Evaluation and Selection of Railway Station for the Case of Addis Ababa/Sebeta – Dire Dawa Network Line

ADDIS ABABA UNIVERSITY

ADDIS ABABA INISTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

SCHOOL OF MECHANICAL AND INDUSTRIAL ENGINEERING

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfilment of the Requirements for the Degree of Masters of Science in Mechanical Engineering (Railway Engineering stream)

By

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Advisor

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DECLARATION

I hereby declare that the work which is being presented in this thesis entitled “Evaluation and Selection of Railway Station for the Case of Addis Ababa/Sebeta – Dire Dawa Network Line” is original work of my own, has not been presented for a degree of any other university and all the resource of materials used for this thesis have been duly acknowledged.

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This is to certify that the above declaration made by the candidate is correct to the best of my knowledge.

______________________ ___________________

Dr. Gulelat Gatew Date

(Advisor)

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ABSTRACT

The main objective of this paper is to evaluate and select railway station for the route Addis Abeba – Dire Dawa network line. Railway station site selection has a great role on the development, safety and accessibility of customer and resources. As many researches and experience of developed countries railway progress shows special attention have to be given for station site selection. To select the railway station at the right place, there are a number of criterias including internal and external factors to be considered. The new Addis Ababa - Djibouti railway network that passes through Dire Dawa which is now on construction needs railway station. The station needs to be selected using all the selection criteria according to the international railway site selection criteria and according to the situations compatibly. Even though the Ethiopian Railways Corporation has already proposed railway stations for Sebeta- Dewenle network line, it is not selected and analysed well as per the required criteria, technique / method and procedure of railway station site selection. Knowing the purpose of the railway station and understanding the proposed stations problem, this paper dealt with railway station site selection. The main data required for this research was collected from different sources like Ethiopian Railways Corporation head office and project managers, reviewing feasibility study on railway station, site visiting and using different related books, web sites, journals and related researches done in experienced countries. The data collected through data collection techniques are organized according to their categorization & analysis of the data has executed by using the selection factor and constraint criteria and multi criteria decision analyses. Then analysed by manual calculation and Microsoft excel. Finally this research evaluated the currently selected stations, identified the gap and proposed accessible and sustainable railway station of freight and passenger station for Addis Ababa - Dire Dawa line, and developed model for all railway station site selection which fit to the case of Ethiopias Railway in the future. Therefore it is applicable on Ethiopian railway system including the future railway network of all rail corridors.

Key Words: Railway Station, Site Selection, Multi Criteria Decision Analysis (MCDA), Analytical Hierarchy Process (AHP)

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LISTS OF SYMBOLS AND ABBREVIATIONS

ERC	Ethiopian Railways Corporation	SG	Slope Gradient
ENRN	Ethiopian National Railway Network	PR	Proximity to Roads
GDP	Gross Domestic Product	LAGD	Level area with good drainage
MCDA	Multi Criteria Decision Analysis	PRS	Proximity to other Rail stations
AHP	Analytical Hierarchy Process	PW	Proximity to Water bodies
GIS	Geographical Information System	PP	Proximity to Power Lines
ROM	Rank Order Method	FM	Financial Mobility around that Area
WLC	Weight Linear Combination	ALG	Allignment

CR	Consistence Ratio	AL	Adequate land
CI	Consistence Index	RI	Random Index
λ	Average value of the Consistence Vector	HV	High Voltage
S	Suitability to the Objective Being Considered	OD	Origin Destination
C	Integrated Constraint	Wi	Weight Factor i
C_n	Criteria Score of Constraint N	Fi	Criteria Score i
MODM	Multi Objective Decision Making	SP	Sending Passenger
MADM	Multi Attribute Decision Making	RP	Receiving Passenger
PNCS	Proximity to Nearby City and Settlements	SF	Sending Freight
PP	Number of Peoples per trip	RF	Receiving Freight

CHAPTER ONE
PROBLEM AND ITS APPROACH

1.1 Introduction

A Railway station is that place on a railway line where traffic is booked and dealt with i.e the places where trains stop to collect and deposit passengers, freights, and where trains are given the authority to proceed forward. A train station, also called a railroad station or railway stations a railway facility where trains regularly stop to load or unload passengers or freight. Sometimes only one of these functions is carried out at station and accordingly it is classified as flag station or block station. In the case of flag station there are arrangements for dealing with traffic but none for controlling the movement of trains. In the case of block stations, a train cannot proceed further without obtaining permission from the next station and traffic may or may not be dealt with. However most railway station performs both the functions indicated above [4].

Railway stations are at the heart of the nation's psyche. They feature in block buster films, romantic novels and the skylines of many towns and cities. However, they are far more important to the nation than as mere artistic reference points. Millions of people use the nation's railway stations every day. Towns and cities have often developed around them, placing railway stations in the heart of many communities. The station can often help to provide an identity or symbol for the town or city; it can act as a point of reference as well as a civic amenity for people who want to use the station's facilities, whether they are travelling or not. Done well, their design and operation helps to facilitate the success of the national rail network [6].

A successful railway station will add to the passenger experience as well as support the economic, social and environmental benefits of rail. Their effective integration with other modes of transport and the surrounding area can provide for an end-to-end journey experience that makes sustainable public transport a real alternative to private vehicle usage. Given these varying demands on stations it is vitally important that they are properly selected, planned, designed and improved in a manner that recognizes all that they have to offer [6].

To be those activities performed safely, effectively and efficiently, the station must be allocated at a right place. If not; the railway system will not earned with long lasting service and profit because of unaccessiblity and saftey problem of the railway system. Selection of the railway station location is therefore not optional for healthy railway system. In order to select site for railway station there are many considerations to be taken. For this there are many basic criterions to be carefully considered including internal and external factors [4]. The government of Ethiopia has launched railway new network to help and motivate the rapid growth of the country's economy. Now the country is highly growing in all aspects. Following this many towns are emerging, agricultural products are increasing, Industries are rising, import and export demand in each city is increasing. At that time simply proposing one city to be station becomes difficult. For this matter station site selection for the new railway system is very important.

This research answer those questions by selecting appropriate railway station, and evaluating the existing railway stations using all site selection criteria considering the countries reality, using all selection methods and procedures. This makes the station site everlasting even if the railway network rehabilitated because of different reasons including its age.

1.2 Statement of the Problem

Now days due to the growth of population, the movement of people and goods from place to place becomes increasing. As the movement of these things increases the transportation problem increases as well and the demand of transportation is strong. This needs to facilitate different modes of transportation. To solve this problem, the Ethiopian railways corporation /ERC/ has launched railway network. From this the Ethiopian National Railway Network /ENRN/ project is one in which, the country's GDP increment is highly motivated and sustained for the future. For this ENRN project, railway station is the heart since every activity of the railway system is nothing without railway station [6]. It is required because Ethiopian national railway network is being contracting newly. For the new Addis Ababa - Djibouti railway network that passes through Dire Dawa which is among the primary target of ERC, and now on construction needs railway station. Railway station is required at new railway network line because of different reasons like economic growth, agricultural and industrial revolutions, population growth, political issue and others. The station needs to be selected using all the station criteria according to the international railway site selection criteria and according to the situations compatibly. Ethiopian Railways Corporation has already proposed railway stations for Sebeta- Dewenle network line. But for the new railway line the proposed stations are not selected and analyzed well in accordance of the criteria, technique / method and procedure of railway station site selection, and the selection criteria, method of their selection and criteria weightings are not clearly used in selection process except some common criterias used as the researcher got from Ethiopian Railway Corporation. In addition to the currently selected railway stations, the problem of railway station site selection of the country will be more complicated and severe in the future if the stated way of site selection is not in use. This is because of the reality of the country's different views of the country today and in the coming years. Now there are no many sites to choose from but in the future many towns and cities are emerging near to each other. It was difficult to identify the best alternative without detail analysis and better selection technique using same limited selection criterias. This way of selection of railway station site leads to different problems discussed above since the country is growing and many things are changing from time to time. Properly selecting the railway stations by the use of international railway station selection criterion, methods, procedure and considering the countries actual situation deeply is important to solve this problem. Therefore the Addis Ababa – Dire Dawa line station new site selection and evaluation is mandatory to have profitable, accessible, safe and long lasting railway system.

Research Questions

- What are the relation ships betwen railway station site selection and the sustainablity and durablity of the railway system?
- What are the relation ships betwen railway station site selection and the accessiblity of the railway system?
- What are the relation ships betwen railway station site selection and the safety of the railway system and the invironment?

1.3 Objective of the Research

- General objective

The general objective of the research is to Evaluate and select appropriate site of railway station on the route Addis Abeba – Dire Dawa line.

- Specific objective

In order to achieve the general objective; the following specific objectives have been formulated.

1. Examine railway station site selection criteria of ERC according to Ethiopias experience and natural conditions.
2. Identify the criterias and weighting system for all site selection criteria which fit to the case of Ethiopias Railway by developing model
3. Evaluate the curently selected railway stations and identify the gap
4. Suggest new railway stations for the case of Addis Ababa to Dire Dawa

1.4 Organization of the Study

The paper contains six chapters including the first chapter seen previously. The second chapter is literature review of the study containing most common definition and bench marking analysis of different related site selections with factors and constraint criteria using MCDA by AHP method. The third chapter contain methodology of the study. The fourth chapter mainly contained data collection and presentation with mathematical analysis and Microsoft-excel. The fifth chapter contain model development and finally the last chapter, chapter six contain conclusion, recommendation of the study and future works which could be done by other researchers for further future research works.

1.5 Significance of the Study

This study is mainly targeted with the problem of siting of railway station for Addis Ababa/Sebbeta – Dirre Dawa network line. To solve this problem MCDA method was used in order to select railway station at the right place. The primary merits of this study is solving the problem of railway station placement of Ethiopian railways mainly Sebbeta – Dire Dawa network line. The currently proposed railway station by the corporation in the stated direction is not selected properly using all the selection criteria and technique, for that matter the stations are not sited at the right place. Some are proposed at an irrigated, cultivated and forested land; others are proximity to city and settlements problem and locating station in the middle of city. These all will create conflict with the environment and economy of the country. The implementation of MCDA with common and determinant factor and constraint criterias is the suggested way for positioning of railway station at the right place. The researcher believes that, the Ethiopian Railways Corporation will be motivated to implement and revise the proposed sites, and specially use the developed model for other unselected railway rout.

1.6 Limitation of the Study

The limitation of this study is lack of significant data. The data required for this research is qualitative and quantitative data. But only the qualitative and general data collected for the research especially for financial activity and population size in the line. This is because of the fact that, in the network line there is no detail data of population density/size and agricultural product, financial activities of villages and city in which the railway passes through. The other limitation is that, for this research to get full information there were a need of each site visit in the network line from Sebbeta to Dire Dawa, but because of lack of budget the researcher unable to visit each site.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

As railway station is the heart of railway system, the station has to be selected properly. Otherwise if it is selected without detail analysis, there are many problems that follow the system. The best example for such problem is the Ethiopian old railway line and stations which is by now not used for the new railway network. This is because of the fact that, the old railway station had not selected scientifically using all criteria and methods properly. Therefore this un accurate selection of Addis Ababa – Dire Dawa line railway station will not serve for long time (will become out of service with short time) because of alignment of the land, lack of place for expansion, drainage problem, lack of water supply, lack of access users like passengers, goods, Industries, minerals and financial mobility, lack of feeding roads, geological property of the land etc. To solve the above mentioned and unmentioned crises the best solution is, properly selecting the railway stations by the use of international railway station selection criterion, methods, procedure and considering the countries actual situation deeply. Therefore the Addis Ababa – Dire Dawa NRNL station new site selection is mandatory to have profitable, accessible, safe and long lasting railway system. This can be achieved by use of different methods including sharing different countries experience, using Literatures and bench marking analysis. The Addis Ababa – Dire Dawa NRNL is the target area of this research. That is the reason to call the title of this research Evaluation and Selection of Railway Station for the Case of Addis Ababa/Sebeta – Dire Dawa Network Line.

2.2 Bench Marking Analysis

There are different researches done with site selections. More of these are not done specifically in railway station site selection but on different public service giving organization, like hospital site selection, land fill site selection and others. Landfill site selection by using geographic information systems[8], Multi criteria decision making and GIS for railroad planning [10], GIS-Based Multi-Criteria Analysis for Hospital Site Selection and multi criteria decision method and Analytical hierarchy process [16], are those points. The next section shows this literature review from different sources and bench marking analysis.

2.2.1 Landfill site selection

In this study, candidate sites for an appropriate landfill area in the vicinity of the research area are determined by using the integration of Geographic Information Systems and Multi criteria Decision Analysis [8]. For this purpose, sixteen input map layers including topography, settlements (urban centres and villages), roads, railways, airport, wetlands, infrastructures (pipelines and power lines), slope, geology, land use, floodplains, aquifers and surface water are prepared and two different MCDA methods (Simple Additive Weighting and Analytic Hierarchy Process) are implemented in GIS environment[8]. The next section deals with critical factors discussed by the researcher.

A. Critical factors for Landfill Site Selection

As of this research, the major goal of the landfill site selection process is to ensure that the disposal facility is located at the best location possible with little negative impact to the environment or to the population [8]. For a sanitary landfill siting, a substantial evaluation process is needed to identify the best available disposal location which meets the requirements of government regulations and best minimizes economic, environmental, health, and social costs. Evaluation processes or methodologies are structured to make the best use of available information and to ensure that the results obtained are reproducible so that outcomes can be verified and defended [8].

B. Criteria for Landfill Siting

According to this research, there are a number of criteria for landfill site selection. These are environmental criteria, political criteria, financial and economic criteria, hydrologic and hydrogeological criteria, topographical criteria, geological criteria, availability of construction material and other criteria [8]. Each criterion will be discussed briefly in the next sections.

1. Environmental Criteria

i. Ecological value of the flora and fauna

The direct and indirect spatial use of a landfill will destroy the actual vegetation and fauna. When making a decision, the ecological value of the actual vegetation and fauna should be evaluated carefully for the candidate area. Ecological value is based on diversity, naturalness and characteristic feature. An example of indirect use is the disturbance of the quietness in the surroundings caused by the activities on the landfill [8].

ii. Odour and dust nuisance

A new landfill should not be located within a distance of a housing area because of the dust and odour emissions. Dependent of the local wind direction and speed, the safe distance necessary to locate a landfill site should be determined to prevent sensing dust and odour. The problems of odour and dust can also be minimized by proper soil cover [8].

iii. Nuisance by traffic generation

A new landfill will generate more traffic. How much more traffic depends of the distance to the collection area, the kind of transport and the use of transfer stations. Access roads passing through housing areas will cause more nuisance than access roads through the open country side [8]. So, routing vehicle traffic through industrial, commercial or low density population areas decreases the noise impacts of landfill related vehicles.

iv. Risks for explosion or fire

Because of the presence of landfill gas, there is a chance for explosion and/or fire. Soil cover also functions to smother fires and to form a barrier preventing the spreading of fires. Proper policing of incoming trucks can further reduce fire risk by minimizing the dumping of flammable loads [8].

v. Other nuisance for neighbouring area

Other nuisance includes vermin that is attracted by the organic parts of the waste on the landfill (rats, mice, birds, insects), windblown litter, noise caused by construction, compaction or trucks on the landfill. The daily cover is a solution for nuisance developed by the presence of vermin [8]. Continuous grading of soil cover to fill in low spots is essential to prevent the development of stagnant pools of water in which mosquitoes can breed.

vi. Ecological, scientific or historical areas

Especially national parks and natural conservation areas and also historical areas are not suitable for the location of a landfill [8].

vii. Tourist/recreation areas

A new landfill should not be planned within an existing recreational area or adjacent to it. However, a landfill is possible in some kinds of recreation areas like car/motor racing. Also the final use of a landfill can be planned as a recreational area [8].

2. **Political Criteria**

i. Acceptance by the local municipalities

The political acceptance of a new landfill location can differ in each region and sometimes the potential sites are located in different regions. The level of political acceptance has influence on the willingness of the local municipalities to make their regional physical plans and to give permission for the construction of a landfill [8]. The unwillingness will cause to a delay of the decision on the landfill location.

ii. Acceptance by the pressure groups involved

The acceptance by the public of a landfill in their own region or municipality is an important factor in the decision making process. The so-called Nimby syndrome is becoming a common attitude [8]. The influence of the public is significant if there are local groups which are well organized and having good relations with the local authorities and the media (papers, radio and television). The level of the public acceptance can be measured how far the local pressure groups are succeeding to delay the decision making process.

iii. Property of the landfill area

The ownership of the needed land for the landfill is very important. Public ownership is easier than private ownership because the private ownership will give problems with the cost of the land. Sometimes, expropriation is needed and this procedure will cause delays [8].

3. Financial and Economic Criteria

Costs of land, Costs for the access of the landfill, Transport costs, Costs for personnel, maintenance and environmental protection, Costs for the after-care s are Financial and Economical Criterias considered by this researcher [8].

4. Hydrologic/Hydrogeological Criteria

i. Surface water

The landfill site should not be placed within surface water or water resources protection areas to protect surface water from contamination by leachate. Safe distances from meandering and non-meandering rivers should be achieved to prevent waste from eroding into rivers and major streams [8].

ii. Ground water

To protect subsurface drinking water, landfills should not be situated over high quality groundwater resources. Fresh groundwater should be avoided or protected with a compound liner system and monitoring wells [8].

5. Topographical Criteria

The topography of an area is an important factor on site selection, structural integrity, and the flow of fluids surrounding a landfill site because it has important implications for landfill capacity, drainage, ultimate land use, surface and groundwater pollution control, site access and related operations. Deciding the type of landfill design is directly related to topography of a site [8]. Flat and gently rolling hills that are not subjected to flooding are the best sites for area- and trench-type landfills. However, this kind of topography is also suitable for other land uses like agriculture, residential or commercial development that lead to higher land prices. Depressions such as sinkholes commonly associated with unstable caverns should be avoided because they may cause to contamination of groundwater sources of drinking water. Other topographical depressions resulting from human activities, such as stone quarries, clay pits, and strip mines can be reclaimed by using landfills. The floor of these depressions typically consists of low permeable formations such as clay, siltstone, or shale. Clay pits are more suitable for depression-type landfills whereas sand gravel pits should be avoided according to permeability, except when the bottom formations are impermeable [8].

6. Geological Criteria

The geology of an area will directly control the soil types created from the parent material, loading bearing capacity of the landfill's foundation soil, and the migration of leachate. Rock and its structure type will determine the nature of soils and the permeability of the bedrock. Geologic structure will influence the movement of leachate and potential rock-slope failure along joints and tilted bedding planes. Comparing extreme permeability rates, un fractured crystalline rocks will transmit little (if any) fluids whereas poorly cemented sandstones will allow rapid transport of fluids [8]. Due to higher permeability rates, sandstone is less suitable as landfill bedrock than other sedimentary rocks such as limestone and shale. Limestone are more suitable than shales due to susceptibility of the carbonate rocks to dissolution from low pH leachate, and are commonly associated with discontinuities and karst features such as collapses, sinkholes, and caverns. Shale formations are well suited for landfill sites since shales commonly act as a retarding bed slowing or confining the transmission of fluids [8].

7. Availability of Construction Material

Sanitary landfill design usually involves an adequate source of soil with textures appropriate for daily and final covering. Soil is important in landfill development for three basic reasons [8]:

- Cover: Material used to cover the solid waste daily and when an area of the landfill is completed. The permeability of the final cover will greatly influence the quantity of leachate generated.
- Migration control: The material that controls leachate and methane movement away from the landfill. An impermeable formation will retard movement; a permeable soil will provide less protection and may require installing additional controls within the landfill.
- Support: The soil below and adjacent to the landfill must be suitable for construction. It must provide a firm foundation for liners, roads and other construction.

8. Other Criteria

Residential and urban areas, Military areas, Airports, Industrial areas, difficult infrastructural provisions are other criterias discussed by the researcher [8].

9. Climate

The site selection process must consider climate characteristics such as prevailing winds, precipitation, evapotranspiration and temperature variations because they are related to odours, dust, leachate generation, blowing litter, cover soil and erosion [8].

2.2.2 Multi Criteria Decision Making and GIS for Railroad Planning

The study identified the information needs of different factors and evaluation criteria for locating station and railroad planning. To achieve these objectives spatial multicriteria decision making processes for planning the rail station and the routes were designed and developed using GIS. The relative importance of the parameters in rail station location and rail route selection has been determined in cooperation with rail experts. The obtained scores were used in pairwise comparison to determine the weight of factors/criteria maps related to these parameters. These weighted factors/criteria maps were overlaid and suitability maps were created in GIS for rail station location and rail route selection. The Weighted linear combination (WLC) and the Analytical Hierarchy Process /AHP/ were used to derive these suitability maps [10]. This work is intended to investigate and show the capabilities of GIS in railroad planning and station location processes using part of the China-Kyrgyzstan-Uzbekistan railway in the south of Kyrgyzstan as a case study

1. **Establishing the Criteria Constraints and Factors**

   The first step in the MCE process is to identify and develop criteria which have been developed by experts and environmental groups which included criteria for preserved areas and wildlife [10]. Criteria are of two types; constraints and factors. Here four constraints and eight factors have been identified as being of concern for locating the rail station close to the city. The procedure for establishing the criteria and standardizing for both constraints and factors is explained below.

2. **Boolean Constraint Standardization**

   The most common method used to solve a MCE problem is a Boolean approach where

   All criteria and constraints are standardized to Boolean values 0 and 1 [10]. The value 0 is given to areas that should not be considered while those that should be considered are given the value 1[10]. All of the continuous factors also have been effectively reduced to Boolean values. The following considerations for each factor have been expressed as a Boolean constraint. The constraints are: Limitation Distance to the city, Landuse Constraints map, Limitation Distance to Water bodies, Limitation to Slope Gradient.

3. **Fuzzy Factor Standardization**

   The standardization procedure for weighted linear combination (WLC) is necessary to change the different measurements units of the factor images into comparable suitable and unsuitable areas. All factor images are standardized to a continuous scale of suitability from 0 (least suitable) to 255 (most suitable) [10]. To derive this continuous scale has been used the decision support module fuzzy Factor Standardization. The factor ctiterias taken by the researcher in the specified area is: Proximity to Uzgen city, Slope Gradient, Landuse Map, Proximity to Settlements, Proximity to Roads, Proximity to Water bodies, Proximity to Power Lines, Proximity to Rail stations.

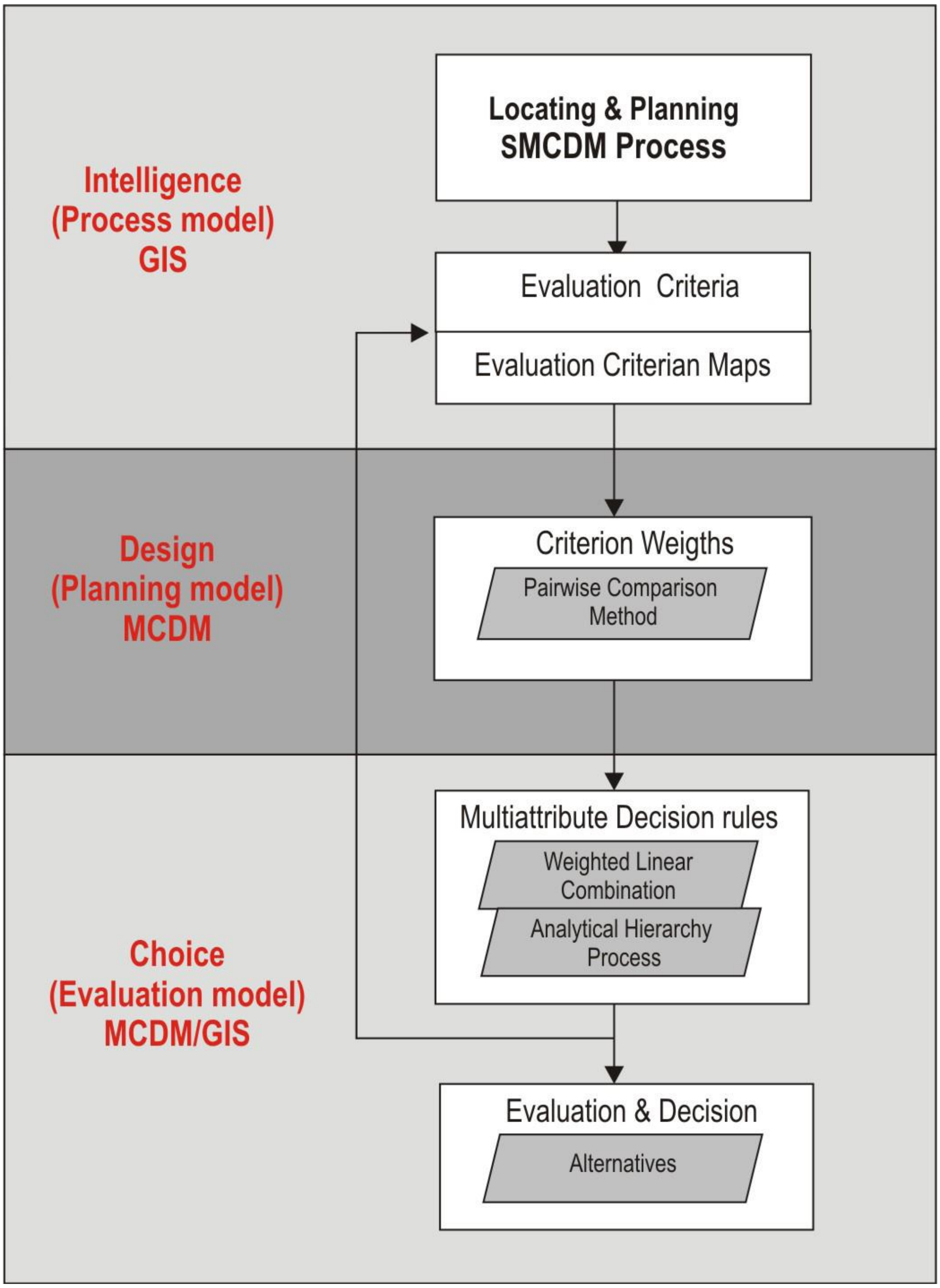


Figure 2.1 Frameworks for Locating and Planning Decision Making [10]

2.2.3. GIS-Based Multi Criteria Analysis for Site selection

The main focus of this paper is to select a site for building a new hospital in Haidian distrect of Beijing using GIS-based Multi-Criteria Analysis. With Analytical Hierarchy Process and Rank Order Method for the weight setting on factor criteria, necessity tests and sensitivity tests are applied to check which criteria are really necessary and how the results are sensitive to their weight change [16]. Further, this research used different site selection factor and constraint criteria. The factor and constraint criteris are described below respectively;

1. **Factor criteria**

The eight factor criteria with its value setting according the researcher is summarised in the table below.

Table 2.1 Factor Criteria Setting [16]

Factor	Setting
Existing hospital	The nearer away from the residential area, the better
Residential area	The nearer away from the residential area, the better
Road	The nearer away from the road (>=100m), the better
street	The nearer away from the street (>=100m), the better
Sub- street	The nearer away from the sub-street (>=100m), the better
Metro	The nearer away from the metro station (>=100m), the better
River	The further away from the river (>=300m), the better
Public toilet	The further away from the public toilet (>=200m), the better

2. **Constraint Criteria**

The eight constraint criteria with its value setting according the researcher is summarised in the table below.

Table 2.2 Constraint Criteria Setting [16]

Constraint	**Setting (0= forbiddance; 1=allowance)**
University area	Inside the area =0, outside =1
Ring road	Inside the Forth ring road =0, outside =1
Highway	500 meters buffer zone is set. Inside =0, outside =1
Railway	1000 meters buffer zone is set. Inside =0, outside =1
Restaurant	25 meters buffer zone is set. Inside =0, outside =1
Greenbelt	Greenbelt area=0, others=1

Reservoir	Reservoir =0, others =1
Altitude	(DEM)100 meters over the sea level =0, others=1

2.3 Multi Criteria Decision Analysis (MCDA)

Decision Analysis is a set of systematic procedures for analyzing complex decision problems. These procedures include dividing the decision problems into smaller more understandable parts; analyzing each part; and integrating the parts in a logical manner to produce a meaningful solution [12]. In general, MCDA problems involve six components [21 & 22]:

- A goal or a set of goals the decision maker want to achieve,
- The decision maker or a group of decision makers involved in the decision making process with their preferences with respect to the evaluation criteria,
- A set of evaluation criteria (objectives and/or physical attributes)
- The set of decision alternatives,
- The set of uncontrollable (independent) variables or states of nature (decision environment)
- The set of outcomes or consequences associated with each alternative attribute pair.

MCDA techniques can be used to identify a single most preferred option, to rank options, to list a limited number of options for subsequent detailed evaluation, or to distinguish acceptable from unacceptable possibilities [8]. There are many MCDA approaches which differ in how they combine and utilize the data. MCDA approaches can be classified on the basis of the major components of multi criteria decision analysis. Three different classifications can be made as;

1. Multi objective decision making (MODM) versus multi attribute decision making (MADM)
2. Individual versus group decision maker problems, and
3. Decisions under certainty versus decisions under uncertainty

2.3.1 Steps of Spatial Multi criteria Decision Analysis (MCDA)

Any spatial decision problem can be structured into three major phases: intelligence which examines the existence of a problem or the opportunity for change, design which determines the alternatives and choice which decides the best alternative [8]. The major elements involved in spatial decision making process are discussed below.

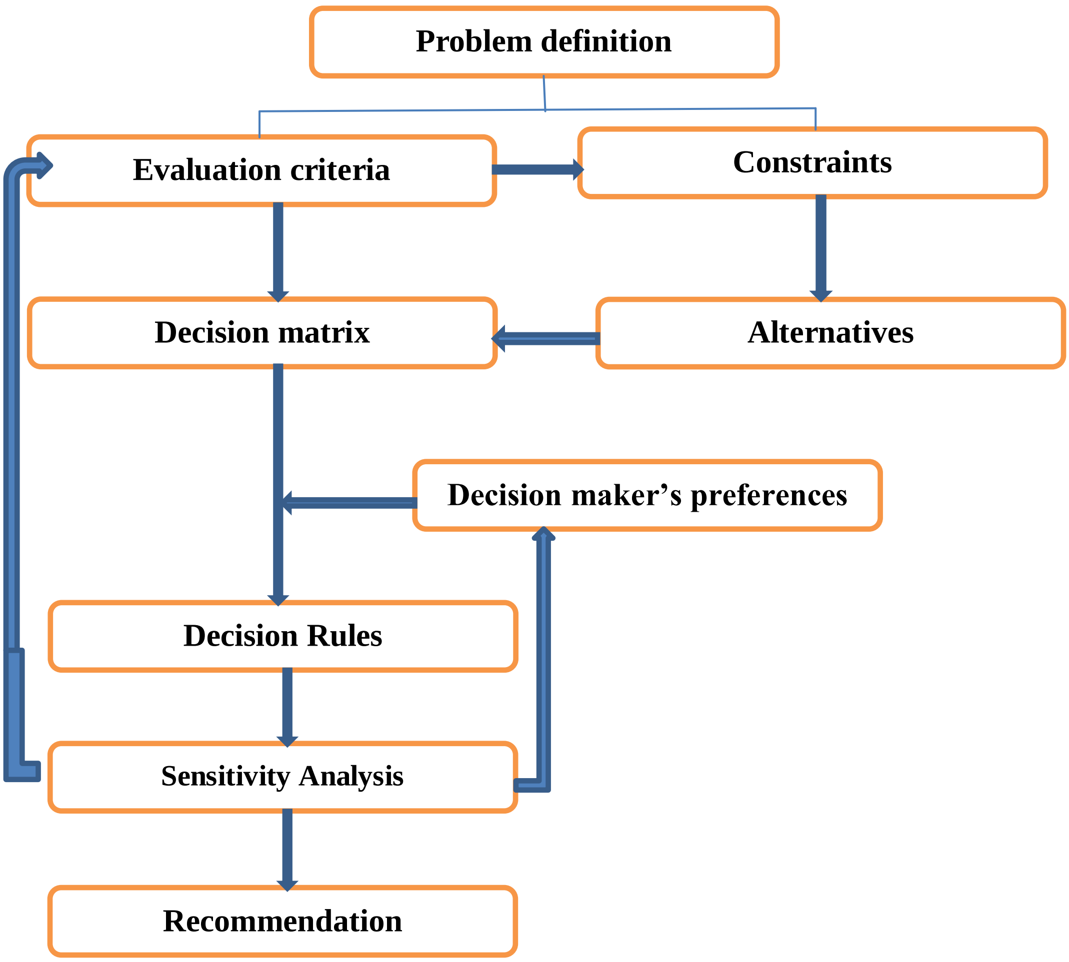


Figure 2.2.Framework for Spatial Multi Criteria Decision Analysis [8]

1. Problem Definition

A decision problem is the difference between the desired and existing state of the real world. It is a gap which is recognized by a decision maker. Any decision making process begins with the recognition and the definition of the problem. This stage is in the intelligence phase of decision making and it involves searching the decision environment for conditions, obtaining, processing and examining the raw data to identify the problems [12].

2. Evaluation Criteria

After the determination of the problem, the set of evaluation criteria which includes attributes and objectives should be designated [22]. This stage involves specifying a comprehensive set of objectives that reflects all concerns relevant to the decision problem and measures for achieving those objectives which are defined as attributes. Because the evaluation criteria are related to geographical entities and the relationships between them, they can be represented in the form of maps which are referred as attribute maps. Data handling and analyzing capabilities are used to generate inputs to spatial decision making analysis [12].

3. Criterion Weights

A weight can be defined as a value assigned to an evaluation criterion which indicates its importance relative to other criteria under consideration. Assigning weights of importance to evaluation criteria accounts for:

i. the changes in the range of variation for each evaluation criterion

ii. The different degrees of importance being attached to these ranges of variation [8].

There are four different techniques when assigning the weights: Ranking, Rating, Pairwise Comparison and Trade of Analysis Methods.

A. Ranking Methods

This is the simplest method for evaluating the importance of weights which includes that every criterion under consideration is ranked in the order of decision maker's preferences. Due to its simplicity, the method is very attractive. However, the larger the number of criteria used, the less appropriate is the method. Another disadvantage is lack of theoretical foundation [8].

B. Rating methods

The method requires the decision maker to estimate weights on the basis of a predetermined scale. One of the simplest rating methods is the point allocation approach. It is based on allocating points ranging from 0 to 100, where 0 indicates that the criterion can be ignored, and 100 represents the situation where only one criterion need to be considered. Another method is ratio estimation procedure which is a modification of the point allocation method. A score of 100 is assigned to the most important criterion and proportionally smaller weights are given to criteria lower in the order. The score assigned for the least important attribute is used to calculate the ratios. Again the disadvantage of this method like ranking method is the lack of theoretical foundation. And also the assigned weights might be difficult to justify [8].

C. Pairwise Comparison Method

The method involves pairwise comparisons to create a ratio matrix. It takes pairwise comparisons as input and produced relative weights as output. The pairwise comparison method involves three steps:

1. Development of a pairwise comparison matrix: The method uses a scale with values range from 1 to 9 [8]. The possible values are presented in Table 2.3

Table 2.3 Scale for Pairwise Comparison [14]

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	A reasonable assumption
1.1–1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities

2. Computation of the weights: The computation of weights involves three steps. First step is the summation of the values in each column of the matrix. Then, each element in the matrix should be divided by its column total (the resulting matrix is referred to as the normalized pairwise comparison matrix). Then, computation of the average of the elements in each row of the normalized matrix should be made which includes dividing the sum of normalized scores for each row by the number of criteria. These averages provide an estimate of the relative weights of the criteria being compared [8].

3. Estimation of the consistency ratio: The aim of this is to determine if the comparisons are consistent or not. It involves following operations:

a) Determine the weighted sum vector by multiplying the weight for the first criterion times the first column of the original pairwise comparison matrix, then multiply the second weight times the second column, the third criterion times the third column of the original matrix, finally sum these values over the rows,

b) Determine the consistency vector by dividing the weighted sum vector by the criterion weights determined previously,

c) Compute lambda (λ) which is the average value of the consistency vector and Consistency Index (CI) which provides a measure of departure from consistency and has the formula below:

$CI = (\lambda - n)/(n-1)$

d) Calculation of the consistency ratio (CR) which is defined as follows:

$CR = CI / RI$

Where RI is the random index and depends on the number of elements being compared If $CR<0.10$, the ratio indicates a reasonable level of consistency in the pairwise comparison, however, if $CR \geq 0.10$, the values of the ratio indicates inconsistent judgments. This research used this method because of its latest and clear way of comparisons [8].

4. Decision Rules

The criterion map layers and weightings must be integrated to provide an overall assessment. This is accomplished by an appropriate decision rule or aggregation function [8]. Since a decision rule provides an ordering of all alternatives according to their performance with respect to the set of evaluation criteria, the decision problem depends on the selection of best outcome [8].

2.3.2 Analytical Hierarchy Process (AHP)

The AHP developed by Saaty (1980) is a technique for analyzing and supporting decisions in which multiple and competing objectives are involved and multiple alternatives are available. The method is based on three principles: decomposition, comparative judgment and synthesis of priorities. In the AHP, the first step is that a complex decision problem is decomposed into simpler decision problems to form a decision hierarchy. When developing a hierarchy, the top level is the ultimate goal of the decision. The hierarchy decreases from the general to more specific until a level of attributes are reached. Each level must be linked to the next higher level.

Typically a hierarchical structure includes four levels: goal, objectives, attributes and alternatives. Each layer consists of the attribute values assigned to the alternatives (cell or polygon) which are related to the higher level elements (attributes). Once decomposition is completed, cardinal rankings for objectives and alternatives are required. This is done by using pairwise comparisons which reduces the complexity of decision making since two components are considered at a time. It involves 3 steps: (1) development of a comparison matrix at each level of hierarchy (2) computation of weights for each element of the hierarchy and (3) estimation of consistency ratio which is mentioned in Pairwise comparison section.

The final step is to combine the relative weights of the levels obtained in the above step to produce composite weights. This is done by means of a sequence of multiplications of the matrices of relative weights at each level of the hierarchy. First, the comparison matrix is squared and the row sums are calculated and normalized for each row in the comparison matrix. This process is continued when the difference between the normalized weights of the iterations become smaller than a prescribed value [13]. The AHP has widespread use due to its flexibility, easy to useE, scalable; hierarchy structure can easily adjust to fit

many sized problems, not data intensive.In addition, the AHP can even be implemented in spreadsheet environment, Performance-type problems, resource management, corporate policy andstrategy, public policy, political strategy,and planning. However, ambiguity in relative importance, inconsistent judgments by decision maker and the use of 0 to 9 scale can be thought as the disadvantages of this method. The ratio scale makes sense when dealing with something like distance, or area which is natural ratio scales, but not when dealing with like comfort, image, or quality of life, for which no clear reference levels exists. Furthermore, for large problems too many pairwise comparisons must be performed [12], and the constraint criteria (0,1) .This method of the analysis is the best as described above and this research is done using this technique.

2.4 Conclusion

Site selection of different public service organization has to be performed by using different selection criteria and determinant factors, and selecting the analyzing method. From different railway related literatures, we can set the site selection criteria and choose the methods to analyze. From those sources and experience of different countries, we use different determinant factors and constraints for this research. This can be achieved by the use of actual experience of our world on site selection and site selection techniques used by other countries in addition to consideration of our countries conditions and facts

CHAPTER THREE
METHODOLOGY

3.1 Introduction

Site selection plays a vital role for both social and economic activities, from the habitat choice of our human ancient ancestors to all kinds of present commercial site selection. Everybody knows that inappropriate site selection leads to heavy losses, but may not very sure what is the exact importance. Take the business operations as an example, site selection is the first key factor and directly related to the customer groups, capital investment and recovery, development strategy. Therefore, making good preparations and analysis on the parameters of the site selection is absolutely necessary [16].

Literature survey, Data collection, data presentation, data analysis and model developments are the methodologies required in order to achieve the objectives of the research.

1. **Literature Survey**; In order to have deep understanding of the subject matter, to share others experience on the railway system, to have additional datas on the topic and to strengthen the way of implementation, literature survey is very essential. The literature surveying has taken from journals, websites, related books and feasibility study of ERC done in the network line.
2. **Data Collection;** The data has collected by using different data collection techniques such as interviews, observation and reviewing feasibility study in the railway system of the line. The data in this research is mainly collected from the network line of Ethiopian national railway network specifically the Addis Ababa – Dire Dawa line of Ethiopian Railways Corporation project office, from design department of ERC, from Sebeta-Mieso and Mieso- Dewenle project offices. Therefore some of railway line of Addis Ababa –Dire Dawa network has been visited in detail and all the appropriate data was collected as per the requirement. In the network line about twenty one citys was considered from Addis Ababa to Dire Dawa and data was collected for all of these sites. But ERC has those data for only sites they proposed to be stations. Most of other sites have no required datas; in this paper those data was taken by assumption and other datas like proximity to power station and the amount of passengers/freight to be collected/deposited was not clearly available for those proposed sites by ERC; So it has taken in the same way by assumption. Both qualitative and quantitative data was used to do this research.
3. **Data Presentation;** The data collected through data collection techniques are organized according to their categorization sectioning the twenty one sites in to seven region containing three sites each. Detail data of each sites in the region was discussed and the value of each criteria for each site in the region presented by comparing it with the minimum requirement to show the gap in each proposed sites.

4. **Data Analysis;** Analysis of the data has executed by using AHP under MCDA method. Using this method, about ten factor and six constraint criterias discussed under section 3.2 has developed from literature review by considering worldwide site selection criteria, method and procedure in collaboration with the realities of the country like land policy, and nomadic peoples situation in the country. The detail discussion of the factor and constraint criteria has presented in section 3.2. Weighting of each criteria's analysed and sated by the method of MCDA. Consistence of the weighting has chalked by the analysis. Mathematical analysis by AHP in the region was done to choose the suitable one among the rest in the region. This has executed by considering the factor criterias, criteria value and criteria weight of each criteria for all sites in the region as shown in the figure 3.1 below. As for the weighted summations procedures, the weighted linear combination of factor criteria is shown as Equation below:

$$S = \Sigma \; wi \; fi \qquad (1)$$

Where S = Suitability to the objective being considered,

wi= Weight of factor i [the sum of all weights equal 1],

fi = Criteria score of factor i.

As for the Boolean overlay operations, the formula for the constraint criteria is depicted in Equation as following:

$$C = C1*C2*\dots*Cn \qquad (2)$$

Where C = Integrated constraint Cn = Criteria score of constraint n

After the factor criteria and constraint criteria being settled separately, MCA process integrates them together by multiplying S with C, and gets the final result.

S*c= final result of the selection (3)

Where S= Suitability to the objective being considered C = Integrated constraint

Figure below gives an overview of MCA model [8].

In this paper, not only the proposed sites by ERC was seen and analysed but also another city through which the railway passes was taken as an alternative as discussed in the data collection section above.

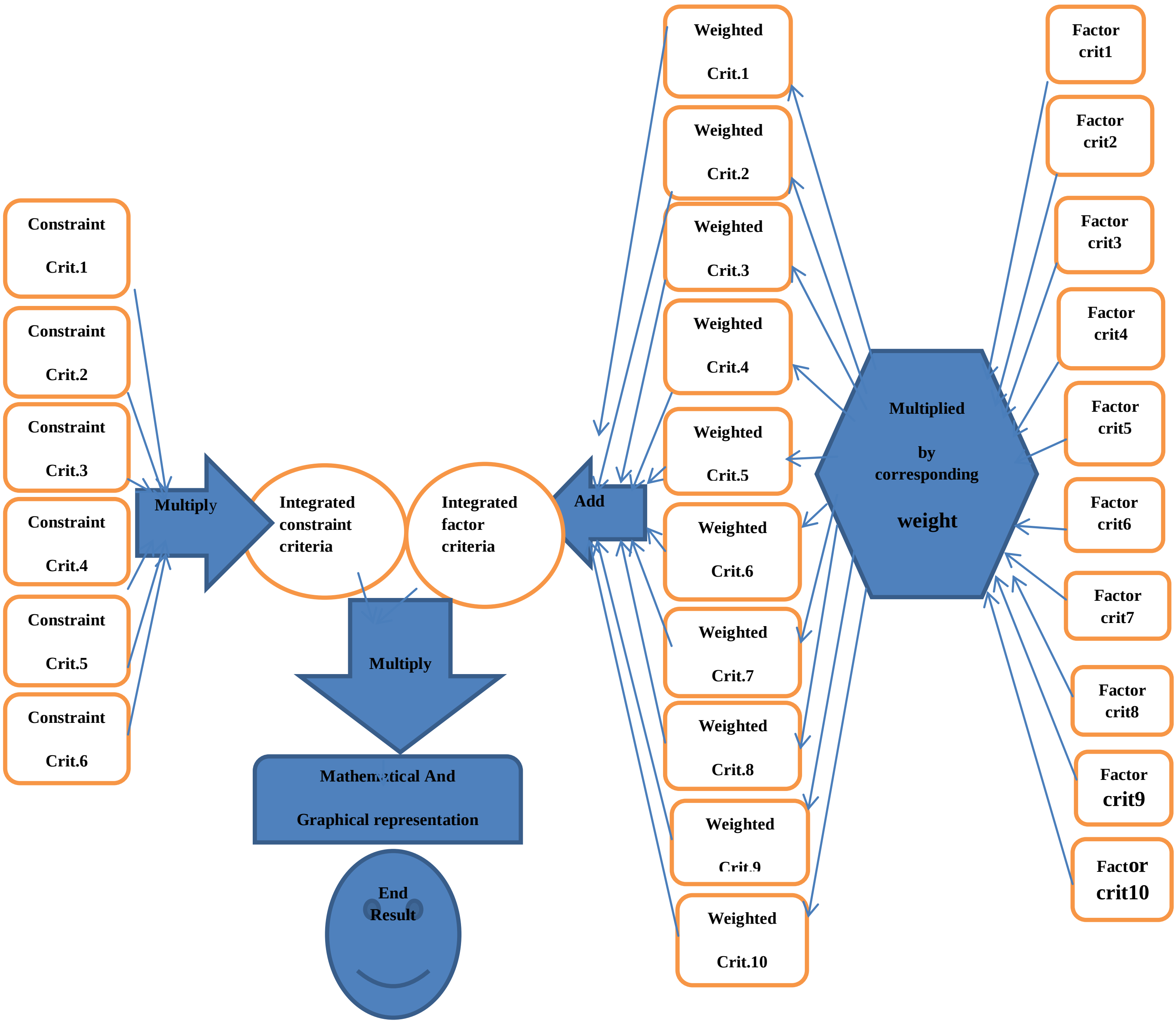


Figure 3.1 MCDA Model Applied in this Work [16]

Finally the appropriate site in each region has selected using manual calculation and Ms excel tool used and displayed the values graphically and by table.

5. **Model Development;** using the literature review and the reality of the country, under each constraint and factor criteria main consideration that have to be taken and the determining position of each specific condition has formulated to be applied for every related work.

3.2 Setting the Constraint Criteria and Factor Criteria

The first step in the MCE process is to identify and develop criteria, which have been developed by different countries experience, literature review, and according to the reality of the country which included criteria for preserved areas and wildlife. Criteria are of two types; constraints and factors. Here six constraints and ten factors have been identified as being of concern for locating the rail station for Addis Ababa –Dire Dawa network line. The procedure for establishing the criteria and standardizing for both constraints and factors is explained below.

I. Factor Criteria and its Weighting

The standardization procedure for weighted linear combination (WLC) is necessary to change the different measurements units of the factor images into comparable suitable and unsuitable areas [8]. For this work, all factor images are standardized to a continuous scale of suitability from 0 (least suitable) to 10 (most suitable). To derive this continuous scale has been used the decision support module Fuzzy Factor Standardization. This module provides the type of membership function like Sigmoid, J-shaped, Linear and the type of shape of membership function like monotonically increasing, monotonically decreasing, and symmetric [10]. According to given criteria each factor map specified one of the corresponding type and shape of membership function and also given the control points of a, b, c and d. The control points were needed to determine the shape of the fuzzy curve. The following considerations for each factor have been expressed using Fuzzy function – Fuzzy set membership function.

1. Proximity to the Nearby City and Settlement

The proximity to the nearby city factor was developed as linear distance decay function, such as developers want to see for the location of a rail station in a distance within 500m and 5,000m from the entire city. It is appropriate for these criteria to rescale the distance factor by choosing the Symmetric Linear Function and used the control points a, b, c and d. Figure 3.2 below shows, as an example for only one criterion, the requirements of Fuzzy set membership function generating the standardization map. The criteria distance of 500m on Distance Criteria image that is standardized with a linear membership function shows the result of standardization with value 10 of suitability on the image of Standardised Distance Criterion. In the graph (Figure 3.2) of the Linear Membership Function we can see that the first control point (a) is the value at which suitability starts to rise above 0 and the second control point (b) at a value of 500 approaches a maximum suitability of 10 and keeps at the same level until the third control point (c) with value of 2500. It then starts to decrease to the forth control point (d) at value 5000. And Construction rules do not allow for a railway station within 100m of settlements. But it is desirable that a station be as close to a settlement as possible.

Therefore the distances from settlements were rescaled using a monotonically decreasing linear function. The suitability decreases in areas from settlements with distance.

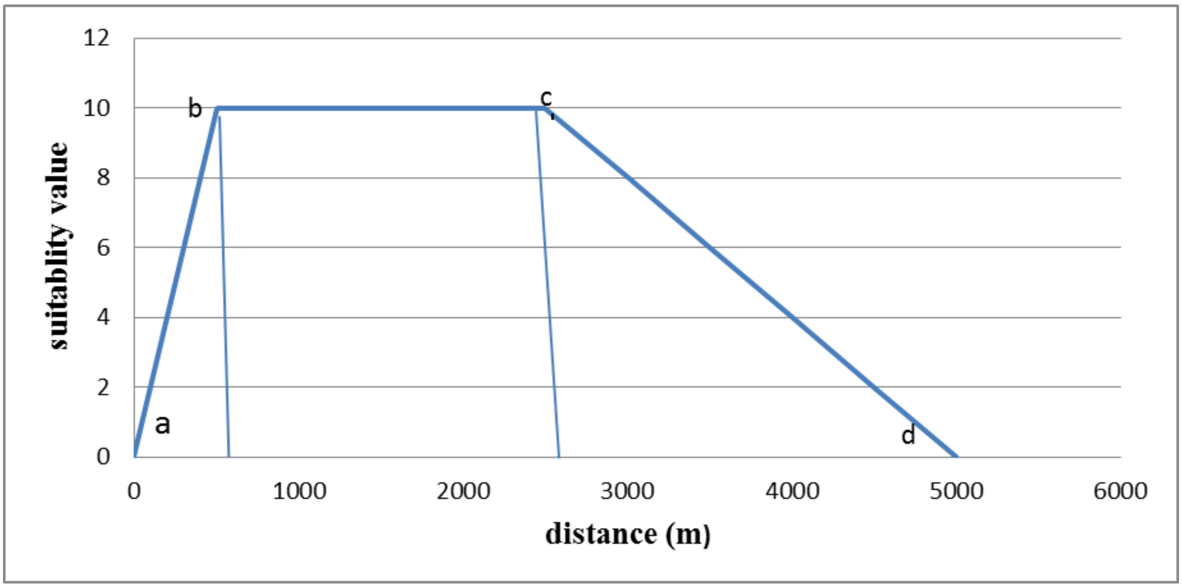


Figure 3.2 The Linear Membership Function [10]

In the graph we can clearly see that the suitable areas in range 500m – 2500m distances which covers the given criteria [10].

2. Slope Gradient

For the Slope Gradient a monotonically decreasing Sigmoidal function with a value of 15% for the first control point (c) and 2% for the value of the second control point (d) has been used. This means that slopes below 15% are the most effective for the construction of the rail station. The lowest slopes in the range 2%-5% indicate the best suitability areas and slopes above 15% are unsuitable [10].

3. Proximity to Roads

The experts prefer to see a location for rail station within 30m of roads as most suitable for cargo handling, the service of rail customers and also preferable for suitability within 500m of roads. The area beyond 30m is continuously decreasing suitability that the distance from roads rescaled by using a monotonically decreasing function [10]. For this function have been used 30 for the value of the first control point (c), at which the suitability starts to decline from maximum suitability to 500 for the value of the second control point (d) [4].

4. Proximity to Water bodies

The appropriate values for these criteria have been done using a monotonically increasing sigmoidal function in order to rescale the values of distance from water bodies. This function gives the desirable result for the environmentalists and construction experts that require being at least 150m and would be good if a distance of 1000m was used. For this factor a value of 150 was given for control point (a) and a value of 1000 for control point (b). The suitability is very low within 150m of water bodies and beyond 150m starts to increase with distance to maximum suitability at 1000m [10].

5. Proximity to Power Lines

Power lines are necessary for rail station and allocation rail station in areas closer to existing power lines are more suitable than areas in distant. These distances also were rescaled using a monotonically decreasing linear function where given the minimum distance value for the first control point (c) and the maximum distance value for the second control point (d) [10].

6. Proximity to Rail stations

The location of proposed rail station in an optimal distance from the existing stations is important for future development of a rail network among these stations. The rail experts prefer within distance 3000m and 5500m. The appropriate for these criteria that rescaled the distance factor by choosing the Symmetric Linear Function and used the control points a, b, c and d. the weighting of this method condensed concluded here. 4,000m distance is more suitable than the other and as increase to 5500m or decrease to 3000m Suitability decrease [10].

7. Adequate land

Eventhough the land policy of Ethiopia the ouner of the land is government and the payment is for the goods on the land which is relatively chip when compared with others; there should be adequate land available for the station building, which is not only for proposed line but also for any future expansion. The proposed area shoul also be with out any religious building. The land area should be greater than 400mx200m [4].

8. Level area with good drainage

The proposed site should preferably be on a fairly level ground with good drainage arrangements. It should be possible to provide the maximum permisible gradient in the yard. As It is more labled its suitablity increase [4].

9. Alignment

The station site should preferably have stright alignment so that the various signal are clearely visible.the proximity of the station site to curve leads to operational problams. The allignment of track to both aproching and departing should be streat unless signals are dificult to sight or out of sight. Intermediate station, overtaking station and passing station should be set on the straight line. Under difficult condition, if the station needs to be set on the curve, in the section where design travelling speed of passenger train is 120km/h, the radius of curve generally shall not be less than 1200m and it shall not be less than 800m under difficult condition. Suitability increase with an increase curve radios starting from 800m [23].

10. Financial mobility around that area

There should be users/peoples who demmand the railway service around that place. Wether agricaltural, trade or other capital movevement also encarages for proposal of rail way station. Big indastries which demand raw materials or wich disribute there product for customer like sugar, cement and fertilizer factoris need service of railway and additionally natural resource location area have to be concidered well. The freight volume; Large freight yard (annual freight volume is 1.0Mt and above), Medium freight yard (0.3Mt～1.0Mt) ,Small freight yard (below 0.3Mt) and Dedicated passenger station should be set in the city with larger passenger flow[23]. (For example, Labu station set in Addis Ababa in the project is dedicated passenger station.

II. Constraint criteria and value setting

The most common method used to solve a MCE problem is a Boolean approach where all criteria and constraints are standardized to Boolean values 0 and 1. The value 0 is given to areas that should not be considered while those that should be considered are given the value

1. All of the continuous factors also have been effectively reduced to Boolean values. The following considerations for each factor have been expressed as a Boolean constraint [8].

1. Limitation Distance to the proposed cities

The rail station is to be located outside of the city - as the construction of an underground railway transportation system requires a huge amount of money. Also, administrative and environmental considerations do not allow locating the rail station in the city. CN&R 11-60-75 (Construction Norms and Rules) «Planning and building up cities, towns and village settlements. Norms of designing» claims that a rail station should be at least 350m from the city, for the future city extension and of course in order to provide a decrease of noise level in settlements [10].

2. Limitation Distance to Water bodies

According to CN&R “The protection and resources water conservation” as applied to planning rail station. Any construction like a rail station should provide protection of water storage from pollution. In order to avoid of this case and according rules of construction any constructions, buildings is preferred in distance 300m from water storage and 100m from rivers that are expressed as a suitable [10].

3. Limitation to Slope Gradient

The Boolean aggregation demands all criteria be standardized to the same values. Slope data was effectively reduced to these values, areas where the slope was between 2% to 15% were considered suitable [10].

4. Limitation to geological/seismic property of the land

As railway station is a place where the whole railway service takes place; these service needs different types of constructions which have to be safe and durable. For this the selected station geological/seismic nature of the land should be studied and defined whether safe or not [8].

5. Limitation of Adequate land for station

As we all know the Ethiopian land policy, the land owner is the government. For this, for the required land the government pay only for the visible goods on the land. But the land because of different factors may not be occupied large area. In order to select the appropriate site there should be adequate land available for the station building, which is not only for proposed line but also for any future expansion. The proposed area should also be without any religious building. The occupied area should be not less than 400mx200 m [4]

6**. Land use Constraints map**

Land use Constraint map is a combination of layers where the criteria given for Land cover, settlements and roads. The considered criteria as follows:

- The limitation for preventing the location a rail station on irrigated and forested areas. This is more important in the selection and construction of a rail station that causes damage and influence to agricultural and forest areas.
- As mentioned above CN&R 11-60-75 claims that in order to provide decreasing of noise level in settlements. The distance between railways stations and settlements Should be greater than 100m. So areas of land within 100m of settlements are considered as unsuitable.
- The areas for rail station closer to roads were considered more suitable than those that are distant. The location a rail station on roads is not allowed. For the Boolean analysis were reclassified a continuous image of distance from roads 30m that are suitable [10].

Finally, the Land use constraint map was derived according to Boolean method that has been aggregated from these layers where was given criteria each of them separately and as a result the constraints multiplied.

CHAPTER FOUR

DATA COLLECTION, PRESENTATION AND ANALYSIS

4.1 Introduction

Data collection is the main task of the researcher to select the right railway station of Addis Ababa-Dire Dawa network line and to evaluate the selected stations before. The required data collected by the method of interview and from document in Ethiopian Railways Corporation (erc) is listed below.

Datas for Constraint criteria and Factor criteria

I. Distance from the nearby cities (for both the advantage and its limitation)
II. Distance from Water bodies (both for protection from pollution and for usage)
III. Slope gradient of the site
IV. Geological /seismic property of the land
V. Adequate land for station (area)
VI. Proximity to Settlements
VII. Proximity to Roads
VIII. Proximity to Power Lines
IX. Proximity to Rail stations
X. Drainage access
XI. Alignment ;
XII. Financial mobility around that area (population density ,type of trade , industries , natural resources, agricultural product, cattles)
XIII. Land use Constraints map; the limitation for preventing the location a rail station on irrigated and forested areas.

These all data has collected for all cities through which the railway network passes from Sebbeta to Dire Dawa. These data arranged for those candidate cities to be compared with each other. The researcher collected the data from Sebbeta - Miesso project manager, Mieso – Dewenle project manager, Ethiopian railway corporation head office, researches done on Structural Geology-Tectonics and Rock Mechanics by [15], Ethiopia/Sebeta-Djibouti/Nagad Railway the hole Feasibility Study byEthiopian Railways Corporation [24], HV power supply arrangement to erc traction stations rivised report [25] and site visit. The presented data under the financial mobility is from the short term forecasting in the feasibility study.

A. Proposed railway stations of Ethiopia (Addis Ababa – Dire Dawa line)

According to Ethiopian Railways Corporation**:**

1. At preliminary stage, thirteen stations will be newly arranged for the entire line, which shall include one passenger station, nine intermediate stations and three passing stations. One transition station and seven stations will be respectively reserved for the short term and long term.
2. Eight stations will be arranged to deal with passenger transport business at preliminary stage, including Sebeta, Labu, Mojo, Adama, Awash, Mieso Bike and Dire Dawa.
3. Seven stations will be arranged to deal with freight transport business at preliminary stage, including Sebeta, Indode, Mojo, Adama, Mieso, Bike, And Dire Dawa .

Table 4.1 Addis Ababa /sebeta –Dire Dawa Railway Stations

No.	Name of the station	Station type
1	Sebeta	Intermediate station
2	Labu	Passenger transport station
3	Indode	Intermediate station
4	Modjo	Intermediate station
5	Adama	Intermediate station
6	Feto	Passing station
7	Metehara	Passing station
8	Awash	Intermediate station
9	Sirbakunkur	Passing station
10	Mieso	Intermediate station
11	Bike	Intermediate station
12	Dire Dawa	Intermediate station

4.2 Data Collection and Presentation

A. Region A

I. **Sebeta site**; Sebeta city is located West of Ethiopia which is the rout and starting point of Ethiopian railway from Addis Ababa. The newly proposed place for station is about 1km far from city, there are no water bodies to be polluted and water for consumption is expected to be extracted. The slope gradient is less than 5%, its geological / seismic property is safe and there is an adequate land for station, which is 1km far from the main road. Since Sebet A- II substation (power station) is located here in Sebeta which is supplied with 230kv and 1.4km far from station [25]. The next proposed station is about 15km far from Labu. There is drainage access, safe alignment with curve radius of greater than 1200, no forests and irrigated lands are damaged and influenced by the station. Sebeta is a place where many big Industries are available and there is a need for import of different materials as well need for their product for export and distribute their goods to country side and it is a junction where different railway joined from different corridor. The maximum number of passengers gathering at the station is 100 number of passengers in the waiting room at the same time,and 8×10^4t dispaching passenger volume in the initial stage. The total amount of goods delivery is 5×10^4t in the initial stage, 7×10^4t in the short term, 9×10^4t in the long term [24]. The sending amount of the freight is $4x10^4$ t and resieving amount is 14×10^4t

II. **Labu site ;** Labu is located 15 km east of sebeta and the newly proposed place for station here is 3km from city. The proposed station is far from any water bodies and water for consumption is expected to be extracted. The slope gradient is acceptable, its geological / seismic property is safe and there is an adequate land for station, which is 1km far from the main road. Here HV power is far away from site, so there is a problem with proximity, and needs 15km extension [25]. The next proposed station is about 17km s far from Indode. There is enough drainage access, safe alignment with curve radius of greater than 1200, no forests and irrigated lands are damaged and influenced by the station and it is convenient place for public transportation in addition to large population density to be conveyed in the direction of east and north. The maximum number of passengers gathering at the station is 500 in the initial stage and 3000 in the long term and According to Origin destination **(**OD) Results of Current Passenger Traffic between Towns along Corridor, about 11,697 persons/day will move from Labu to Kaliti [24] and $260x10^4$t dispatching passenger volume [24].

III. **Indode site;** It is located 32km east of sebeta and 17km from Labu and the newly proposed place for station here is 7km from city. Here the proposed station is almost on water well so that it pollutes the water and water for consumption is expected to be extracted. The slope gradient is acceptable, its geological / seismic property is safe and there is an adequate land for station which is 15km far from the main road. Since Akaki- II 400kvb sub station (power station) is located here in Akaki there is safe access power station proximity and supplied with 132kv 1.7km far from station [25]. The next proposed station is about 60km far from Modjo. It is safe with drainage access and alignment, but forests and irrigated lands are not safe because of the placement of the proposed station on irrigated and forested land. The station with maximum operating amount of freight transportation is Indode Station which serves the capital economic circle and transits goods to the western and southern Ethiopia. Its sending and receiving amount at the initial stage is 3.96 million tons, including 1.58 million tons of operating amount of freight yard; operating amount of freight transportation in the short term is 7.71 million tons, of which the traffic volume of freight yard is 3.08 million tons; the sending and receiving amount of cargo is 15.85 million tons in the long term, of which the traffic volume of freight yard is 6.34 million tons. And freight flow density of Indode – Adama section is 530*10^4t in the west direction and 190*10^4t in the east direction [24].

Table 4.2 Gap Analysis in Region A

No.	Criteria	Required value	Sebeta	Labu	Indode
1	Financial mobility	High popn. density and >1M ton freight	4×10^4t SF& 14x10^4t RF 100pp, SP,RP	11,697 persons/day SP&RP	7.71mt 190x10^4tSF&530x10^4t RF
2	Proximity to nearby city and Settlements	500-3km for city >100m for settlement	1km	3km	7km
3	Adequate land	>200m*400m	available	available	available
4	Alignment	Curve R>1200m	R>1200m	R>1200m	R>1200m
5	Slope Gradient	In between 1and15%	5%	6%	5%
6	Proximity to Roads	Max.500m&min 30m	1km	1km	15km
7	Drainage access	availability	Available	Available	Available
8	Proximity to stations	>3000m	15km	17km	30km
9	Proximity to Water bodies	150-1000m	>200m	>200m	On water
10	Proximity to Power Lines	Nearly availability	1.4km	>15km	1.7km

B. Region B

I. **Galan site;** It is located east of Akaki. There are no water bodies to be polluted and water for consumption is expected to be extracted. The slope gradient is acceptable, its geological / seismic property is safe and there is an adequate land for station which is 15km far from the main road. Since Akaki- II 400kvb sub station is located here in Akaki. There is no problem with power station proximity and supplied with 132kv extension can be done easily from Akaki station. There is drainage access, safe with alignment, the sites are far from forests and irrigated lands and influenced by the station. There is a low financial movement and traffic volume as compared to expected criteria and neighbourhood city.

II. **Bishoftu site;** Bishoftu is located between Modjo and Galan and 30km from both Indode and Modjo. The newly proposed place for station here is 3km from city. The proposed station is far enough from water bodies and water for consumption is expected to be extracted. The slope gradient is acceptable, its geological / seismic property is safe and there is an adequate land for station which is far from the main road. Here there is no much problem with HV power proximity, needs simple extension [25]. This Bishoftu site has god drainage access, alignment is good with curve radius of greater than 1200m, it is far enough from forests and irrigated lands so that they are not damaged and influenced by the station and it is convenient place for public transportation in addition to large population density to be conveyed in the direction of east and north because it is centre of tourism and the line is double track. According to Origin destination (OD) Results of Current Passenger Traffic between Towns along Corridor about 5,903 persons/day will move from Kaliti to Bishoftu, And 4683 persons/day to Adama [24]. The maximum number of passengers gathering at the station is 100 number of passengers in the waiting room at the same time,and 8×10^4t dispatching passengers volume in the initial stage.

III. **Modjo site;** is located between Bishoftu and Adama and 60km from indode to the east. The newly proposed place for station here is 2km from city. There are no water bodies to be polluted and water for consumption is expected to be extracted. The slope gradient is acceptable, its geological / seismic property is safe and there is an adequate land for station but it is located inside the city and is 2km far from the main road. Here there is no much problem with HV power proximity, needs simple extension [25]. There is drainage access, safe alignment with curve radius of greater than 1200m, no forests and irrigated lands are damaged and influenced by the station, and it is convenient place for passenger and freight transportation. The maximum number of passengers gathering at the station is 200 number of passengers in the waiting room at the same time,and 8×10^4t dispaching passanger volume in the initial stage and the total amount of goods delivery is 12×10^4t in the initial stage, 30×10^4t in the near term, 57×10^4t in the long term, In addition to its service as a dry port for the Djibouti and Moyale line,$14x10^4$t sending and $28x10^4$t receiving freight will be expected from Modjo [24].

Table 4.3 Gap Analysis in Region B

No.	Criteria	Required value	Gelan	Bishoftu	Modjo
1	Financial mobility	High popn. density and >1M ton freight	<50pp SP, RP&<<.3mt frt SF,RF	5,903 p/day receiving &4,683p/day sending	14×104t sending $28x10^4$t receiving $200pp\&8x10^4$p Dispatchingvolume
2	Proximity to nearby city and Settlements	500-3km for city >100m for settlement	>5km	3km	Middle of the city
3	Adequate land	>200*400m	available	available	available
4	Alignment	Curve R>1200m	R>1200m	R>1200m	R>1200m
5	Slope Gradient	In between 1 and 15%	5%	6%	5%
6	Proximity to Roads	Max.500m&min 30m	15km	>3km	2km
7	Drainage access	Availability	Available	Available	Available
8	Proximity to stations	>3000m	15km	17km	23km
9	Proximity to Water bodies	150-1000m	>200m	>200m	>200m
10	Proximity to Power Lines	Availability	Available	Available	Available

C. Region C

I. Adama Site: Adama city is located east of Modjo 23km away. The newly proposed place for station is about the middle of city which may disturb the people around there. There are no water bodies to be polluted and water for consumption is expected to be extracted. The slope gradient is acceptable, its geological / seismic property is safe and there is an adequate land for station which is 2.5km far from the main road. There is no problem with power station proximity and supplied with 230kv 1.4km far from station [25]. The next proposed station is about 27km far in the east. There is drainage access, safe alignment with curve radius of greater than 1200, no forests and irrigated lands are damaged and influenced by the station. Adama is a place where many big industries are available and it is convenient place for public transportation in addition to large population density to be conveyed in different direction. Freight flow density of Adama – Awash section is $439*10^4$ t in the west direction and $136*10^4$t in the east direction and According to Origin destination(OD) Results of Current Passenger Traffic between Towns along Corridor about 4,683 persons/day will move from Bishoftu to Adama , 883 person/day Adama to Awash [24].

II. **Merebe Site;** Merebe is located east of Adama. The newly proposed place for station is away from city. There are no water bodies to be polluted and water for consumption is expected to be extracted. The slope gradient is acceptable, its geological / seismic property is safe and there is an adequate land for station which is far from the main road. There is an access of power station which can be utilized by extension. There is drainage access, safe alignment with curve radius of greater than 1200, no forests and irrigated lands are damaged and influenced by the station. There is a low financial movement and traffic volume as compared to expected criteria and neighbourhood city.

III. **Feto site;** Feto is a place in the middle of Mereb and Senga beret cities. The newly proposed place for station is away from city. There are no water bodies to be polluted and water for consumption is expected to be extracted. The slope gradient is acceptable, its geological / seismic property is safe and there is an adequate land for station which is far from the main road. There is an access of power station which can be utilized by extension. There is drainage access, safe alignment with curve radius of greater than 1200, no forests and irrigated lands are damaged and influenced by the station. There is a low financial movement and traffic volume as compared to expected criteria and neighbourhood city.

Table 4.4 Gap Analysis in Region C

No.	Criteria	Required value	Adama	Mereb	Feto
1	Financial mobility	High popn. density and >1M ton freight	4,683p/day,156x10^4t dispatching pass.vol & 439x10^4 t ;11x10^4t Sending,31x10^4t receiving freight	<60pp SP,RP & <<.1mt frt SF,RF	<55pp SP,RP & <<.2mt frt SF,RF
2	Proximity to nearby city and Settlements	500-3km for city >100m for settlement	In the Middle of the city	>4000m	>4000m
3	Adequate land	>200*400m	available	available	available
4	Alignment	Curve R>1200m	R>1200m	R>1200m	R>1200m
5	Slope Gradient	In between 1 and 15%	Acceptable	Acceptabl e	Acceptable
6	Proximity to Roads	Max.500m&min 30m	2.5km	3.5km	4km
7	Drainage access	availability	No access	Available	Available
8	Proximity to stations	>3km	23km	27km	23km
9	Proximity to Water bodies	150-1000m	>200m	>200m	>200m

10	Proximity to Power Lines	Availability	Nearly available	Available	N.Available

D. Region D

I. **Metahara site;** Metahara city is located east of Adama 107km away. The newly proposed place for station is about 1km away from Metahara city. There are no water bodies to be polluted and water for consumption is expected to be extracted. The slope gradient is acceptable, but its geological / seismic property is not safe. The extension of Lake Beseka results with flooding and salinity of Abadir farmland and endangering of the routes (road and railway) from Addis Ababa to Djibouti. The expansion of Lake Beseka has necessitated the raising of the level of the road and railway line repeatedly [15] and the land of the station is 1km from main road. There is power station near the city [25]. The next proposed awash station is about 40km far to the east. There is drainage access, safe alignment with curve radius of greater than 1200, no forests and irrigated lands are damaged and influenced by the station. Metahara is a place where big industry like Metahara sugar factory and different agricultural products are available and it is convenient place for public transportation. The maximum number of passengers gathering at the station is 100 number of passengers in the waiting room at the same time and there is $14x10^4$t freight flow.

II. **Awash site;** Awash is located 40 km east of Metahra and the newly proposed place for station here is 4km from city. There are no water bodies to be polluted and water for consumption is expected to be extracted. The slope gradient is acceptable, its geological / seismic property is safe and there is an adequate land for station which is 1.5km far from the main road. Here there is no problem with HV power proximity [25]. The next proposed Sirbekunkur station is about 30km far from Awash to the east. There is drainage access, safe alignment with curve radius of greater than 1200, no forests and irrigated lands are damaged and influenced by the station, and it is convenient place for public transportation in addition to large population density to be conveyed in the direction of east, to Addis Ababa, north and it is a railway junction. And freight flow density of Awash – Dirre Dawa section is $456*10^4$ t in the west direction and $144*10^4$t in the east direction, According to Origin destination(OD) Results of Current Passenger Traffic between Towns along Corridor about 839 persons/day will move from Adama to Awash and 461 person/day Awash -Mieso [24].

III. **Bordede site;** Bordede is located east of Awash. There are no water bodies to be polluted and water for consumption is expected to be extracted. The slope gradient is acceptable, its geological / seismic property is safe and there is an adequate land for station which is 1km far from the main road. Here there is problem with HV power proximity, so needs extension.

There is drainage access, safe alignment with curve radius of greater than 1200, no forests and irrigated lands are damaged and influenced by the station. Even though there are different agricultural products including chat to be transported, there is a low financial movement and traffic volume as compared to expected criteria and neighbourhood city.

Table 4.5 Gap Analysis in Region D

No.	Criteria	Required value	Metahra	Awash	Bordede
1	Financial mobility	High popn. density and >1M ton freight	Factory&agricultural products available 100p/t&14x10^{4}t freight available SP,RP&SF,RF	456*10^4 t receiving,144 *10^{4}t sending freight and 461peop sending, 839 people recei.	<70pp SP,RP & <<.4mt frt SF,RF
2	Proximity to nearby city and Settlements	500-3km for city >100m for settlement	1km	4km	4km
3	Adequate land	>200*400m	available	available	available
4	Alignment	Curve R>1200m	R>1200m	R>1200m	R>1200m
5	Slope Gradient	In between 1 and 15%	Acceptable	Acceptable	Acceptabl e
6	Proximity to Roads	Max.500m&min 30m	1km	1.5km	1km
7	Drainage access	availability	Available	Available	Available
8	Proximity to stations	>3km	40km	20km	15km
9	Proximity to Water bodies	150-1000m	>200m	>200m	>200m
10	Proximity to Power Lines	Availability	Nearly available	N.Available	15km

E. Region E

I. Sirbakunkur site; this station shares the borders of mieso wereda and gubakoricha wereda and is located between Bordode and Asebot, and 30km away from Awash. The newly proposed place for station here is 2km from town/settlement. There are no water bodies to be polluted and water for consumption is expected to be extracted. The slope gradient is acceptable; its geological / seismic property is safe and there is an adequate land for station and is 7km far from the main road. Here there is high problem with HV power proximity and needs extension [25]. There is drainage access, safe alignment with curve radius of greater than 1200, no irrigated lands are damaged and influenced by the station but it is proposed in the middle of forests. Even though there are different agricultural products including chat to be transported, there is a low financial movement and traffic volume as compared to expected criteria and neighbourhood city.

II. **Asebot site;** this station is located between Sirbakunkur and Mieso. The newly proposed place for station here is 2km from town/settlement .there is no water bodies to be polluted and water for consumption is expected to be extracted. The slope gradient is acceptable; its geological / seismic property is safe and there is an adequate land for station and is 4km far from the main road. Here there is high problem with HV power proximity and needs extension [25]. There is drainage access, safe alignment with curve radius of greater than 1200. No forests and irrigated lands are damaged and influenced by the station. There is a low financial movement and traffic volume as compared to expected criteria and neighbourhood city.

III. **Mieso site;** Mieso is located in between Asebot and Mulu 50 km east of Sirbakunkur and the newly proposed place for station here is 1.5km from city. There are no water bodies to be polluted and water for consumption is expected to be extracted. The slope gradient is acceptable, its geological / seismic property is safe and there is an adequate land for station which is 500m far from the main road. Here there is no problem with HV power proximity [25]. Drainage access and alignments are safe, forests and irrigated lands are not influenced by the station. It is convenient place for public transportation in addition to large population density to be conveyed in the direction of east and to Addis Ababa. There are many cattles and camels for export. It is also centre of transportation for all west Harerghe zone. In this zone there are different agricultural products like onion, chat, been, sorghum and others which controls the economic activity of the area. According to Origin destination (OD) results of Current Passenger traffic between towns along corridor about 461persons/day will move from Awash to Mieso and $7x10^4$t sending, $14x10^4$t receiving freight flaw is available [24].

Table 4.6 Gap Analysis in Region E

No.	Criteria	Required value	Sirbakunkur	Asebot	Mieso
1	Financial mobility	High popn. density and >1M ton freight	<50pp SP,RP & <<.2mt frt	<50pp SP,RP & <<.3mt frt	461p/day $7x10^4$t send &$14x10^4$t recieving frt

			SF,RF	SF,RF	
2	Proximity to nearby city and Settlements	500-3km for city >100m for settlement	2km from settlement	2km	1.5km
3	Adequate land	>200*400m	available	available	available
4	Alignment	Curve R>1200m	R>1200m	R>1200m	R>1200m
5	Slope Gradient	In between 1 and 15%	Acceptable	Acceptable	Acceptable
6	Proximity to Roads	Max.500m&min 30m	7km	4km	500m
7	Drainage access	Availability	Available	Available	Available
8	Proximity to stations	>3km	20km	30km	23km
9	Proximity to Water bodies	150-1000m	>200m	>200m	>200m
10	Proximity to Power Lines	Availability	unavailable	unavailable	Available

F. Region F

I. **Mulu site;** Mulu is a town in eastern Ethiopia, located in the MirabHararghe Zone of the Oromia Region 20km to the east of Mieso. It is one of six towns in Mieso woreda. Mulu is served by a railway on the Addis Ababa-Djibouti railroad. Here there are no water bodies to be polluted and water for consumption is expected to be extracted. The slope gradient is acceptable, its geological / seismic property is safe and there is an adequate land for station which is 1km far from the main road. Here there is high problem with HV power proximity and needs extension. There is drainage access, safe alignment with curve radius of greater than 1200. No forests and irrigated lands are damaged and influenced by the station. There is a low financial movement and traffic volume as compared to expected criteria and neighbourhood city.

II. **Afdem site**; Afdem is a town is east central Ethiopia. Located in the Shinile Zone of the Somali Region 40km far from Mieso to the east. It is the administrative center of Afdem woreda. It sprawls on a wide basin surrounded by granitic mountains on all sides. Afdem lies at the base of its namesake Mount Afdem, a volcanic cone with a denuded caldera. Afdem is served by a railway station on the Addis Ababa - Djibouti Railway. There is no water body to be polluted and water for consumption is expected to be extracted. The slope gradient is acceptable; there is an adequate land for station which is 1km far from the main road. Here there is high problem with HV power proximity and needs extension. There is drainage access, safe alignment with curve radius of greater than 1200. No forests and irrigated lands are damaged and influenced by the station. There is a low financial movement and traffic volume as compared to expected criteria and neighbourhood city.

III. **Bike site;** Bike is a town in central Ethiopia. Located in the Shinile Zone of the Somali Region 48 km to the east of Mieso. The territory is flat and vegetation is ordinarily developed. There are major roads nearby connecting to the station, so the traffic is convenient. The maximum number of passengers at the station is 50. The total volume of freight dispatched and received at the station is 11×10^4t in the short term and 15×10^4t in the long term it is convenient place for public transportation in addition to large population density to be conveyed in the direction of east, to Addis Ababa [24], and there are many cattles and camels for export. There are no water bodies to be polluted and water for consumption is expected to be extracted. Its geological / seismic property is safe and there is an adequate land for station which is 1km far from the main road. Here there is problem with HV power proximity, so needs extension [25]. There is drainage access, safe alignment with curve radius of greater than 1200. No forests and irrigated lands are damaged and influenced by the station.

Table 4.7 Gap Analysis in Region F

No.	Criteria	Required value	Mulu	Afdem	Bike
1	Financial mobility	High popn. density and >1M ton freight	<24pp SP,RP & <<.06mt frt SF,RF	<35pp SP,RP & <<.045mt frt SF,RF	11×10^4t 50pp SP,RP&SF, RF
2	Proximity to nearby city and Settlements	500-3km for city >100m for settlement	2km	1.5km	1km
3	Adequate land	>200*400m	available	available	available
4	Alignment	Curve R>1200m	R>1200m	R>1200m	R>1200m
5	Slope Gradient	In between 1 and 15%	Acceptable	Acceptable	Acceptable
6	Proximity to Roads	Max.500m&min 30m	1km	1km	1km
7	Drainage access	availability	Available	Available	Available
8	Proximity to stations	>3km	20km	20km	8km

9	Proximity to Water bodies	150-1000m	>200m	>200m	>200m
10	Proximity to Power Lines	Availability	>10km	5km	8km

G. Region G

I. **Erer site;** Erer is a town in central Ethiopia, Located in the Shinile Zone of the Somali Region 35km far from Bike. It is the administrative centre of Erer woreda and Erer is served by railway on the Addis Ababa - Djibouti Railway. There are no water bodies to be polluted and water for consumption is expected to be extracted. The slope gradient is acceptable, its geological / seismic property is safe and there is an adequate land for station which is 1km far from the main road. Here there is problem with HV power proximity, so needs extension. There is drainage access, safe alignment with curve radius of greater than 1200. No forests and irrigated lands are damaged and influenced by the station. Here in this woreda there are high agricultural product specially fruits and there are money peoples visiting this city daily from Djibouti and different directions inside the country because of the hot water massage (tsebel) located there, but there is a low financial movement and traffic volume as compared to expected criteria and neighbourhood city.

II. **Hurso site;** Hurso is a town in eastern Ethiopia. Located in the Shinile Zone of the Somali Region 37km far from Erer. It is one of four towns in Erer woreda. Hurso is served by a station on the Addis Ababa - Djibouti Railway South of the town is Camp Hurso. There are no water bodies to be polluted and water for consumption is expected to be extracted. The slope gradient is acceptable, its geological / seismic property is safe and there is an adequate land for station which is 1km far from the main road. Here there is problem with HV power proximity, so needs extension. There is a drainage access and alignments are also safe, forests and irrigated lands are not influenced by the placement of railway station. There is a low financial movement and traffic volume in the area.

III. **Dirre Dawa site**; DirreDawa is one of two chartered cities (astedader akabibi) in Ethiopia (the other being the capital, Addis Ababa). Dire Dawa lies in the eastern part of the nation, on the Dechatu River, at the foot of a ring of cliffs that has been described as "somewhat like a cluster of tea-leaves in the bottom of a slop-basin 467km from Sebeta and 7.1km from Hurso in the east direction. The city is an industrial centre, home to several markets and the Aba Tenna DejazmachYilma International Airport. Haramaya University is 40 km away. The station lies northwest of Dire Dawa city and north of Melka town, about 10km away from the city. In the station area, the terrain is flat and vegetation is ordinarily developed. There are major roads nearby connecting to the station, so the traffic is convenient. The maximum number of passengers at the station is 100 per day. The total volume of freight dispatched and received at the station is 11×10^4t in the preliminary stage, 37×10^4t in the short term and 48×10^4t in the long term [24]. There are no water bodies to be polluted and water for consumption is expected to be extracted. Its geological / seismic property is safe and there is an adequate land for the station. Here there is no problem with HV power proximity [25]. There is a drainage access and alignments are also safe, forests and irrigated lands are not influenced by the placement of railway station.

Table 4.8 Gap Analysis in Region G

No.	Criteria	Required value	Erer	Hurso	Dirre Dawa
1	Financial mobility	High popn. density and >1M ton freight	<60pp SP,RP & <<.08mt frt SF,RF	<19pp SP,RP & <<.01mt frt SF,RF	37×10^4t& 100 pP 18×10^4t send. 21×10^4t recei.& 12×10^4passenger dispatching vol.
2	Proximity to nearby city and Settlements	500-3km for city >100m for settlement	1km	3km	10km
3	Adequate land	>200*400m	available	available	available
4	Alignment	Curve R>1200m	R>1200m	R>1200m	R>1200m
5	Slope Gradient	In between 1 and 15%	Acceptable	Acceptable	Acceptable
6	Proximity to Roads	Max.500m&min 30m	1km	1km	100m
7	Drainage access	availability	Available	Available	Available
8	Proximity to stations	>3km	35km	37km	7.1km
9	Proximity to Water bodies	150-1000m	>200m	>200m	>200m
10	Proximity to Power Lines	Availability	Near to gota	N.available	N.available

4.3 Data Interpretation and Mathematical Analysis

The data analysis was done by verifying the constraint and factor creterias with its value setting for the specific criteria**.**

I. Constraint criteria and its value setting

Table 4.9 Constraint Criteria and its Value Setting [8]

No.	Criteria	Setting(0= forbiddance; 1=allowance)
1	Distance from the city	1 in between 350m and 3,000m and 0 for <350or >3000m
2	Distance from water body	1 for> 300m from well and >100m from river and 0 for below

3	Slop gradient	1, where the slope is between 2% and 15% were and 0 for above
4	Geological/seismic property	1 for safe one and 0 for unsafe geology
5	Availability of adequate land	1 for area > 400mx200m and 0 for below
6	Land use constraints	1 for not interfering in irrigated, forested, settlement and closeness to the road <30m and 0 for others.

II. Factor Criteria and its value setting

The value for factor criteria sated according to its convenience from value of 1 to 10.

Table 4.10 Factor Criteria and its Value Setting [8]

No.	**criteria**	**Value setting (0 to 10)**
1	Proximity to nearby city and Settlements	For the distance between 500m and 3,000m; 500m is more preferable so 10 is convenient and sated accordingly up to 3,000m which is lowest in preferably
2	Slope Gradient	2% to 5% is high in suitability. suitability decrease for high slope of 15%
3	Proximity to Roads	Suitability is high for 30m and decrease suitability above 500m
4	Proximity to Water bodies	Suitability is high at 150m and decrease suitability up to 1000m, and suitability highly decrease below and above these numbers
5	Proximity to Power Lines	Suitability for this is high in the interval of 1.5km to 3km. the first one is more suitable and decrease for higher km.
6	Proximity to other Rail stations	Internationally stations have to be from 3000m to 5500m from each other. But according to our country it is better to its suitability start from 5500m
7	Adequate land	The station having area of 400mx200m and above increase suitability
8	Level area with good drainage	More labelled area is more suitable and increase with its suitability as it is more labelled
9	Allignment	As the land is more strata the whole line including entrance and exit of train it is more suitable and weights high.
10	Financial mobility	For high population density, import and export, types of trade available and

	around that area	industries around there, And >1M ton freight scores high value.

Nb: Criteria 10(Financial mobility around that area) is considered individually for freight and passenger station in the region. Therefore one station can be freight station, passenger station or both, so in the specified region there may be one station (intermediate station or holding passenger station and freight station), there may be two stations at different sites in the region (passenger station in one site and freight station in the other site) or only one station in the region (either passenger station or freight station) because of criteria fulfilment and suitability.

4.3.1 Computation of the Criterion Weights

A simple method for this is known as averaging over normalized columns, that involves the following steps,which was proposed by Saaty (1980). Those steps are: I) calculate the sum of the values in each column of the pairwise comparison matrix; II) divide each element in the matrix by its column sum; The result of this computation is referred to as the normalized pairwise comparison matrix and is an estimate of the eigenvalues of the matrix; III) compute the average of the elements in each row of the normalized matrix, that is, divide the sum by the number of factors/criteria in this case by 10. These averages provide an estimate of the relative weights of the factors/criteria being compared (Table 4.10). From the eigenvalues of the comparison matrix we can see the criterion weights in percents where total importance must equal 100%. The detail analysis is showei in Appendix A;

Dividing each element in the matrix by its column sum is the next step ; The result of this computation is referred to as the normalized pairwise comparison matrix and is an estimate of the eigenvalues of the matrix. Appendix B shows this normalized pairwise comparison matrix.

Notice: the weight is calculated by computing the average of the elements in each row of the normalized matrix i.e, dividing the sum by the number of factors/criteria in this case by 10. These averages provide an estimate of the relative weights of the factors/criteria being compared.

For instance let us see the first criteria weight

Weight for financial mobility (w)=

(0.2770+0.3565+0.2000+0.2600+0.2253+0.2000+0.2560+0.3260+0.1690+0.1667)/10=0.244

Likewise we can compute the other criterias and will get the result in Apendix B one to the last columen.

From this analysis we got the determining roles of each criteria among others which is called the weight of the criteria. Table 4.11 shows these weight values in percentage form.

Table 4.11 Criteria weight and Determining Position

No.	Factor criteria	Determining Weight	Determining % of criteria
1	Financial mobility around that area	0.244	24.4
2	Proximity to nearby city and Settlements	0.19	19
3	Adequate land	0.18	18
4	Alignment	0.1	10
5	Slope Gradient	0.095	9.5
6	Proximity to Roads	0.06	6
7	Level area with good drainage	0.043	4.3
8	Proximity to other Rail stations	0.034	3.4
9	Proximity to Water bodies	0.032	3.2
10	Proximity to Power Lines	0.022	2.2

4.3.2 Estimation of the Consistency Ratio

When many pairwise comparisons are performed, some inconsistencies may typically arise. One example is the following. Assume that 3 criteria are considered, and the decision maker evaluates that the first criterion is slightly more important than the second criterion, while the second criterion is slightly more important than the third criterion. An evident inconsistency arises if the decision maker evaluates by mistake that the third criterion is equally or more important than the first criterion. On the other hand, a slight inconsistency arises if the decision maker evaluates that the first criterion is also slightly more important than the third criterion. A consistent evaluation would be, for instance, that the first criterion is more important than the third criterion.

The AHP incorporates an effective technique for checking the consistency of the evaluations made by the decision maker when building each of the pairwise comparison matrices involved in the table [13].

It involves the following steps:

I) determine the weighted sum vector by multiplying the weights for their corresponding values of the original pairwise comparison matrix, sum values over the rows;

II) determine the consistency vector by dividing the weighted sum vector by the criterion weights determined previously (Appendix C).

(2.564/0.244=10.5, 2.072/0.19=10.9, 0.4754/0.043=11.05, 1.05/0.1=10.5, 0.632/0.06=10.533, 0.3558/0.034=10.46, 0.9866/0.095=10.38, 1.727/0.18=9.6, 0.3779/0.032=11.4, 0.18/0.22=8.2)

After successful calculation of the consistency vector, we need to compute values for lambda (λ) and the consistency index (CI). The value for lambda is simply the average of the consistency vector:

λ = (10.5+10.9+11.05+10.5+10.533+10.46+10.38+9.6+11.4+8.2)/10 = 10.35

The calculation of CI is based on the observation that λ is always greater than or equal to the number of criteria under consideration (n) for positive, reciprocal matrixes, and λ = n if the pairwise comparison matrix is a consistent matrix. Accordingly, λ – n can be considered as a measure of the degree of inconsistency and can be normalized as:

CI = (λ – n) / (n - 1) = (10.35 - 10) / (10 - 1) = 0.35/9=0.039

CI provides a measure of departure from consistency, and the calculation of the consistency ratio (CR), which is defined as follows:

CR = CI / RI

Where, RI is the random consistance index, the consistency index of randomly generated pairwisecomparison matrix. The RI depends on the number of elements being compared.If the value of Consistency Ratio is smaller or equal to 10%, the inconsistency is acceptable. If the Consistency Ratio is greater than 10%, we need to revise the subjective judgment.

Table 4.12 Randem Consistance Index (RI) [22]

n	1	2	3	4	5	6	7	8	9	10
Ri	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Where n is the number of criteria and Ri consistance index

For this case since n=10 , Ri is 1.49

CR = CI / RI = 0.039 / 1.59 = 0.0244=2.44%<10% .Thus, the above selection and evaluation of railway station is consistent.

4.3.3 Analysis of Each Site in the Region by Site Value and Criteria Weight

Detail analysis of the site discussed in here leads us to select the right freight and passenger station and model development. In the next section analysis of each region is discussed with model development. The site with high value is selected both for passenger and freight station. The value of the sites in the entire region, criteria 1(Financial mobility around that area) is given in the way x/y; where x stands for freight and y stands for passenger value.

1. Region A

Here in this region we need to consider that the line is double truck from Sebeta to Adama. Because of this the traffic volume of the region is high; So in the region more than one station is selected as a result of the required criteria fulfilled in the region.

Table 4.13 Factor Criteria Weight and Values of Region A

No	Factor criteria	Criteria wt.	Sebeta site		Labu site		Indode site	
			Value	Val*wt	Value	Val*wt	Value	Val*wt
1	Financial mobility around that area	0.244	10/3	2.44/.73	2/10	.48/2.44	10/4	2.44/.97
2	Proximity to nearby city and Settlements	0.19	10	1.9	9	1.71	3	0.57
3	Adequate land	0.18	10	1.8	10	1.8	10	1.8
4	Alignment	0.1	10	1	10	1	10	1
5	Slope Gradient	0.095	10	0.95	10	0.95	10	0.95
6	Proximity to Roads	0.06	8	0.48	10	0.6	2	0.12
7	Level area with good drainage	0.043	9	0.387	10	0.43	10	0.43
8	Proximity to other Rail stations	0.034	10	0.34	10	0.34	10	0.34
9	Proximity to Water bodies	0.032	7	0.224	7	0.224	1	0.032
10	Proximity to Power Lines	0.022	10	0.22	10	0.22	10	0.22
	$S = \Sigma$ wi fi	1	9.741/8		7.75/9.714		8/6.43	

Table 4.14 Constraint Criteria and Values of Sites in Region A

No.	Constraint Criteria	Sebeta site	Labu site	Indode site
1	Distance from the city	1	1	1
2	Distance from water body	1	1	0
3	Slop gradient	1	1	1
4	Geological/seismic property	1	1	1
5	Availability of adequate land	1	1	1
6	Land use constraints	1	1	0
	C= C1*C2*…*Cn	1	1	0

Sebeta site ; For passenger S*C=8*1=8and for fright S= 9.741, c=1 then s*c=9.741*1=9.741

Labu site; for passengr;s=9.714,c=1then s*c=9.714*1=9.714 and for freig s*c=7.75*1=7.75

Indode site; for passenger; s= 6.43,c=0 then S*C= 6.43*0=0 and for freight 8*0=0

Here for Indode site c=0 because the proposed station is very close to the water well that cause pollution on the water. But The station with maximum operating amount of freight transportation is Indode Station which serves the capital economic circle. There for searching other option is required. This option is to choose the railway station away from the water well inorder to stay the indode site in compitation with other sites. Choosing other site for station Distance from water body in the Constraint criteria will be seted to be 1.

So that S*C= 6.43*1=06.43 for passenger and 8*1=8 for freight

As the analysis above indicates Labu site is suitable for passenger station from the rest sites in the region with higher value of 9.714, Sebeta site is suitable for freight station with high value of 9.74 and for passenger station next to Labu Site with the second higher value of 8 in the region. Indode site is the other site which needs station because of its highest freight volume with suitability value of 8. This can be shown graphically below.

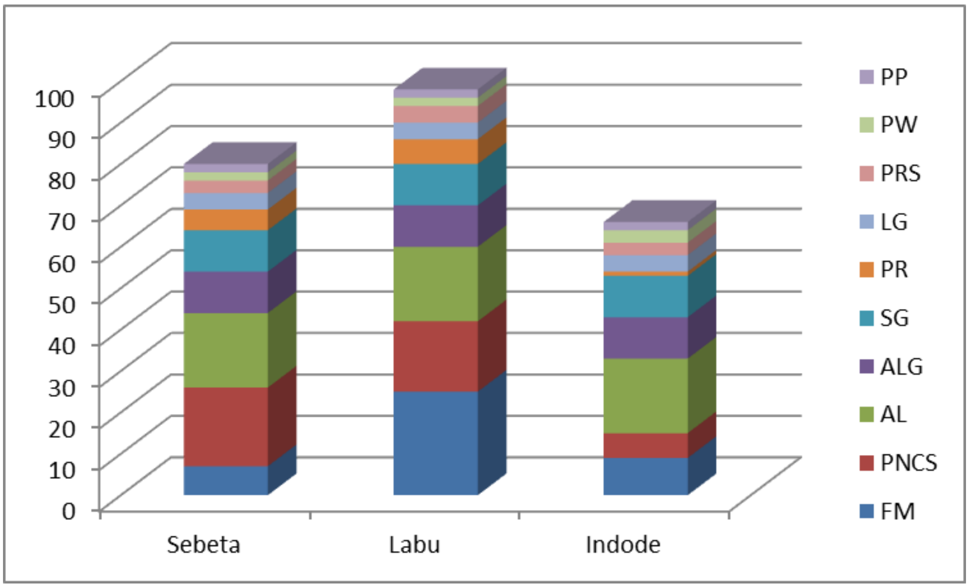


Figure 4.1 Results of the Analysis for Passenger Station in Region *A*

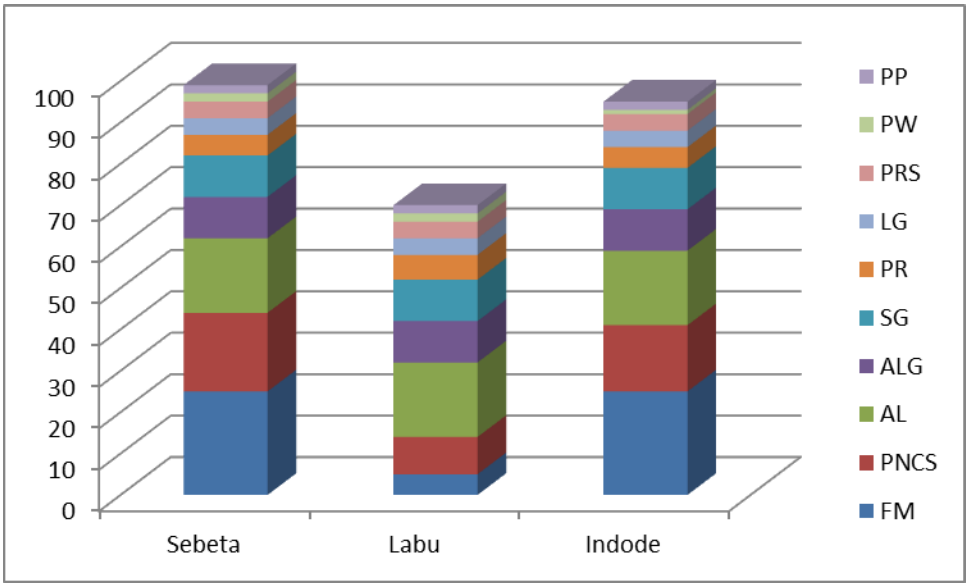


Figure 4.2 Results of the Analysis for Freight Station in Region A

❖ Conclusion for region A

Indode site as stated above, c=0 because the proposed station is very close to the water well that cause pollution on the water and damage irrigated Land. This place is proposed by ERC to be freight station. Acording to this analysis it is not suitable for station. But The station with maximum operating amount of freight transportation is Indode Station which serves the capital economic circle. There for searching other option is required. This option is to choose the railway station away from the water well inorder to stay the indode site in compitation with other sites. Choosing other site for station far from water body in the Constraint criteria will be sated to be 1.So that S*C= 6.43*1=06.43 for passenger and 8*1=8 for freight. Since Sebeta to Adama line is double truck line the trafic volume is high and more than one stations can be selected in the region. Therefore from mathematical analysis and graph above Sebeta site and Indode site is suitable for freight station and Labu Site and Sebeta is suitable for passenger station changing the current Indode site to another suitable place. According to this evaluation the previously proposed statations by ERC, the Indode intermediate station in the region is not located at the right place and there is not enough passenger to assigne this site as passenger station. The major difference betwen the finding of this paper with previously proposed station by ERC in the region is therefore Indode site. The first difference is that, as of this finding by now Indode site cannot have enough passenger to be passenger station as per the data available. Therefore it is only freight station. The second difference here is that, Indode site is not located at the right place which means that, it is not located at suitable area because of four major reasons. These are, it is located 7km far away from city, it is 15km far away from main road, it is placed on water well and on irrigated land. From this finding this researcher strongly believe that, Indode site is suitable and capable for freight station only and its current position has to be changed to fulfill the four un fulfilled criteria and placed in suitable area.

2. Region B

Table 4.15 Factor Criteria Weight and Values of Region B

No	Factor criteria	Criteria wt.	Gelan		Bishoftu		Modjo	
			Value	Val*wt	Value	Val*wt	Value	Val*wt
1	Financial mobility around that area	0.244	4/4	.976/.976	3/9	.73/2.196	10/8	2.44/1.95
2	Proximity to nearby city and Settlements	0.19	8	1.52	10	1.9	5	.95
3	Adequate land	0.18	10	1.8	10	1.8	9	1.8
4	Alignment	0.1	9	.9	10	1	10	1
5	Slope Gradient	0.095	9	.855	9	.855	10	.95
6	Proximity to Roads	0.06	5	.3	9	.54	7	.42
7	Level area with good drainage	0.043	10	.43	10	.43	10	.43
8	Proximity to other Rail stations	0.034	10	.34	10	.34	10	.34

9	Proximity to Water bodies	0.032	7	.224	8	.256	8	.256
10	Proximity to Power Lines	0.022	8	.176	9	.198	9	.198
	S = Σ wi fi	1	7.52/8		8/9.5		8.8/8.3	

Table 4.16 Constraint Criteria and Values of Sites in Region B

No.	Constraint Criteria	Gelan	Bishoftu	Modjo
1	Distance from the city	1	1	1*
2	Distance from water body	1	1	1
3	Slop gradient	1	1	1
4	Geological/seismic property	1	1	1
5	Availability of adequate land	1	1	1
6	Land use constraints	1	1	1
	C= C1*C2*…*Cn	1	1	1*

NB:"*" shows; the site needs improvement

Gelan Site: for Freight, s=7.52, c=1 then S*C=7.52 and for passenger, s=8, c=1 then S*C=8

Bishoftu site: for freight, s=8, c=1 then S*C=8 and for passenger s=9.5, c=1then S*C=9.5

Modjo site; for freight s=8.8, c=1* then s*c=8.8* and for passenger s=8.3, c=1* then s*c=8.3

As the analysis above indicates Bishoftu site is suitable for passenger station from the rest sites in the region with higher value of 9.5 and Modjo site is the second suitable site for passenger with a value of 8.3. in addition to its suitability for freight station with high value of 8.8 . The graph below shows this fact clearly

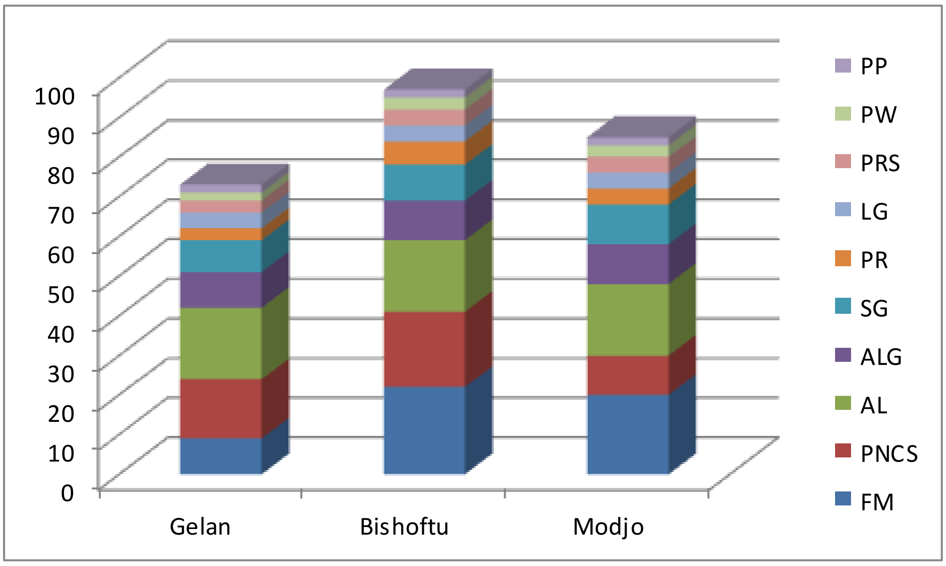


Figure 4.3 Results of the Analysis for Passenger Station in Region B

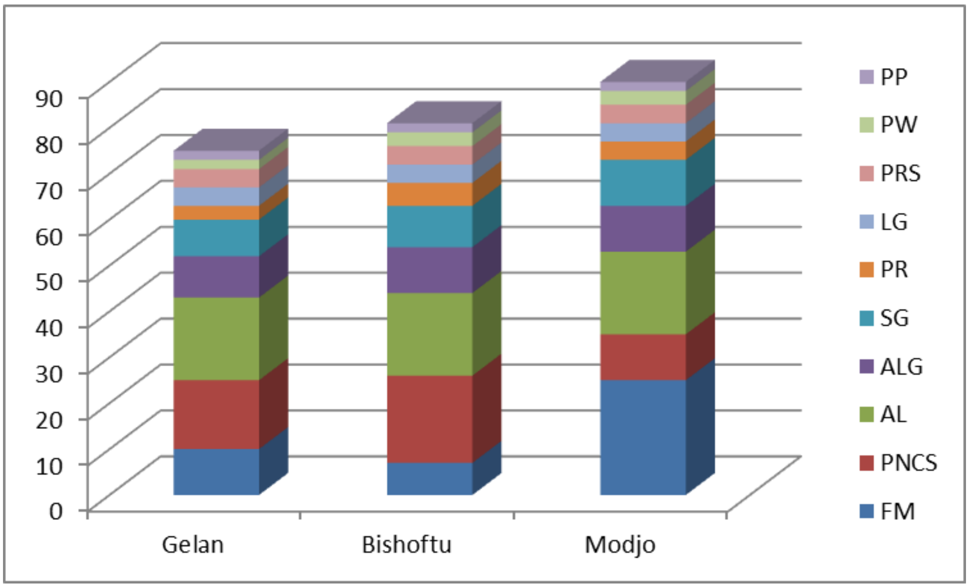


Figure 4.4 Results of the Analysis for Freight Station in Region B

❖ Conclusion for region B

Modjo site as stated above, c=c* wich shows the presence of problem in the spesified site. The site is allocated in the middle of the city wich is not allowed according to the rule of site selection criteria as indicated in the litrature review. This place is proposed by ERC to be freight and passanger station. Acording to this analysis it is not suitable for station. But The city is serving as a dry port for both Moyale and Djibouti line. There for searching other option is required. This option is to choose the railway station away from the center of the city at least for 500m inorder to stay Modjo site in compitation with other sites. Choosing other site for station far from the centre of city, the Constraint criteria will be sated to be 1.So that S*C= 8.3*1=8.3for passenger and 8.8*1=8.8 for freight. For being double truck line, the trafic volume is high and more than one stations can be selected in the region. Therefore from mathematical analysis and graph above Bishoftu and Modjo site is suitable for passenger station. Modjo site is suitable for freight station changing the current Modjo site to another place. According to this evaluation, the previously proposed statations Modjo station have to be allocated to other place at least 500m away from the centre of Modjo city and Bishoftu site is suitable for passanger station which is not proposed by erc. Concerning Bishoftu site the data available is different obout its proposal for being station. What ever it is the data available indicates Bishoftu site receiving passenger is 5,903 people per day and sending passenger of 4,683 people per day, from wich the researcher strongly recomend Bishoftu site has to be proposed for passanger station.The change of Modjo site is required because of the two factor criterias. It is located in the middle of the the city and is 2km far away from the main road. This researcher strongly believe that the place of this Modjo site have to be re allocated because of the above two problem.

3. Region C

Table 4.17 Factor Criteria Weight and Values of Region C

No	Factor criteria	Criteria wt.	Adama site		Mereb site		Feto site	
			Value	Val*wt	Value	Val*wt	Value	Val*wt
1	Financial mobility around that area	0.244	10/10	2.44/2.44	2/3	.488/.732	1/2	.244/.488
2	Proximity to nearby city and Settlements	0.19	7	1.33	6	1.14	5	.95
3	Adequate land	0.18	8	1.44	7	1.26	8	1.44
4	Alignment	0.1	10	1	10	1	10	1
5	Slope Gradient	0.095	10	.95	8	.76	8	.76
6	Proximity to Roads	0.06	9	.54	6	.36	5	.3
7	Level area with good drainage	0.043	5	.215	6	.258	7	.3
8	Proximity to other Rail stations	0.034	10	.34	8	.272	7	.238
9	Proximity to Water bodies	0.032	8	.256	7	.224	6	.192
10	Proximity to Power Lines	0.022	10	.22	5	.11	5	.11
	$S = \Sigma$ wi fi	1	8.8/8.8		5.87/6.1		5.5/5.78	

Table 4.18 Constraint Criteria and Values of Sites in Region C

No.	Constraint Criteria	Adama site	Mereb site	Feto site
1	Distance from the city	1*	1	1
2	Distance from water body	1	1	1
3	Slop gradient	1	1	1
4	Geological/seismic property	1	1	1
5	Availability of adequate land	1	1	1
6	Land use constraints	1	1	1
	C= C1*C2*…*Cn	1*	1	1

Adama site: for freight, s=8.8, c=1* then s*c=8.8* and for passenger, s=8, c=1*then s*c=8.8*
Mereb site: for freight, s=5.87, c=1 then s*c=5.87 and for passenger s=6.1, c=1 then s*c=6.1
Feto site; for freight s=5.5, c=1 then S*C=5.5 and for passenger s=5.78, c=1* then S*C=5.78
As the analysis above indicates Adama site is suitable for both passenger and Freight station from the rest sites in the region with higher value of 8.8

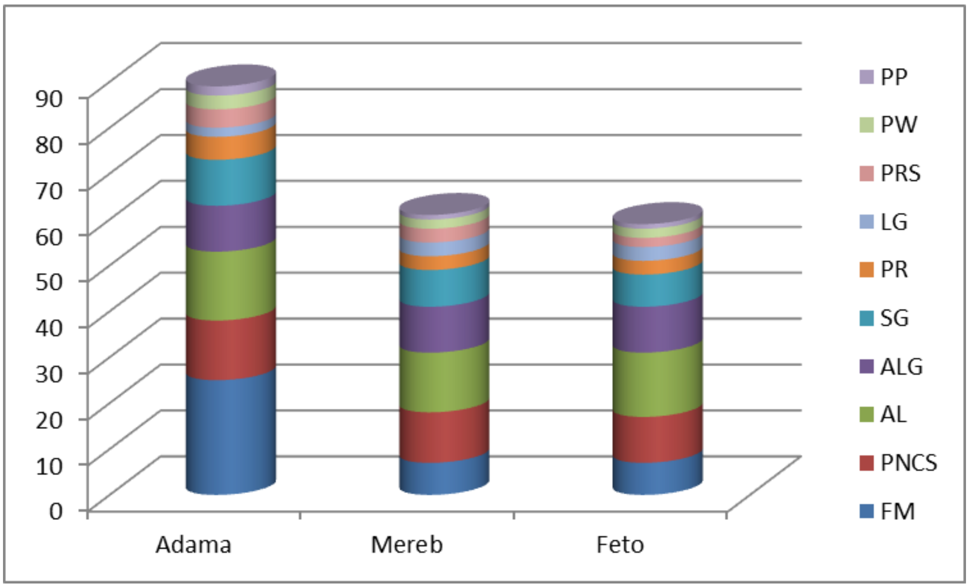


Figure 4.5 Results of the Analysis for Passenger Station in Region C

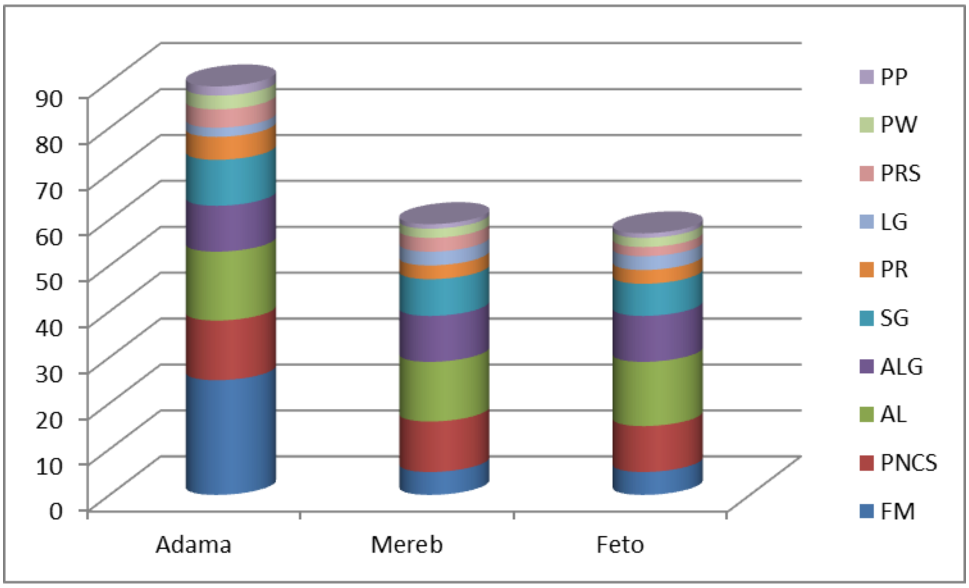


Figure 4.6 Results of the Analysis for Freight Station in Region C

- **Conclusion for region C**

Adama site as stated above,c= c* wich shows the presence of problem in the spesified site. The site is allocated in the middle of Adama city wich is not allowed according to the rule of site selection criteria as indicated in the litrature review. This place is proposed by ERC to be freight and passanger station. Acording to this research analysis it is not suitable for station. But the city is junction for Gasera line with single truck and double track line for Dire Dawa line from Adama to Addis Abeba. There for searching other option is required. This option is to choose the railway station away from the center of the city at least for 500m inorder to stay Adama site in compitation with other sites in the region. Choosing other site for station far from the centre of city, the Constraint criteria will be sated to 1.So that S*C= 8.8*1=8.8 for both passenger and freight. From mathematical analysis and graph above Adama site is suitable for both passenger and freight station changing the current Adama site to another place. This is because of three main reason; the first one is it is proposed in the midle of the city,second it is far away from main road and third is drainage access problem. According to this evaluation the previously proposed statations Adama station has to be allocated to other place at least 500m away from Adama city which is located out of the midle of city with good drainage access .

4. Region D

Table 4.19 Factor Criteria Weight and Values of Region D

No	Factor criteria	Criteria wt.	Metahara site		Awash site		Bordode site	
			Value	Val*wt	Value	Val*wt	Value	Val*wt

1	Financial mobility around that area	0.244	7/6	1.7/1.464	8/7	1.952/1.7	3/2	.732/.488
2	Proximity to nearby city and Settlements	0.19	8	1.52	8	1.52	7	1.33
3	Adequate land	0.18	10	1.8	10	1.8	10	1.8
4	Alignment	0.1	10	1	10	1	10	1
5	Slope Gradient	0.095	9	.855	10	.95	10	.95
6	Proximity to Roads	0.06	9	.54	9	.54	8	.48
7	Level area with good drainage	0.043	10	.43	9	.387	9	.387
8	Proximity to other Rail stations	0.034	10	.34	9	.3	8	.27
9	Proximity to Water bodies	0.032	7	.224	7	.224	6	.19
10	Proximity to Power Lines	0.022	10	.22	10	.22	7	.154
	S = Σ wi fi	1	8.63/8.4		8.9/8.65		7.2/7	

Table 4.20 Constraint Criteria and Values of Sites in Region D

No.	Constraint Criteria	Metahara site	Awash site	Bordode site
1	Distance from the city	1	1	1
2	Distance from water body	1	1	1
3	Slop gradient	1	1	1
4	Geological/seismic property	0	1	1
5	Availability of adequate land	1	1	1
6	Land use constraints	1	1	1
	C= C1*C2*…*Cn	0	1	1

Metahara Site: for Freight, s=8.6, c=0 then S*C=0 and for passenger, s=8.4, c=0 then S*C=0

Awash site: for freight, s=8.9, c=1 then s*c=8.9 and for passenger s=8.65, c=1 then s*c=8.65

Bordede site; for freight s=7.2, c=1 then S*C=7.2 and for passenger s=7, c=1* then S*C=7

The mathematical analysis above shows Awash site is more suitable for both freight and passenger station with highest value of 8.9 for freight and 8.65 for passenger.

Figure 4.7 and 4.8 below shows this fact clearly

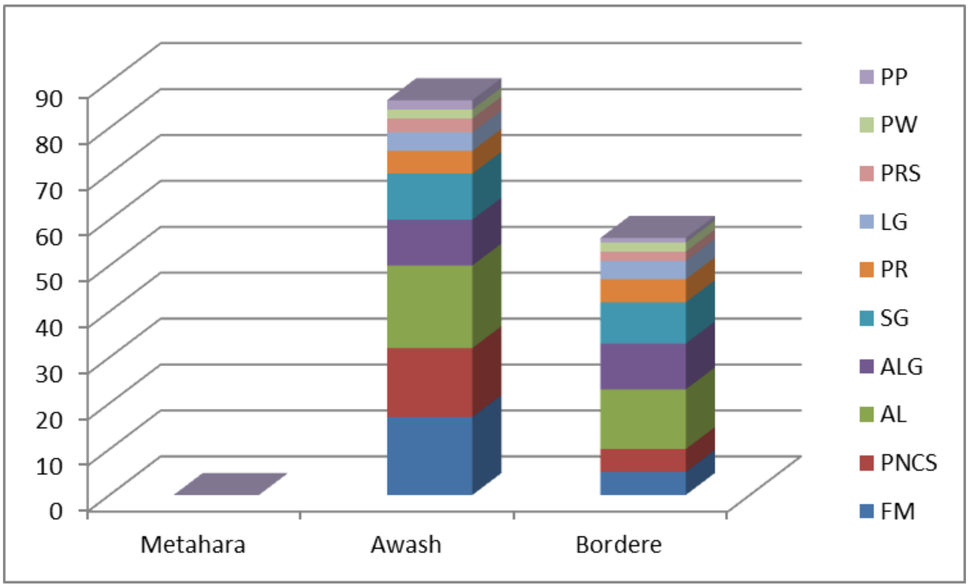


Figure 4.7 Results of the Analysis for Passenger Station in Region D

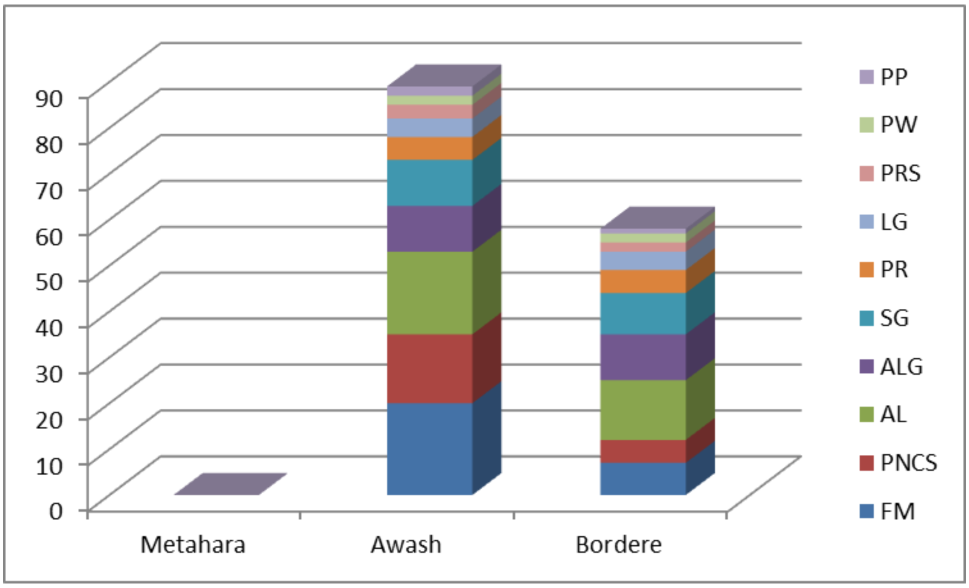


Figure 4.8 Results of the Analysis for Freight Station in Region D

❖ Conclusion for region D

From mathematical analysis and graph above Awash Site is more suitable for both passenger and freight station. Acording to this research evaluation, the proposed site in the region by erc is correctly sited. But Metahara site; which is proposed by erc for passing station for now and intermidate station for the future is not suitable because of the expasion of Beseke water. As the contraint criteria/ geological property of the land indicates Metahara site is not suitable. From this the researcher strongly believe that Metahara site can never be proposed for station.

5. Region E

Table 4.21 Factor Criteria Weight and Values of Region E

No	Factor criteria	Criteria wt.	Sirba kunkur site		Asebot site		Mieso site	
			Value	Val*wt	Value	Val*wt	Value	Val*wt
1	Financial mobility around that area	0.244	3/4	.732/.976	4/4	.976/.976	9/8	2.196/1.952
2	Proximity to nearby city and Settlements	0.19	7	1.33	8	1.52	10	1.9
3	Adequate land	0.18	8	1.44	9	1.62	10	1.8
4	Alignment	0.1	10	1	10	1	10	1
5	Slope Gradient	0.095	8	.76	9	.855	10	.95
6	Proximity to Roads	0.06	2	.12	5	.3	10	.6
7	Level area with good drainage	0.043	9	.387	10	.43	10	.43
8	Proximity to other Rail stations	0.034	8	.272	9	.3	10	.34
9	Proximity to Water bodies	0.032	7	.224	6	.192	5	.16
10	Proximity to Power Lines	0.022	5	.11	6	.132	8	.176
	S = Σ wi fi	1	6.375/6.6		7.3/7.3		9.55/9.3	

Table 4.22 Constraint Criteria and Values of Sites in Region E

No.	Constraint Criteria	Sirbakunkur site	Asebot site	Mieso site
1	Distance from the city	1	1	1
2	Distance from water body	1	1	1
3	Slop gradient	1	1	1
4	Geological/seismic property	1	1	1
5	Availability of adequate land	1	1	1
6	Land use constraints	1	1	1
	C= C1*C2*…*Cn	1	1	1

Sirbakunkur site: for freight, s=6.37, c=1 then s*c=6.37 and for passenger, s=6.6, c=1 then s*c=6.6
Asebot site: for freight, s=7.3, c=1 then s*c=7.3 and for passenger s=7.3, c=1 then s*c=7.3
Mieso site; for freight s=9.55, c=1 then s*c=9.55 and for passenger s=9.3, c=1* then s*c=9.3
The mathematical analysis above shows Mieso site is more suitable for both freight and passenger station in the region with highest value of 9.55 for freight and 9.3 for passenger.
Figure 4.9 &4.10 below shows this analysis graphicaly

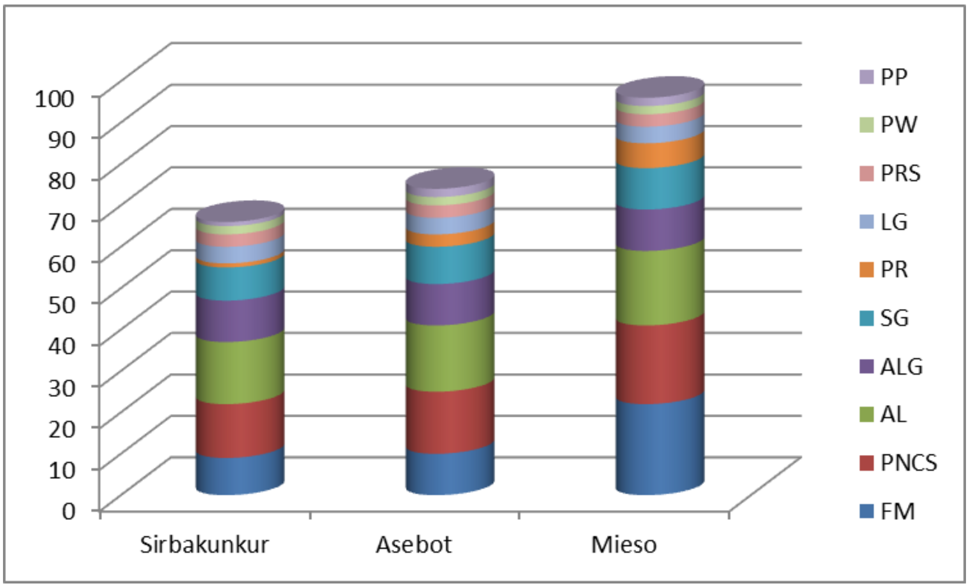


Figure 4.9 Results of the Analysis for Passenger Station in Region E

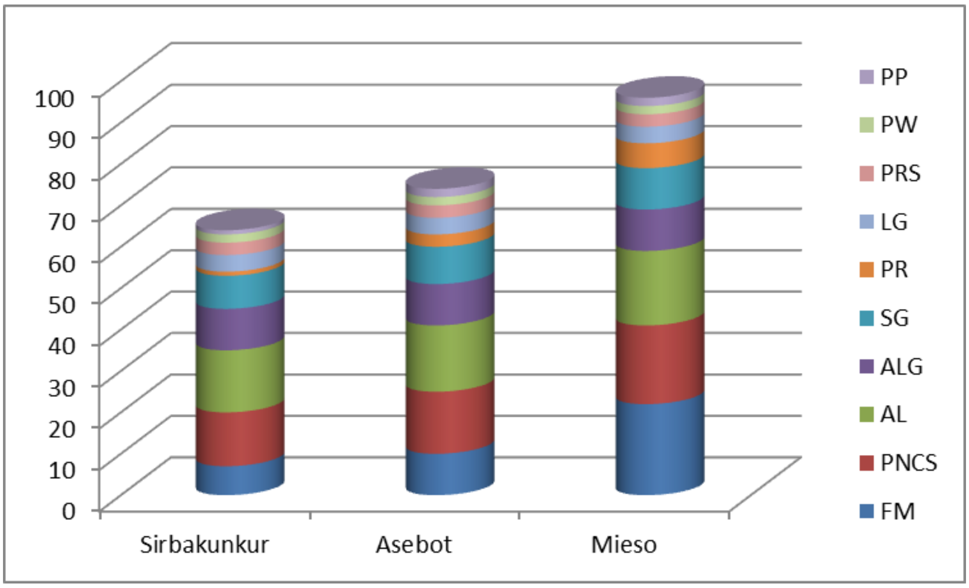


Figure 4.10 Results of the Analysis for Freight Station in Region E

❖ Conclusion for region E

From mathematical analysis and graph above Mieso Site is more suitable for both passenger and freight station in the region. Acording to this research evaluation, the proposed site in the region by erc is correctly sited.

6. Region F

Table 4.23 Factor Criteria Weight and Values of Region F

No	Factor criteria	Criteria wt.	Mulu site		Afdem site		Bike site	
			Value	Val*wt	Value	Val*wt	Value	Val*wt
1	Financial mobility around that area	0.244	3/2	.732/.488	3/3	.732/.732	7/5	1.71/1.22
2	Proximity to nearby city and Settlements	0.19	8	1.52	7	1.33	8	1.52
3	Adequate land	0.18	8	1.44	8	1.44	9	1.62
4	Alignment	0.1	10	1	10	1	10	1
5	Slope Gradient	0.095	8	.76	8	.76	9	.855
6	Proximity to Roads	0.06	6	.36	6	.36	7	.42
7	Level area with good	0.043	8	.344	8	.344	8	.344

	drainage							
8	Proximity to other Rail stations	0.034	8	.272	8	.272	9	.31
9	Proximity to Water bodies	0.032	6	.192	5	.16	8	.256
10	Proximity to Power Lines	0.022	7	.154	7	.154	7	.154
	S = Σ wi fi	1	6.77/6.53		6.55/6.55		8.2/7.9	

Table 4.24 Constraint Criteria and Values of Sites in Region F

No.	Constraint Criteria	Mulu site	Afdem site	Bike site
1	Distance from the city	1	1	1
2	Distance from water body	1	1	1
3	Slop gradient	1	1	1
4	Geological/seismic property	1	1	1
5	Availability of adequate land	1	1	1
6	Land use constraints	1	1	1
	C= C1*C2*…*Cn	1	1	1

Mulu Site: for Freight, s=6.7, c=1 then S*C=6.7 and for passenger, s=6.53, c=1 then S*C=6.5
Afdem site:for freight, s=6.5, c=1 then s*c=6.55 and for passenger s=6.55, c=1 then s*c=6.55
Bike site; for freight s=8.2, c=1 then S*C=8.2 and for passenger s=7.9, c=1then S*C=7.9 From mathematical analysis above; Bike site is more suitable for both freight and passenger station in the region with highest value of 8.2 for freight and 7.9 for passenger.Figure 4.11 & 4.12 below shows this analysis graphicaly

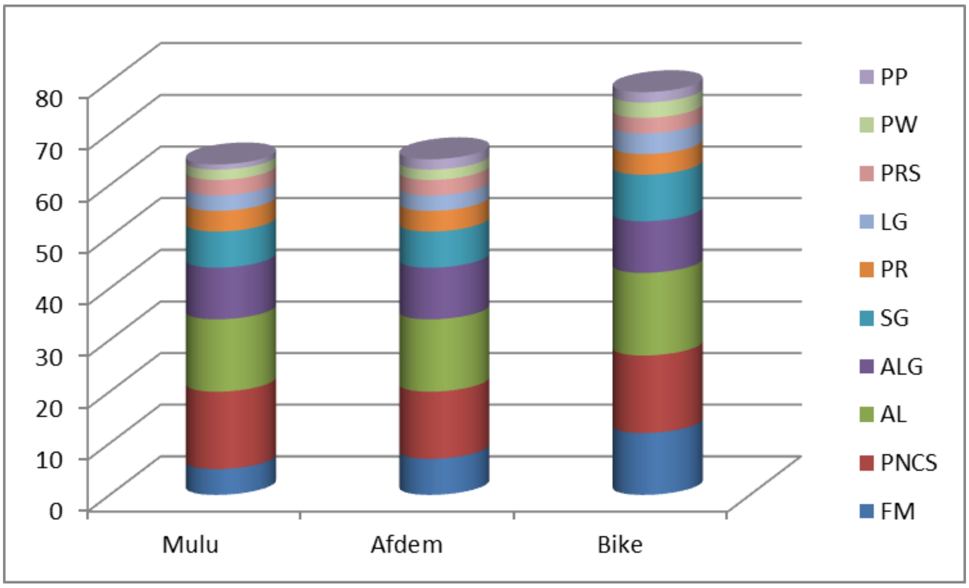


Figure 4.11 Results of the Analysis for Passenger Station in Region F

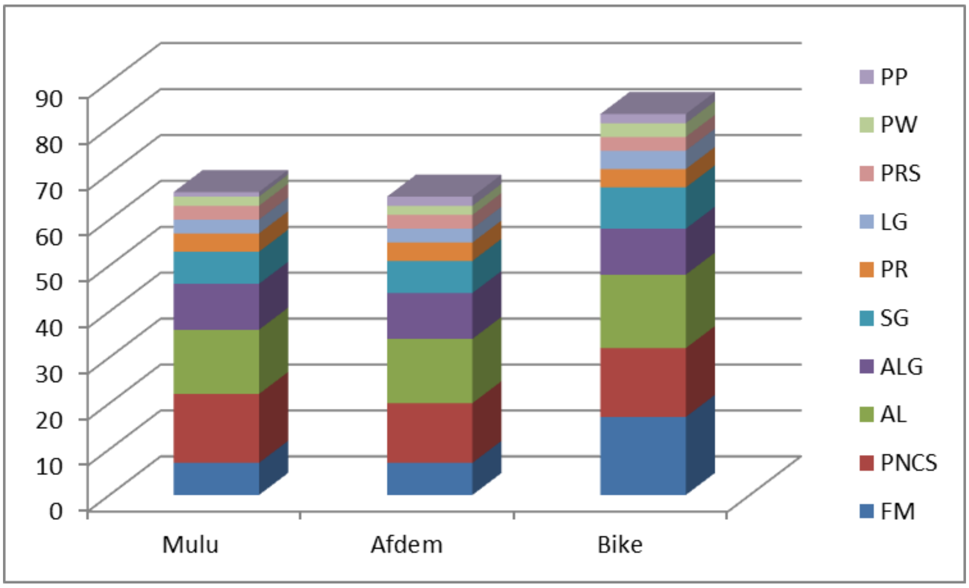


Figure 4.12 Results of the Analysis for Freight Station in Region F

❖ Conclusion for region F

From mathematical analysis and graph above Bike Site is more suitable for both passenger and freight station in the region. Acording to this research evaluation, the proposed site in the region by erc is correctly sited.

7. Region G

Table 4.25 Factor Criteria Weight and Values of Region G

No	Factor criteria	Criteria wt.	Erer site		Hurso site		Dire Dawa site	
			Value	Val*wt	Value	Val*wt	Value	Val*wt

1	Financial mobility around that area	0.244	6/5	1.464/1.22	3/2	.732/.488	10/9	2.44/2.16
2	Proximity to nearby city and Settlements	0.19	9	1.71	7	1.33	9	1.71
3	Adequate land	0.18	7	1.26	7	1.26	9	1.62
4	Alignment	0.1	8	.8	7	.7	10	1
5	Slope Gradient	0.095	9	.855	9	.855	10	.95
6	Proximity to Roads	0.06	6	.36	5	.3	8	.48
7	Level area with good drainage	0.043	8	.344	8	.344	10	.43
8	Proximity to other Rail stations	0.034	8	.272	7	.238	10	.34
9	Proximity to Water bodies	0.032	7	.224	6	.192	8	.256
10	Proximity to Power Lines	0.022	6	.132	6	.132	10	.22
	S = Σ wi fi	1	7.42/7.177		6/5.84		9.446/9.2	

Table 4.26 Constraint Criteria and Values of Sites in Region G

No.	Constraint Criteria	Erer site	Hurso site	Dire Dawa site
1	Distance from the city	1	1	1*
2	Distance from water body	1	1	1
3	Slop gradient	1	1	1
4	Geological/seismic property	1	1	1
5	Availability of adequate land	1	1	1
6	Land use constraints	1	1	1
	C= C1*C2*…*Cn	1	1	1*

Erer Site: for Freight, s=7.42, c=1 then S*C=7.42 and for passenger, s=7.2, c=1 then S*C=7.2

Hurso site: for freight, s=6, c=1 then S*C=6 and for passenger s=5.84, c=1 then S*C=5.84

Dire Dawa site; for freight s=9.44, c*=1 then S*C=9.44* and for passenger s=9.2, c*=1then S*C=9.2*

From mathematical analysis above; Dire Dawa site is more suitable for both freight and passenger station in the region with highest value of 9.44 for freight and 9.2 for passenger.

Figure 4.13 & 4.14 below shows this analysis graphicaly

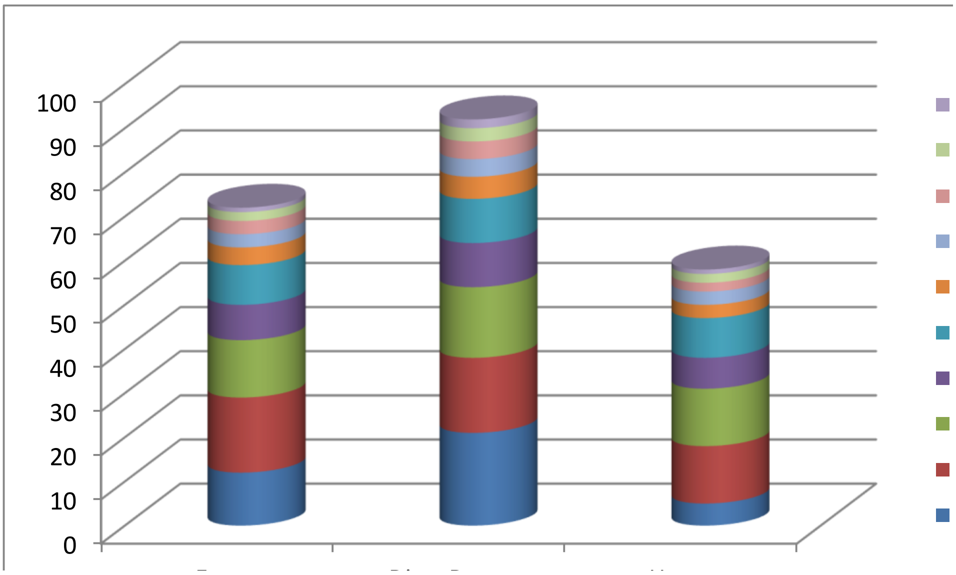


Figure 4.13 Results of the Analysis for Passenger Station in Region G

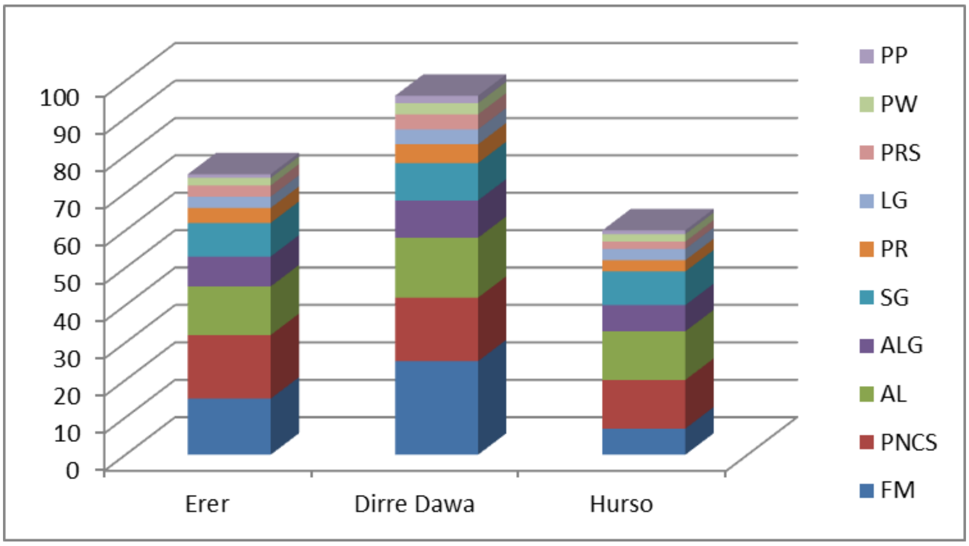


Figure 4.14 Results of the Analysis for Freight Station in Region G

❖ Conclusion for region G

Dire Dawa site as stated above,c= c* wich shows the presence of problem in the spesified site. The site is allocated 10 km away from Dire Dawa city wich is not allowed according to the rule of site selection criteria as indicated in the litrature review. This place is proposed by ERC to be freight and passanger station. Acording to this research analysis it is not suitable for station at the specified site. But as indicated in the data and mathematical analysis Dire Dawa site highily require railway station. Therefore searching other site for station neer Dire Dawa city is highly important. This option is to choose the railway station near to the city at least in the range of 500m and 2.5km inorder to stay Dire Dawa site in compitation with other sites in the region. Choosing other site for station near to Dire Dawa city, the Constraint criteria will be sated to be 1. So that S*C= 9.44*1=9.44 for freight and 9.2 passenger.

From mathematical analysis and graph above Dire Dawa site is suitable for both passenger and freight station changing the current Dire Dawa site to another place. According to this evaluation the previously proposed statations Dire Dawa station has to be re allocated to other place 500m near to Dire Dawa city. If not, railway station cannot be selected 10km away from city. This researcher strongly believe that, this station placed 10km away Dire Dawa city cannot be taken as railway station in this much range distance, this is because of the international railway station selection criteria concerning proximity to city more suitablity is bounded in the range of 0.5km to 2.5km, and decrease suitablity to 5km. Distance above 5km is totaly not accepteble.

4.4 Conclusion

To conclude this chapter, from data collection and presentation the required data was collected using interview, related researches done in the area and feasiblity study of the Ethiopian railways corporation. The data was collected for twentyone sites sectioning in seven region from Sebeta to Dire Dawa and presented according to its value in the table form and in comparision to minimum required value.

Then using method of multi criteria decision analyses, and mathematical analysis like analytical hierarchy process, Setting of criteria was done and weight of each criterias analysed for each criteria.

Finally using method above freight stations and passenger stations selected early by ERC was evaluated and new proposal of station was given by the help of mathematical analysis and ms- excel.

In this work Bishoftu site is added as new station for passenger and Metahara site is omitted because of geological problem. The other work in this chapter is that; eventhough some of the proposed stations are correctly selected the city; some of the citation of the place was wrongly placed, so placement proposal for those cities was given by this researcher. Indode station has to be rearranged and placed away from irrigated land and near to the main road at least 500m. Modjo station has to be taken out from the middle of the city and located outside the city distance in the range of 500m to 2.5km. in the same way Adama station has to be taken out from the middle of the city and located outside the city in the range of 500m to 2.5km and additionally the drainage problem have to be taken under consideration during site location.

Finally Dire Dawa station which is curently located 10km away from the city has to be positioned near the city in less than 2.5km.

CHAPTER FIVE

MODEL DEVELOPMENT

5.1 Developing an Assessment Model for Selecting the Sites of railway station

Critical decisions made at the very beginning of every capital development project have major consequences for the overall success of the project. The site selection decision has a dramatic impact on almost every facet of the design and operation process. The site affects the organization; massing; functionality; sustainability; operational and economic efficiency; security; and last, but certainly not least, the aesthetic qualities of the railway system operation.

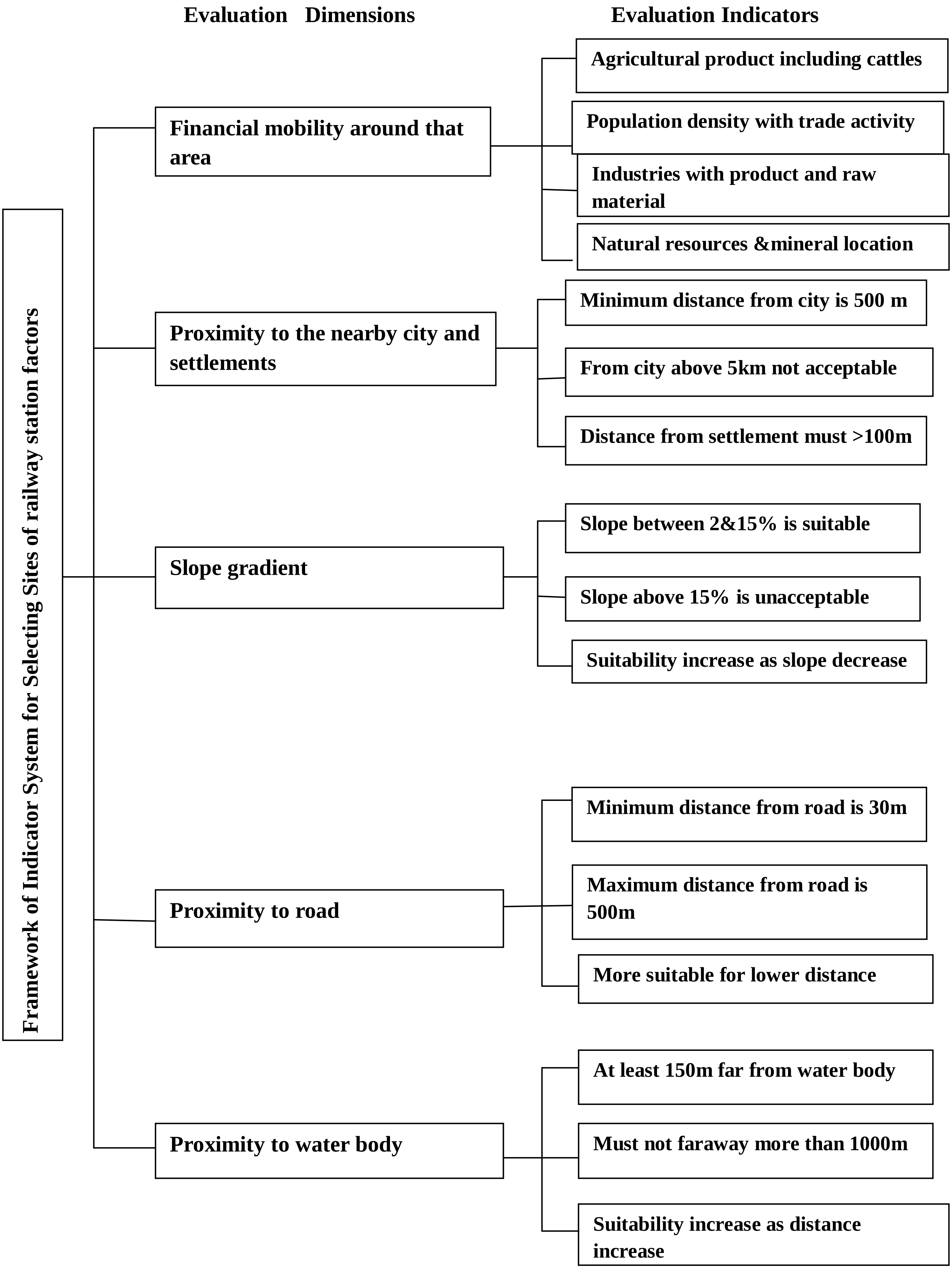
For the porpose of this research, site selection can be defined as ; site selection is a “life cycle" decision that recognizes the balance among the initial cost of the railway station, the overall cost of executing the project, and the cost of operating the facility. It also recognizes the benefit (or cost) to the local community and the environment. While the initial cost may be a significant driver, all factors must be considered in order to make the right decision. [27]

Railway stations are at the heart of the nation’s psyche. They feature in block buster films, romantic novels and the skylines of many towns and cities [6]. The description of railway station in this way is that; as the heart in human being is motor and without which man is dead, station is that place without which railway system is dead.

In order to systematically select suitable sites for railway station in the rail transit corridors under study, developing a framework of the proposed assessment model is necessary. Based on the result of literature review and a survey of the sites in the network line, considering the facts and conditions of the country , the following framework of the indicator system is proposed and tested in this study. The framework includes ten main selection factor criterias/ dimensions, and and six main selection constraint criteriass/dimensions that, each has its oun indicators. The indicators were selected based on the results of literature review and interviews, local environmental characteristics, as well as the availability of data for analysis.

We develop the effective evaluation model to settle the problem of previous station location in selecting a new railroad station. The inter-city railroad is examined, and the developed method is applied in the selection process. In this study, to select the best model for evaluating the feasibility of selecting a new railroad station, many multi-criteria assessment models are examined, and AHP analysis can more properly explain the problem of selecting a new station than any other methodology.

This model works not only for selection of railway station sites in a spesified/limited rout instaid, for evry routs of railway system in the country side. There fore from this factor criteria /dimensions and constraint criteria/dimensions with indicators discused one can take it as a model work for any related works of railway station site selection since it serves as a basement of selecting new railway station for new railway line or for addision of other stations in the network line. In this paper, the model is prepared and presented grapically to make it clear and precised. Figure 5.1 and 5.2 belows this model site selection wich is described in the form of factor criteria/dimension and constraint criteria/dimension with its indicators.


Evaluation Dimensions
Evaluation Indicators
Framework of Indicator System for Selecting Sites of railway station factors
Financial mobility around that area
Agricultural product including cattles
Population density with trade activity
Industries with product and raw material
Natural resources &mineral location
Proximity to the nearby city and settlements
Minimum distance from city is 500 m
From city above 5km not acceptable
Distance from settlement must >100m
Slope gradient
Slope between 2&15% is suitable
Slope above 15% is unacceptable
Suitability increase as slope decrease
Proximity to road
Minimum distance from road is 30m
Maximum distance from road is 500m
More suitable for lower distance
Proximity to water body
At least 150m far from water body
Must not faraway more than 1000m
Suitability increase as distance increase

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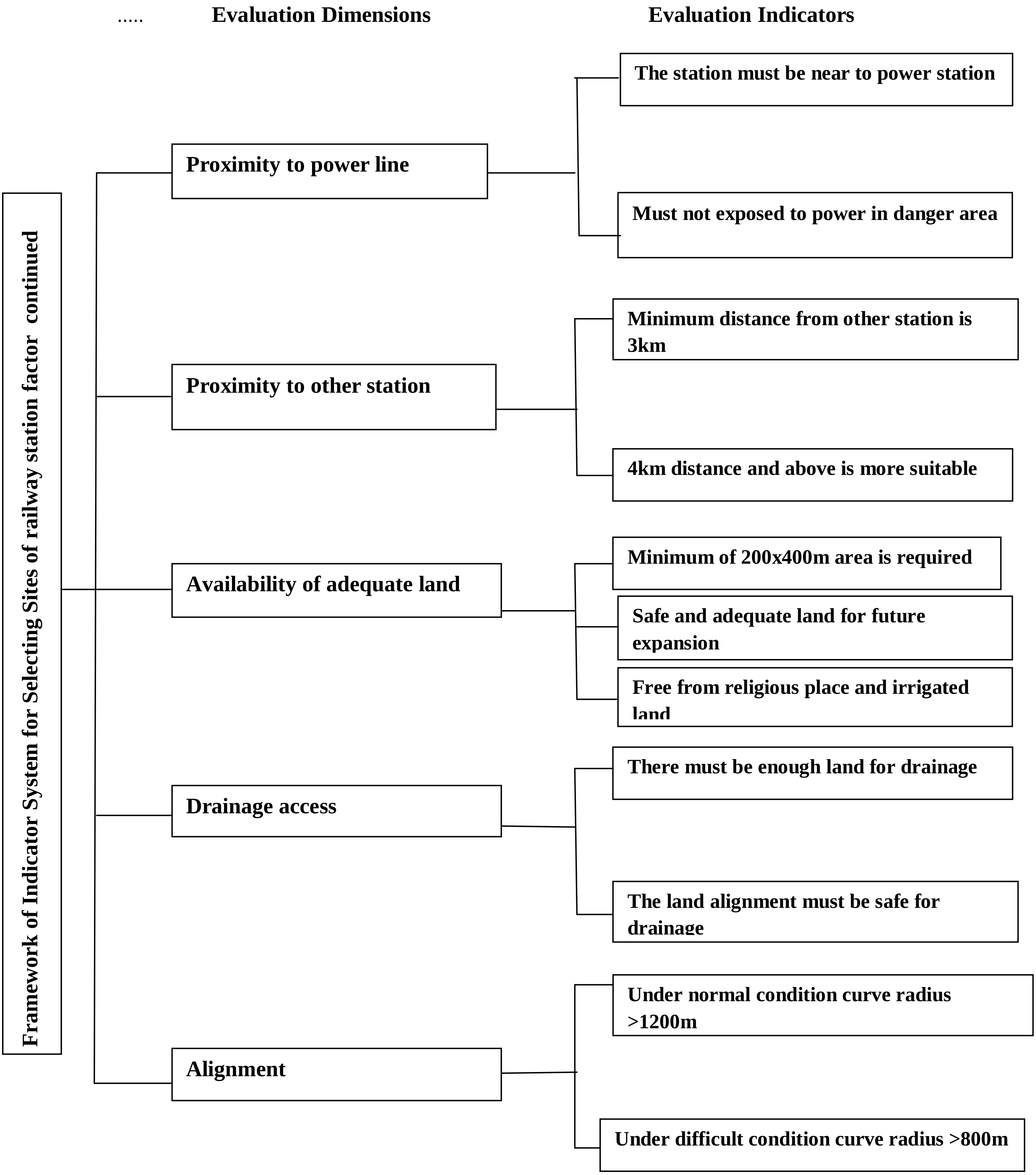

Figure 5.1 The Proposed Framework of the Assessment Factor Model

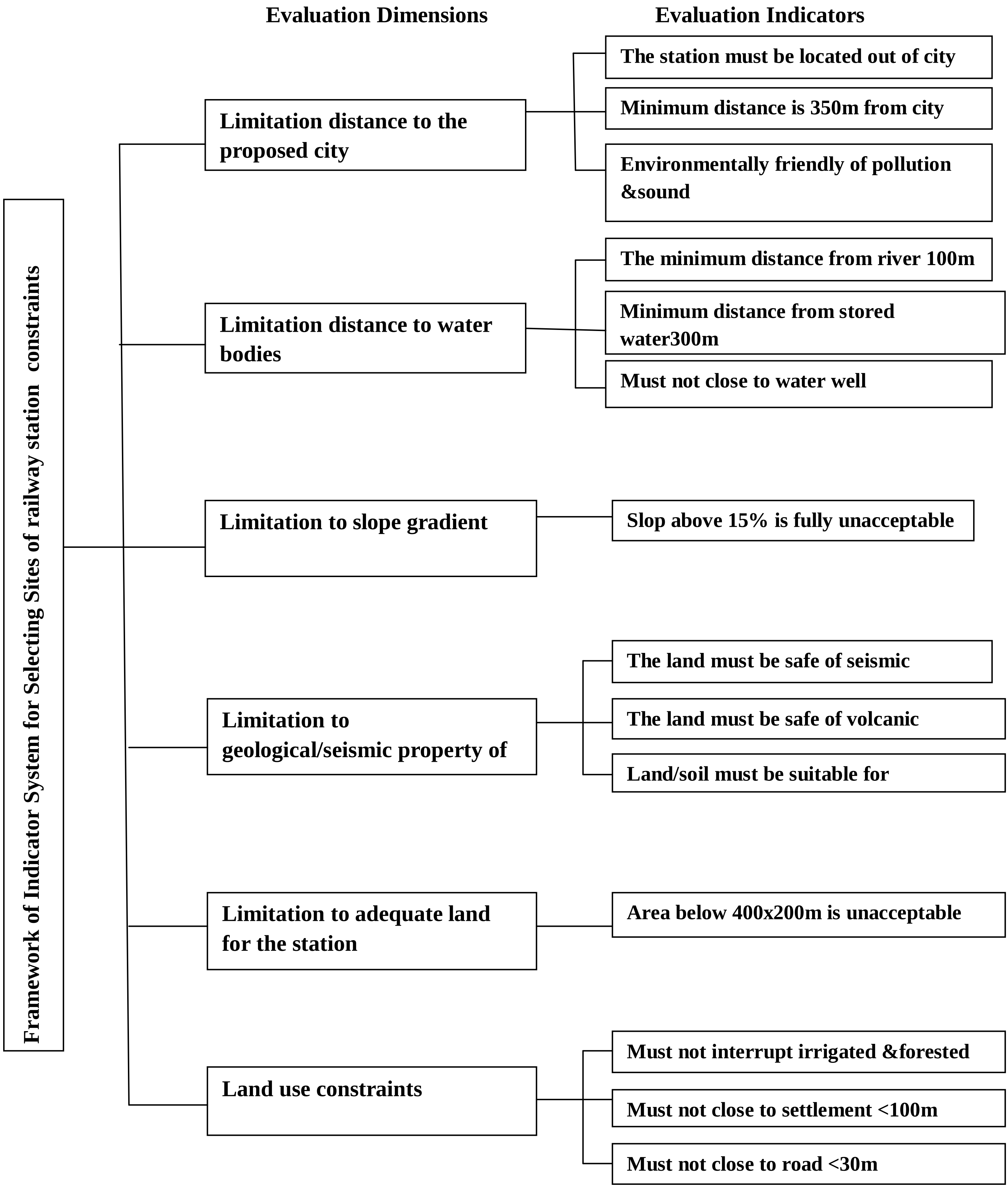

Figure 5.2 The Proposed Framework of the Assessment Constraint Model

5.2 Determining the Weights of the Indicators of the Assessment Model

After collecting and coding all the data, the AHP method was conduct to explore the relative importance of evaluation dimensions and indicators. After calculating the matrix and conducting a consistency test (using CR＜0.1 as the criteria), the results are shown in

Table5.1 and Figure5.3. In summary, the results revealed that while the ten dimensions of the framework seem to be all are important, while a bit more on emphasis is place on same criterias with the order of importance is Financial mobility around that area, Proximity to nearby city and Settlements, Adequate land, Alignment, Slope Gradient, Proximity to Roads, Level area with good drainage, Proximity to Power Lines, Proximity to Water bodies and Proximity to other Rail stations. This result is consistent and under each of these criteria weight there are other sub criteria weights described in detail.

Table 5.1 Weights of the Evaluation Indicators

Evaluation Dimensions	Relative Weight	Evaluation Indicators	Detail Relative Weight
Financial mobility around that area	0.244	Population density with trade activity	0.11
		Agricultural product including cattles	0.054
		Industries with product and raw material	0.04
		Natural resources & mineral location area	0.04
Proximity to nearby city and Settlements	0.19	Minimum distance from city is 500 m	0.08
		From city above 5km not acceptable	0.06
		Distance from settlement must >100m	0.05
Adequate land	0.18	Minimum of 200x400m area is required	0.1
		Free from religious place and irrigated land	0.05
		Safe and adequate land for future expansion	0.03
Alignment	0.1	Under normal condition curve radius	0.05

		>1200m	
		Under difficult condition curve radius >800m	0.05
Slope Gradient	0.095	Slope between 2&15% is suitable	
		Slope above 15% is unacceptable	
		Suitability increase as slope decrease	0.095
Proximity to Roads	0.06	Minimum distance from road is 30m	0.02
		More suitable for lower distance	0.02
		Maximum distance from road is 500m	0.02
Level area with good drainage	0.043	There must be enough land for drainage	0.023
		The land alignment must be safe for drainage	0.02
Proximity to other Rail stations	0.034	Minimum distance from other station is 3km	0.02
		4km distance and above is more suitable	0.014
Proximity to Water bodies	0.032	At least 150m far from water body	0.012
		Suitability increase as distance increase	0.01
		Must not faraway more than 1000m	0.01
Proximity to Power Lines	0.022	The station must be near to power station	0.01
		Must not exposed to power in danger area	0.01

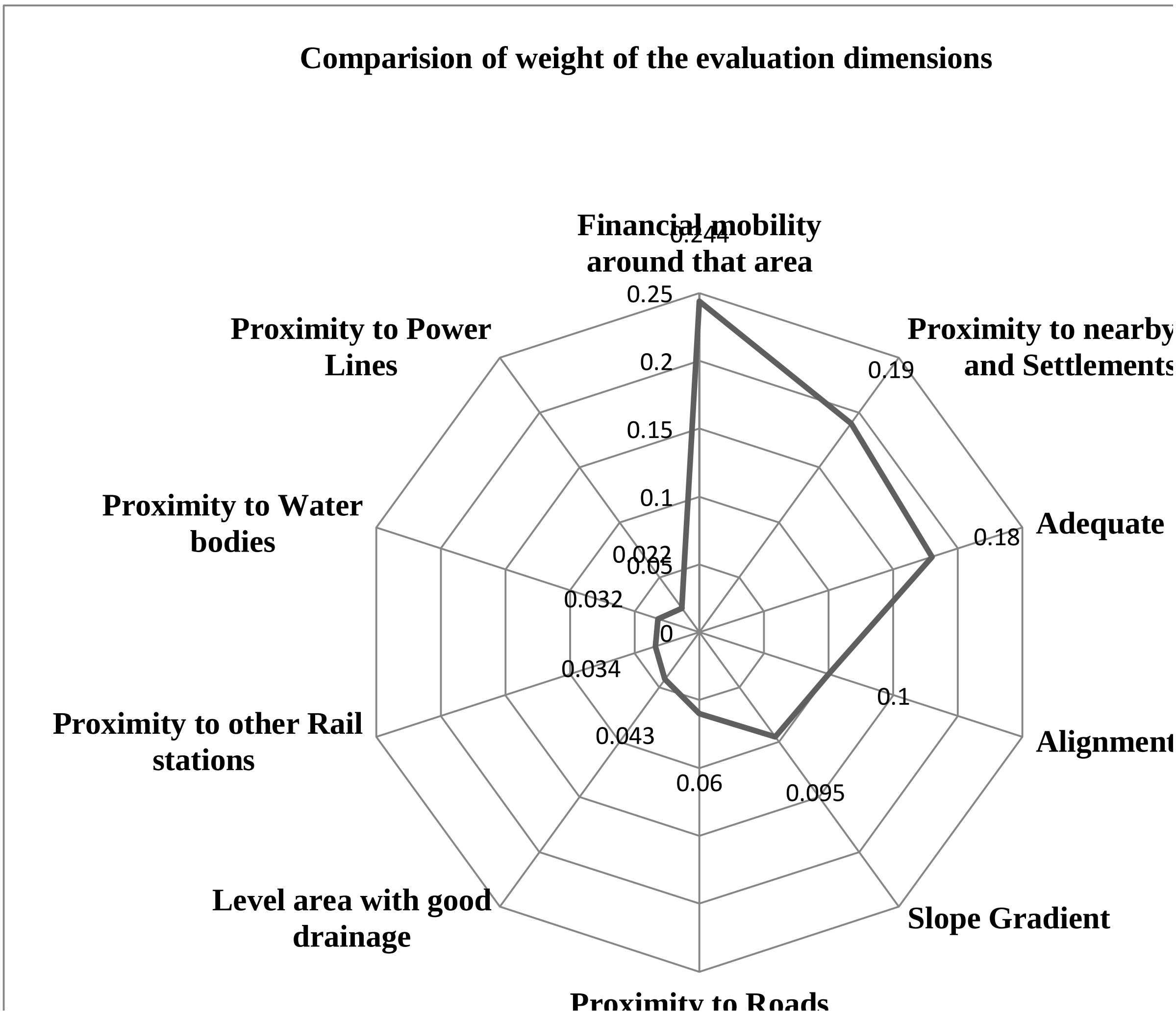

Figure 5.3 Comparison of the Weights of Evaluation Dimensions of the Assessment Model

5.3 Conclusion

In this study assessment model for selection of new railway station and evaluation of the early selected one has developed to settle one of resentments related to railway station using MCDA method with AHP technique. Factor and constraint criteria/dimensions with their indicators are the main focus of this evaluation and selection of railway staton done under this model.

The evaluation and selection model using AHP has developed which can evaluate both qualitative and quantitative information that leads to chose the best and suitable one from the alternative available. Through the consistance analysis, the resalts are proven when calculating the determaining weight of each factor dimesions and indicators. Using the litrature review, standards of experinenced country, studying the realitys of the country on the case of financial access and land policy of the country, about ten factor dimensions and six constraint dimensions has developed with specific indicators for each dimensions. Each factor dimensions and indicators given their specific consistant weight showing their specific determining position.

Using an assessment model for selecting the sites of railway station as part of the site selection process will help to make the selection of a potential site for railway station activity and facility more transparent. The developed assessment model for Selecting the sites of railway station fulfils political, social, economic and environmental obligations associated with site selection in a non-biased way, and the methodology ensures that there is a clear and scientific rationale behind the choice of a site. The model provides a tool and a methodology for railway station site selection to local authorities, which will enable them to conduct their own railway station site selection screening process.

For the applicabity of the model developed in this study,the Addis Ababa/Sebeta-Dire Dawa network line was surveyed and feasiblity study reviwed. There fore for the case of Ethiopia, the model is applicable and very usefull if applied. It can be applied not only for the case of Addis Ababa- Dire Dawa network line but also for every railway rout in all corridor of the contry.

CHAPTER SIX

CONCLUSION, RECOMMENDATION AND FUTURE WORK

6.1 Conclusion

To conclude this research, railway station is every thing in the railway system. Special attention have to be given for railway station because of its role in the railway system. This attention is to choose the location of the railway station in order to have politically acceptable, socially usable, economically profitable and environmentally friendly serving railway system in the country; specifically this paper targeted to examine the erc's current railway station selection criteris, and methods, to evaluate the proposed sites and its placement for railway station of Sebeta – Dire Dawa railway network line by the corporation. The other objective is that, to show the gap in each sites and suggest new station location and placement rearrangement in order to fill the gap in the specified sites, finally developing a model that can be applicable in the country in all rail corridor. This objective has targeted to fill the gap of railway station site selection in Ethiopia today. Even though the Ethiopian Railways Corporation has already proposed railway stations for Sebeta- Dewenle network line, it is not selected and analysed well as per the required criteria, technique / method and procedure of railway station site selection. As a result, most of the station sites are not selected properly and is positioned wrongly. That was the reason to focus this paper on Evaluation and selection of railway station for Addis Ababa- Dire Dawa line. Multi criteria decision making method using AHP and Ms Excel is the best way of railway station site selection used in this work.

In this network line using the above criteria and method, this work examined the current railway station site selection criterias and methods. To examine the detail works of station selection method and criteria there is no a documented material. But orally there are some selection criterias which are not well organised as per the international site selection criterias and considered all the reality of the country; in addition to this there is no clear railway station site selection methods available that this researcher got from the corporation during this work.

Finally the currently proposed railway stations by Ethiopian Railway Corporation has evaluated. According to this evaluation, Indode site is located wrongly when evaluated by the railway station site selection criteria. It is 7km away from the city, 15km away from the main road; it is located on water well and irrigated land. Labu site in the same way is far away from HV power station. Modjo site is more than 2km far away from main road and it is located in the middle of the city which makes it wrongly proposed because of its impact on the society and distance from the main road. Adama site has no drainage access, located in the middle of the city with high environmental impact on the society and it is about 2.5 km away from the main road which fails when evaluated by those criterias. Metahara site cannot be candidated for railway station because of geological problem of the land. Dire Dawa site is 10km away from the city which is totally wrong positioning even difficult to compromise when evaluated by the criteria which says distance above 2.5km to 5km away from city suitability decrease and is not suitable to be selected as railway station for distance above 5km. Those listed sites with the specified problems are not suitable to be railway station because of those criterias. But can be suitable for station by rearranging their position satisfying the specified criteria without leaving the city except Metahare site.

Suggested new railway station location; Sebeta, Labu, Bishoftu, Modjo, Adama, Awash, Mieso, Bike, Dire Dawa sites are proposed for passenger station and Sebeta, Indode, Modjo, Adama, Awash, Mieso, Bike, Dire Dawa sites are proposed for freight station. Bishoftu site is proposed to be passenger station, Metahara site is omitted fully because of geological problem. The rest proposed sites are as it is, but by rearranging the placement and filling the gap above.

Finaly Identified the criterias and weighting system for all site selection criteria which fit to the case of Ethiopias Railway in the future as indicated in the model development. six constraint and ten factor criterias are indentified and used to evaluate and select the railway stations and suggested for the future work of the railway station site selection.

6.2 Recommendation

A successful railway station will add to the passenger experience as well as support the economic, social and environmental benefits of rail. Their effective integration with other modes of transport and the surrounding area can provide for an end-to-end journey experience that makes sustainable public transport a real alternative to private vehicle usage. Given these varying demands on stations it is vitally important that they are properly selected, planned, designed and improved in a manner that recognizes all that they have to offer. Ethiopian Railways Corporation has already proposed railway stations for Sebeta- Dewenle network line. In addition to the problem of the now selected railway stations, the future will be more complicated and the problem will become series. This is because of the situation of the country that there are no many alternatives to choose from today. But if the country had many towns to choose from near to each other, it was difficult to identify the best alternative without detail analysis and better selection technique using same limited selection criterias.

Ethiopia is highly growing country in all aspects. Following this many towns are emerging, agricultural products are increasing, Industries are rising, import and export demand in each city is increasing. At that time simply proposing one city to be station becomes difficult.

Therefore, the following recommendations are made for ethiopian railways corporation based on the study that has been conducted.

It is better to revise the current site selection criteria and identify own station site selection criteria and methods using internationally acceped and fit with the countries reality. For this it is better to use the model development developed by this work for the next railway station site selection and is better to use multicriteria desicion making method. It is also better to revise and re allocate its position some of the railway station sites proposed early because of miss placement and rivese sites ought to be proposed and ought to be omited as discussed in this work.

6.3 Future Work

After conducting the research and analyzing the different aspects of railway station site selection, Multi criteria dessision making method using Analytical Hierarchy Process (AHP) and Ms Excel was aplied in this study. Since the location of railway station is sensitive and play a vital role in the railway industry, it has to be selected in the right way using the right method, criteria and tools.

For the future it is better to do detail analysis and tecnique using GIS software hopping that, there will be detail qualitative and quantitative data.

APPENDICES

Appendix A Determining the Relative Criterion Weights

Factor criterias	FM	PNCS	LAGD	ALG	PTR	POTS	SG	AL	PWB	PPL
Financial mobility around that area	1	2	5	3	4	6	3	2	5	8
Proximity to nearby city and Settlements	1/2	1	5	3	4	6	3	1	5	8
Level area with good drainage	1/5	1/5	1	1/2	1/2	2	1/3	1/5	2	3
Allignment	1/3	1/3	2	1	2	4	1	1/2	4	7
Proximity to Roads	1/4	1/4	2	1/2	1	2	1/2	1/3	2	4
Proximity to other Rail stations	1/6	1/6	1/2	1/4	1/2	1	1/3	1/4	2	3
Slope Gradient	1/3	1/3	3	1	2	3	1	1/2	3	5
Adequate land	1/2	1	5	2	3	4	2	1	5	7
Proximity to Water bodies	1/5	1/5	1/2	1/4	1/2	1/2	1/3	1/5	1	2
Proximity to Power Lines	1/8	1/8	1/3	1/7	1/4	1/3	1/5	1/7	1/2	1
Sum	3.6	5.61	24.333	11.64	17.75	28.83	11.7	6.2	29.5	48

Appendix B The Eigenvalues of the matrix

Factor criterias	FM	PNCS	LAGD	Alg	PTR	POTS	SG	AL	PWB	PPL	weight	%
Financial mobility around that area	.277	.3565	.2	.26	.2253	.2	.256	.326	.169	.1667	.244	24.4
Proximity to nearby city and Settlements	.138	.178	.2	.26	.225	.2	.256	.163	.169	.1667	.19	19
Level area with good drainage	.055	.0356	.041	.043	.028	.069	.028	.033	.068	.0625	.043	4.3
Allignment	.092	.0594	.0822	.086	.1127	.1387	.085	.081	.1356	.1458	.1	10
Proximity to Roads	0.06	.0445	.082	.043	.056	.069	.042	.054	.0678	.0833	.06	6
Proximity to other Rail stations	.046	.0297	.02	.021	.028	.0346	.028	.041	.0678	.0625	.034	3.4
Slope Gradient	.092	.0594	.1233	.086	.1127	.104	.085	.0815	.105	.104	.095	9.5
Adequate land	.138	.1782	.2	.172	.169	.139	.171	.163	.1695	.1458	.18	18
Proximity to Water bodies	.055	.0356	.02	.021	.028	.0173	.028	.0326	.0339	.0416	.032	3.2
Proximity to Power Lines	.034	.0222	.0137	.0123	.0143	.0115	.017	.023	.05	.0208	.022	2.2
Sum	1	1	1	1	1	1	1	1	1	1	1	100

Appendix C Determining the Consistency Ratio

Factor criteria	Determining weighted sum vector
Financial mobility	(1*.244+2*.19+5*.043+3*.1+4*.06+6*.034+3*.095+2*.18+5*.032+8*.022) = 2.564
Nearby city	(.5*.244+1*.19+5*.043+3*.1+4*.06+6*.034+3*.095+1*.18+5*.032+8*.022) = 2.072
Adequate land	(.2*.244+.2*.19+1*.043+.5*.1+.5*.06+2*.034+.3*.095+.2*.18+2*.032+3*.022) = 0.4754
Alignment	(.3*.244+.3*.19+2*.043+1*.1+2*.06+4*.034+1*.095+.5*.18+4*.032+7*.022) = 1.05
Slope Gradient	(.25*.244+.25*.19+2*.043+.5*.1+1*.06+2*.034+.5*.095+.3*.18+2*.032+4*.022) = 0.632
Roads	(.16*.244+.16*.19+.5*.043+.25*.1+.5*.06+1*.034+.3*.095+.25*.18+2*.032+3*.022) = 0.3558
Drainage	(.3*.244+.3*.19+3*.043+1*.1+2*.06+3*.034+1*.095+.5*.18+3*.032+5*.022) = 0.9866
Other stations	(.5*.244+1*.19+5*.043+2*.1+3*.06+4*.034+2*.095+1*.18+5*.032+7*.022) = 1.727
Water bodies	(.2*.244+.2*.19+.5*.043+.25*.1+.5*.06+.5*.034+.3*.095+.2*.18+1*.032+2*.022) = 0.3779
Power Lines	(.125*.244+.125*.19+.3*.043+.14*.1+.25*.06+.3*.034+.2*.095+.14*.18+.5*.032+1*.022) = 0.18

REFERENCES

[1]. American railway engineering and maintenance-of-way association (AREMA) Manual for railway engeneering: “Infrastructure and Passenger ” ,volume3, 2010.

[2]. Ministry of Railways of the People's Republic of China Chief Development Organization, “Code for Design of Railway Line” ,GB 50090-2006, June 1, 2006.

[3]. UIC code, “passenger stations ”, 301-1 6th edition April 2002, translation.

[4]. S.P.Arora and S.C.Sayena, “Text book of railway engeneering”, DHANPOT rail publication , 7the Edition, 2006

[5]. Ministry of railways (railway board) government of india, “Operational Manual for Indian railways”, 2008.

[6]. Network rail, “Guide to station planing and dessign”, issue 1 july 2011.

[7]. Fransisco J.Tapidor, “Characterising the Europian high speed rail stations using intermodal time and Entropy metrics”, University of castilla – La- Tolodo spain, 2005.

[8]. Basak Sener, “landfill site selection by using geographic information systems”, school of natural and applied sciences of middle east technical university, 2004.

[9]. Victorias railindustry oprators group standard, “Railway station dessign standard and guide lines”, issue date 29/03/2011.

[10]. Akjol Djenaliev, “Multicriteria decision making and GIS for railroad planning in Kyrgyzstan”, Geoinformatics TRITA-GIT EX 07-007: School of Architecture and the Built Environment Royal Institute of Technology (KTH) 100 44, Stockholm, Sweden, 2007

[11]. Banai, R. K., 1989. “A new method for site suitability analysis, the analytic hierarchy process” Environment Management, **6**, 685-693.

[12]. Malczewski, J “GIS and Multicriteria Decision Analysis”, New York, John Wiley, 1999.

[13]. Saaty, T.L. “The Analytic Hierarchy Process”, McGraw-Hill, New York, pp.20-25, 1980.

[14]. Saaty T.L. “Multicriteria Decision Making – the Analytic Hierarchy Process”, Vol.Iof the AHP Series, University of Pittsburgh,1992.

[15]. Berihu Abadi, “Brittle Fracture and Lake Level Change at beseka: main Ethiopian rift, Metehara area”, Addis Ababa University Department of Earth Science Faculty. Addis Ababa, 2007.

[16]. Lina Zhou, Jie Wu, “GIS-Based Multi-Criteria Analysis for Hospital Site Selection in Haidian District of Beijing”, Hogskolan Igavle, Faculty of Engineering and Sustainable Development, Department of Industrial Development IT and Land Management,Bejing, 2012.

[17]. Kardi Teknomo, “Analytic Hierarchy Process (Ahp) Tutorial”, Revoledu.com.

[18]. Mark Velasquez1 and Patrick T. Hester2, “An Analysis of Multi-Criteria Decision Making

Methods", International Journal of Operations Research Vol. 10, No. 2, 56,66. Virginia Beach, 2013.

[19]. Bhushan, N;Rai,k "Strategic Decision Making Applying the Analytical Hierarchy Process". http://www.springer.com/978-1-85233-756-8, 2004.

[20]. Stuart H. Mann, "Using the Analytic Hierarchy Process for Decision Making in Engineering Applications: Some Challenges", School of Hotel, Restaurant and Recreation Management the Pennsylvania State University 201E Mateer Building University Park, PA 16802, U.S.A.

[21]. Pitz, G. F., McKillip,J.,. "Decision analysis for program evaluations", Sage Publications, Thousand Oaks, CA, 1984.

[22]. Keeney, R. L., Raiffa, H.,. "Decisions with multiple objectives, preferences and value tradeoffs". Wiley, New York, 1976.

[23]. TSDI "Design of railway station" Tianjin, 2013.

[24]. Ethiopian Railways Corporation, "New Standard Gauge Railway Ethiopia/Sebeta-Djibouti/Nagad Railway Feasibility Study", Part II Volume Executive, Edition, Addis Ababa, 2012.

[25]. ERC expert reports, "HV power supply arrangement to erc traction stations", rivised report, 2014.

[26]. Washington Metropolitan area transit authority, "station site and access planning Manual", Washington DC, 2008.

[27]. U.S. General Services Administration Public Buildings Service Office of the Chief Architect, "the Site Selection Guide".