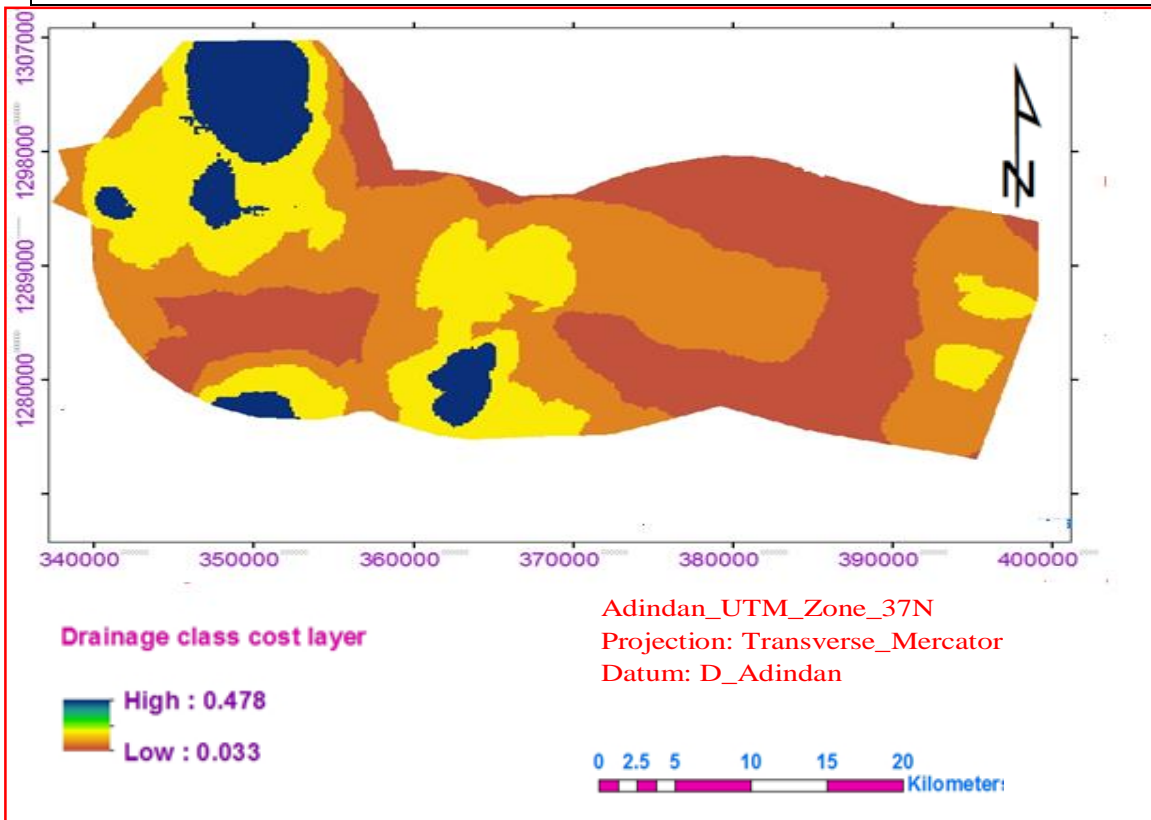


Figure 18: Cost surface for drainage density class

Table 13: Geology type weight

Geology Type	Basalt	Trachyte	Volcanic rock	Weight
Basalt	1	2	3	0.449
Trachyte	0.5	1	2	0.272
Volcanic rock	0.333	0.5	1	0.18
Sedimentary rock	0.333	0.25	0.4	0.099

$\lambda=4.006$
 $CI=4.006-4/3 =0.001$
 $RI=0.9$
 $Cr=0.001/0.9= 0.001$
 Since Cr (0.001) is < 0.1 the values are consistent

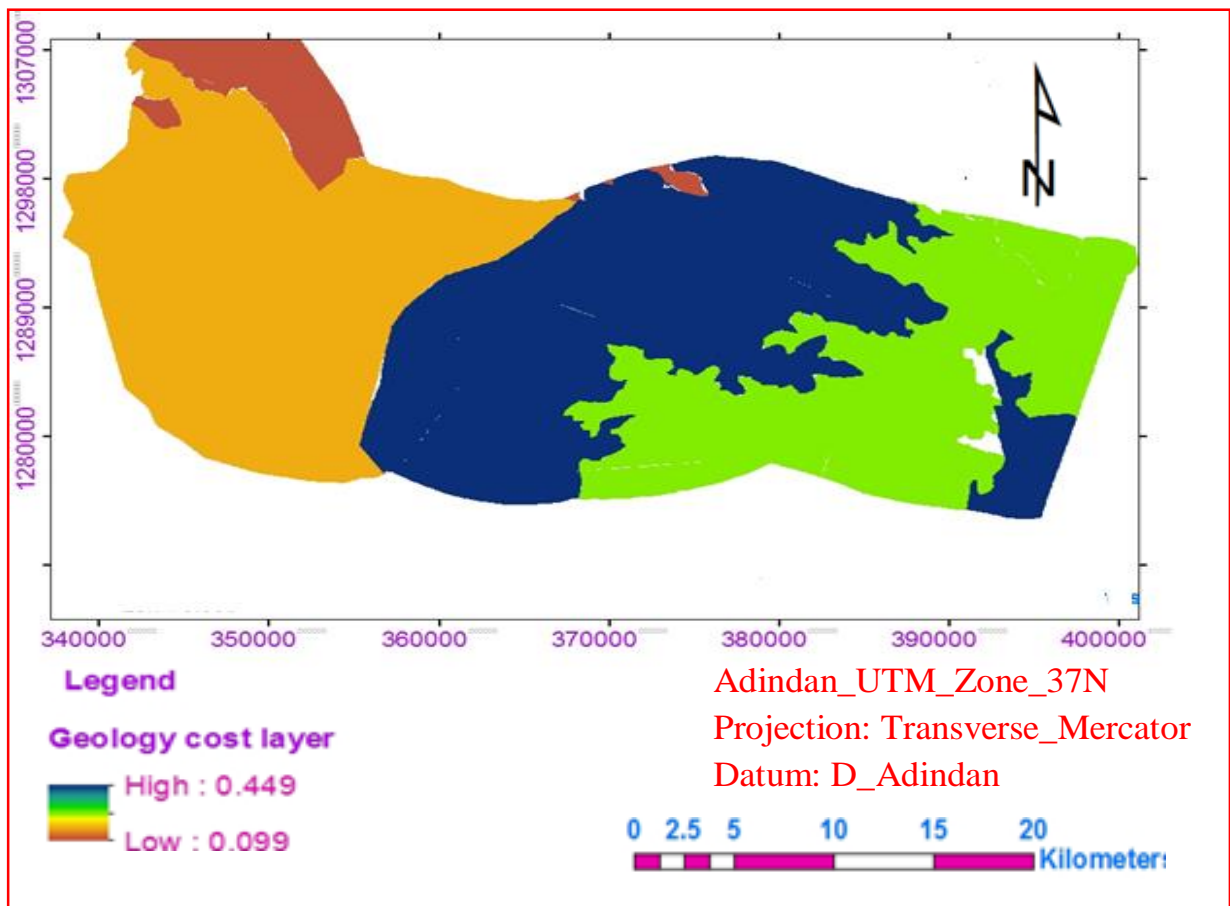


Figure 19: Cost surface for geology type

Table 14: Soil type weight

Soil type	Vertisoil	Gleysoil	Regosoil	Nitiosoil	luvisoil	Leptosoil	Weight
Vertisoil	1.0	2.000	3.000	7	6	9	0.455
Gleysoil	0.5	1.000	2.000	2	4	9	0.216
Regosoil	0.3	0.500	1.000	2	3	5	0.141
Nitiosoil	0.14	0.250	0.500	1	2	5	0.099
luvisoil	0.17	0.250	0.333	0.5	1	2	0.056
Leptosoil	0.11	0.111	0.200	0.2	0.5	1	0.001
$\lambda=6.102$ $CI=6.091-6/5 =$ $RI=1.24$ $Cr=0.02/1.24=0.016$ Since $Cr (0.016)$ is < 0.1 the values are consistent							

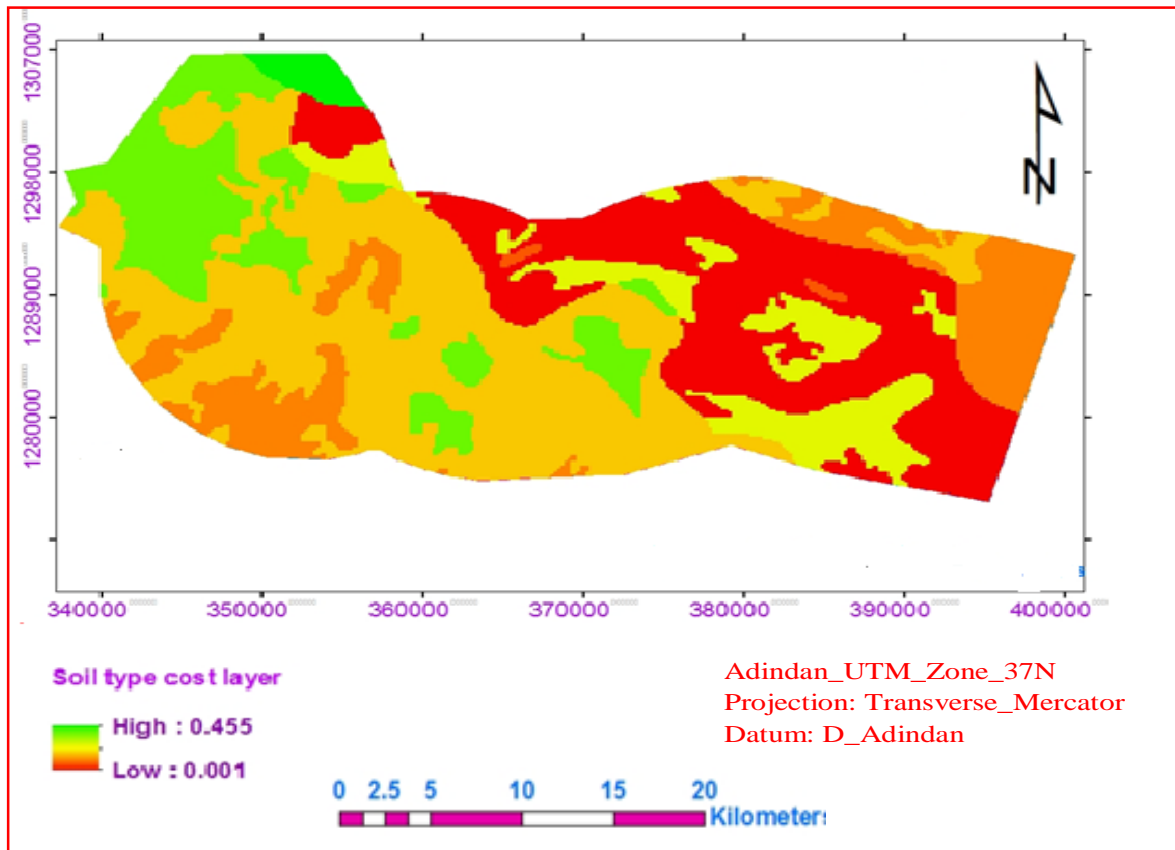


Figure 20: Cost surface for soil type

3.6.3. Creating Least cost path scenarios and calculating the relative weight

After calculation of factors weight and preparation of factors cost map two decision making scenarios were created as engineering decision making and social and environmental decision making scenarios (David .M et al., 2005).

Relative Weights for engineering decision making factors and Social and environmental decision making factors were computed according to factors level of importance table

Table 15: Relative weight of criteria by engineering scenario group

Criteria type	Drainage	Land use	Slope	Geology	Soil	Weight
Drainage	1	2	2	2	2	0.306
Land use	0.5	1	2	2	2	0.229
Slope	0.5	0.5	1	4	3	0.232
Geology	0.333	0.5	0.2	1	3	0.140
Soil	0.333	0.5	0.3	0.5	1	0.093
$\Lambda=5.0392$ $CI=5.373-5/4 =0.0392$ $RI=1.12$ $Cr=0.039/1.12= 0.035$ Since Cr (0.035) is < 0.1 the values are consistent						

Table 16: Relative weight of criteria by social and environmental scenario group

Criteria type	Land use	Drainage	Geology	Soil	Slope	weight
Land use	1.0	3	3	3	5	0.416
Drainage	0.333	1.	2	2	4	0.216
Geology	0.333	0.5	1	3	3	0.178
Soil	0.333	0.5	0.2	1	5	0.137
Slope	0.200	0.25	0.33	0.2	1	0.053
$RI=1.12$ $\lambda=5.362$ $CI=5.362-5/4 =0.09$ $Cr=0.090/1.12= 0.08$ Since Cr (0.08) is < 0.1 the values are consistent						

In this study two different Weighted Cost Surfaces were obtained by using the relative weights of the criteria computed by the decision making factors (scenarios) as Social and Environmental decision making and Engineering decision making cost surface.

Weighted Cost Surface were computed using Arc GIS spatial analyst tool by each factor cost map multiply the relative weights obtained from the engineering and social and environmental decision makers scenarios as follows:

1. Engineering scenario cost= [(slope cost layer *Eng SW of slope)+
(Soil cost layer*Eng SW of soil)+
(Geology cost layer*Eng SW of geology)+
(Land use cost layer*Eng WS weight of LULC)+
(drainage cost layer*Eng WS weight of drainage)]

Where Eng SW= Engineering scenario weight of factors

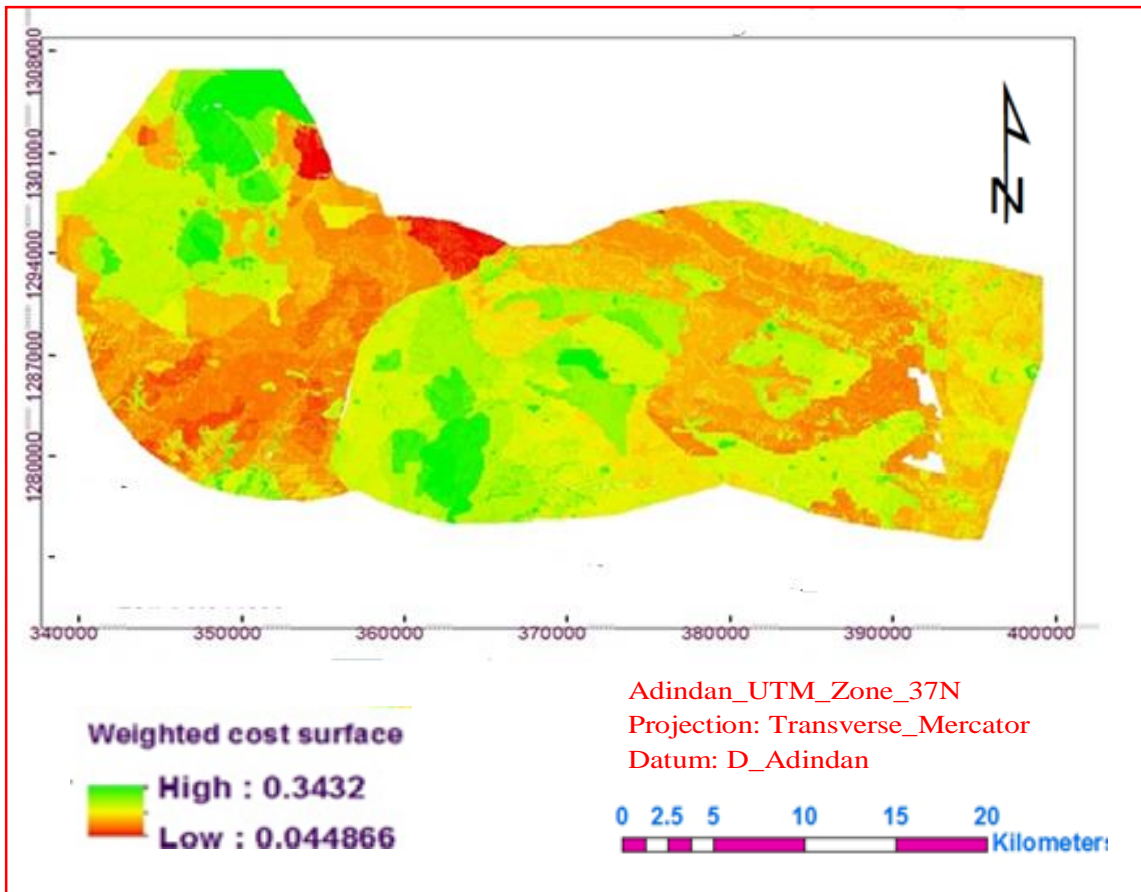


Figure 21: Weighted cost surface for engineering decision maker scenario groups

2. Social and Environmental Scenario cost=

$$\begin{aligned} &[(\text{slope cost layer} * \text{SAEnt SW of slope})+ \\ &(\text{Soil cost layer} * \text{SAEnt SW of soil})+ \\ &(\text{Geology cost layer} * \text{SAEnt SW of geology})+ \\ &(\text{Land use cost layer} * \text{SAEnt WS weight of LULC})+ \\ &(\text{drainage cost layer} * \text{SAEnt WS weight of drainage})] \end{aligned}$$

SAEnt= Social and Environmental Scenario weights of factors

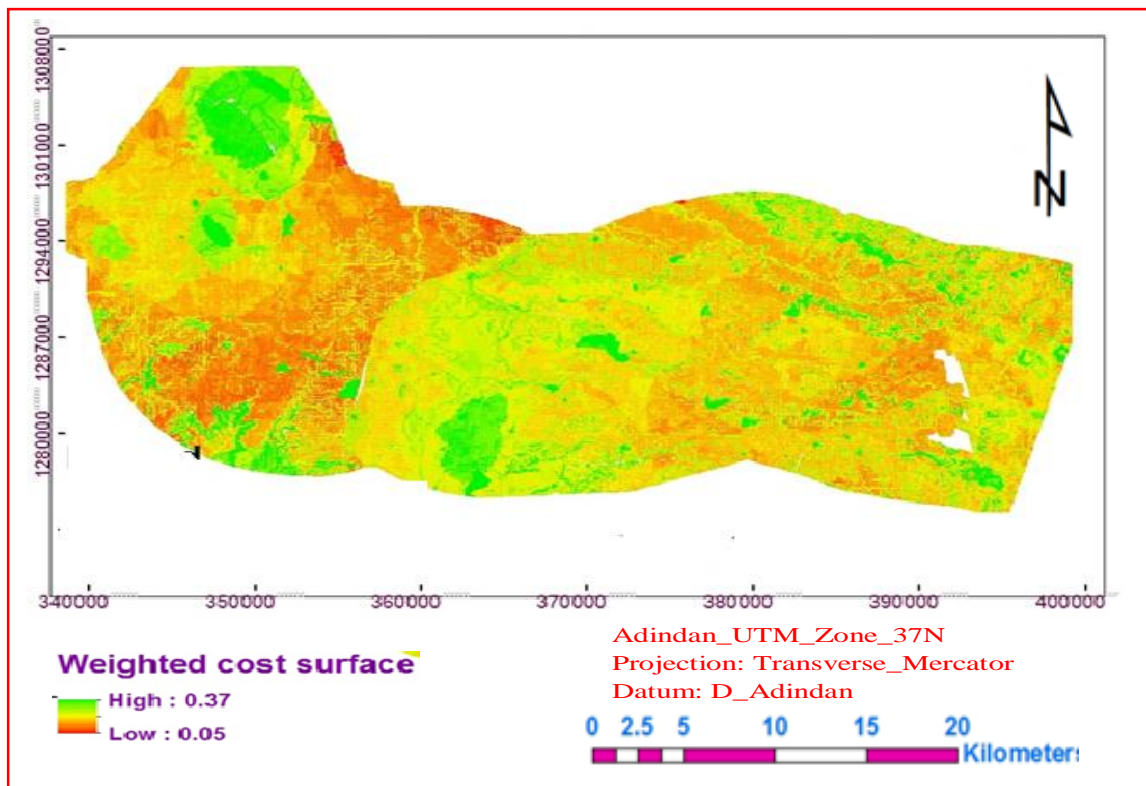


Figure 22: Weighted cost surface for social and environmental decision scenario group

3.6.3. Employing Least Cost Path Algorithm

Least cost path analysis is a distance analysis tool within ARC GIS spatial analysis that uses the least cost path or the path between two locations that costs the least to those travelling along it to determine the most cost effective route between a source and destination. Cost can be a function of time, distance or other criteria that is defined by the user. When using least cost path analysis in GIS the eight neighbors of a raster cell are evaluated and the generated path moves to the cells with the smallest accumulated or cost value (Distance Analysis Using Arc GIS).

This process is repeated multiple times until the source and destination are connected. The completed path is the smallest sum of raster cell values between the two points and it has the lowest cost

In order to generate the least cost path route for the two weighted cost surface that is (Social and Environmental decision makers and engineering decision maker cost route) the cost distance and the Back link direction were created.

The cost distance tools are similar to Euclidean tools but instead of calculating the actual distance from one location to another the cost distance tools determine the shortest weighted distance (or accumulated travel cost) from each cell to the nearest source location. These tools apply distance in cost units, not in geographic units Arc GIS 10 help

Back link direction while the output cost distance raster identifies the accumulative cost for each cell to return to the closest source location it does not show which source cell to return to or how to get there. The Cost Back Link tool returns a direction raster as output providing what is essentially a road map that identifies the route to take from any cell along the least-cost path, back to the nearest source. Arc GIS 10 help

Since in the case study area there are two intermediate towns between the starting and the destination. The cost distance and the back link direction were created three times for each of the weighted cost surface using Arc GIS spatial analysis extension and the result is shown in appendix 2.

The least cost path (route) was generated by Arc GIS shortest path analysis extension tool using the cost distance and back link raster appendix 2. The cost distance raster is generated with the source cells and the weighted cost surfaces. The new route alignment generated by preferences of engineering decision maker group and the weighted cost surface Fig. 23.

4. RESULTS AND DISCUSSION

For the GIS based optimal road alignment selection using multicriteria analysis method the selected criteria was slope, land cover geology, soil, and fault line and drainage order. Among these factors slope was classified as flat, mountainous, rolling, and escarpment and the land cover class contains dense forest, sparse vegetation, rivers, open land agricultural and built up areas. After the analyses, two alternative scenario road alignments (Engineering, social and environmental scenario alignments) have been obtained as shown in the. Figure (23 and 24)

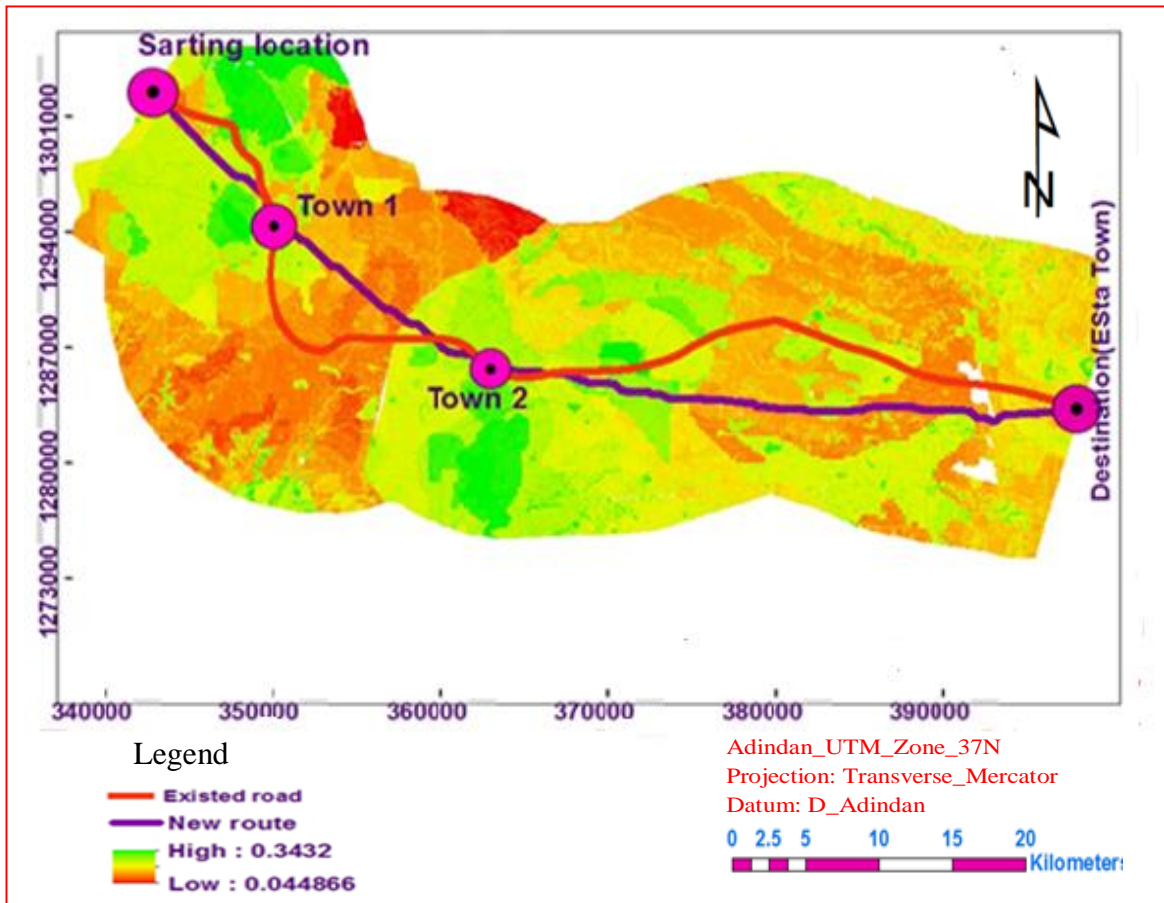


Figure 23: Existed and the engineering scenario alignment

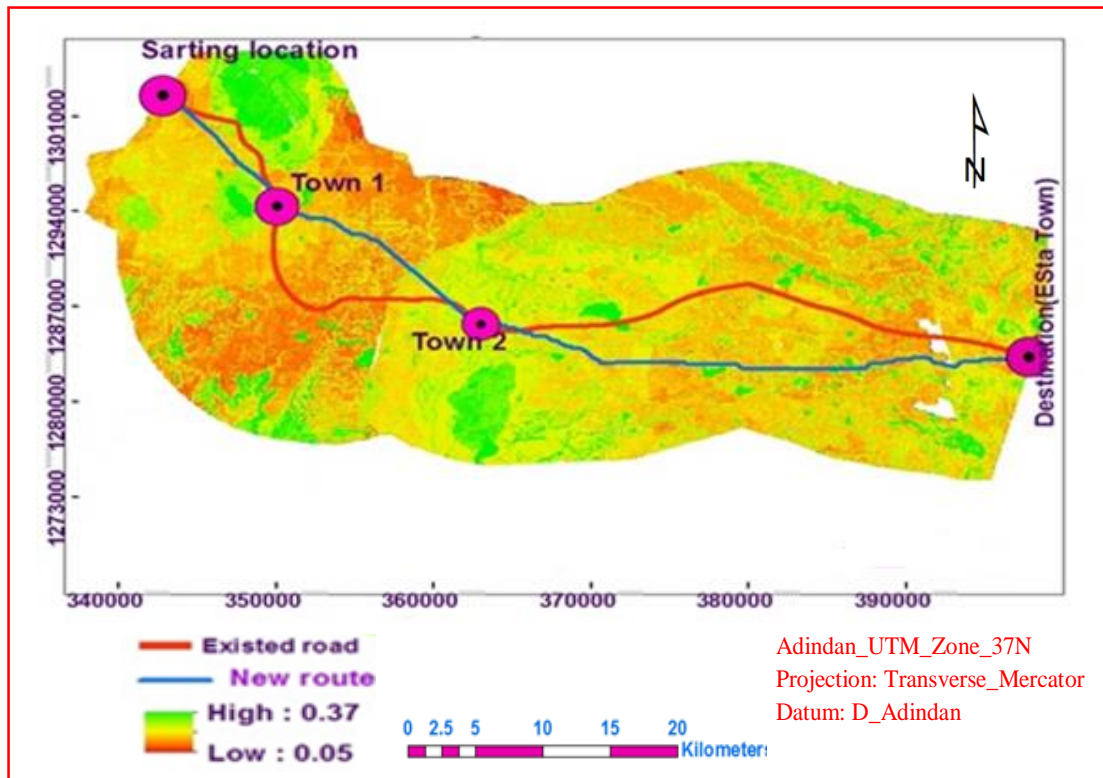


Figure 24: Social and environmental scenario alignment

4.1 Evaluation of each of alternative road alignments

After the alternative alignments have been generated. In order to see the impact of the alignments and to select the preferable alignment the following comparison criteria such as grade/slope, length, agricultural area affected, settlement area affected, number of permanent rivers and drainage orders crossing, forest area affected and proximity to the fault lines were analyzed. The evaluation was done using ARC GIS spatial analysis 40 meter buffer analysis for both (engineering, social and environmental) scenario alternative alignments from the center line and the area affected by each of the alignment was analyzed, quantified and discussed as follows

4.1.1 Evaluation of alternative road alignments in economic, social and environmental impact issues

4.1.2 Area of forest covered affected by road alignments

Natural or human planted forests provide a wide range of products, soil and water protection, biodiversity conservation, social services, social and economic opportunities.

In order to evaluate the impacts of the alternative alignment in environmental issues forest layer was extracted from the land cover layer and then 40 meter buffer analysis was created around each alternative to get the impacted area of forest. And then intersect function was performed for both (engineering, social and environmental scenario alignments) and the result is illustrated in (table17, 18 and figure25, 26).

The result shows that none of forest area and only 0.16%% of sparse vegetation destroyed for engineering scenario alignment and 1.3% and 0.3% sparse vegetation and forest respectively destroyed for social and environmental scenario alignment. Generally less environmental impact.

4.1.3 Agricultural area impacted by social and environmental scenario alignments

Agriculture layer was extracted from the land use land cover layer. Then, using Arc GIS software 40 m buffer analysis have been created from the center line of each alternative alignments and the impacted agricultural area obtained as 72.83 % and 66.6% for engineering, social and environmental scenario alignments respectively. Table17, 18 and figure25, 26 illustrates the result in detail respectively.

4.1.4 Residential area affected by the alignment

The impact analysis of the alignment on Community disruption was evaluated by computing the area of buildings lying within a 40 meter buffer from the alignment. This impact analysis was done using GIS buffering analysis and the results obtained as 16.5% for engineering scenario, and 23.3% for social and environmental scenario alignments. This is shown in Table17, 18 and figure 25, 26 respectively for engineering, social and environmental scenario alignments

Table 17: Land use affected by engineering scenario alignment

Land use type	Area (km ²)	%(percentage)
Built up	317.63	16.49%
Agriculture	1403.03	72.83%
River	29.35	1.52%
Open area	173.40	9.00%
Sparse vegetation	3.09	0.16%
Total	1926.500714	100.00%

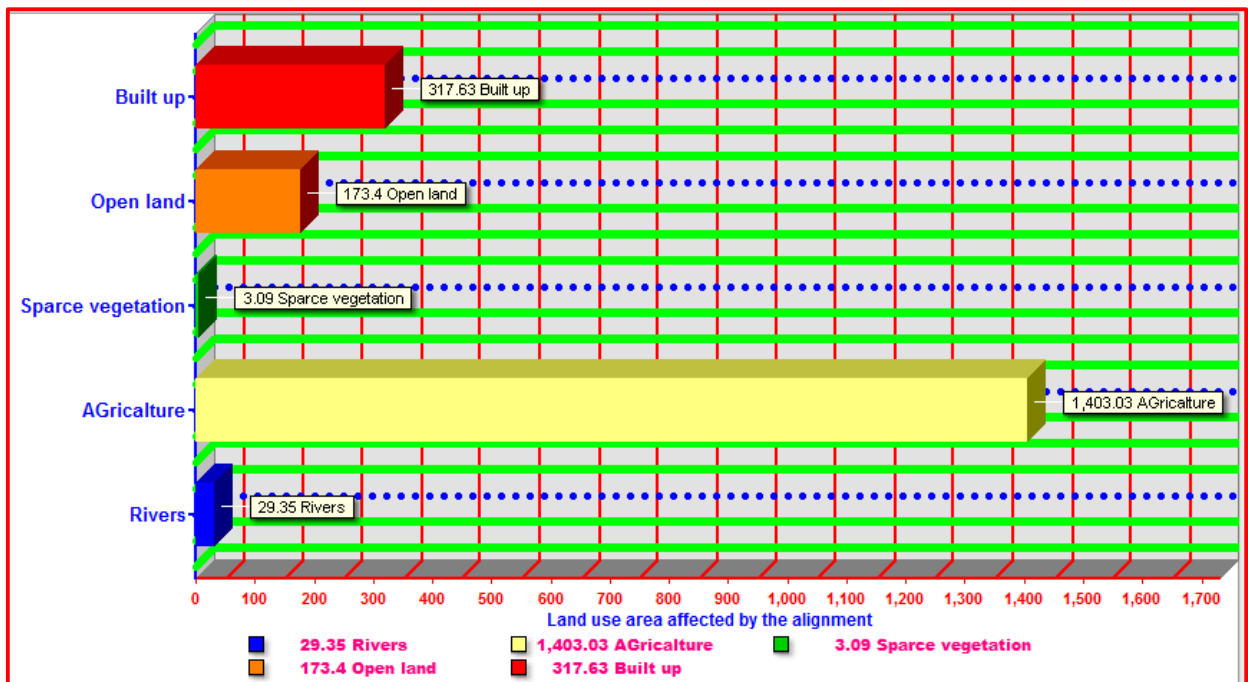


Figure 25: Land use affected by engineering scenario alignment

Table 18: Land use affected by social and environmental scenario alignment

Land use type	Area (km ²)	%(percentage)
Built up	444.946	23.3%
Agriculture	1269.805	66.6%
River	42.072	2.2%
Open area	119.831	6.3%
Sparse vegetation	25.613	1.3%
Forest	5.505	0.3%
Total	1907.772	100.0%

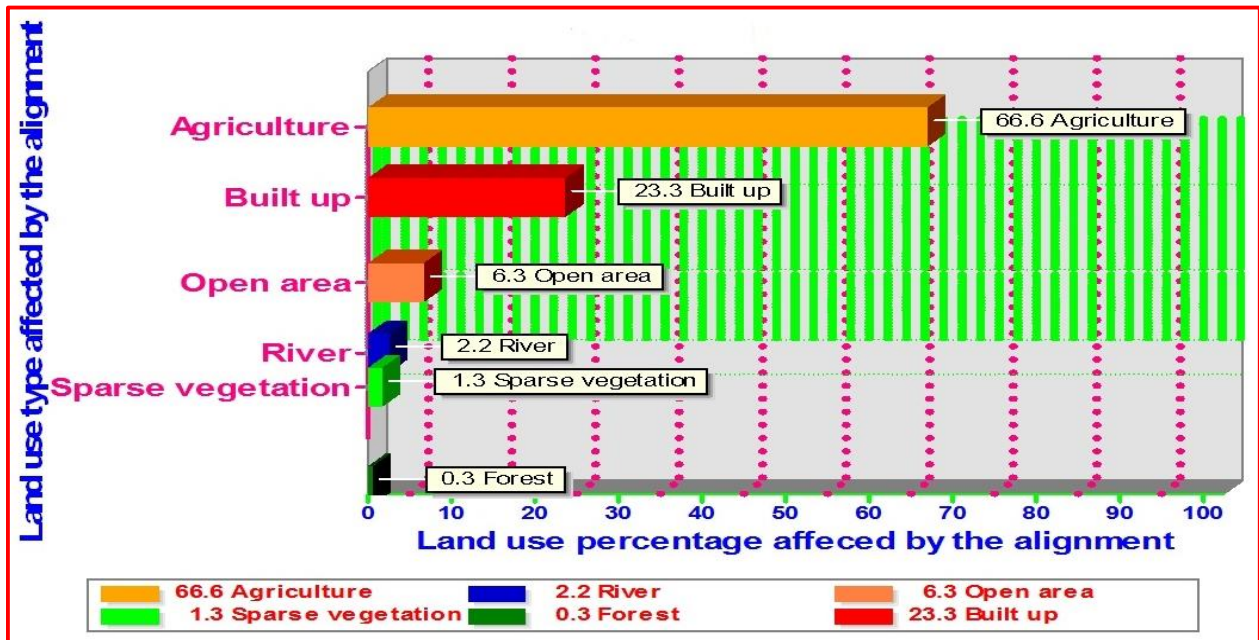


Figure 26: Slope class impact for social and environmental alignments

4.1.5 Terrain analysis

Slope is one of the major factor for increasing and decreasing the cost of the road construction by the amount of fill/ cut and also it determines vehicle operation and passenger's safety. Therefore

each area slope class within the limit of 40 meters from the center line of the alignment for both (engineering, social and environmental scenario alignments) have been extracted and quantified by Arc GIS buffering analysis (table 20 and figure 28) for engineering and (table 19, and figure 27) for social and environmental. The result shows that 96.62% of the engineering and 85.06% of social and environmental scenario alignment passes through flat to mountainous terrain class. This shows less cost (Cut/fill) issues.

Table 19: Slope class impact for social and environmental scenario alignment

Slope type in degree	Terrain type	Area (km ²)	%(percentage)
0-2	Flat	491.36	23.54%
2-14	Rolling	1306.8	62.624%
14-37	Mountainous	288.61	13.83%
Total		2086.26	100.00%

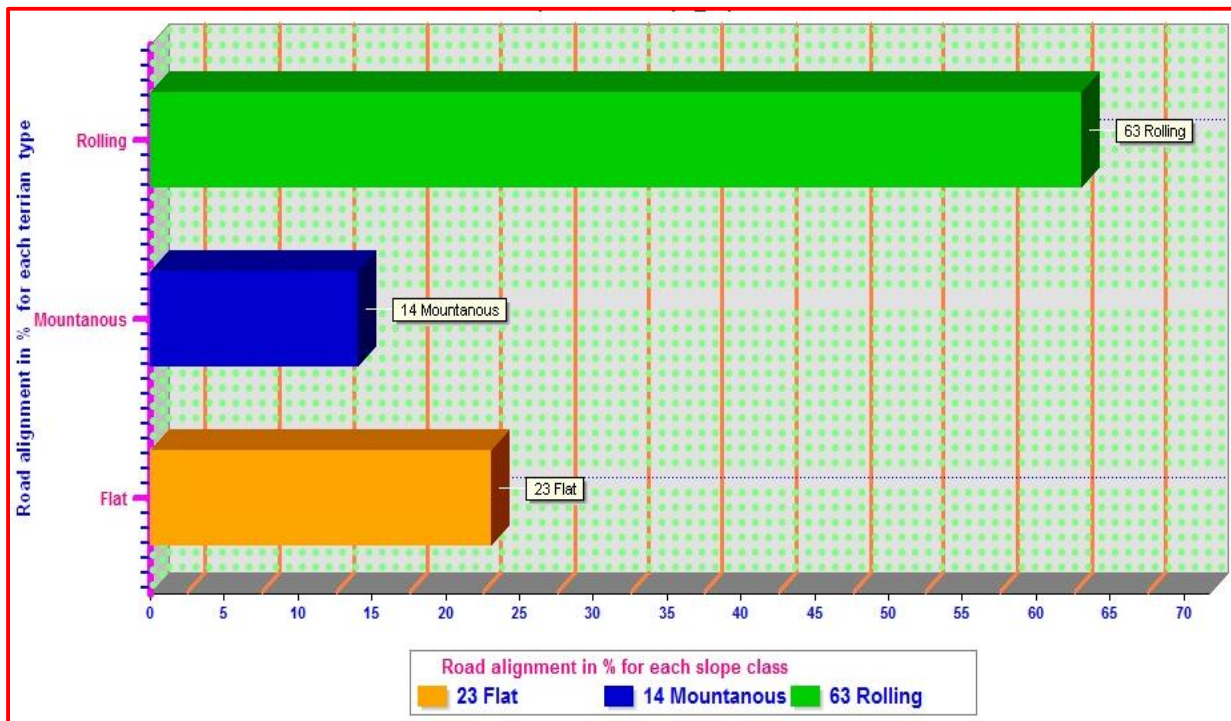


Figure 27: Slope class impact for social and environmental scenario alignment

Table 20: Slope class impact for engineering scenario alignment.

Slope type in degree	Terrain type	Area (km ²)	%(percentage)
0-2	Flat	779.108	40.32%
2-14	Rolling	1088.003	56.30%
14-37	Mountainous	65.428	3.39%
Total		1932.539	100.00%

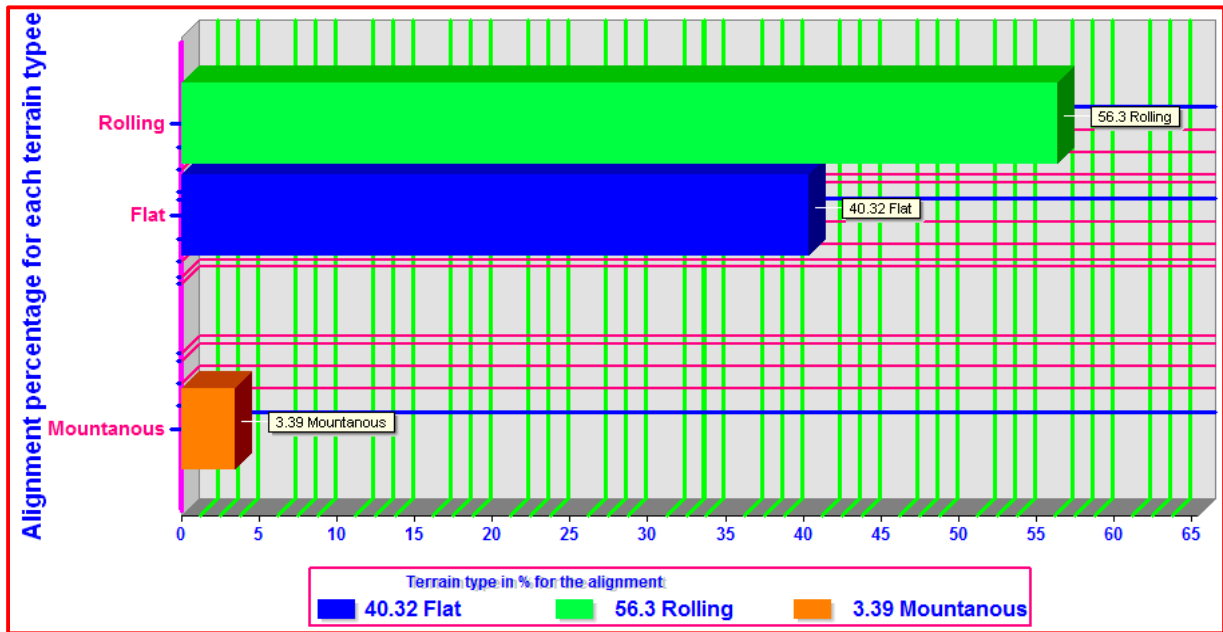


Figure 28: Slope class impact engineering scenario alignment

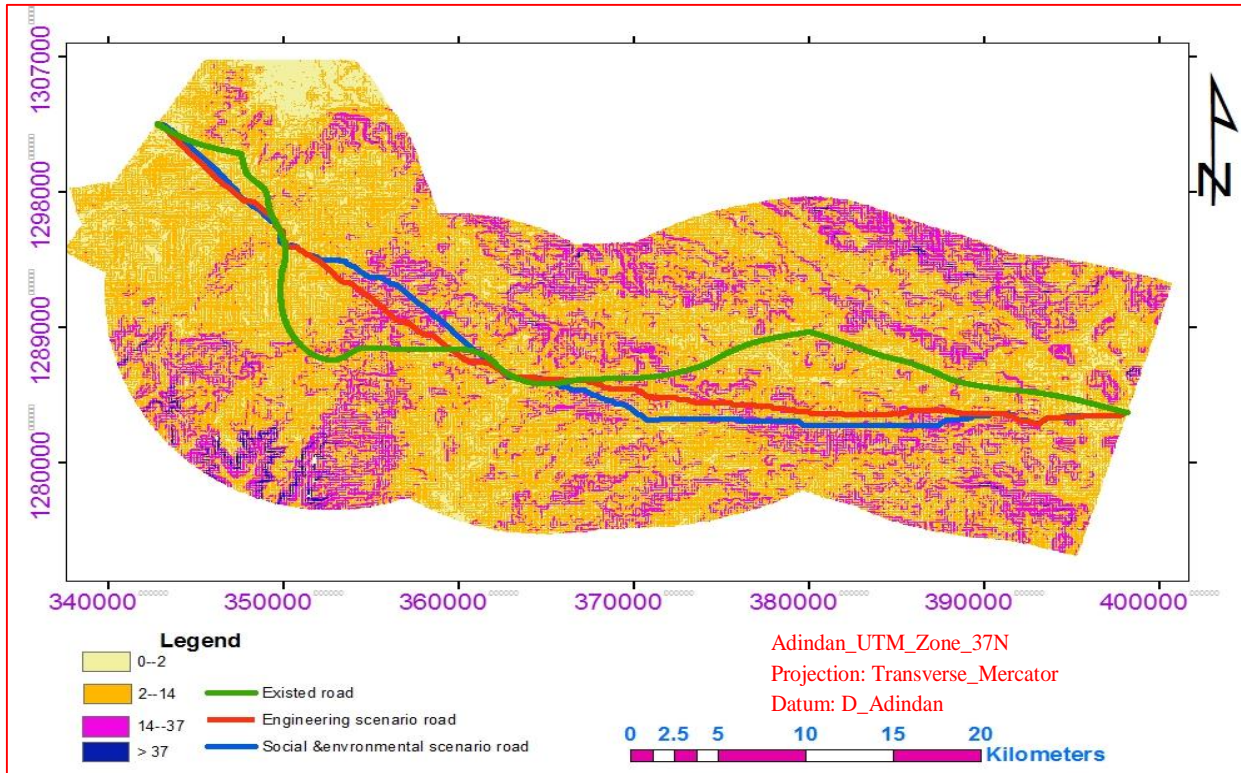


Figure 29: Alignments super imposed on slope for terrain observation

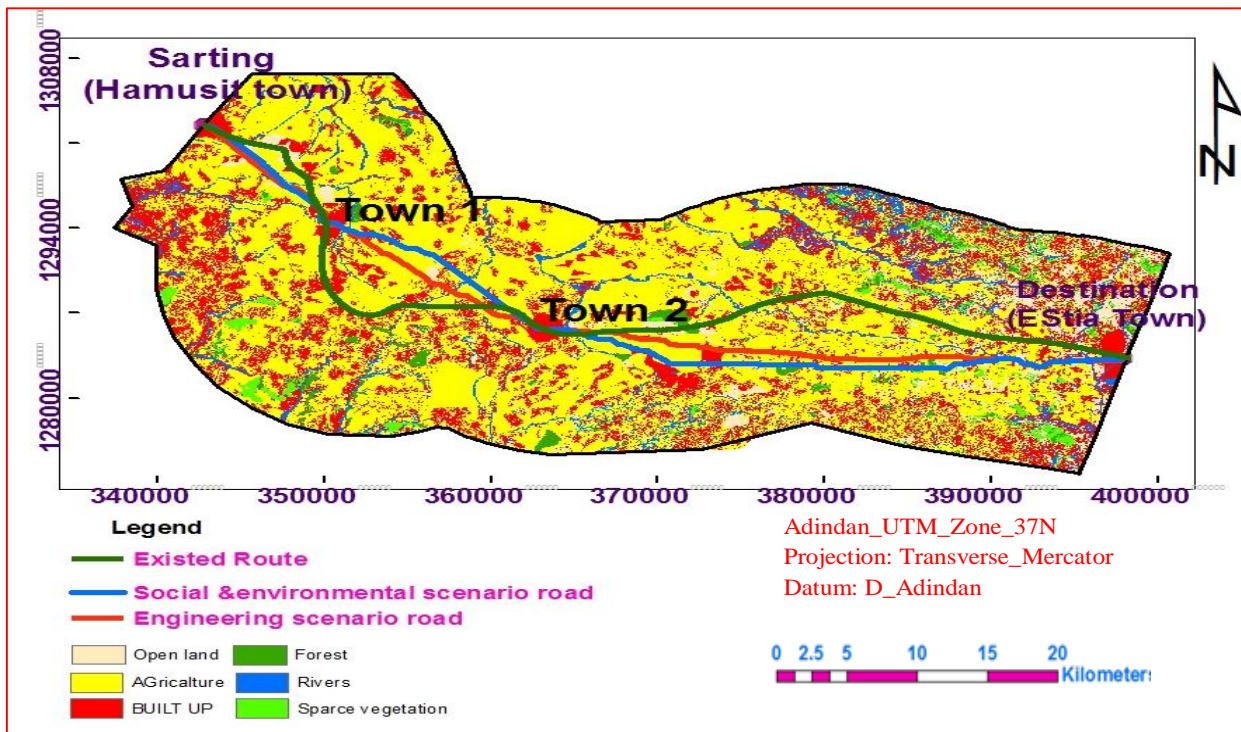


Figure 30: Alignments super imposed on land use for social impact observation

4.1.6. Proximity to geological faults

The proximity analysis of the alignments to geological fault line using buffering analysis shows that the social and environmental scenario alignment was crossed one times and passed by distances of 0.14km, 3.5km, 4km 4.6km and 5.6 km in both sides of the route. And also engineering scenario alignment passes at a distance of 2.3km 4.2km4.6km and 5.6km figure 31 shows in detail.

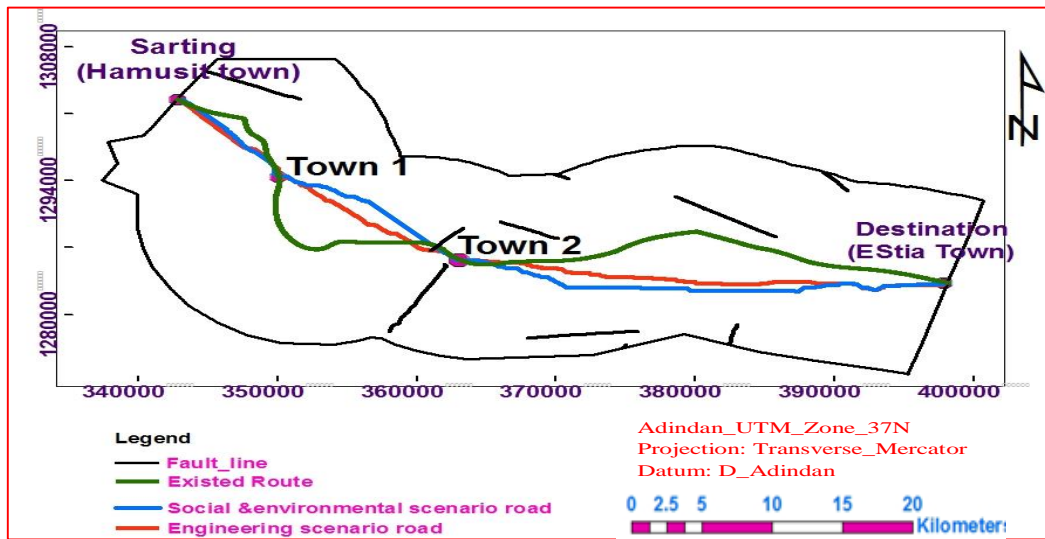


Figure 31: Alignments proximity to fault lines

4.1.7. Rivers and streams crossing the alignment

In order to determine number of permanent and intermittent rivers cross the two scenario alignments using Arc GIS intersection analysis have been done between the river and the alignments and the result is shown in table below and figure 32

Table 21: Rivers and streams crossing the alignments

Alignment type e type	Crossing river type	Quantity	No of streams
Alignment by social and environmental	Permanent	7	3
Alignment by Engineering scenario	Permanent	6	2
Existed road	Permanent	7	6

4.1.8 Number of bridges/culvert required.

From the result of intersection analysis between Rivers, stream and alignments table 16.the number of bridges for engineering scenario alignment is six and culvert boxes is two. At the same time for social and environmental scenario alignment seven bridges and three culvert boxes. Relatively the engineering scenario alignment is least cost.

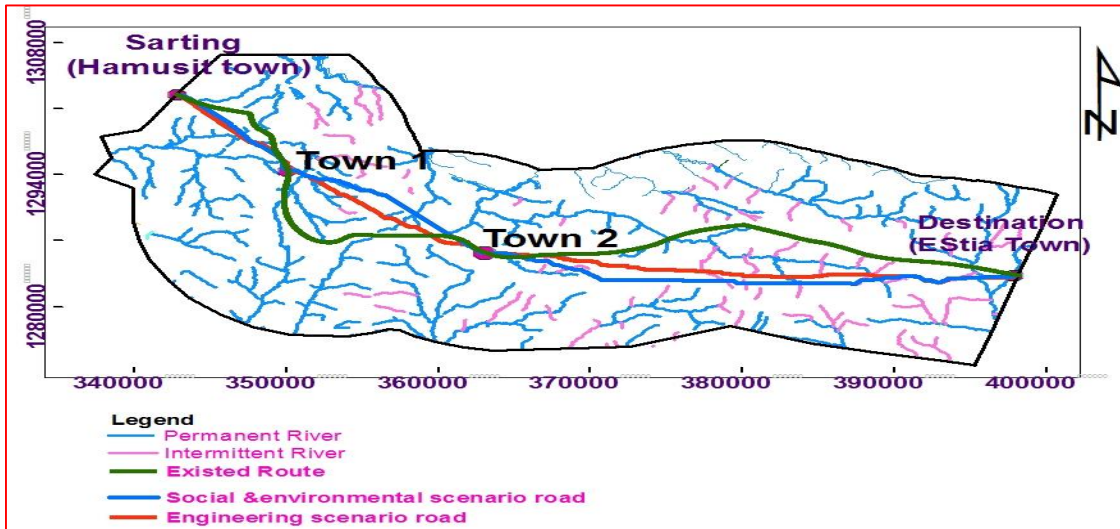


Figure 32: Rivers and streams crossing the alignment

1.7.1 4.1.9. Population served

The analysis for the number of population served by the alignment should be done using proximity and population density analysis but in this study the researcher is used simply statistical analysis means considering number of population with in the kebelas crossed by the alignment table 17. This is because of no locational data of the population in Ethiopia at all.

Table 22: Summary for alternative alignment impact analysis

Criteria type	Alternative routes		Relative cost of Routes				
	Route 1	Route 2	Existed route(R3)	R1	R2	R3	Rank
				Low	medium	High	
Slope range in km ²							
0-2	1543.53	1451.66	1314.17	L	M	H	
2-14	2825.13	3298.7	3259.05	H	L	M	
14-37	306.3	629.62	297.425	M	L	H	
Fault line	0.14km	crossed	crossed	M	H	H	
	3.5km	2.3km	1.5km	L	M	H	
	4.08km	4.2km	2.3km	M	L	H	
	4.6km	4.6km	4.2km	M	M	H	
	5.6km	5.6km	5.6km	M	M	M	
Population Served	288,806	374,806	340,786	M	M	M	
No of kebelas	29	29	34	L	L	L	
Forest affected in km ²	5.30	2.55	7.5	M	L	H	
No rivers crossing	7.00	6.00	8	M	L	H	
streams crossing	3.00	0.00	5	M	L	H	
Settlement affected in km ²	102.34	127.88		M	H	No	
Length in km	65.00	64.00	76	M	M	H	
Agricultural area in km ²	321.55	294.21	No data	H	M	NO	
All over relative cost:				R1M	R2L	R3H	Cost

Where L= low cost, H=high cost and M=medium cost

Route2=Engineering scenario road alignment

Route1=Social and environmental scenario road alignment

Afield survey was done for the purpose of verification the result obtained from the analysis by recording coordinates of the alternative routes and feed in the coordinates to the hand held GPS random searching of location shows very good result.

The other verification was done using the goggle earth .this was done as, first the raster format of the route alignment was changed to poly line and then covert to kml format which can be read by the goggle earth and finally the alternative routes was opened with goggle earth and verification shoes appropriate result relative to existing topographic features.

Generally the engineering scenario road alignment is relatively pass through low cost and can be said it is preferable road alignment

5. CONCLUSIONS AND RECOMMENDATION

5.1. Conclusion

In this study, Geographic Information System (GIS) was used to explore the various route application that would cross Hamusit to Estaie. The Least Cost Path analysis (LCP) and multicriteria decision analysis(AHP) model applied for the selected cause study road paths and this were quite successful in minimizing the economic, social and environmental impact issues(forest, faults lines, high slopes, water bodies and built-up areas) and thus satisfying the objective of this study within the given criteria and data.

It is concluded that if Geographic Information System and its shortest path algorithm integrated with multi criteria decision making analysis would be implanted in the early road alignment selection phase. It proves to be well appropriate, economic and then saving for a sustainable road location design. It can avoid many constraint location problems: in addition, the ability of the technique to provide several alignment alternatives and to compare such alternatives is a benefit for designers and planners.

The existing road length was 76 km long. Results indicate that the alignment which was generated applying GIS method is more economically, socially and environmentally effective and cheaper which is 64.5km. This proposed alignment (Figure.33) provides minimum economic, social and environmental impacts, operating for movement of vehicle. Time and consumption of fuel will also be reduced considerably. This has shown a potential savings which can be obtained by automating the road alignment selection process using ArcGIS.

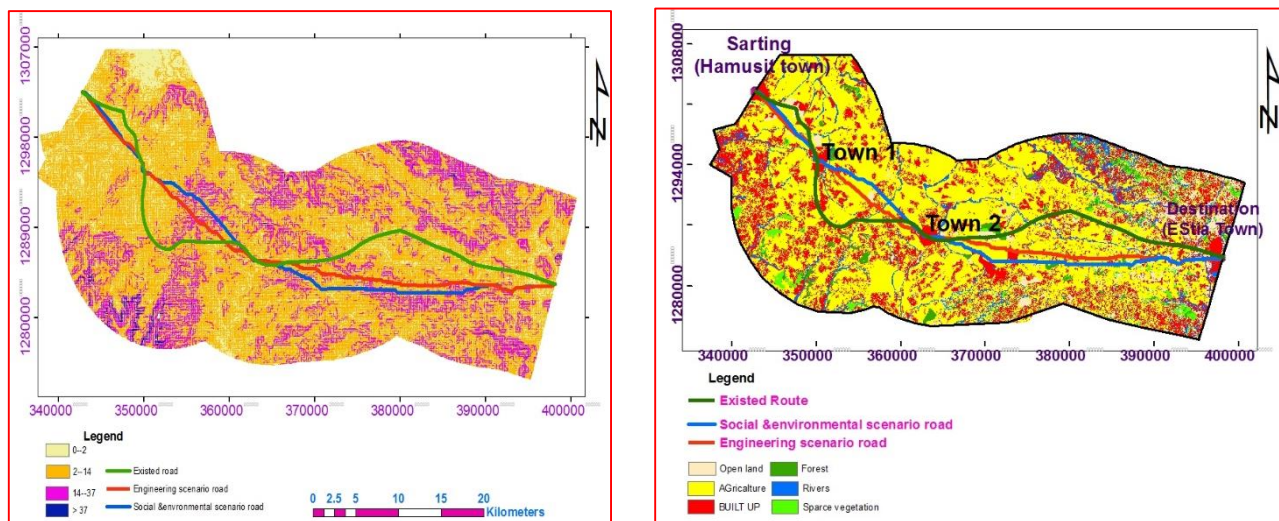


Figure 33 : Alignments superimposed on slope and land cover class

5.2. Recommendations

It is recommended to use Arc GIS as decision making tool in road alignment selection. So that this can automatically analyze and calculate the earthworks volumes and also calculate impact on surrounding areas. On the other hand, can select the best alignment from different alternative using an input impact weightage system.

Higher level educational institutions such as colleges and universities are better to included Arc GIs and remote sensing course for departments like civil engineering, water resource engineering, environmental engineering and geological engineering trainees.

Federal and regional road and transport offices are better to include the ArcGIS based road alignment selection approach in their alignment selection policies, rules, manuals and guide lines.

Feature work:

High spatial resolution satellite data and high resolution DEM that is 1m or less like below 1m is recommended to get more accurate results

Since in this study the weighting used in AHP pair wise comparisons were determined by limited participants in number as well in profession type and Weight determinations is complex and subjective thus it will be better to take the opinions of group of experts by a questionnaire (increasing in number and in type of profession.

Include factors, which are not included in my study such as noise, air pollution, water pollution, land price and CBR value of soil will

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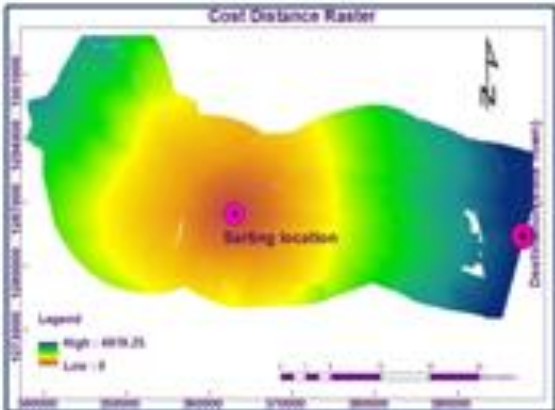
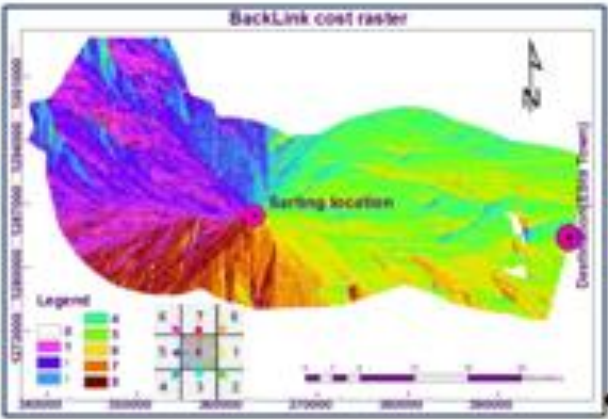
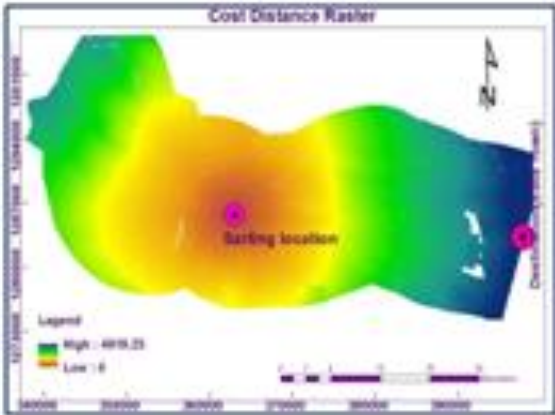
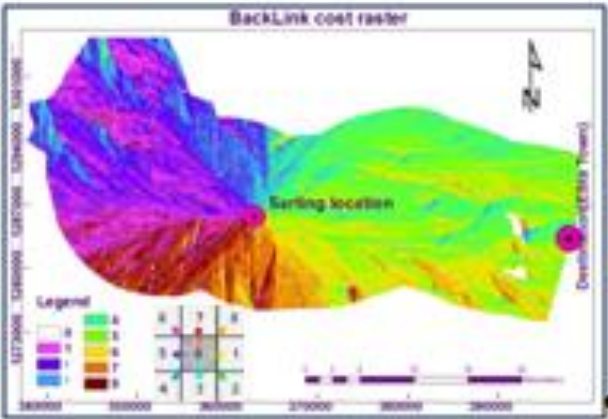
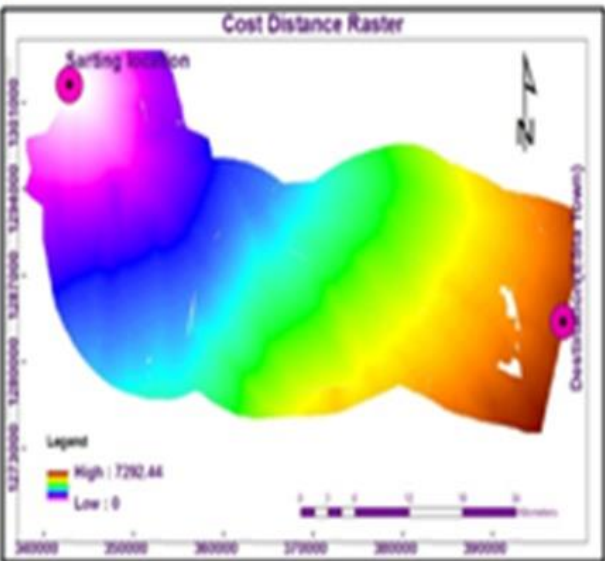
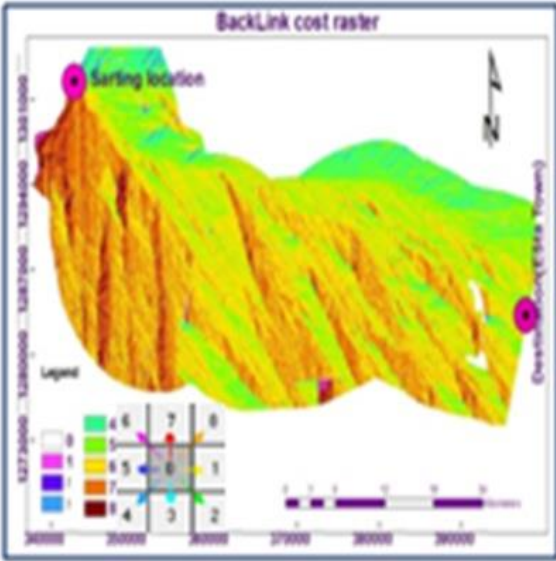
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APPENDIXES

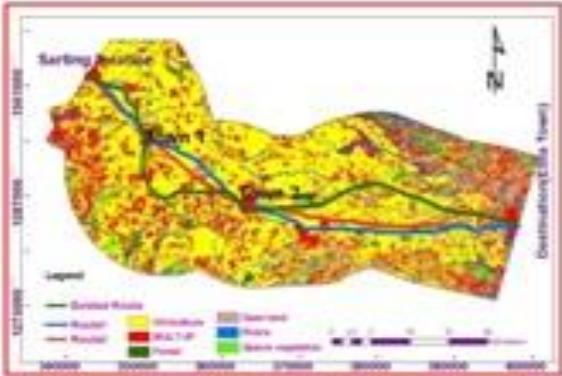
Appendix 1: Ground control points for land use classification

NO	X	Y	Feature type
1	343,698	1,302,415	Built up
2	350,496	1,294,257	Built up
3	363,337	1,285,571	Built up
4	370,513	1,282,172	Built up
5	371,269	1,283,833	Agriculture
6	347,324	1,304,002	Agriculture
7	357,672	1,280,963	Agriculture
8	374,819	1,295,013	Agriculture
9	390,304	1,283,078	Dens vegetation
10	346,644	1,296,448	Dens vegetation
11	382,523	1,288,894	Dens vegetation
12	371,304	1,286,912.046	Dens vegetation
13	377,719	1,282,348	Sparse vegetation
14	355,825.	1,283,274	Sparse vegetation
15	352,055	1,295,511	Sparse vegetation
16	369,848	1,286,118	Sparse vegetation
17	347,755	1300,009	Open land
18	374,611	1278,181	Open land
19	397,629	1,287,838	Open land
20	363,035	1,291,542	River
21	346,168	1,304,903	River
22	342,596.173	1,283,67	Rivers

Appendix 2: Back link and Cost distance surface



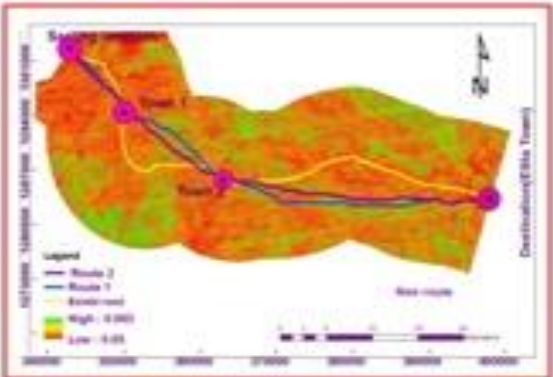
Appendix 3: Road alignments with respect to factors



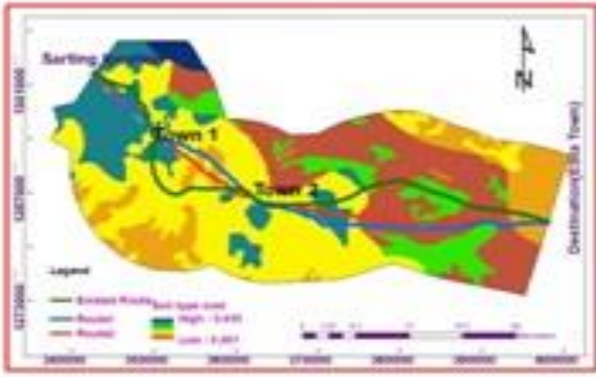
a: Land cover type cost



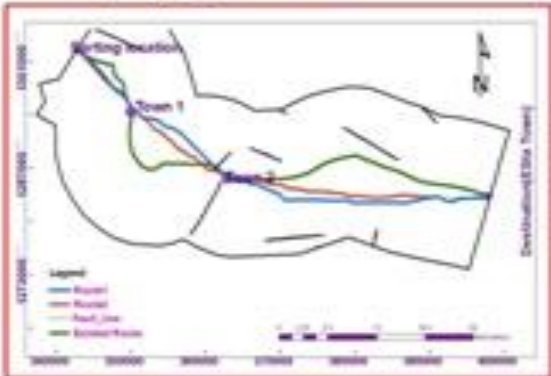
b: Rivers and streams cost



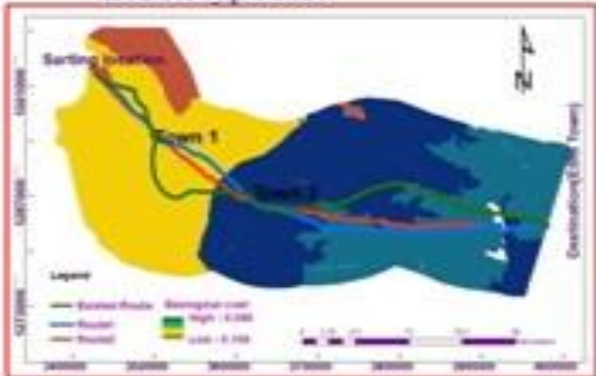
c: Topographical cost



d: Soil type cost



e: Fault line Cost



f: Geological cost

Appendix 4: Personal discussion for Criteria identification and Weighting

Name	professional	Academic rank	Working office
Dr. Addiszemen Teklay	Geotechnical	PHD	Bahirdar university
Dr.Seifu Admas	Hydrualogy		Bahirdar university
Yimer Degu	Matarial eng	Msc	Bahirdar university
Girma Worku	Environmetalist	Msc	ARRA
Alelign	Environmetalist	Msc	ARRA
Tesfahun Alemu	Highway engineer	Msc	ARRA
Mulat	Scio economist	First degree	ARRA
Belachew Tarekegn	Highway engineer	Msc	Bahirdar university

