URS

Route Selection Manual

Draft Contents

19 September 2012

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Route Selection Manual

Chapter 1: Introduction

1.1 Institutional Background

The Ethiopian Road Authority (ERA) was established in 1951 as a legally autonomous agency. In general terms, ERA is charged with the following responsibilities:

- Construction and maintenance of the country's road network
- Rehabilitation, upgrading and expansion of the national trunk road network
- Highway administration including liaison with regional, district and local road authorities
- Establishment and the monitoring of road design, construction and maintenance standards

1.2 Definition and scope of route selection studies

ERA has a medium to long-term comprehensive programme to rehabilitate, upgrade and expand the trunk road network throughout the country to improve accessibility, connectivity and balanced development. It is the pre-eminent road authority in Ethiopia and although certain highway functions are decentralised, issues relating to route selection, even for relatively low status roads, are generally dealt with centrally by ERA leaving little room for regional or local variation.

This manual covers the selection of routes for new roads, but is also relevant to road realignment where it is required as part of an alignment upgrade for road improvement schemes. In relation to the latter, a decision will need to be made as to whether or not to follow an existing alignment more or less in its entirety or to consider completely new alignment options. It is usual, however, to follow existing roads to the greatest extent possible, if they exist. Bypasses and spur roads are also encompassed by this document.

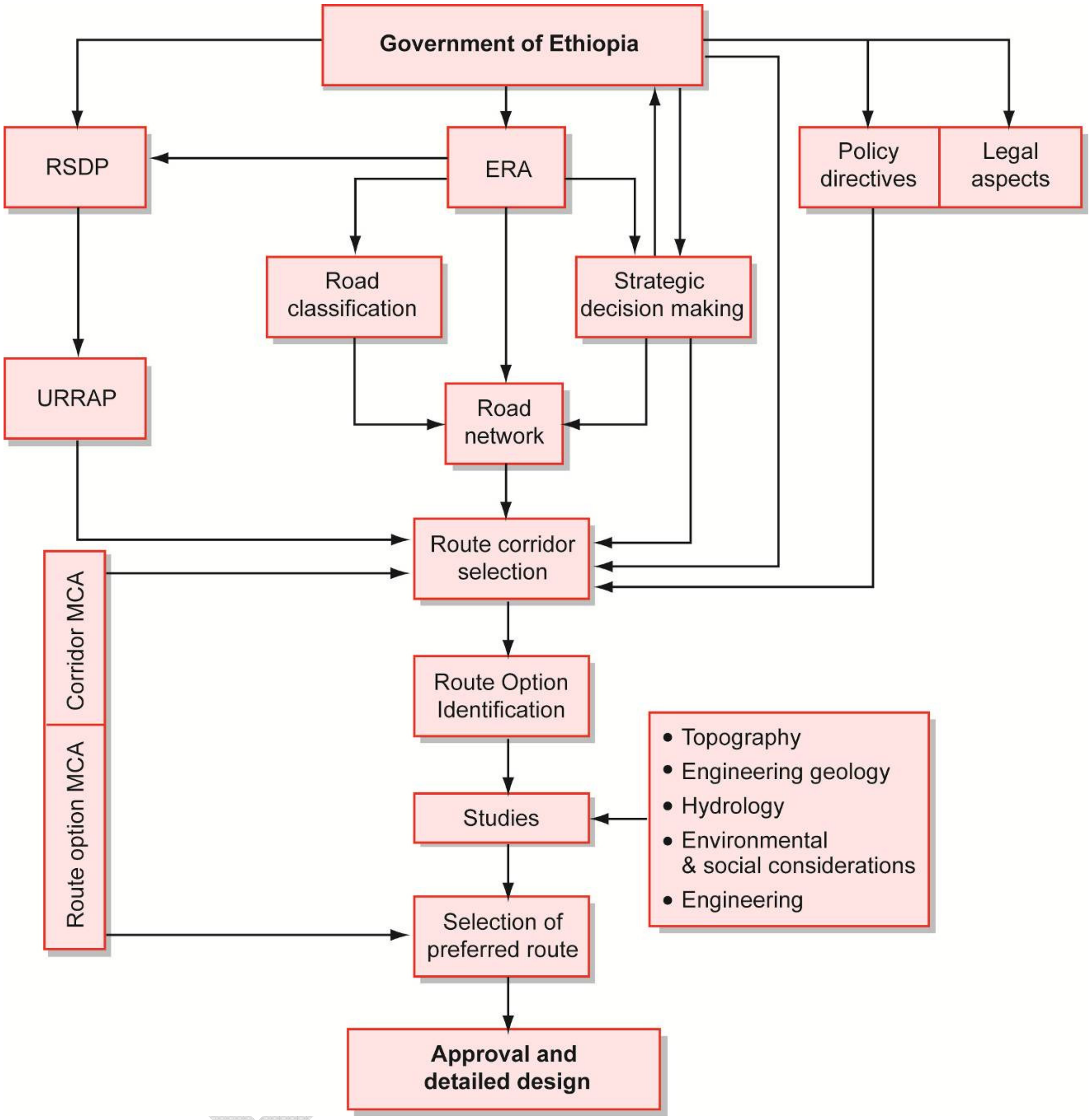
The manual was the last to be commissioned under the AFCAP technical assistance programme to ERA. All of the other manuals (Section 1.3) are updates and expansions of previous ERA documents produced in the early 2000s. This route selection manual is the first of its kind in Ethiopia, though other documents, including the AFCAP Low Volume Roads Manual, include relevant discussion.

As far as decision making is concerned for new roads, there are essentially three steps:

1) selection of the corridor within which routes are selected
2) identification of a minimum of three route options
3) selection of the preferred route option.

Figure 1.1 summarises the processes and data sources that combine to make up the corridor selection and route selection stages of a new road construction project and indicate where in this document each process is discussed.

Figure 1.1 Activity Flow Chart for Route Selection



1.2.1 Corridor Definition and Identification

No definition of "corridor" is provided in any of the ERA/AFCAP manuals. From the perspective of a road network a corridor can be considered in two ways,

- as a regional transportation corridor for the whole of an arterial route within a road network (i.e. Addis Ababa to Mekele), or,
- as a project corridor consisting of the topographic band through a particular project passes.

Regional corridors consist of many sections (i.e. individual projects) and possibly require several modes of transport (i.e. road and rail) to be included in the analysis. In this case the regional corridor width can be very wide as many different routes between two distant termini can be considered for development. A combination of new alignments and improvement of existing roads may be considered for each section. The width of a transportation corridor can be 50% or more of its length in order to include the full range of possible route options. Such analyses are usually made at higher government level.

The project corridor case is more relevant to this manual and identifies the corridor for a single project only. Where a new alignment is being considered again the width of corridor could again be up to 50% or more of the project length. Where an existing road is being improved however the corridor is likely to be more limited in width but will vary with terrain: more corridor width usually being required as the terrain steepens and more options considered.

As discussed elsewhere in this and other ERA manuals, at this stage the resources practically available for identifying a corridor are:

- Existing topographic and other specialized mapping
- Satellite imagery
- Site reconnaissance
- Local information
- Government and regional development plans

Corridor identification is a high level planning function usually carried out by ERA and can be considered a system for the prioritization of highway development projects. The implications of the above are described elsewhere in this manual, particularly Chapter 2, and will have been taken into consideration by ERA, usually based on:

- Strategic Road Planning Network Analysis
- Input from other Ministries and Authorities
- Issues raised by regional and local authorities
- Road Sector Development Programme (currently RSDP IV)

The outcome of this corridor identification process is a definition the limits of the project corridor termini and control points through which various route options can be developed to meet project goals.

1.2.2 Route Definition and Identification of Options

Route options are defined as approximate alignments within the chosen corridor that are compared in order to select the preferred route. The band width of each route option is defined according to the topography and geometric constraints, but for purposes of route comparison is usually 500m. Current practice in Ethiopia is to use freely-available satellite digital elevation data to develop route option centrelines based on the required geometric standard. However, as discussed in Chapter 4, there can be significant errors associated with this analysis in certain terrains.

The ERA Geometric Design Manual (Section 1.5) lays out general considerations and best practice with regard to route selection. These include:

"the road should be as direct as possible (within the bounds of the geometric standards for the particular class of road) between the cities, towns or villages to be linked, thereby minimising road user transport costs and probably minimising construction and maintenance costs as well."

ERA defines the purpose of the route selection process as "to identify possible options for the proposed project road and evaluate these in terms of technical, financial and economic, environmental, social and strategic terms."

Consultants are required to identify at least three possible alignment options, making reference to the Geometric Design Manual, which satisfy the requirements of connecting the stated start and end points via specified control points.

1.3 Procedure for Corridor and Route Selection

Ordinarily, the order of activity would be:

- Identify the strategic or economic justification and drivers for a new road
- Specify road function and category
- Identify corridor
- Define the fixed points that route options must go through, including, *inter alia*:
  - Start and finish point, and any intermediate towns to be connected
  - Topographic low points in mountain terrain in order to minimise rise and fall
  - Most suitable locations for major river crossings or fan crossings
  - Interchanges, where applicable
- Identify three or more route options from topographic maps plus broad consideration of environmental, engineering geological and hydrological factors
- Carry out desk study with selected field investigations of the options including all relevant factors
- Combine all factor analysis into an overall assessment for final route selection.

Selection of the route corridor is undertaken by ERA on strategic and macro-economic and macro-environmental grounds, while the identification and selection of routes within the chosen corridor is usually undertaken by consultants. This manual provides a review of the factors normally considered in route corridor selection in Chapter 2 and provides some illustration and insight with respect to the Ethiopian context. Chapter 3 reviews the issues normally considered in the identification of route options and the remainder of the manual (Chapters 4-9) deal with the studies and processes required to select the preferred route. The remainder of the manual deals with route selection within the pre-defined corridor.

Table 1.1 shows how route corridor and route selection activities ordinarily correspond to the phasing of the project cycle, from pre-feasibility study to route selection. The tendency in Ethiopia is to carry out to carry out too much preliminary design as part of the Feasibility Study thereby incurring additional costs in the development of designs for route options that later become rejected.

Table 1.1 Outline of activities normally undertaken according to project stage

Project Stage	Project Identification	Pre-Feasibility	Feasibility	Design	Construction	Improvement/ Upgrading	Maintenance/ Operation
Principal Activities	Identification of the need for a new road, based on strategic, economic or social/rural mobility	Definition of route corridor & identification of fixed points through which route options must pass. Preliminary estimates of project length, cost, environmental & social impacts & benefits	Identification of route options, desk & field studies to yield comparisons of length, cost, stability & geo-hazard, environmental & social considerations	Sometimes undertaken as Preliminary & Detailed. If the FS is sufficiently detailed then a PD is not usually required. If the FS is generalised or absent then PD is required. DD involves geometric design, design of EWs, drainage, geo-hazard control, & environmental mitigation & land acquisition & compensation Detailed BoQ & cost estimate.	Construction of designed alignment and ancillary works. Inspection of ground conditions during excavations to ensure compatibility. Redesign to take account of any unforeseen conditions or environmental effects	This may require road realignment, either locally or over longer distances, to allow for higher geometric specification. This could involve pre-feasibility level studies as well as Feasibility Study and Design.	Maintenance and operation of the constructed alignment.
Relevant AFCAP/ERA Manuals (Section 1.2)	ERA Project Planning and Procurement Manual (Volume 1)	Route Selection	Route Selection Geometric Design, Site Investigation	Low Volume Roads, Geometric Design, Bridge Design, Drainage Design. Geotechnical Design, Site Investigation. Rigid Pavement, Flexible Pavement, ERA Environmental and Social Management Manual	All, except Route Selection	All, including Route Selection	All, except Route Selection

1.4 Range of Criteria for Route Selection

Table 1.2 lists the criteria most commonly taken into consideration during route selection and the chapters in this Manual where guidance and illustration is provided on each.

Table 1.2 Common route selection criteria and relevant chapters of this Manual

Selection Criteria	Relevant Chapters in this Manual
Route length	4 and 8
Construction cost	4 and 8
Maintenance cost (where persistent geo-hazards require ongoing investment)	8 and 9
Cumulative rise and fall	4 and 8
Length at steep gradients	4 and 8
Length at reduced horizontal standard due to topographic and other constraints	4 and 8
Number and span of required bridges (though ordinarily covered in cost)	6 and 8
Ease of construction and required construction technology	8
Environmental, social impact and cultural constraints – though most of the 'showstoppers' should have been avoided during corridor selection	7
Geological conditions and geo-hazards	5
Existing landslide areas	5

Selection Criteria		Relevant Chapters in this Manual
	Areas potentially prone to future landslides	5
	Areas prone to flooding (river floods and high water tables)	6
	Active faults in relation to bridges and other major structures	5
	Fault scarps, such as those bordering the rift valley	5
	Problematic soils (eg smectities, allophanes, bentonites, colluvium and taluvium)	5
Construction materials availability		5

1.5 Existing Guidelines

The ERA road design manuals updated and expanded under AFCAP are listed in Table 1.3 along with a brief summary of their relevance to route selection. Table 1.1 indicates the project stage at which these various manuals, and this Route Selection Manual are most relevant.

Table 1.3 Existing ERA road design manuals updated and expanded under AFCAP

Manual Title	Date	Relevance to Route Selection	Relevant Chapter in this Manual
AFCAP Manuals			
Low Volume Roads Design Manual	Apr 2011	Very useful all-round manual for low volume roads, but limited value to route selection *per se*	All
Geometric Design Manual	Sep 20[illegible]	Relates specifically to the geometric design of the selected route, however considerations of horizontal and vertical alignment specifications and associated traffic and safety issues need to be considered at route selection stage.	8
Bridge Design Manual	Mar 2011	Relates specifically to the design of bridges, limited discussion on site selection for river crossings, limited value to route selection *per se*	6
Geotechnical Design Manual	2012	Relates specifically to the description and mitigation of problematic soils, design of earthworks and foundations for structures, limited value to route selection *per se*	5
Site Investigation Manual	2012	Useful description of regional variation in geography and geology, ground conditions, geo-hazards and sources of published data – useful for route selection	5
Drainage Design Manual	2012	Relates specifically to the design of road cross drainage, limited value to route selection *per se*	6
Flexible Pavement Design Manual	2011	None	None
Rigid Pavement	2[illegible]	None	None

Manual Title	Date	Relevance to Route Selection	Relevant Chapter in this Manual
Design Manual			
Pavement Rehabilitation and Asphalt Overlay Design Manual	2011	None	None
Other Manuals			
ERA Project Planning and Procurement Manual (Volume 1)	2006	Provides very useful background to the strategic, network planning and economic basis for project identification, though not route selection *per se*	2
ERA Environmental and Social Management Framework	2008	Provides outline description of environmental and social issues relating to infrastructure development, as well as planning applications, roles and responsibilities. No guidance on route selection specifically.	7

Internationally, there is a significant volume of literature that deals with the geometric design of alignments, but nothing has been found that deals specifically and comprehensively with corridor and route selection, though some useful guidelines and illustrations (including from Ethiopia) are given in Hearn (2011).

1.6 Policy Directives Relevant to Route Selection

1.6.1 Legislative Background

ERA's authority was confirmed by a series of proclamations:

- Established as "Imperial Highway Authority" by Proclamation No. 115 of 1951
- Re-established as "Ethiopian Transport Construction Authority " by Proclamation No. 189 of 1980
- Finally, Re-established as "Ethiopian Roads Authority" by Proclamation No. 80/1997

The majority of its current powers are covered by the last of these proclamations together with Regulation 247/2011.In particular, Proclamation 80/1997 gives ERA powers to 'classify and designate the national road network' and 'maintain highways by its own force or through contractors'.

Regulation 247/2011 aims to augment the 1997 Proclamation and includes the following duties for ERA:

- 'prepare coordinated national network plan'
- 'acquire land required for road works'
- 'declare roads as toll roads'

ERA aims to develop a network of toll roads with motorists paying tolls while existing roads provide for non-motorway traffic. Their specific place in ERA legislation is necessitated by the levying of tolls on road users. The 2011 regulation lays the ground for the operation of toll roads.

The legal powers granted to ERA are inclusive rather than specific and, as such, route selection, road construction and upgrading are not directly defined. Likewise, bypasses and spur roads are not directly referred to in the official proclamations and directives.

Roads in border areas come under the authority of military directives.

Chapter 2 Network and Strategic Considerations in the Selection of Route Corridors

2.1 Introduction

This chapter deals with the process of route corridor selection. This is a strategic level process that is normally undertaken by ERA and involves both national and regional level objectives associated with long-term network planning. Corridor selection should involve consideration of a range of traffic forecasting, connectivity, economic and environmental issues and should consider intended road function within the classification system of the existing network.

2.2 Road classification system

Ethiopia's current functional road classification dates from 1997 and ERA's responsibilities in this field are laid out in Proclamation 80/1997. The classification is based on the socio-economic importance of roads linking Traffic Generating Areas as recommended in the Road Functional Classification Study.

Ethiopia is divided into a number of Traffic Generating Areas (one hundred and twenty three for classifying the main network) which were ranked and classified according to their socio-economic importance. The weight assigned to each socio-economic criterion was, where possible, based on the distribution of GDP to reflect an area's significance compared with the whole country. Traffic Generating Areas having been ranked and classified, roads were then classified according to the classes of the Traffic Generating Areas they connect. The method was applied to the entire Ethiopian road network and was intended to be used also for roads under construction as well as planned roads.

Six groups of socio-economic criteria were used in classifying Traffic Generating Areas, as follows:

- Demography
- Agriculture including Livestock
- Mines and Quarries
- Industry
- Services
- International Road Borders

Out of the study the following main classifications were established:

- A Class: Trunk Roads
- B Class: Link Roads
- C Class: Main Access Roads
- D Class: Collector Roads
- E Class: Feeder Roads

The initial classification defined Classes A to C as Federal Roads and thus directly under the responsibility of ERA, with Classes D to E as Regional Roads which were to be looked after by Regions or local administrative bodies. However, in reality the current role the ERA requires it to become involved in the lower two classes of road. Through District Maintenance Offices (DMO) ERA maintains certain Class C and D roads plus some that are unclassified.

For any new road it is important early on to determine its required standard in general terms, i.e. whether or not the proposed road will be an expressway, a dual carriageway, a sealed road or a gravel road. This standard should be based on overall network and strategic considerations and will be confirmed or modified once traffic data and analysis are obtained and undertaken during Route Option Engineering (Chapter 8). Generally, the design standard adopted for a project should not vary from that of an adjacent project by more than a single standard unless dictated by ERA.

2.3 Strategic Decision Making

ERA faces a number of interlinked issues and challenges in the development of the national road network:

- Size of country: 1.1m km^2, 10^{th} largest in Africa
- Terrain: considerable diversity of terrain and altitude with a significant proportion of land area classified as mountainous/escarpment
- Poverty and vehicle ownership: low by international standards
- Road network density and accessibility: low by international standards

2.4 Government Objectives and Programmes

ERA, on behalf of the Government of Ethiopia, has outlined the following road network development priorities:

- Hinterland/connection to commercial centres/international ports
- Major potential development areas, e.g. connections between capital and/or regional centres
- Areas warranting development, e.g. important agricultural links or having tourist potential
- Links between surplus areas and drought prone areas
- Connections between trunk roads

2.4.1 Road Sector Development Plan (RSDP)

In response to the issues of poverty and accessibility, the Government of Ethiopia formulated a strategy to improve the socio-economic conditions of the country. The implementation of the strategy depends on effective road infrastructure to improve access to social facilities such as health centres. Accordingly, the Road Sector Development Program (RSDP) was formulated in 1997 as part of the wider development strategy.

RSDP places an increased emphasis on improving the quality and quantity of the road infrastructure, accelerating the expansion of Ethiopia's road network. The formulation of RSDP included the establishment of a road sector environmental unit to handle the environmental issues of road planning.

The phases of the RSDP can be briefly described as follows:

- RSDP I (1997-2002): restoration of the road network
- RSDP II (2002-2007): increase network connectivity and provide a sustainable road infrastructure to rural areas
- RSDP III (2007-2010): manage the road network and strengthen development of the domestic construction industry.
- RSDP IV covers the period 2010 – 2015 and sets out priorities at each level. Its main objectives are:
    - Improving transport operating efficiency
    - Providing access to all Kebele centres and potential areas
    - Developing technical capacity at all levels

2.4.2 Universal Rural Road Access Program (URRAP)

The Universal Rural Road Access Program (URRAP) is a large scale program for rural accessibility enhancement. Unlike RSDP it is a purely Ethiopian project. URRAP is a successor program to the Ethiopia Rural Travel and Transport Program (ERTTP), the capacity building elements of which have migrated to URRAP. Lessons learnt from ERTTP have been adopted in URRAP.

Objectives of URRAP

URRAP aims to connect all Kebele centres by roads of a standard that provides all-weather, year round access.

This is designed to:

- Meet the needs of the rural communities in:
    - ensuring access to market and agricultural inputs
    - ensuring access to social services facilities
    - integrating rural areas with urban areas
- Be affordable
- Be maintainable

2.5 Route Corridor Selection

2.5.1 Introduction

Road projects are initially identified in a number of ways:

- Through ERA's strategic road network planning analysis
- Via initiatives of other ministries
- From proposals by regional governments

- From requests by people’s representatives.

Projects are then identified according to a number of selection criteria which can broadly be classed as:

- Economic investment development criteria
- Socioeconomic development criteria
- Environmental impacts

These criteria are used to screen projects as to whether they should be:

- undertaken immediately
- in the near future
- delayed until a later time

Compatibility with the objectives of RSDP and other development programmes is essential for a project to be shortlisted for immediate authorisation.

A second screening of shortlisted projects includes the following preliminary assessments:

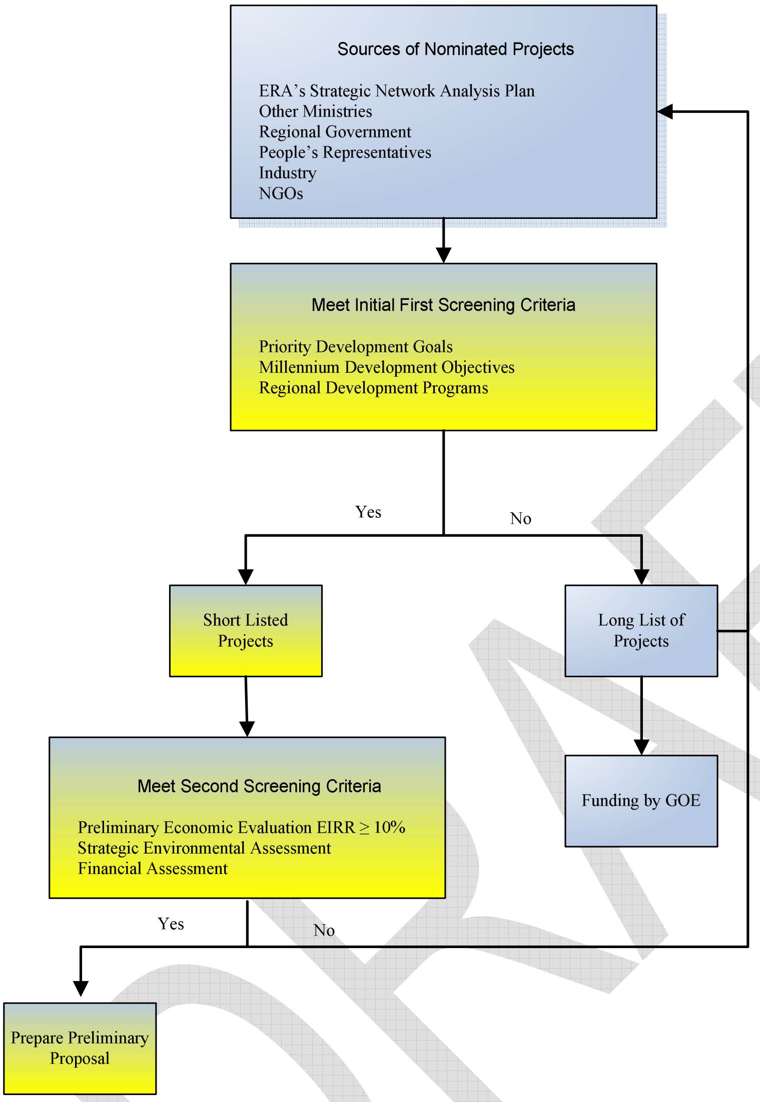
- Economic
- Environmental
- Financial

More specifically, the Planning and Programming Division (PPD*)* of ERA carry out a number of preliminary assessments of the components of a proposed project including:

- Likely changes to current volume and mix of traffic and the resulting impact on the environment
- Financial cost of the project including contingencies
- Economic benefits of the project to road users and the communities served
- Analysis of the risks associated with the projected project benefits being achieved

The process is illustrated in Figure 2.1 below taken from ERA’s “Project Planning and Procurement Manual Volume 1 – Planning”. Of considerable importance in route corridor selection is the requirement to minimise and preferably avoid conflict with existing environmental conservation issues and initiatives.

Figure 2.1 Process of Project Identification



These activities should give rise to the identification of a suitable corridor for the selected project. This corridor must take due consideration of the following issues, namely the need to:

- ensure that the corridor is wide enough to allow route options within it to be identified (Chapter 3), this will be dependent on the following consideration:
    - nature of topography, i.e. the extreme the topography the broader will need to be the corridor to allow flexibility within it
    - classification of the intended road, as this will determine minimum-standard geometry and the flexibility to accommodate the topography in the engineering (Chapter 8)
- avoid sensitive environmental and cultural areas or monuments, such as National Parks and other areas of environmental protection

- avoid areas of geological and hydrological hazard, especially areas prone to landslides and flooding.

In most cases there will be a requirement to consider a number of factors in route corridor selection and definition, and these may require some form of multi-criteria analysis to be performed to ensure objectivity.

2.5.2 Application of Multi-Criteria Analysis in Corridor Selection

Multi-criteria analysis is used in the evaluation of route corridor selection based on criteria which are aimed at covering all of the objectives of road network development policy under two main headings, as follows:

A. Socio-economic return on investment:

- Level of transport demand
- Cost effectiveness
- Degree of urgency
- Relative importance of investment cost
- Environmental effects
- Financing feasibility

B. Functionality and coherency of the network:

- Type of relation
- Relative importance of international demand of traffic - passengers
- Relative importance of international demand of traffic - goods
- Probability of development roads being achieved
- Interconnection of existing networks
- Meeting ERA standards of service

For the above mentioned criteria brief explanation is as follows:

(i) Level of transport demand:- relative level of traffic using the infrastructure, determined according to ranges of existing traffic

(ii) Cost effectiveness:- an indication of the likely level of EIRR for the project, determined by type of investment, importance of demand and relative magnitude of project benefits

(iii) Degree of urgency:- whether a project has to be implemented as soon as possible or whether its implementation may be delayed

(iv) Relative importance of investment costs:- whether the project is expensive or cheap given its type and size and the costs of similar projects

(v) Environmental effects:- importance of the project for protection/improvement of the environment, in particular whether or not it conflicts with environmental and conservation issues

(vi) Financing feasibility:- indication to potential financing institutions of (i) the capability of the project to generate the necessary additional resources for its own operations and (ii) the reliability of the cost estimate and of the definition of the project

(vii) Type of relation:- international importance of the link or the itinerary associated with the project, politically as well as economically

(viii) Relative importance of international demand of traffic:- indicates the amount of international transport (by passenger and goods) in the total transport demand for the project

(ix) Probability of development objectives being achieved:- where the anticipated project benefits are less likely to be achieved due to economic, social, political or environmental factors

(x) Interconnection of existing networks:- extent to which the project improves communications between one regional/national network with another

(xi) Meeting ERA standards of service:- whether the existing facility provides a level of service close to the standards defined by the ERA in terms of comfort, speed or safety.

These criteria can be used in conjunction with ERA’s five road network development priorities outlined above in the section on Government Objectives and Programmes. “Project Planning and Procurement Manual Volume 1 – Planning” proposes that the five priorities be augmented by three further criteria to give the following as a functional basis for MCA at a wider level under ERA:

- Hinterland/connection to commercial centres/international ports
- Major potential development areas
- Areas warranting development
- Links between surplus areas and drought prone areas
- Connections between trunk roads
- Environmental status
- Right of way status
- Road pavement condition

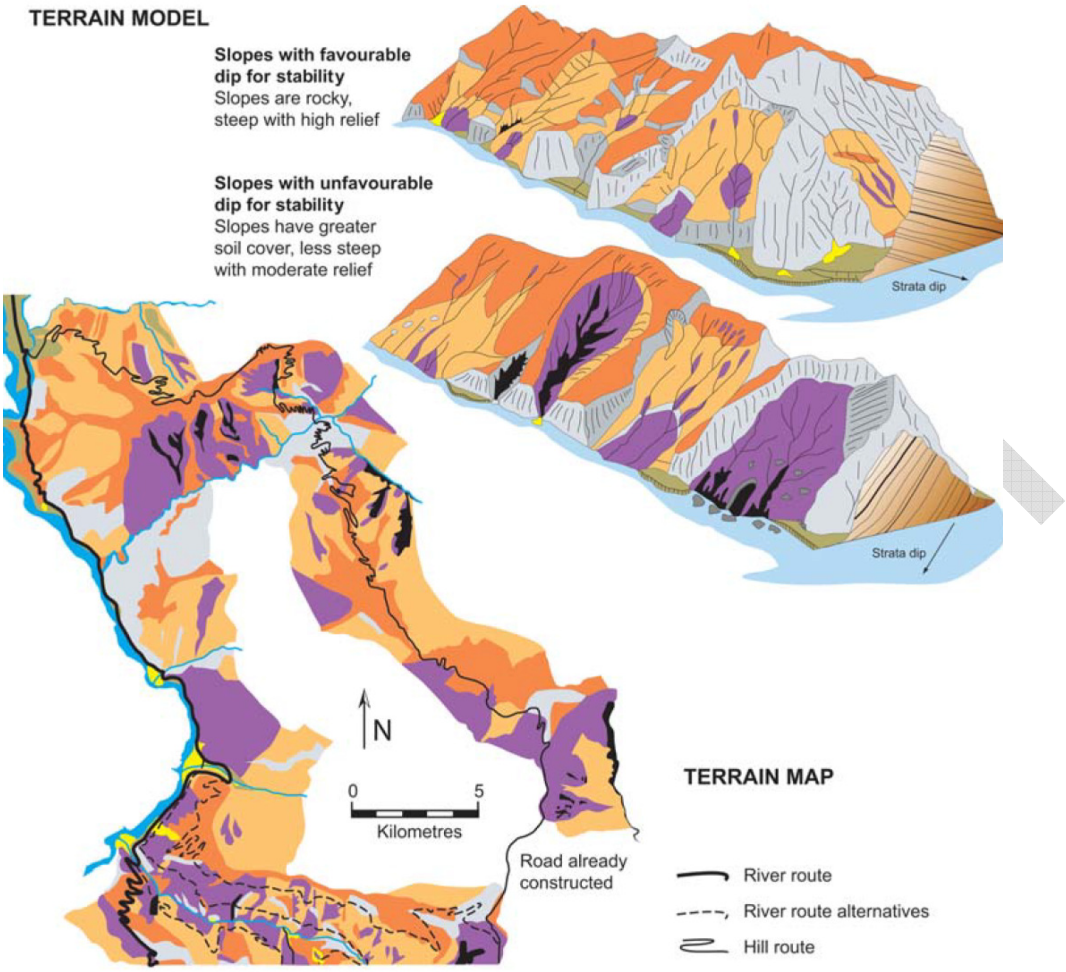
2.6 Illustration of Route Corridor Selection

Figure 2.2 shows an example of route corridor selection from Nepal in the Himalayas; a country that has a population made up significantly of mountain communities, a topography that poses considerable difficulty for road construction and a geology and hydrology that combine to pose significant problems associated with landslides and floods. The example relates to the provision of road access to a proposed hydro-power scheme in the Middle Himalayas from a road head in the Lower Himalayas. The initial client responsible for the corridor selection was the Department of Roads. The DoR’s priority in corridor selection was to ensure that the maximum number of hill towns and rural communities would be served by the road, thus maximising the socio-economic advantages to be gained by the operation of the road. Route options were then identified within this hill route corridor and the selected route was developed into an engineering design.

However, a change in funding and procurement arrangements resulted in the decision to appoint the Nepal Electricity Authority as the executing agency for the project. This brought about a realignment of objectives; from rural connectivity to shortest distance. Consequently a revised corridor was identified on this basis that followed a more direct river route corridor. These two corridors are shown on Figure 2.2 along with the preferred alignment option within each. A terrain assessment was undertaken for each corridor in order to compare the topography, ground conditions and geo-hazards present within each.

The decision to change the corridor selection priorities necessitated a significantly longer feasibility and design period with attendant doubling of the costs of survey, land acquisition and design.

Figure 2.1 Terrain Assessment for Corridor Selection - an Example from Nepal (Hearn 2011)



LANDFORM TYPE	LANDFORM SUB-TYPE*
Residual soil slopes	• Rounded ridge and spur summits, and gently sloping ground with residual soil cover • Mid slope erosional benches with residual soil cover • Structurally-controlled dip slopes with residual soil cover
Rock slopes: miscellaneous	• Miscellaneous rock cliffs • Rock cliffs forming landslide scarps • Irregular steep slopes (up to 45°)
Rock slopes: structurally-controlled	• Bedding, foliation or joint-plane controlled slopes • Structural bench • Structurally-controllled ridge and ravine topography
Transported soil slopes	• Taluvium and colluvium (undifferentiated)
Unstable slopes Previously failed slopes	• Mudslides, debris slides and rockslides on steep slopes adjacent to eroding rivers and streams • Mudslides and debris slides associated with local erosion and high groundwater • Large, deep-seated slope failures usually with adverse structural-control
Fan deposits	• Active fan surface, usually on flood plains • High level fan deposits, usually associated with high level terraces or deposited by catastrophic landslides
Terrace gravels	• Flood plain terrace (periodically inundated). • Terrace flank • High level terrace

*In the original terrain classification and mapping these landform sub-types were shown separately but for the sake of clarity at this scale they are shown combined

Chapter 3 Identification of Route Options Within the Selected Corridor

3.1 Introduction

Once the route corridor is selected (Chapter 2) there is a requirement to identify route options within that corridor. The assessment of each of these options (Chapters 4 to 8) needs to be to a sufficient level of detail to allow objective and confident comparisons between them to be made, leading to the selection of the preferred option for detailed design.

In Ethiopia, a minimum of three options are required to be considered. Current practice is to develop these options to a preliminary design level in order to derive a cost estimate for each that allows a valid comparison and selection to be made (Chapters 8 and 9). Clearly it is critically important to ensure that these route options are chosen taking adequate consideration of all relevant factors. These factors will have already been reviewed at the corridor selection level described in Chapter 2, but a greater level of detail will be required for option identification. In fact, it could be argued that the process of route option identification is equally, if not more, important than route comparison (Chapters 4-8) and ultimately route selection itself (Chapter 9).

Route option identification is usually undertaken by consultants on behalf of ERA, and needs to consider the following:

- Ease of topography
- Practicality of designing an alignment according to geometric standard within the topography
- Avoidance of areas of known geo-hazard, including landslides, flooding and problematic soils
- Avoidance of environmentally protected areas and other sensitive habitats
- Avoidance of location or areas of cultural heritage value
- Need to maximise connectivity of villages and towns and improve rural mobility
- Need to maximise traffic connectivity and access to economic resources and markets
- Need to select the shortest distance alignment, beating in mind the above factors.

This list of considerations is not comprehensive and is not presented in order of importance, but the need to select the shortest length has been placed at the end of the list for a reason. The shortest distance, in theory, might lead to the lowest construction cost in the majority of situations, but critically important issues, such as slope stability and environmental impact, can result in unaffordable maintenance costs and unacceptable environmental damage. These considerations are discussed in more detail in Chapters 5 and 7, but are critically important to the identification of options in the first place.

3.2 Geometric Considerations for Route Option Identification

The determination of design standard should be undertaken at project identification and route corridor selection stage (Chapter 2) as is important to the identification of route options within the chosen corridor. Confirmation of the intended road standard will either rule out or rule in route options for consideration based on topography. It will be necessary during route option identification stage to ensure that the options identified are likely to be feasible considering both the ruling geometry and the constraints imposed by the terrain. This exercise is probably best done using topographical maps and desk study assessment, however satellite imagery, and particularly SRTM data, will also be useful in this exercise (see discussion in Chapter 4). Walkover reconnaissance surveys may be required to confirm any uncertainties from the desk study.

3.3 Other Considerations

As mentioned above, these include geological, geo-hazard and environmental issues. They can be reviewed initially by desk study and, in particular, through the use of remote sensing, but the level of detail is likely to be insufficient and so field reconnaissance surveys should be planned. These reconnaissance surveys should be rapid and should be designed to collect sufficient information to enable no-go areas to be identified. These no go areas might include:

- Valley sides or slopes prone to landslides
- Very steep and complex topography
- Areas liable to frequent inundation by floods
- Marshy areas
- Terrain underlain by problematic soils, such as compressible soils, collapsing soils and soils prone to significant erosion
- Areas of high agricultural value
- Areas where water resources might be adversely affected
- Any environmentally and culturally protected areas that have not been avoided through corridor selection (Chapter 2)
- Areas of forest
- Built up areas.

Other considerations should include the identification of preferred locations for major bridge sites and cols or saddles in mountain terrain that act as fixed points in defining route options. For low standard roads it may also be necessary to identify route options that avoid large areas of expansive (Black Cotton) soils, as mitigating the effects of these could represent a significant proportion of the overall construction cost.

Ridge-top route options are often preferred and are necessary routes because of the locations of existing settlements, however, when compared with valley bottom alignments incur much greater vehicle operating and construction costs. Typically construction costs for a new road in mountainous area can be two to five times greater than a road of the same design standard in rolling and flat terrain (Chapter 4). However, valley floor route options may be required to cross more frequent and wider rivers and other water courses (Chapter 6), thus increasing potential costs significantly. These considerations will need to be taken into account when selecting route options for further study and comparison.

Reconnaissance surveys should be undertaken by a mutt-disciplinary team, typically comprising of the following:

- Geometric Design Engineer
- Engineering Geologist
- Hydrologist/Drainage Engineer
- Environmental/Social Specialist

The time period required for reconnaissance survey will vary according to the size of the project, the breadth of the corridor and the extent of data already available at desk study. However, it would not be uncommon for such an exercise to take at least 2 weeks to complete. Some of the more important issues to be considered during these reconnaissance surveys are listed in Table 3.1.

Table 3.1 Common Considerations for Route Option Reconnaissance Survey

Category	Sub-category	Remarks	Mandatory	Optional
Alignment	Terrain Classification	Assess the alignment re location type (ridge, valley etc) assess design standard in relation to topographic constraints.	Yes	
	Alignment type		Yes	
	Design Standard			
	Traffic composition and volume			Yes
Structures	Required major river crossings and required spans	Identify preferred locations in terms of approach, approximate required width and suitability of river reach and banks for waterway and abutment stability.	Yes	
Construction Materials	Sources	General observations regarding potential sources of material and water for construction and access to them		Yes
	Access arrangements			Yes
Geotechnical Issues	Landslides	Check desk study analysis of landslides and soils. Consider feasibility of mitigation.	Yes	
	Problematic soils		Yes	
	General founding conditions			Yes
	Stabilization		Yes	
Hydrology/Drainage	Natural drainage pattern	Review desk-top study conclusions of drainage patterns. Contribute to assessment of bridge location fixed points.	Yes	
	High water levels		Yes	
	Bridge locations (see above)		Yes	
Environmental/Social Conditions	Land use	Review current land use, types of crop & extent. Examine potential water resource conflicts. Confirm desk study assessment of protected area status and sensitive habitats. Review project benefits in terms of access provision. Review project dis-benefits in terms of land acquisition, livelihood disruption etc.	Yes	
	Population distribution		Yes	
	Water resources		Yes	
	Sensitive habitats		Yes	
	Protected/Reserved Areas		Yes	

3.4 Illustration from Arba Minch - Konso

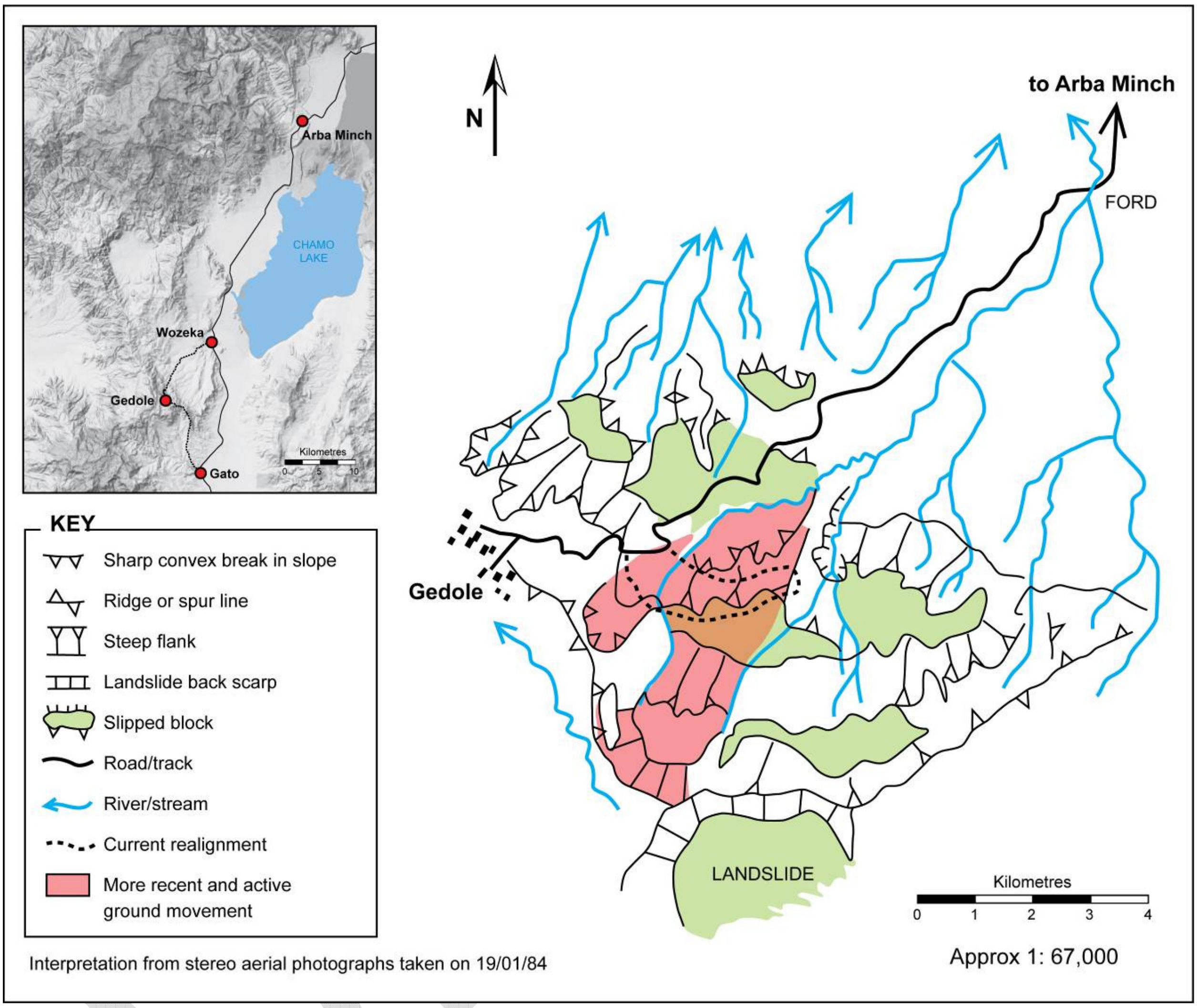
The importance of selecting viable route options is illustrated by the case of the road between Arba Minch and Konso in southern Ethiopia. The existing road between Arba Minch and Konso follows flat to gently sloping side long ground, mostly cultivated and affected by several large drainage courses that have created significant problems of erosion and flooding along the road. One of the requirements in the identification of route options was the need to link the hill town of Gedole into the road network. The possible route options for the road upgrading scheme include:

1. Upgrade to the existing alignment between Wozeka and Gato with the construction of a spur road to Gedole from Wozeka
2. As 1. but with a spur road to Gedole from Gato rather than Wozeka
3. Construction of a road from Wozeka to Gedole and from Gedole to Gato.

A decision was made to select option 3 and a design was prepared for the construction of this 34 km long road. Construction commenced in 2009 but construction of the section between Wozeka and Gedole was abandoned in 2012 due to the development of severe landslide problems along it (Figures 3.1 and 3.2). This section of road is located in a zone of ancient deep-seated movement and road excavation has reactivated significant instability. It may have been possible to have found a more stable route along this section than the one selected for design and construction. A route option following the existing part-constructed route between Wozeka and Gedole should never had been identified on both geotechnical and environmental grounds; its selection being apparently due to administrative reasons.

Figure 3.1 Landslides triggered by construction of the section of road between Wozeka and Gedole

Figure 3.2 Geomorphological interpretation of the Wozeka – Gedole area



Chapter 4 Topography

4.1 The Topography of Ethiopia

The general topography of Ethiopia is shown on Figure 4.1. Between the valley of the Upper Nile and Ethiopia's border with Eritrea is a region of elevated plateaux from which rise the various tablelands and mountains that constitute the Ethiopian Highlands. On nearly every side, the walls of the plateaus rise abruptly from the plains, constituting outer mountain chains. The eastern wall of this plateau follows closely the line of 40° E for some 600 km. About 9° N there is a break in the wall, through which the Awash River flows eastwards. The main range at this point trends southwest, while south of the Awash Valley, which is some 1,000 m below the level of the mountains, another massif rises in a direct line south.

This second range comprises a chain (the Ahmar mountains) pointing eastwards toward the Gulf of Aden. The two chief eastern ranges maintain a parallel course south by west, with a broad upland valley in between - in which valley are a series of lakes - to about 3° N, the outer (eastern) spurs of the plateau still keeping along the line of 40° E. The southern escarpment of the plateau is highly irregular, but has a general direction northwest and southeast from 6° N to 3° N. It overlooks the depression in which is Lake Turkana and - east of that lake - the southern Debub Omo Zone.

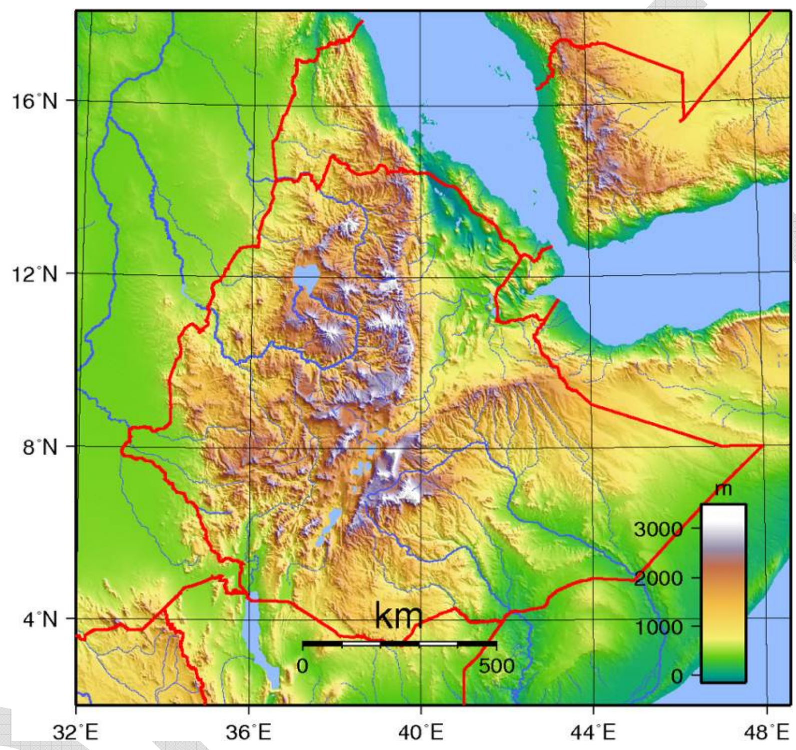
The western wall of the plateau from 6° N to 11° N is well marked and precipitous. North of 11° N the hills turn more to the east and fall more gradually to the savannah plains at their base. On its northern face, the plateau falls in terraces to the level of the eastern Sudan. The eastern escarpment is the best defined of these outer ranges. It has a mean height of 2,100 to 2,400 m, and in many places rises almost perpendicularly from the plain. Narrow and deep clefts, through which descend mountain torrents that lose themselves in the sandy soil of the Eritrean coast, afford means of reaching the plateau, or the easier route through the Awash Valley may be chosen.

The northern portion of the highlands, lying mainly between 10° and 15° N, consists of a huge mass of rocks with a mean height of 2,000 to 2,200 m above sea level, and is flooded in a deep central depression by the waters of Lake Tana. Above the plateau rise several irregular and generally ill-defined mountain ranges which attain altitudes of from 3,700 m to just under 4,600 m. Many of the mountains are of unusual shape. Characteristic of the country are the enormous fissures which divide it, formed over time by the erosive action of water. They are in fact the valleys of the rivers which, rising on the uplands or mountain sides, have cut their way to the surrounding lowlands. Some of the valleys are of considerable width; in other cases the opposite walls of the gorges are as little as two or three hundred meters apart, and fall almost vertically thousands of meters, representing an erosion of many hundred thousand cubic metres of hard rock. One result of the action of the water has been the formation of numerous isolated flat-topped hills or small plateaus, known as *ambas*, with nearly perpendicular sides. The highest peaks are found in the Simien and Bale ranges. The Simien Mountains lie northeast of Lake Tana and culminate in the snow-covered peak of Ras Dashen, which has an altitude of 4,550 m.

The Bale Mountains are separated from the larger part of the Ethiopian highlands by the Great Rift Valley, one of the longest and most profound chasms in Ethiopia. The highest peaks of that range rise in excess of 4000 m. Below 10° N, the southern portion of the highlands has more open tableland than the northern portion and fewer lofty peaks. Though there are a few heights between 3,000 and 4,000 m, the majority do not exceed 2,400 m, but the general character of the southern regions is the same as in the north: a much-broken hilly plateau.

East of the highlands at the north end of the Rift Valley, towards the Red Sea there is a strip of lowland semi-desert that eventually forms the Danikil Depression, more than 100m below sea level, with very high temperatures and numerous active volcanoes.

Figure 1 Topography of Ethiopia

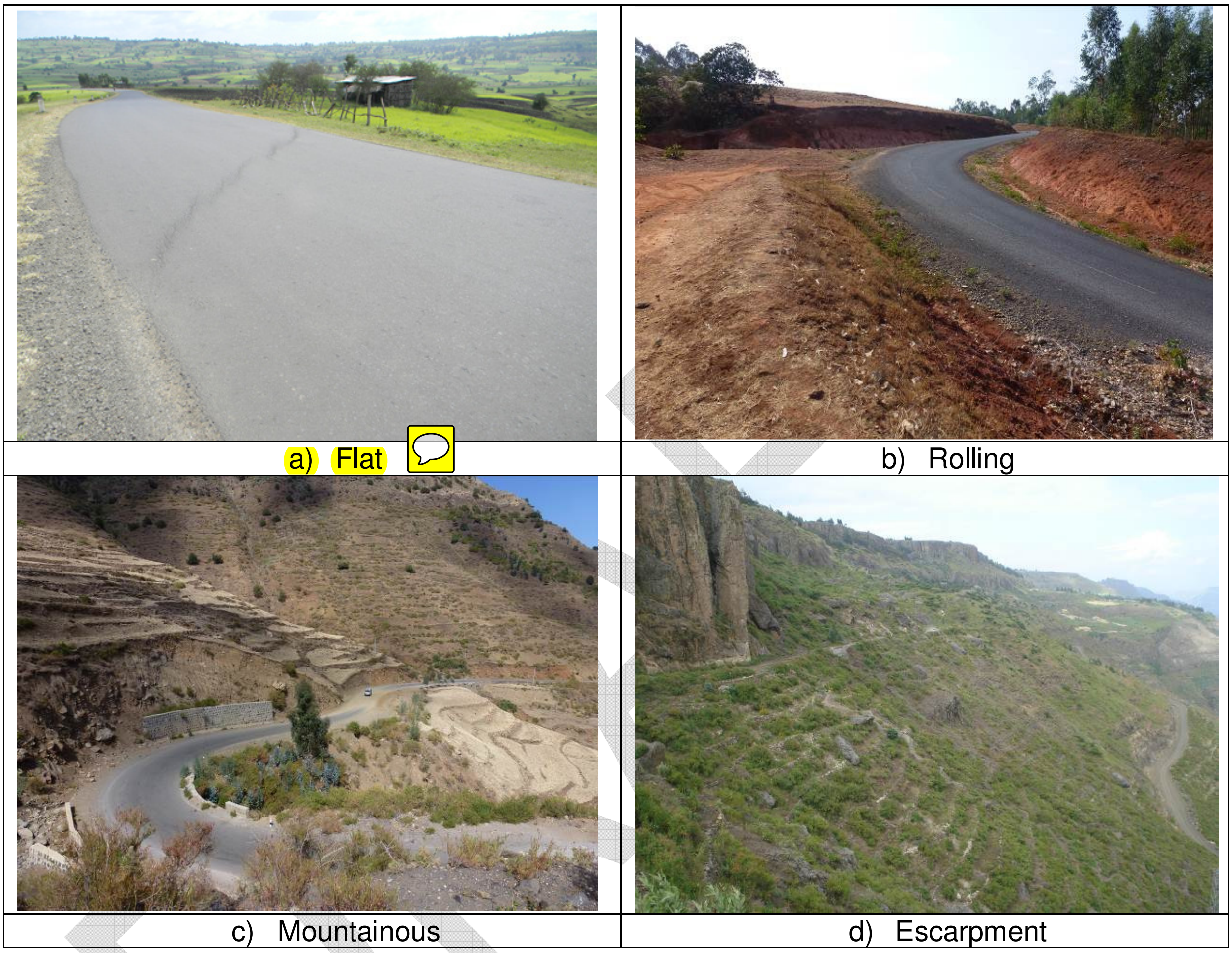


Elsewhere in the ERA design manuals, all of these topographic features have been divided into four types of terrain:

- **Flat** terrain requiring a largely unrestricted horizontal and vertical alignment, with 0-10 five-metre contours per km. The natural ground slopes perpendicular to the ground contours are generally below 3% (2^o slope)
- **Rolling** terrain with low hills introducing moderate levels of rise and fall with some restrictions on vertical alignment with 11-25 five-metre contours per km. The natural ground slopes perpendicular to the ground contours are generally between 3 and 25% (2^o to 14^o slope).
- **Mountainous** terrain that is rugged and very hilly with substantial restrictions in both horizontal and vertical alignment; 26-50 five-metre contours per km. The natural ground slopes perpendicular to the ground contours are generally above 25% but below 75% (14^o to 37^o slope).
- **Escarpment** terrain that is steep topography requiring switchback sections and side hill traverses; transverse terrain slopes are greater than 75% (37^o slope)

However, in terms of route selection there is so much overlap between mountainous and escarpment terrain that it is probably more convenient to combine these two.

Figure 4.2 illustrates the various terrain types.



a) Flat | b) Rolling | c) Mountainous | d) Escarpment

Figure 4.3 shows typical route selection problems associated with Mountainous and Escarpment terrain. This terrain model was developed for the Mekhane Selam to Gundewein road crossing the Blue Nile Gorge showing the proposed road substantially following a ridge alignment before descending into the gorge in a series of switchbacks in order to cross the river at a suitable crossing point. Significantly, the alignment has to descend two limestone cliffs and the locations of these descents were a critical factor in route selection. Figure 4.4 illustrates some of the terrain depicted in this model. Appendix 1 contains terrain models developed for other parts of the Ethiopia, emphasising the importance of topography and geology in the identification and selection of route corridors.

Figure 4.3 Terrain model for the Blue Nile Gorge (Hearn 2011)

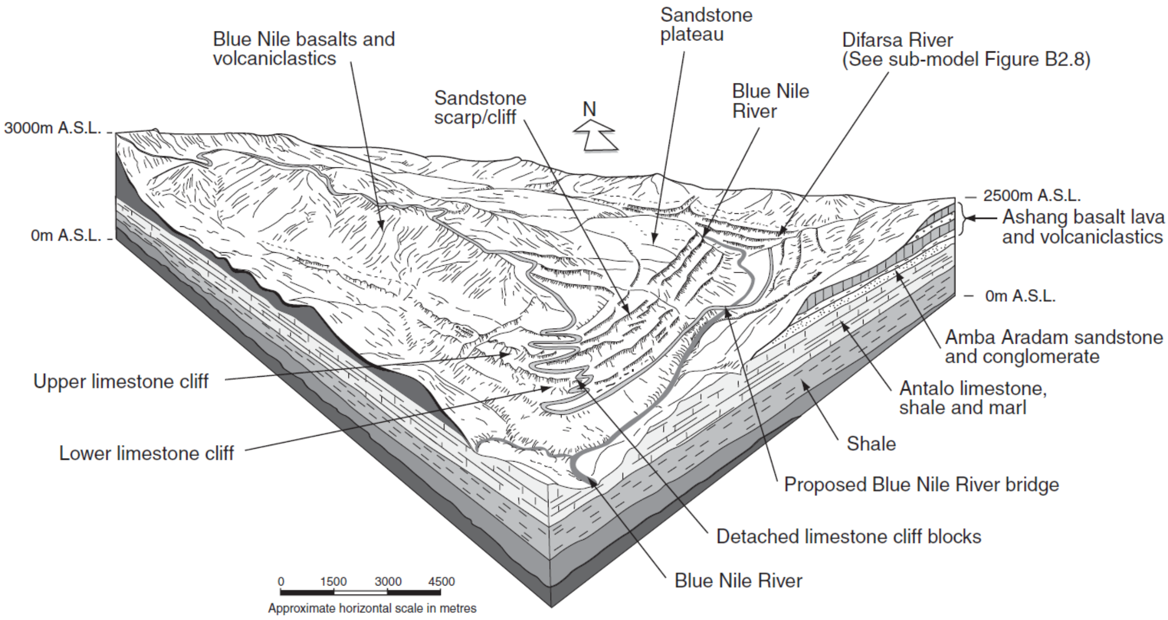


Figure 4.4 Part of the terrain shown in Figure 4.3

4.2 Topography and Route Selection Implications

The type of terrain encountered in the route selection process can have a profound influence on the choice of alignment.

4.2.1 Flat Terrain

Geographic feature	Facet	Typical problems encountered	Likelihood of slope existing instability
Plateau top	Flat ground	Deeply weathered soils likely; some erosion potential in stream and river courses. Possibility of expansive soils*	None
	Wide, gently sloping valleys	Deeply weathered soils likely; some erosion potential in stream and river courses. Possibility of expansive soils*	Possible soft ground
Lowland	Flat ground	Probable alluvium with some deeply weathered soils; possibility of expansive or dispersive soils*	Possible soft ground
	Shallow depression	Deeply weathered soils; possibility of expansive or dispersive soils; possibility of saline soils in semi-arid areas* High water tables, flooding hazards	Possible soft ground

* See Chapter 5 for further details on problem soils

4.2.2 Rolling Terrain

Geographic feature	Facet	Typical problems encountered	Likelihood of slope existing instability
Low hill	Rounded relief	Deeply weathered soils likely; some erosion potential.	Unlikely
Shallow valley	Rounded relief	Deeply weathered soils likely; some erosion potential; possibility of expansive soils	Unlikely
	Streams and minor rivers	Possible compressive alluvial soils. High water table, flooding hazards (Figure 4.5)	Unlikely

4.2.3 Mountainous and Escarpment Terrain

Geographic feature	Facet	Typical problems encountered	Likelihood of existing slope instability
Ridge top	Rounded relief	Deeply weathered soils likely; some erosion potential.	Unlikely
	Sharp relief	Rock at surface; costly and difficult rock excavation possible.	Unlikely
	Irregular relief	Difficult alignment along ridge top between high points and low points.	Possibly
	Asymmetric relief	Joint-controlled slopes will influence stability of alignments and cut slopes.	Possibly - check for debris mass downslope
	Ridge lines generally	May be subject to greater rainfall than valley sides	Possibly
	Ridge lines	May be more affected by seismicity	Possibly

Geographic feature	Facet	Typical problems encountered	Likelihood of existing slope instability
	generally	(topographic amplification).	
Stepped escarpment	Steep slopes with intermediate benches	Deep tension cracks behind cliff faces, very difficult topography for alignment design, seepage zones and highly variable rocks within cut slopes, potential for slope instability	Possibly – check for debris mass on intermediate benches and rock fall hazards from cliff faces
Failed escarpment	As above but masked by failed material, including failed cliffs (Figure 4.6)	Deep tension cracks behind cliff faces, very difficult topography for alignment design, seepage zones and highly variable rocks within cut slopes, failed/failing slopes and materials, poor founding conditions	Definitely – check for widespread instability, including failed cliffs
Valley side	Slopes are steeper than 40°	Probably underlain by rock; therefore likely to be more costly to construct but less costly to maintain.	Unlikely
	Slopes are 35° to 40°	Potential to be shallow taluvium on rock	Possibly
	Slopes are 20° to 35°	Potential to be deep taluvium, colluvium or failed slope	Possibly
	Continuous rock slopes with persistent jointing approximately parallel to slope	Likely to be formed in dominant joint set controlling long-term stability of the slope. Depending on strength of rock this joint set could be problematic in excavations and foundations.	Possibly - check for failed debris downslope
	Embayments	Either erosional in origin or formed by landslide(s).	Probably
	Areas of irrigated crops	Drainage problems likely; soils possibly taluvial/colluvial in origin and potentially unstable locally	Possibly, but mass as a whole may be stable
	Forested areas on otherwise cultivated hillside	Possibly areas of wet ground, steep slopes, instability that cannot be cultivated	Possibly
	Rounded spurs	Probably formed in residual soils and stable	Unlikely
	Elongated mid-slope benches	Either ancient river terraces or rock benches; both stable and 'easy' for road construction	Unlikely
	Local mid-slope benches	Could be as above, or part of deep seated landslide	Possibly
Valley floor	Steep slopes forming margins of river channel (i.e. no river terrace)	Possibly unstable; difficult for road alignments, especially on meander bends; possible flood risk and high water table.	Likely
	Steep slopes forming valley side margins to river terrace	Possible ancient landslides and high water table	Possibly
	River terrace	Possible flood risk, soft soils and terrace edge scour; high water table	Unlikely, except at terrace edges
	Tributary streams	Possibly active debris flows and debris fan deposition causing scour and blockage/damage to road structures; possible flood risk and high water table	Debris flows only

Figure 4.5 Flooding in Rolling Terrain

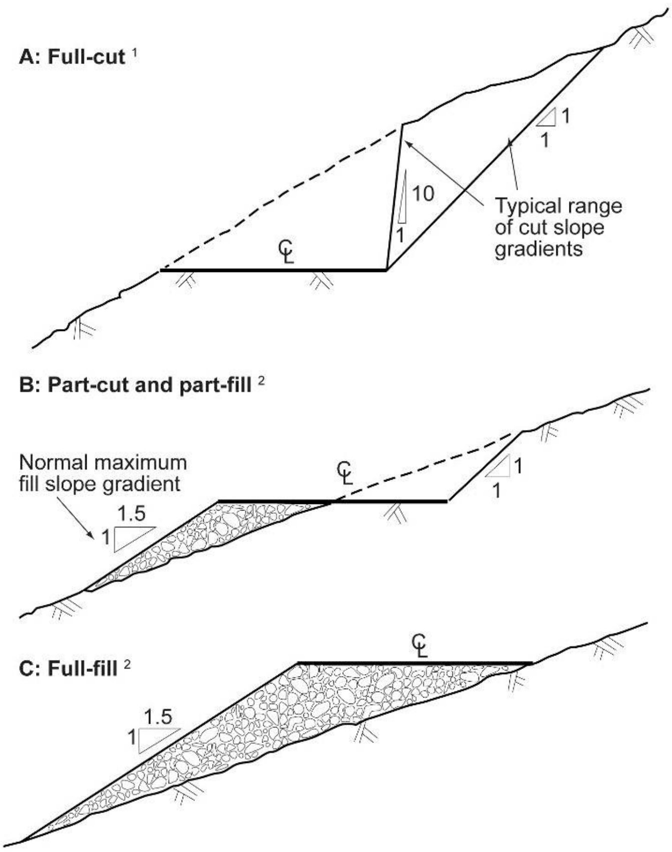
Figure 4.6 Failed Sections of Cliff on Escarpment Slopes

4.3 Choice of Cross Section

The choice of cross section for a new road in rolling, mountainous and escarpment terrain can be of critical importance in terms of cost and impact on the landscape. Small increases in road width on steeply sloping ground can create significant increases in earthwork volumes and the need for retaining structures. Formation widths commonly used in flat and rolling terrain may be economically difficult to justify in mountainous and escarpment terrain. In addition, the greater the formation width the greater the disturbance to the natural environment. Larger volumes of spoil will need to be disposed of, resulting in the potential to create even further disturbances.

Figure 4.7 shows three typical cross sections; full cut, part cut and part fill, and full fill. The slope of the terrain is assumed to vary from horizontal to 5^o (roughly approximating to the definition of flat terrain), 5^o to 10^o (rolling terrain), 10^o to 35^o (mountainous terrain) and 35^o to 50^o (escarpment terrain). Up to 10^o, the ground profile is assumed only to comprise soil; from 10^o to 45^o, the profile is assumed to comprise 2m of soil overlying 1.5m of rippable rock overlying rock requiring blasting. From 50^o and above, the profile is assumed only to comprise rock requiring blasting. When the hillside slopes exceed 25^o, a below-road cemented masonry retaining wall is assumed to be necessary to retain the fill.

Figure 4.7 Typical road cross sections (Hearn and Hunt 2011)

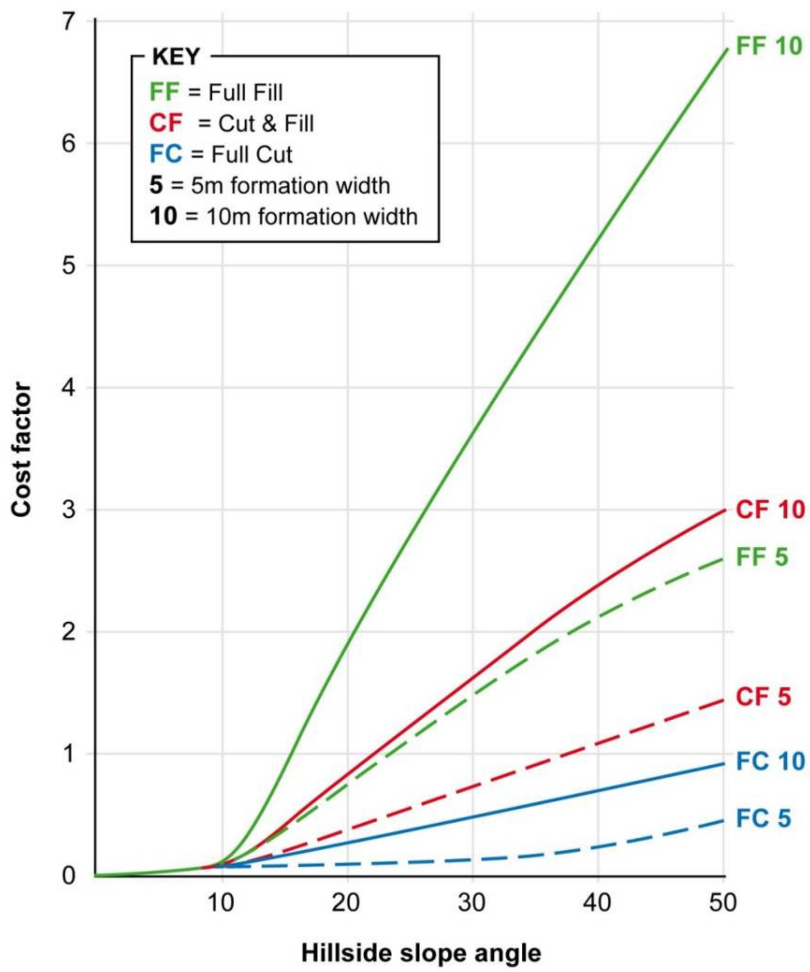


[1] May require cut slope protection or stabilisation above the road.

[2] Will require below-road retaining wall on slopes steeper than 25º unless rock fill or reinforced fill is used.

Unit rates were obtained from a number of recent road construction projects in Ethiopia for bulk and structural excavation in soil, in rippable/excavatable rock, blasting in rock, soil fill and compaction in embankments and for structures. Total earthwork and retaining wall costs are compared for two formation widths, 5m and 10m. In both cases, provision was made for an additional 1m width side drain (where appropriate). The results are shown on Figure 4.8.

Figure 4.8 Comparative costs for differing road cross-sections in varying side slopes



Although the costs undoubtedly represent a simplification in absolute terms, there are nonetheless a number of important observations:

- Generally up to about a 10° side slope there is little to choose between the three cross sections in terms of cost (although the full cut and part cut and part fill cross sections are clearly inapplicable below say 5°).
- For side slopes in excess of 10° there is a rapid escalation in cost, with the full fill cross section being the most expensive by up to a factor of 3 to 6 times in steep sidelong ground compared to a full cut cross section.

- Doubling the width of the formation from 5m to 10m will double costs for shallow side slopes but may increase costs by up to 2.6 times in 50° side slopes and significantly more than this in steeper ground.

Table 4.1 compares the various advantages and disadvantages of the road cross sections.

Table 4.1 Comparison between road cross sections

Type of section	Advantages	Disadvantages
Full cut	Road formation requires minimum compaction because it is formed entirely in natural ground.* No requirement for fill slope placement or compaction. Potential source of fill material for use elsewhere along the road. Potential source of rock, if present, for aggregate and drainage. Usually the only practical solution if existing ground slope > 50°	Greater height of cut may lead to greater instability and/or erosion. May result in large volumes of surplus spoil requiring safe disposal.
Part cut and part fill	Volume of spoil minimised if balanced cut/fill can be obtained. Minimum impact on landscape.	Requirement for fill placement and compaction. May require below-road retaining wall or reinforced fill to avoid excessive area of fill if existing ground slope > 25°.
Full fill (including wall-retained fill)	Usually only practical solution when existing ground slope < 10° or when traversing re-entrants or water courses. Could be the only practical solution (with fill retaining structure) on steep rock slopes if jointing is adverse to stability.	Requirement for significant fill import, ground preparation (including benching on sloping ground), placement and compaction. Will require below-road retaining wall or reinforced fill to avoid excessive fill area if existing ground slope > 25°. Impractical if existing ground slope > 40°.

* Some subgrade soils may require significant compaction or possible replacement.

Although the conclusion could be drawn that a full-cut solution in sloping ground is the most cost effective, in practice the vertical and horizontal alignment constraints will impose a significant control on the choice of cross section at any one location. Furthermore, a full-cut solution is likely to require a greater maintenance commitment since the cut face will weather over time, leading to erosion and instability. Another potentially significant problem will be the disposal of large volumes of spoil, and although spoil dumping areas can be identified and specified within the construction contract, this inevitably results in damaging environmental impact and land use problems. A solution whereby the excavated material can be incorporated into properly constructed fills beneath the road within a short distance along the alignment (say one or two kilometres) is much preferred. This balancing of cut and fill (earthworks balance) will help to reduce haul distances and minimise the problem of spoil disposal, as well as reducing the overall environmental impact.

4.4 Traversing Problem Areas

The choice of cross-section also needs to be taken into account when traversing problem areas in steep and potentially unstable ground. Figure 4.9 gives some potential methods of traversing difficult and unstable terrain. Table 4.2 summarises the main factors involved.

Figure 4.9 Potential methods to traverse difficult and potentially unstable ground (Hearn and Hunt 2011)

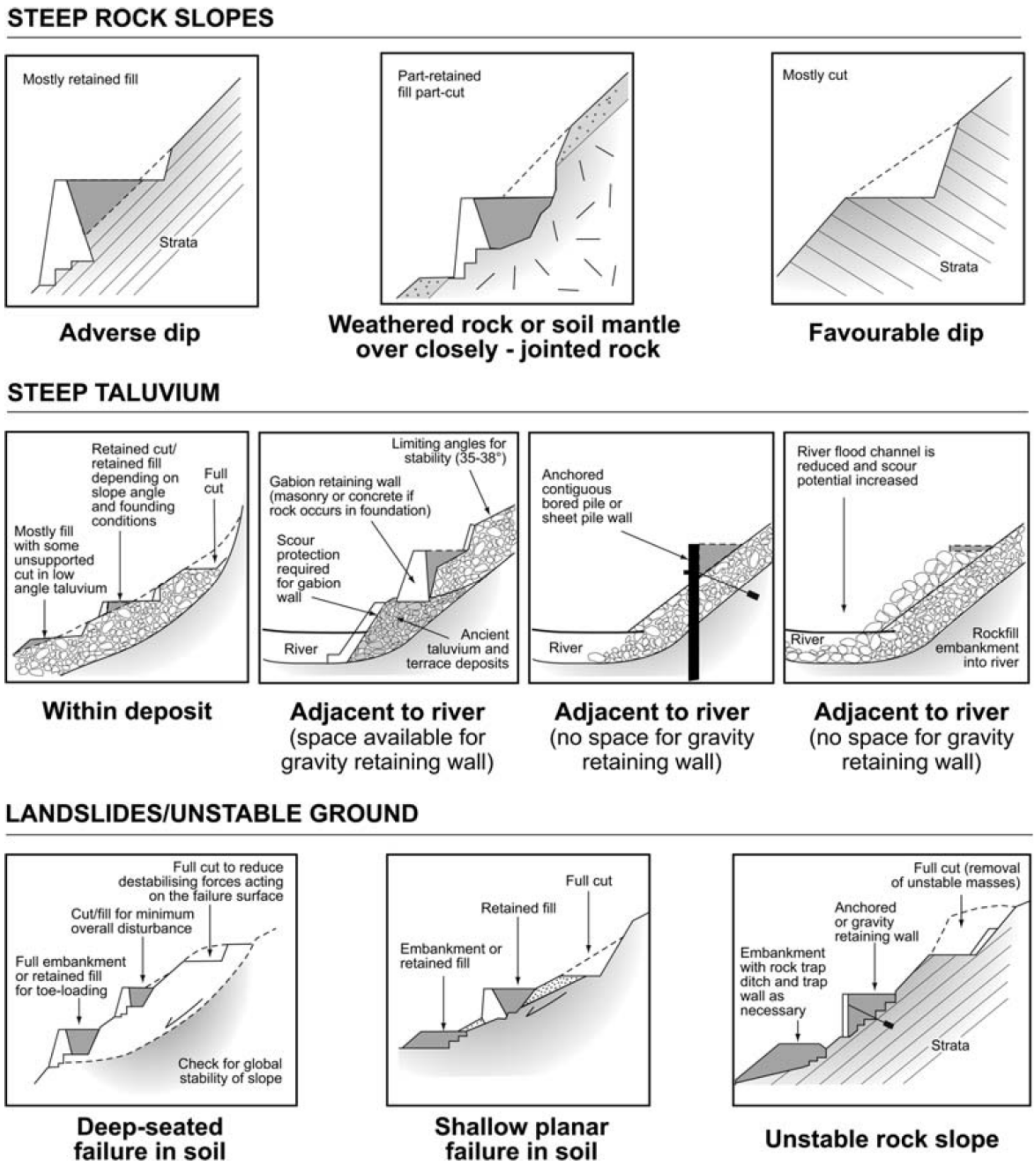


Table 4.2 Preferred alignment location and section (Hearn and Hunt 2011)

Instability type	Alignment location	Preferred section	Notes
Existing unstable ground, taluvium/ Colluvium	Close to ridge crest	Full cut	Will reduce destabilising forces but locally may still require below-road retaining wall founded beneath any failure surfaces
	Middle slope	Balanced cut and fill	If existing ground cannot be stabilised economically, then preference is for least disturbance, with reduced road width and flexible* retaining structures on either side of road
	Foot of slope	Full fill	Will increase stabilising forces, but may require frequent and sizeable culverts and larger roadside drains. Scour protection required in riverside locations
Adversely oriented discontinuities in rock	Applies to all cases	Full fill	Avoids excavation and undercutting of rock strata. Below-road retaining walls will need to be keyed and dowelled into a benched rock surface

*Flexible in the sense that some movement can be tolerated without structural failure.

4.5 Source Information

Source information on topography includes existing topographic mapping, stereo aerial photographs, satellite imagery and data, airborne imagery and data. Topographic ground survey is not a practical option for route selection. See Section 8.3.4 for further discussion on the comparison of road construction quantities derived from remote and terrestrial-based sources.

4.5.1 Topographic mapping

Topographic mapping is available from the Ethiopian Mapping Agency (EMA). EMA provides mapping at scales of 1:50,000, 1:125,000 and 1:1,000,000, some of which has been digitised, but even the larger scale mapping is only suitable for assessing very preliminary route selection options. However, some suburban areas (particularly Addis Ababa) have been mapped at 1:25,000 and 1.20,000 scale and would be more useful.

4.5.2 Aerial photography

EMA can also provide existing stereo imagery at 1:50,000 scale with some areas available at a larger scale. When viewed through a stereoscope, aerial photography can give a very good three-dimensional image in which the user can observe the topographical constraints, but there will be no information on elevation and hence gradients and side slopes. New aerial photography can be commissioned, which combined with suitable ground control can yield good photogrammetry, but this is expensive and time-consuming and would be subject to military permission.

4.5.3 Satellite Imagery

Satellite data are now increasingly used to generate digital terrain or digital elevation data. The data can be used as topographical mapping as well as the derivation of drainage and catchment area mapping. The digital elevation model (DEM) can also be used as a base layer upon which other satellite imagery or aerial photography can be draped in order to enhance three-dimensional visualisation. Table 4.3 lists the main sources and accuracy of satellite-derived and airborne digital mapping.

Table 4.3 Digital mapping data derived from common sensors

Sensor	Horizontal resolution (m)	Horizontal accuracy (m)	Vertical accuracy (m)	Scene size	Data collected
ASTER GDEM	30	30	15-30	60km x 60km	Since 1999
SRTM	90	30	10-15	1° lat x 1°	August 2000
SPOT	20	15	10-15	60km x 60km	Since 2002
IKONOS	1-2	1-2*	1-2*	11km x 11km	Since 2000
World View-2	0.5	1-2*	1-2*	16.4km x 16.4km	2009
GeoEye-1	0.5	1-2*	1-2*	15km x 15km	2008
Airborne LiDAR	0.5	0.1-0.25	0.1-0.25	Dependent on area of interest	On demand

*Dependent on the supply of Differential GPS (Global Positioning System) points (Hearn 2011)

Free-to-download satellite imagery and DEM data currently comes in two formats, SRTM Shuttle Radar Topographic Mapping) and ASTER (Advanced Spaceborne Thermal Admission and Reflection Radiometer). Of these two formats, SRTM is currently favoured for route selection by design consultants working for ERA due to its better vertical accuracy.

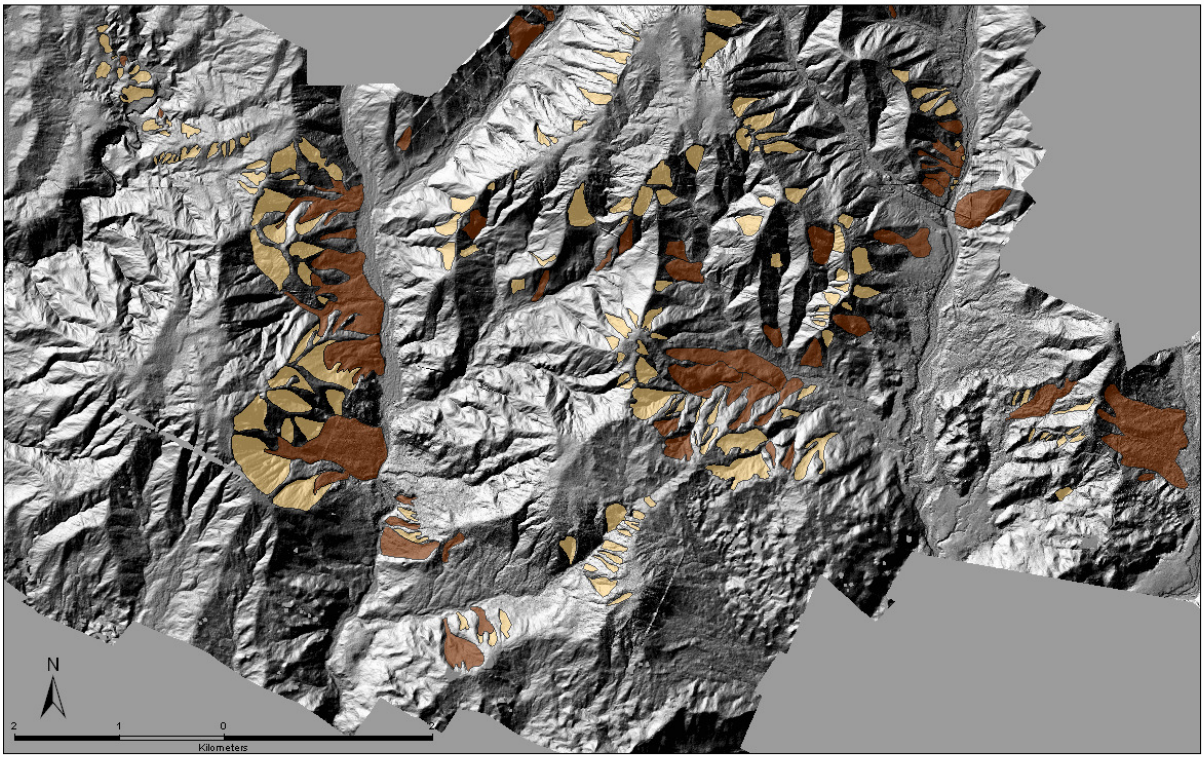
SRTM data was acquired by the space shuttle Endeavour in the year 2000. It has a horizontal resolution of 90 m (pixel size), a horizontal accuracy of 30 m and a vertical accuracy of 3 – 15 m. The main problem is the question of accuracy, particularly when comparing say an alignment on relatively flat terrain (for which the earthwork quantities should be reasonably accurate) with an alignment in mountainous or escarpment terrain (for which not only the earthwork quantities might not be particularly accurate, but also the alignment itself). This is discussed further in Section 4.6.

Stereo satellite data is likely to be largely unavailable in archive form and therefore very expensive to commission. EMA can provide satellite DEM data and should be contacted in the first place.

4.5.4 Airborne Imagery

This imagery and data is captured from an aircraft and very unlikely to be available in archive form. A typical format is LiDAR (Light Detection and Ranging) with an accuracy given in Table 4.3. Stereo imagery can also be acquired at the same time. However, LiDAR is expensive and will also require military permission. Although impractical for corridor selection, its use could be justified for the preferred alignment, particularly for high category roads. The use of hillshade LiDAR, whereby a sense of visual three-dimensional relief is obtained by using computer graphics to cast shadow over LiDAR data (Figure 4.10) can help considerable in the interpretation of topography for the identification and comparison of route options.

Figure 10 Hillshade LiDAR Showing Mapped Landslides as an Aid for Route Selection



Chapter 5 Engineering Geology

5.1 Introduction

Road infrastructure development (in fact all civil engineering works) are required to deal with geology and geology (together with its influence on topography) is a key factor that significantly controls route selection through the following:

- Earthworks and ease of excavation
- Foundation conditions
- Geo-hazards such as landslides and other ground movements, expanding and collapsing soils, earthquake and volcanic hazards, surface and sub-surface erosion, dune migration etc.
- Availability and suitability of materials for construction.

Route selection, probably more so than any other aspect of the project cycle, is reliant on adequate assessment of geology and, in particular, engineering geology. The outcome of insufficient attention to engineering geology is often an uneconomic, unsafe, environmentally incompatible and unsustainable product in the long term.

5.2 Geological Domains of Ethiopia

A comprehensive account of the Ethiopian regional geology has been published by the Geological Survey of Ethiopia (GSE). A 1:2,000,000 map covering the whole country is available with accompanying description of the geology. In addition, map sheets of larger scale (1:250,000) are available for most parts of the country. These should be consulted as a routine desk study exercise before embarking on any detailed route comparison. Appendix 2 contains a description of the geological setting of Ethiopia as background to this Manual.

5.3 Data Sources

Table 5.1 lists the main sources of data pertaining to the geological, soils, seismic, hydrogeological and geo-hazard conditions of Ethiopia. While it is imperative that these data sources are consulted during any route selection study, it should be noted that most of the information contained therein is of a small scale and generalised nature and it will be necessary to resort to other means to derive the required project-level information. These other means include the interpretation of remote sensing, including aerial photograph interpretation and field observations.

Table 5.1 summary of relevant engineering geological data sources

Data/Information	Sources	Relevant bodies
Geology	Published literature Unpublished reports Geological maps and sections Records of previous and current geologic explorations Remote sensing datasets	The Geological Survey of Ethiopia (GSE) Regional Geological Surveys Universities
Soil	Published literature Unpublished reports	Universities Ministry of Agriculture and Agricultural

Data/Information	Sources	Relevant bodies
	Soil maps* [1]Archived data and logs Remote sensing datasets	Research bureaus The Geological Survey of Ethiopia (GSE) Regional Geological Surveys **Road agencies (Federal and regional) and firms engaged in road construction in the country
Hydrogeology	Published literature Hydrogeological maps, reports and well logs Remote sensing datasets	The Geological Survey of Ethiopia (GSE) Water Resources Authority Regional Geological Surveys and Water Resources Bureaus Universities
Seismicity	Published literature Unpublished reports Seismic hazard maps Historical earthquake records Remote sensing datasets	The East African Geophysical Observatory in Addis Ababa The Geological Survey of Ethiopia (GSE) Regional Geological Surveys Universities Disaster preparedness and prevention offices United States Geological Survey
Geo-hazards	Published literatures Unpublished reports Hazard maps Remote sensing datasets	The Geological Survey of Ethiopia (GSE) Regional Geological Surveys Universities Disaster preparedness and prevention offices

*So far, agricultural soils maps based on pedological classifications are available for the entire country. Even though direct information on soil engineering characteristics cannot be obtained from such maps, information that can be broadly relevant to engineering applications can be derived as presented in Appendix 2.

5.4 Common Rock and Soil Types of Ethiopia and their Engineering Geological Characteristics

A wide variety of rock and soil types are found in Ethiopia, each with distinct engineering characteristics. These are summarized in Tables 5.2 and 5.3 respectively. The ERA Geotechnical Design Manual contains extensive reference to problematic soils and their engineering significance in Ethiopia.

[1] Data from decades of construction activities possibly archived in road agencies and firms engaged in road construction activities

Table 5.2 Common rock types in Ethiopia and their General Engineering Geological Characteristics

Common Rock Types	Engineering geological characteristics
Igneous rocks: Extrusive/volcanic: Basalt, andesite, dacite, trachyte, rhyolite Intrusive/plutonic: Granite, gabbro Pyroclastic: Scoria, Pumice, ash, tuff, agglomerates	Most of the extrusive and intrusive igneous rock varieties can make good construction materials (concrete and road aggregate including surfacing, base-course, sub-base, wearing-course (gravel), subgrade, fill materials and masonry stones etc.) depending on the degree of weathering and disintegration. Fresh and massive varieties are strong and highly durable, exhibit high safe bearing pressure providing very good foundation conditions. When decomposed, the mafic varieties produce active clay minerals making determination of the degree of alternation important. Mica-rich varieties could be problematic. Quartz rich varieties could be highly abrasive. Pyroclastic varieties are characterized by extremely variable engineering characteristics and performances, which is often problematic (variable strength, non-uniform engineering behavior, expansion, rapid degradation, softening etc.). For further details refer to the previous ERA site investigation manuals.
Sedimentary rocks: Rudaceous: conglomerates, grits Arenaceous: sandstone, arkose, greywacke Argillaceous: siltstone, claystone, shale, marl Carbonates: limestone, dolomite, chalk Chemical precipitates: gypsum, evaporate deposits (salt)	Rudaceous and Arenaceous varieties such as conglomerates, sandstone and arkose depending on the hardness of the cementing matrixes[2], composition, bedding and jointing patterns can make good construction materials and provide very good foundation conditions. The carbonate varieties particularly limestone can make good construction materials (road aggregate including base-course, sub-base, wearing-course (gravel), subgrade and fill materials, masonry stones etc.). Polishing under traffic could be a problem in case of uses as surfacing and concrete (exposed for traffic). Solution cavities are typical problems in carbonate rocks. Most of the argillaceous varieties are unsuitable and often troublesome (softening, rapid degradation, sliding along cleavage etc.). The chemical precipitate types are typically unsuitable for construction materials, and their deleterious impacts for instance on concrete and steel structures should be considered. Further details can be found in the previous ERA site investigation manuals.
Metamorphic rocks: Non-foliated: Hornfels, Quartzite, Marble Foliated: Gneiss[3], Schist, Slate, Phyllite	Metamorphic rocks show varying engineering characteristics and performances, depending on the degree of metamorphism, composition, structure and texture. Non-foliated and high grade metamorphic varieties are very strong and highly durable. The quartz rich varieties show poor adhesion to bitumen as smooth surfaces promote detachment of bitumen especially in the

[2] Weak cementing matrices often result in rapid disintegration.
[3] At places where sulphide mineralization is expected (e.g., pyrite's mode of occurrence along foliations in gneisses rocks), effects on concrete structures is a concern as pyrite easily weathers to sulphuric acid, rust and significantly deteriorate concrete structures. Certain sandstones may also contain sulphide especially pyrite.

Common Rock Types	Engineering geological characteristics
	presence of water. Stabilization could be required for use as base-course and sub-base materials. Presence of opaline silica and pyrite should be checked for use as concrete aggregate. Foliated varieties, particularly low grade, fine grained, micaceous and clayey ones are often troublesome (anisotropic strength, planar weaknesses and sliding along planar weaknesses etc.). Further details can be found in the previous ERA site investigation manuals.

Table 5.3 Common Soils in Ethiopia and their General Engineering Geological Characteristics

Common Soil Types	Engineering Geological Characteristics
Alluvial soils (Fig. 5.1): Fluvial (boulders to colloidal clay particles depending on river speed and carrying capacity)	• Very narrow particle size range (poor grading). • Normally unconsolidated (clays tend to be soft and sands tend to be loose to medium dense) often with high void ratio and porosity. • Typically stratified and could be extremely variable with frequent inter-bedding. • Coarser units are highly permeable (generally with permeability being higher in the horizontal direction than in the vertical direction). • Fine grained varieties may contain expanding clay minerals. In cut slopes, as a result of their variability in compositions and engineering properties, fluvial deposits are often highly susceptibility to slides if left unsupported.
Lacustrine (fine grained material deposited on lake bottoms)	• May contain appreciable amounts of organic matter, fragments of shells and skeletons from aquatic animals. • Soil swelling and shrinkage problem is expected due to presence active clay minerals. • Can present slope problems if exposed in valley walls or cuts, land areas that were former lake beds etc. • Slides of considerable magnitude may occur where (1) lake clays are inter-bedded with or overlain by granular deposits, and (2) lake clays overlie bedrock at shallow depth. Alluvial sand deposits are important sources of sand for concrete and mortar works. Depending on their quality, alluvial gravel deposits can also be sources of road and concrete aggregates, wearing-course, sub-base and fill materials.
Colluvial soils (Fig. 5.1)	• Often loose and unconsolidated. • Poorly graded, highly permeable, and compressible. • Marginally stable, further movement can be triggered with minor topographic changes (especially on those resting on slopes), changes in water level (rainfall, rising ground water table), weathering, earthquake etc.

Common Soil Types	Engineering Geological Characteristics
	• Often contain highly plastic materials (e.g., colluvium in a black cotton soil matrix). Consequently, cut slopes on colluvial soils may not be stable and usually lead to failure unless proper engineering mitigations are implemented. Parent materials and topography have strong influence on the characteristics of colluvial soils. Very often, colluvial soils are poor construction materials.
In situ weathered (residual) soils (Fig. 5.1)	• Heterogeneity is common (laterally and with depth) due to differential weathering patterns. • May contain discontinuities, un-weathered boulders (core-stones) and rock layers. • Structure and clay minerals are important with respect to residual soil characteristics. • Expansive (smectite rich), highly plastic varieties such as black cotton soils and tropical red clays (dominated by halloysite) are particularly problematic. Parent material has a pronounced influence on the characteristics of residual soils. Residual soils are commonly used for sourcing gravel (wearing-course), sub-base, sub-grade and fill materials.
Volcanic soils - common within the Rift Valley, and locally at different parts in the volcanic terrain of the country in association with pyroclastic deposits (Fig 5.1)	• Volcanic soils are residual soils derived from pyroclastic deposits such as tuff, volcanic ash and dust. The ash and dust are often altered by weathering processes into allophane, immogolite, smectite and illite clay minerals. • Tend to be highly dispersive and expansive (reactive soils). Potentially unstable ground conditions and hill slopes are marked by gullies, heave, terracettes, mudflows and landslides; construction activity on such slopes may tend to lead to renewed movements.
Aeolian soils	• Uniformly graded usually fine to medium grained quartz rich sand and silt particles. • Loose, permeable, collapsible and compressible. • Water has a significant influence on the engineering characteristics and performance of aeolian soils. Aeolian soils can be used as embankment fill provided compaction is done at an appropriate moisture conditions, and a very good protection against piping erosion is ensured. Aeolian soils often provide problematic cut slope and foundation conditions (prone to sliding, collapse and settlement), and should be avoided to the extent possible.

Figure 5.1 Illustrated Soil Types

	
Alluvium	**Colluvium**
	
In Situ Weathered Soils: Tropical Red Soils	**In Situ Weathered Soils: Black Cotton Soils**
	
Volcanic Soils: Ash	**Volcanic Soils: Agglomerate**

5.5 Engineering Geological Considerations for Route Selection

5.5.1 Geological Controls on Topography and Surface Processes

The influence of geology on topography and the engineering geological of various terrain facets found in Ethiopia is reviewed and discussed in Chapter 4 and the general engineering geological implications of different rock and soil types in Ethiopia are outlined in Section 5.4. Variation in weathering and erosion resistance of rocks is commonly reflected on topographic features. For instance, weathering resistant rocks such as high grade metamorphic rocks, igneous intrusions, dykes and sills often form prominent features in the landscape (e.g., cliffs, scarps, ridges, plateau etc.). Geological structures such as faults, folds, anticlines and synclines, unconformities, contacts, horizontal and inclined bedding often produce characteristic topographic features. Terrain underlain by sedimentary rocks with beds of distinctly different strength is a common feature of Ethiopia, leading to marked topographic contrasts. These contrasts in the underlying geology not only have profound influences on topography (Chapter 4) but also pose significant engineering geological implications for route selection. Some of these implications are shown on Figures 5.2 and 5.3.

Figure 5.2 Typical Terrain Formed on Inclined Sedimentary Rocks in Semi-Arid Climates (from Fookes 1997)

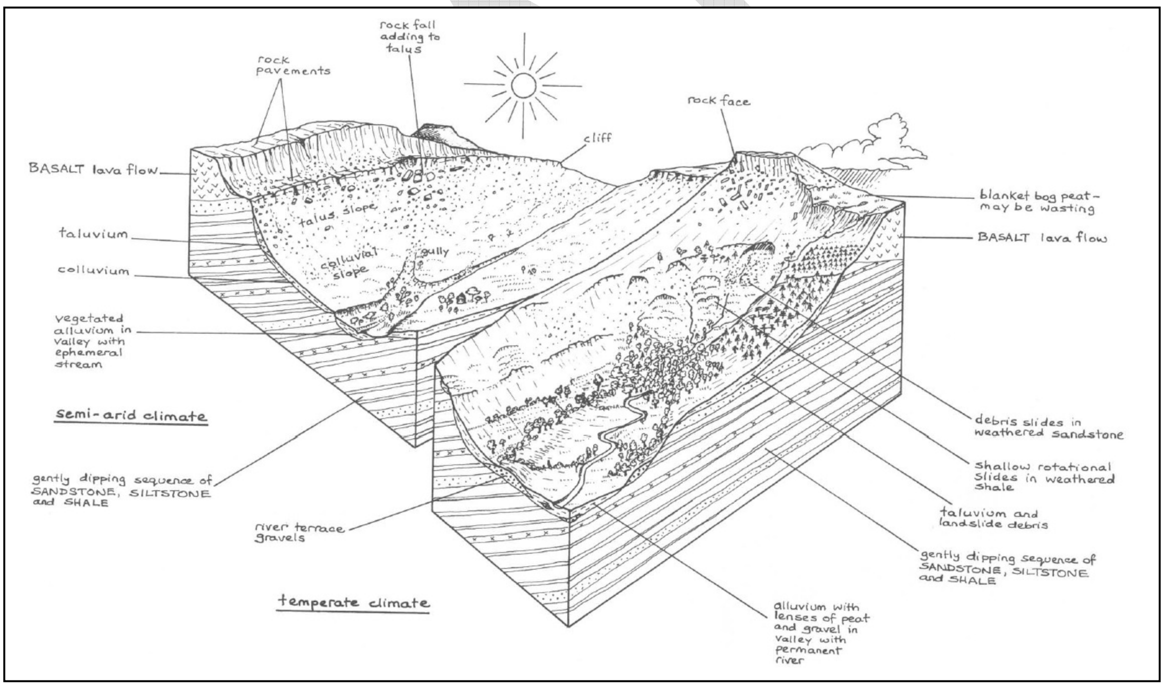
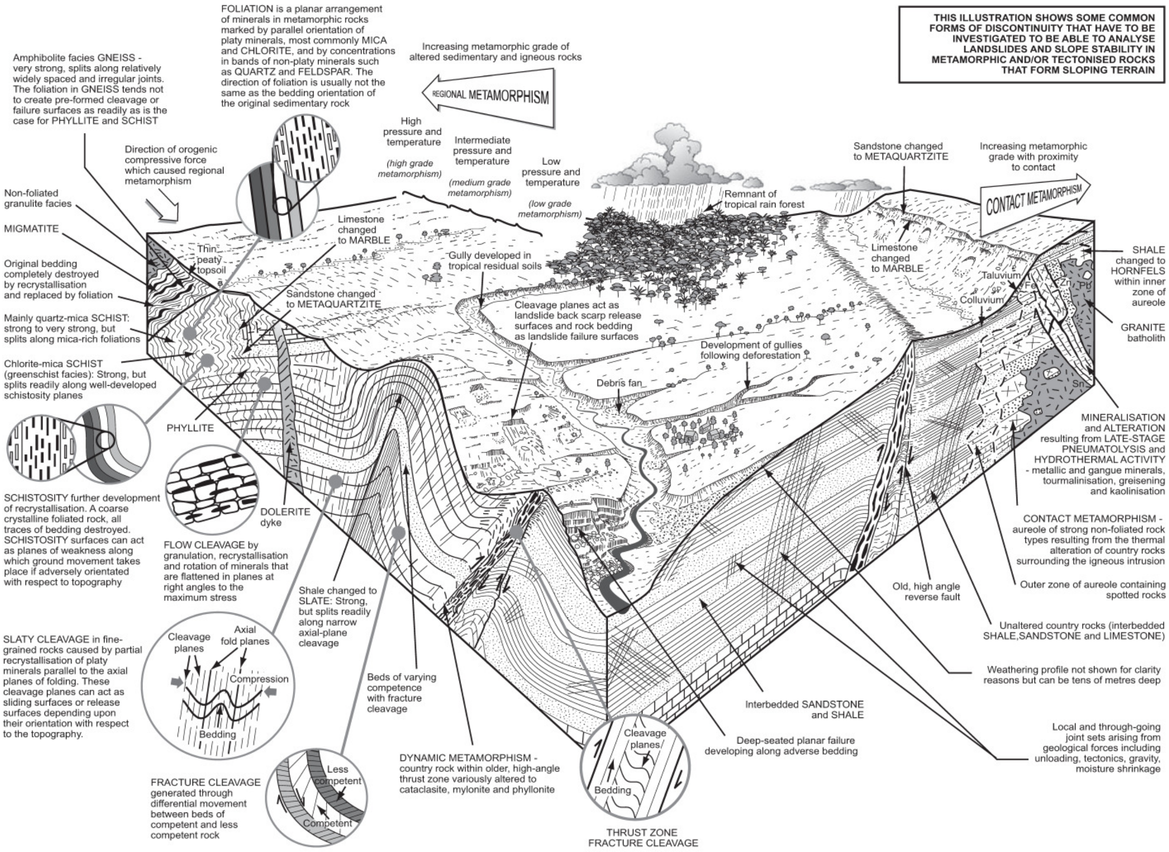


Figure 5.3 Typical Geological and Topographic Features Encountered in Metamorphic Rocks and their Influence on Slope Stability (from Hearn, 2011).



5.5.2 Geo-hazards

Geo-hazards can pose significant constraints to the construction and operation of road infrastructure, and therefore should be critically important to route selection in all terrain types. In Ethiopia, geology and tectonic setting, combined with climate and hydrology, create conditions that encourage the occurrence of a range of geo-hazards. These occur naturally and are often also triggered or exacerbated by road construction. These geo-hazards are briefly outlined below. Further information on them is provided in the ERA Site Investigation Manual and the ERA Geotechnical Design Manual.

a) Landslides

While landslides in Ethiopia are most common in steep terrain with high relative relief, they can also occur in more gentle terrain of low relief. For example, slopes formed in residual soils, colluvium and clay shales may fail if their angles exceed 30-40°, 10-20° and 8-15° respectively or if support is removed at their toe; both outcomes can be effected by natural processes in the long term and road construction in the short term.

Early recognition of landslides and related slope instability enables decisions to be made regarding avoidance, reduction or elimination of hazard. These are decisions that need to be made in route selection because it may be less expensive to cross a landslide and invest in its stabilization than it is to avoid it by increasing the alignment length or crossing otherwise more difficult ground. Vice versa, and especially on low volume roads, the cost of landslide management can be a significant contribution to the overall cost of road construction and operation. Hearn (2011) describes how the cost of reinstating the 90 km Hirna-Kulubi road in 26 landslide areas amounted to 5% of the total cost of road widening and upgrading works between 1996 and 2005. Table 5.4 summarises common mechanism of landslides and mass movement, their constituent materials and their means of identification.

Table 5.4 Summary of landslide mechanisms, constituent materials, common causes and means of identification.

Landslide Mechanism	Constituent Materials and Common Causes	Identification
Creep	cohesive materials and soft rock masses on moderately steep to steep slopes	parallel transverse low angle slope ridges/ "cow paths" perpendicular to the direction of movement, gulley scours (gullies appear parallel to each other and perpendicular to the slope), down slope leaning of trees and manmade structures such as fences
Falls and topples	vertical to near-vertical slopes in weak to moderately strong soils and highly jointed, fractured and sheared rock masses	intersecting joints and tension cracks, fresh rock face, talus and scree accumulations at the toe, irregular appearance at the base of cliffs linear scars in vegetation along frequent rock fall paths
Planar/ translational slides in rocks	bedded sedimentary rocks dipping downslope at an inclination similar to, or less than the slope face; faults, foliations, shears or joints forming long, continuous planes of weakness that intersect the face of the slope; jointed hard rocks, exfoliation in granite masses (intersecting joints result in wedge failures)	tension cracks (transverse) and vertical displacement, scarps, surface denuded of vegetation, hummocky and grooved slopes
Lateral spreading	stiff fissured clays, shales, horizontal or slightly dipping strata with a continuous weak zone, colluvium over gently sloping residual soils or rock, river valleys, particularly where erosion removes material from the river banks	open tension cracks, fractures and linear depressions separating large blocks, irregular arrangement of large blocks tilting in various directions (block size decrease with distance from source), scarps, disrupted surface drainage (failure can be sudden under earthquake loading)
Rotational slides in rocks	shales and other soft rocks, and heavily jointed stratified sedimentary rocks with weak beds, increased slope inclination, weathering, and seepage forces	(radial, transverse) tension cracks, seepage lines, scarps, transverse ridges and spoon-shaped slump topography, accumulation of debris and surface irregularity at the toe
Rotational	thick deposits of cohesive soils:	tension cracks (concentric and curved towards

Landslide Mechanism	Constituent Materials and Common Causes	Identification
slides in soils	soft to firm clays, residual soils, seepage forces and increased slope inclination, and relict structures in residual soils	movement direction), series of small slumps and step like slopes, scarps, toe bulge, hummocky and irregular ground, back-tilting slope facets, bad drainage conditions, ponding, seepage points/lines and marshy conditions and accumulation of debris at the toe
Debris slide	colluvial or residual soils, including where these soils overly a dipping rock head surface, increased seepage forces and slope inclination	tension cracks, elliptical scars, seepage lines, accumulation of material and surface irregularity at the toe
Debris flows and avalanches	mountainous terrain with steep slopes of residual or colluvial soils where topography causes runoff concentration, decomposed and closely-jointed rock masses	scar characterizing source area, depositional levees, almost complete destruction along the path (absence of vegetation in recent failures), surface drainage disturbance (streams blocked or deflected), movement is usually sudden, however, tension cracks may develop, (particularly prone are steep slopes and irregular landform necessitating numerous cuts)
Flows (soil, mud)	saturated or nearly saturated fine-grained soils, particularly sensitive clays, and dry loess or sands, earthquake is a major triggering factor, also build-up of high pore-water pressure (heavy rainfall and changes in groundwater regime)	generally funnel shaped, steep and irregular upper part, levees at the lower part, commonly narrow and striated , concave towards movement, spreading and lobate toes, ponding and disrupted surface drainage, movement is generally sudden (could be anticipated on the basis of geological conditions, topography and climate)

Complex/compound landslides are characterized by movements involving two or more of the above mechanisms. Disturbed surface drainage (e.g., abrupt changes in width and pattern of streams, asymmetric valley slopes etc.), hummocky and irregular morphology and ponding in depressions, back-tilting ground and flow structures are some of characteristic features enabling recognition.

Engineering geological studies carried out for route selection must also consider the potential for the development of first-time failures, i.e. landslide that could occur in the future either as a result of natural processes or, more commonly the effects of road construction, including slope excavation, embankment loading and drainage disturbance (see the Geotechnical Design Manual for further discussion). In addition, many landslides in mountain areas have the potential to travel significant distances downslope as debris flows, mudflows or debris/rock avalanches (Hearn 2011) and these should also be considered, especially in relation to the crossing of tributary rivers and alluvial fans.

Some of the important conditions to look out for in the assessment of landslides and slope instability hazards for route selection are listed below.

- Renewed landslides movements are inevitable on fault scarps and ruptures.
- Slopes in pre-existing landslides are often prone to further movement.

- Colluvium represents unstable conditions: colluvium deposited on steep slopes is often prone to further instability. Colluvium overlying geologically young, soft alluvium in valleys is typically hazardous.
- Metamorphic rocks such as phyllite and schist, sedimentary rocks such as shale, marl and other argillaceous rocks, and igneous rocks such as pyroclastic deposits (mainly tuff and ash) are particularly prone to movement when destabilized through high groundwater or toe erosion.
- Schistosity, cleavage, foliations, beddings and jointing in rocks dipping out of slope faces are prone to instability (Figures 5.2 and 5.3).
- Stratified beds of sand or gravel overlying clay, competent rocks overlying weaker rocks (e.g., sandstone overlying shale with an unfavourable dip), could lead to slope failure.
- Rivers and streams undermining toe support to slopes can give rise to continuous failure.

b) Problematic rocks and soils

Problematic rocks range from expansive, soft, porous, deformable, susceptible through soluble and highly fissile to those prone to softening, slaking and rapid deterioration (Table 5.5). Such rocks owe their adverse engineering characteristics to their mineralogical composition, fabric and discontinuities (geological structures). Problematic rocks can be of igneous, sedimentary or metamorphic origin.

Table 5.5 Common problematic rocks and typical problems that they present.

Origin	Rock types	Typical problems
Igneous	pyroclastic deposits -tuff	softening, expansion, dispersion and rapid deterioration
	-ash	softening, dispersion, expansion and rapid deterioration
Sedimentary	Shale	softening, expansion, rapid deterioration, and sliding along cleavage planes
	Marl	softening, expansion and rapid deterioration
	Marly limestone	softening, rapid deterioration
	Argillaceous (sandstone, conglomerates and limestone)	softening, rapid deterioration, and some degree of expansion
	Limestone	solubility and cavity formations (porous limestone is prone to deformation)
	Chalk	weak and soluble
	Gypsum	weak and soluble
	Salt	soluble and deleterious impacts on concrete and steel structures
Metamorphic	Talc	softening and weak
	Phyllite	softening, rapid deterioration and (sliding as it is highly fissile)
	Slate	anisotropic strength and sliding along schistose planes
	Schist	anisotropic strength and sliding along schistose planes

Problematic soils include expansive, dispersive, collapsible, compressible and saline soils. The adverse engineering characteristics of problematic soils are also primarily attributable to their mineralogical composition, structure, fabric, and depositional environments. These soils are described and illustrated in Appendix 2 and discussed in more detail in the ERA Geotechnical Design Manual. Knowledge of local geology and terrain analysis can greatly assist anticipating potentially collapsible, dispersive, compressible and expansive soils. For example, soft ground (compressible conditions) is mostly provided by alluvial clays, lake sediments, organic soils and geologically-young clay deposits.

c) Ground subsidence and collapse

Ground subsidence and collapse refer to vertical movement of the ground caused by the presence of cavities and open joints in rocks, tubes in 'ropy lava' and large voids in chaotic landslide debris. Ground subsidence can be classified into three general categories:

- Regional subsidence related to excessive ground water abstraction, cavities from abandoned underground mines.
- Sudden ground collapse related to soluble carbonate and sulphate rocks such as limestone, dolomite, gypsum, salt rocks; and open tubes and former lava vents in volcanic rocks.
- Soil subsidence and heave related to hydro-compaction in collapsible soils, settlement in compressible soils, piping failures in dispersive soils and swelling and shrinkage in expansive soils.

For route selection it will be necessary from desk study to:

- Identify local aquifer characteristics, areas of abandoned underground mines and avoid highly hazardous conditions.
- Identify solution susceptible rocks, collapsible, dispersive, compressible and expansive soils.

Terrain formed on Antalo Limestone is particularly prone to subsidence as a result of cavity collapse. The distribution of susceptible rock types can be ascertained by reference to published geological maps geological maps and from remote sensing images by drainage patterns and association. Landforms associated with soluble rocks such as lack of surface drainage systems or short and suddenly disappearing streams, intermittent and deranged drainage, development of circular depressions and sinks etc. are readily recognizable from aerial photos and other remotely sensed images.

d) Earthquakes

The assessment of earthquake risk should be considered in route selection, and it may have an important bearing when long lengths of alignment encounter active faults or where large structures, including major bridges might be required to be constructed in the vicinity of active faults and seismically active zones. Information such as the spatial distribution of significant historical earthquakes and recurrence of events, epicenter depth and focus, magnitude, peak ground acceleration, attenuation with distance from the focus and duration of the force will be required in any seismic risk assessment. The extent to which these factors will influence route selection *per se* will vary from project to project: it may be the case that all route options are affected in the same way by seismic risk and the issue is therefore more of a consideration for route corridor selection and detailed design. The following considerations should be born in mind when reviewing seismic risk for alignment selection:

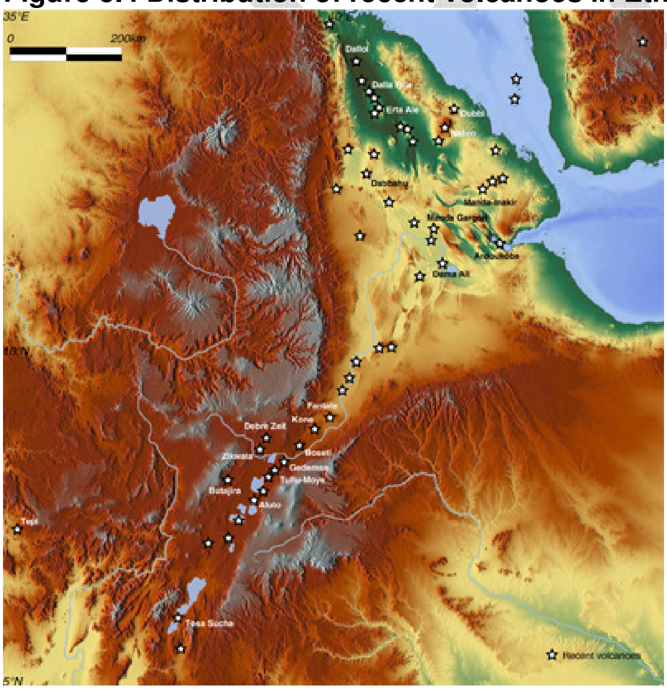
- Faults, depending on their activity, could present a significant source of seismic hazard. Identify active and potentially active fault lines and fault zones and avoid locating structures in their vicinity.
- Identify and avoid unstable soils such as loose, saturated sands as they are particularly susceptible to liquefaction during earthquakes, leading to flow slides or unstable foundation conditions.
- Volcanoes, depending on their activity (see below), could present localized seismic hazards. Identify and avoid areas where there is a history of active volcanic activity.

Cluff et al. (1972) presented general criteria for identifying active faults (Appendix 2). Faults can be recognized by scarps or offsets of strata. Faults and generally lineaments can be easily identified from remote sensing data.

e) Volcanicity

The Ethiopian Rift Valley is characterized by numerous historically active and active volcanoes. Most volcanoes especially in the Afar region have documented activity during recent geological times. The Erta Ale volcano has been active for the last 100 years while the Dabbahu volcano erupted between 2005 to 2010, the DallaFilla volcano in 2008 and the Nabro volcano (near the Ethiopia-Eretria border) in 2011. Dallol, Ardoukoba, Manda-Inakir, Alayta, Dobi, Fentale, Kone, Aluto etc. are also historically active volcanoes (Figure 5.4). In addition to related seismic activity, active volcanoes pose hazards from ash and other eruptive materials, lava flows and lahars if previous volcanic materials become remobilized as flows during heavy rain.

Figure 5.4 Distribution of recent volcanoes in Ethiopia (Courtesy: USGS)



f) Dune movements

In arid and semiarid regions of Ethiopia (e.g., parts of the Afar region), dune (mainly sand) movements can present substantial problems for road serviceability. Route location should thus consider this potential hazard:

- Avoid loose and shifting sands.
- Ensure minimum interference to the flow of sand laden winds by merging road alignments with the lie of the land.
- Avoid locating road alignments on the face of dunes (e.g., in cases of longitudinal dunes, a road alignment along the ridges or in the inter-dunal space is preferred).

Dune deposits are recognizable as low elongated or crescent-shaped hills, with flat slope windward and steep slope leeward of the prevailing winds. Usually, such deposits have very little vegetation cover. The material is very rich in quartz and it typically exhibits a narrow particle size distribution. Shifting sand usually comprises fine- or medium-grained material with no cohesive strength, is moderately to highly permeable and has high compressibility.

g) High Groundwater

Groundwater investigation and assessment should form part of engineering geological studies carried out for highway design, but should also be considered in general terms during route selection. Potential adverse effects of high groundwater include:

has a crucial role in slope stability as it influences strength of slope forming rocks and soils. Increasing pore water pressures, and subsequent decrease in shear strength, reducing apparent cohesion of slope forming materials due to capillary forces upon saturation, softening of weak materials (clay, shale, marl, tuff, ash etc.), chemical and hydrothermal alteration and solution (limestone, gypsum, salt) are some of the detrimental effects of groundwater. In addition, groundwater and seepage has implications in:

- Increased susceptibility of slopes to landslides
- Hydrothermal alteration, solution and salt precipitation, and the influence of these processes on material strength, the presence of cavities and the weakening of concrete and corrosion of steel
- Excavation stability and practicality of compaction, drainage of pavement layers and potential pumping and heaving effects
- Foundation of structures in relation to hydrostatic uplift

While these effects are more relevant to detailed design they should be considered in route selection, and the following studies are recommended:

- Identify saturated zones and avoid areas with shallow water tables to the extent possible
- Identify and avoid seepage lines and springs
- Identify and avoid faults, fault zones and auto-brecciated contacts as they are typical weakness planes and may potentially provide sources of large seepage flows, and failure zones in slopes and foundations.

5.6 Assessment Techniques

Table 5.6 lists the recommended assessment techniques for deriving engineering geological and related data for route selection purposes, broadly divided into desk study and field investigations.

5.6.1 Desk Studies

For route selection purposes maximum use should be made of desk study sources in order to avoid unnecessarily lengthy and expensive fieldwork. Geological mapping is available for the entire country at 1:250,000 scale (and at 1;50,000 scale for some urban areas). 1:250,000 scale geological mapping will give an overall picture of the general geology of a road corridor but will offer little detail regarding local geological structure, nor will it provide any information on soils types and thicknesses. This information can only be determined by field investigations.

Stereo aerial photography exists at a small scale (commonly 1:40,000-1:50,000) for much if not all of the country. It dates from the 1980's and 1990's date in terms of recent land use change, the terrain itself is unlikely to have changed much, if at all since the photography was flown and therefore these photographs represent an important source of geomorphological data for route selection. The interpretation of ground conditions for Arba Minch shown in Figure 3.1 was derived from the interpretation of this photography. This interpretation required approximately 2-3 hours of desk study time and it might be appropriate to suggest that the period of time required for an aerial photograph interpretation of route options within a corridor of 50 km length and 10 km width might be of the order of 1 -2 weeks. Stereo aerial photograph interpretation can yield a range of useful information for route selection including:

- The locations of settlements (villages and towns) and other infrastructure (depending upon date of photography)
- Land use (possibly locally out of date on older photography)
- Topographic features (ridges, cliffs and plateaux etc)
- Drainage patterns
- Geological structures, including faults and persistent influences of jointing patterns on terrain
- Landslides and areas prone to erosion

Table 5.7 lists some of the common indicators in aerial photographs that can be used to recognise landslides and landslide-affected terrain.

Satellite imagery provides updated information on the earth's surface, but is rarely available in stereo form and can, to date, only be combined with very course ground elevation data derived from STRM (Chapter 4) to yield a 3D model for geomorphological interpretation. Nevertheless, high resolution (>1m) 2D imagery (including Geo Eye, World View – 2, Quickbird and Ikonos) is available via Google Earth for much of the country and provides an extremely useful data source for land use and vegetation patterns, drainage patterns, settlements and infrastructure. Large geological features, such as cliffs, faults, volcanic landforms and some landslides can be distinguished on such imagery. A recent study undertaken for ERA as part of the 2011-2014 Landslide Study found that, out of 115 landslides located on the Federal Road Network around the country, slightly less than 80% were covered by sub-metre resolution imagery; the remainder were covered by SPOTV with a resolution of approximately 10m. All imagery shown on Goole Earth is presented in the visible wavelengths only; multi-spectral imagery at these large resolutions needs to be purchased.

Assuming that multi-spectral analysis is not used in conjunction with route selection then it is envisaged that most interpretations of the imagery available on Google Earth would take 2-3 days to complete, depending upon the size of the area.

GIS has become the normal means by which spatial data sets are stored, interrogated and printed, and it is expected that most route selection exercises will utilise GIS. GIS also offers the opportunity to very easily download information recorded by GPS. Various forms of spatial analysis can be performed using GIS, and these include, for example Spatial Multi-Criteria Analysis and Landslide Susceptibility Analysis. The decision as to whether to proceed with these methods of spatial analysis will depend on the quality and resolution of data and the complexity of the terrain and the variables used in the analysis. Establishing the database and the protocols for analysis can be quite time-consuming and if the quality of available data does not match the level of computational procedures required then the cost-effectiveness of these analytical methods should be seriously considered. Further consideration of the use of GIS-based landslide susceptibility mapping for road alignments is given in Hearn (2011).

5.6.2 Field Investigations

Field investigations are only required to the detail necessary to be able to confirm the preferred option. If possible the collection of detailed data for route options that later become rejected should be minimised. Field investigations should be designed to ensure that the following information is obtained for each of the route options:

- An assessment of the proportion of each route option length likely to be underlain by soil or rock – this is important in terms of applying cost rates for excavation
- A record of the main rock and soil types encountered thus allowing engineering geological units or 'reference conditions' to be developed for each alignment (Figure 5.5)
- Identification and record of any landslides and other geo-hazards discussed in Section 5.5.2) along each route, together with an assessment of the hazard they pose and the likely measures required to mitigate them
- If realignment is considered necessary to avoid high risk geo-hazards, for which mitigation is considered either impracticable or too costly, then alternative alignments should be sought. This will require field liaison between the engineering geologist and the highway engineer, as part of the multi-disciplinary team that should be engaged to carry out this work – inputs will be required from hydrology and environmental experts to confirm these details.
- Assessments will also need to be made of preferred cross-sections (full cut, balanced cut fill, full fill/retaining wall) and the general conditions for rock and soil excavation, fill materials and embankment construction and foundations for retaining structures. However, this information should only be collected to the extent required to enable broad assessments for cost comparisons to be undertaken. Table 5.8 lists the reference condition units developed for the project illustrated in Figure 5.5. These were used to apply a provisional design along the entire route length, irrespective of site-specific details. Further information on nominal cutting angles for different soils and rocks for different heights of cut are given in the ERA Geotechnical Design Manual and these form a useful starting point for route option comparison.

The time required to undertake this fieldwork will vary according to project and the complexity of the underlying geology and the terrain encountered. However, it could take up to a period of one month for a suitably experienced engineering geologist to carry out the necessary fieldwork for a 50 km long route option. This period should be multiplied by the number of options studied to estimate the total period required. The time required to analysis the field data and integrate it with desk study information might amount to approximately the same amount of time.

In some circumstances it might be necessary to carry out ground investigation to furnish the information required for decision making. Trial pits can provide useful information on near-surface ground conditions if access is feasible and there is insufficient natural exposure available to aid in broad materials classification. Drilling investigations can be time-consuming and expensive and are usually only undertaken at the route selection stage to assist in defining ground conditions at high risk locations that influence the feasibility of the entire route. These might include the need to investigate the foundations for a major bridge or the depth of a substantial landslide. Geophysical investigations can provide a cheaper and quicker alternative, but usually require borehole calibration anyway.

Table 5.6 Summary of Desk Study and Field-Based Assessment Techniques

	Techniques	Information
Desk study	Reviewing published and unpublished literature, geo-hazard (landslide, seismic etc.) records, archived construction and maintenance data and logs, records of geologic explorations	Indication of geology, surface and groundwater conditions, soil characteristics, foundation conditions, past instabilities and hazards etc.
	Topographic map interpretation	Identification of landforms, drainage patterns, surface water bodies etc., which can give a useful indication and general characteristics of geology , geomorphology and possible geo-hazards
	Geological maps, sections and memoirs interpretation	Identification of surface and subsurface formations, stratigraphic sequence, geological structures, weak and strong ground, adverse geological conditions, though this will require field verification or field derivation if desk study data is insufficient
	Hydrogeological map, reports and well logs interpretation	Identify shallow groundwater table, aquifers, possible seepage areas, quality of ground water etc – again the extent to which this can be done as a desk study exercise will be data-dependent.
	Water resources map interpretation	Identify availability, quality of water sources for construction
	Soil map interpretation	Identify types, distribution and characteristics of soils, though the scale of this mapping and its availability for any given area will need to be checked and supplemented significantly by field observations
	Terrain modelling and classification	Identify site geomorphology and geology, and interpret surface and ground conditions, delineate areas of relatively homogenous engineering geological units with respect to lithology, morphology and processes
	Remote sensing data (aerial photo, satellite and airborne images, DEM's) interpretations	Identify drainage pattern, fluvial geomorphology, geological structures, probable distribution of broad soil types, landslides, erosion areas and areas possibly liable to flooding.
	Reviewing climate data and maps	Identify climatic conditions and draw broad conclusions regarding potential for high groundwater, landslides, flooding and erosion.
	Preparing geo-hazard inventory and susceptibility (e.g., landslide susceptibility) maps	Indicate the distribution of known geo-hazards, and susceptibility to geo-hazards through combination of factors. This can be modelled using GIS if data and resources permit. Most of this information at desk study would be derived from interpretation of stereo aerial photographs

	Techniques	Information
Field investigation	Walk-over surveys, including engineering geological and geomorphological observations and mapping (1:10,000-1:20,000) and route classification for reference condition purposes.	Examine rock and soil exposures, supplement and check the accuracy of information gathered from desk studies and remote sensing data interpretations, establish major topographical and engineering geological conditions to complete preliminary assessment of routes. Information from local inhabitants concerning past geo-hazard events can be extremely important.
	Ground investigation	Trial pitting at key locations to aid in engineering geological classification, and especially where natural exposures are limited. Some tests can be undertaken on disturbed samples to assist in the assessment of strength parameters.

Note: In addition to spatial resolution and availability, thick vegetation and cloud cover may restrict the use of remote sensing data especially in some parts of the country where vegetation is dense and cloud cover is persistent throughout the year.

Table 5.7 Landslide and Related Features Commonly Identifiable on Stereo Aerial Photographs (from Hearn 2011)

Feature	*Appearance in aerial photographs*
Landslides by mechanism	
Progressive Soil creep	Immature / uncharacteristic vegetation with disturbed / hummocky ground surface, small ridges / terracettes perpendicular to movement direction, discontinuous / uneven irrigation and cultivation
Debris slide	Exposed soils in well-defined back scarp/source area, clearly defined deposit containing boulders
Mudslides and mudflows (earth slides and earth flows)*	Long, narrow, planar flow track/deposit with lobate toe, clear lateral boundaries, disturbed vegetation, weathered rock or freshly exposed soils in back scarp, springs, ponds and wet ground indicative of high groundwater levels
Debris flow	Clearly defined flow track containing poorly-sorted, often chaotic deposits of debris, depositional fan at toe, flow lines composed of debris forming margins of flow track
Progressive rock creep	Difficult to identify on aerial photographs, often found in fractured rock masses, occupying high, steep slopes, ridges and trenches running across the slope may be visible and indicative, possible rock spalls on margins
Rockfall	Rockfall scarp, sometimes with arcuate form, freshly exposed rock in source area, progressive rockfall may form concave talus slope, boulders at toe or on less steep slopes below
Catastrophic rockslide/ avalanche	Usually large scar with failed mass of chaotic boulders and rafts of rock, slope angle of failed material usually lower than adjacent slopes, trail of boulders often extends considerable distance downslope/downstream
Slow rock slide	Hummocky and furrowed slopes in head of failure, boundaries of failing mass may be linear where joint-controlled, slope rupture and small vertical displacements along margins
Rotational landslide in soil	Arcuate back scarp in plan, concavo-convex slope profile in section from back scarp to toe, well-defined lateral shears, back-tilted blocks with reverse slope below scarps, ponds at junction of scarps and back-tilted blocks and in areas of spring seepage, in some cases, multiple-slipped blocks are seen forming a 'staircase'

Feature	*Appearance in aerial photographs*
Landslides by activity	
Active	Fresh failure scarp with high reflectance and low vegetation levels, slipped mass with immature / disturbed vegetation and areas of bare ground, landform disturbed and uncharacteristic of surrounding topography, possible rock spalls on margins, springs, ponds and wet ground in slipped mass, disruption of drainage patterns, areas of slope in tension (cracks) and in compression (hummocks and bulges)
Dormant or intermittent	As above, but vegetation more mature with scarps beginning to revegetate Possibly cultivated
Relict	As for above, but more subdued topographic distinctions, vegetation may be well-established, land may be cultivated and inhabited
Other important features	
Thin Soil cover	High percentage of rock outcrop, marked structural control on topography, patchy vegetation
Deep soil cover	Concavo-convex slope profile with lobate and gently rounded lower slopes Dendritic drainage pattern
Residual Soil	Red / red-brown appearance in colour aerial photographs Often occupies rounded ridge and spur summits and/or flat/gently sloping ground Benches often intensely cultivated, soil prone to erosion
Rockfall/ rockslide taluvium	Deposits of boulders below rock cliffs, unsorted with chaotic arrangement, steep slopes common, low levels of vegetation, often of shrub-type
Undifferentiated taluvium/ colluvium	Long slopes, often with constant slope angle, shallow landslide scarps may be visible where deposits are unstable, boulders at toe due to longer travel distances, immature drainage patterns with water seepage on lower slopes
Rock outcrop	Steep slopes, high reflectance from bare surfaces and low levels of vegetation, repeated pattern of structural control on topography and drainage
Strong rock	Steep and rugged topography, V-shaped gullies and valleys, knife-edge ridges
Weak rock	Gentle slopes with rounded spurs and ridges, and concave slopes No visible outcrop
Springs	Wet ground with dense vegetation in many cases, often located at concave breaks of slope and/or geological boundaries, often located at the head of a stream

* Cruden & Varnes (1996).

Figure 5.5 Perspective Map Showing Reference Condition Distribution Along Part of the Mekhane Selam – Gundewein Road (Hearn 2011)

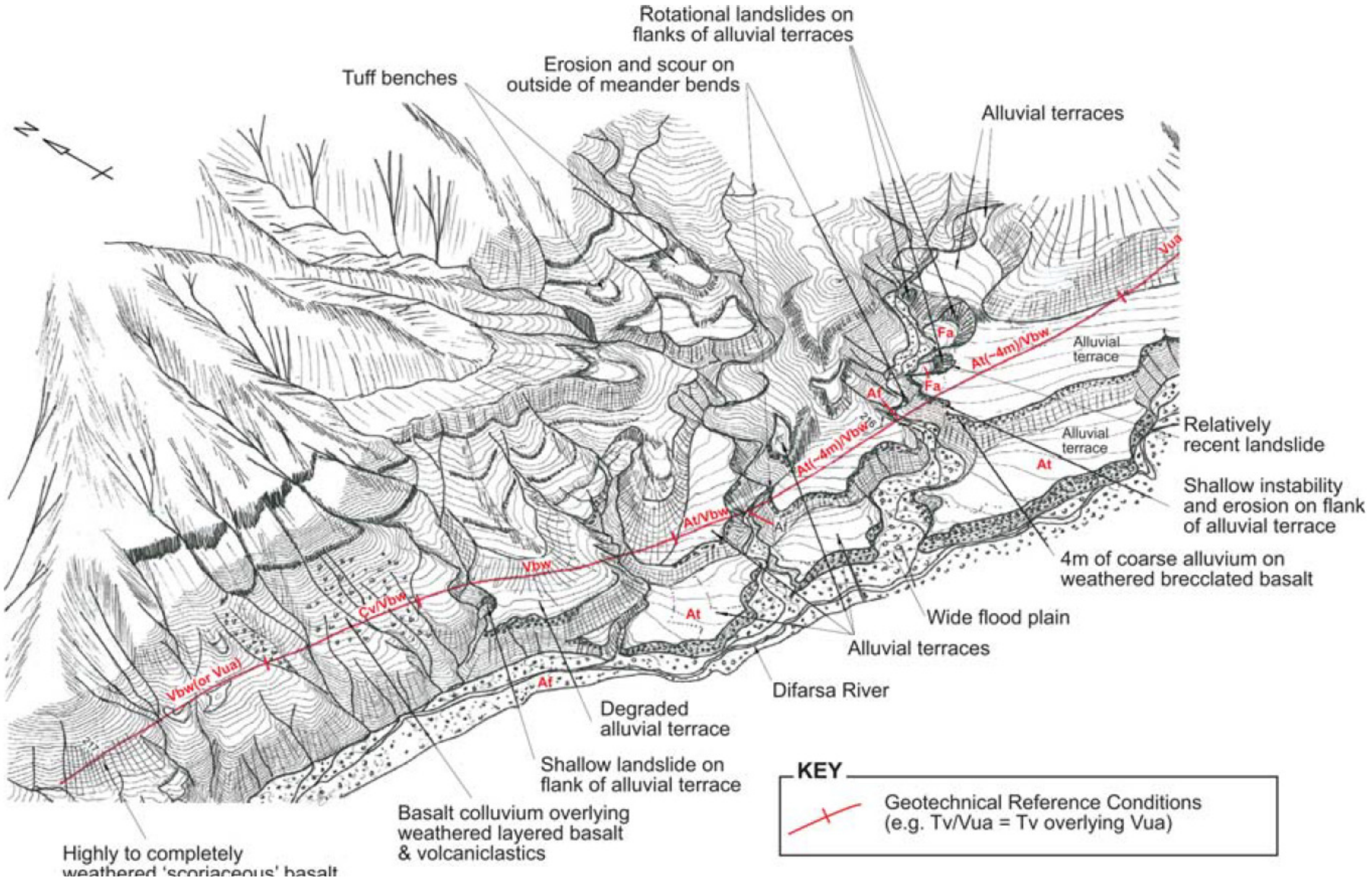


Table 5.8 Reference Condition Summary for *in situ* Rock and Transported Soil Units shown on Figure 5.5 (Hearn 2011)

Reference condition	*Lithology*	*Landforms*	*Materials*	*Associated engineering geological considerations*	*Preferred cross-section*	*Embankment foundation suitability*	*Cut slope stability*	*Anticipated maximum cut slope angles V : H*	*Expected Excavation Techniques*	*Specific retaining, slope protection or drainage measures anticipated*
IN SITU										
Vbw	Highly to completely weathered basalt	Basalt plateau, moderate slopes	Spheroidal weathering of basalt creates gravels, cobbles and small boulders with a clayey and sandy matrix.	Both rock and soil type behaviour. Differential weathering, ravelling. Low material strength promoting circular failures through rock mass and relict discontinuities.	Full cut	Variable and unreliable, dependent on weathering profile and depth	May be controlled either by rock structure or soil type behaviour.	1:1 (<5m) 1:1.75 (5-10m) These weathering grades not expected beyond 10m depth.	Conventional excavation.	Removal of loose boulders. Rock catch ditches below slope.
Vua	Undiff-erentiated, interbedded basalt lava and tuff ('Ashangi Basalt' formation)	Moderate to steep slopes	Subhorizontal layers of jointed and fractured basalt, fine to coarse tuff and volcaniclastic sandstone/siltstone and volcaniclastic breccia.	Variable strengths, differential weathering and erosion, ravelling of undermined layers, structurally controlled failures in stronger basalt and tuff layers. Possible thin clay layers, including paleosols.	Cut or retained fill	Very good.	Generally good, subject to local structural control and rock types. Some ravelling in breccia and agglomerates expected. Buried paleosoils and clayey horizons may encourage shear failures.	Nominal angle of 1:1 suitable. Refer to individual reference conditions on exposure during construction. Multi-sloped design may be required where considerable variations in materials are encountered with depth.	Variable, generally conventional excavation and ripping, with some blasting of locally stronger materials.	Rock catch ditches below slopes. Consider anchored wire netting on slopes with particularly variable and ravelling slopes. Consider slope drainage
TRANSPORTED										
At	Alluvium	Terraces and alluvial fans, flat to very gently sloping, elevated surfaces	Uncemented sands, gravels, cobbles and boulders of variable lithologies with a minor silt/clay content.	Fines content highly prone to erosion. Terrace and fan flanks subject to river scour, oversteepening and landsliding.	Fill	Generally acceptable for low embankments, though some variable ground conditions.	Moderate. Controlled by groundwater, fines content and plasticity. Vertical variations in particle size and density may warrant multi-sloped design.	1:1.5 (<5m) 1:2 (5-20m) 1:2.5 (20-30m)	Conventional excavation.	Controlled slope drainage. For cut slopes in areas of higher groundwater, toe walls with additional drainage measures may be required.
Af	As above	Flood plains, flat infill on valley floors		Flood plain, mobilization of fine to coarse debris.	Fill	Potentially troublesome as some materials compressible and highly prone to erosion and scour.	Avoid due to groundwater/water bearing fines content and plastic fines.		Conventional excavation. Dewatering or stabilisation may be required during excavation.	Scour protection from existing watercourses and floods.
Cv	Colluvium derived from volcanic rocks (basalt, tuff and breccia)	Gentle to moderately steep, concave slopes, often steeply incised	Uncemented well graded clay, silt, sand, gravels, cobbles and occasional boulders of volcanic rock origin.	Soil type failure. Broad stratigraphic layering occasionally parallel to ground surface promotes translational landslides. Possibly subject to creep. Circular failures through fine-grained materials. Highly erodible and transportable on steep slopes (debris flows) Otherwise stable.	Balanced cut and fill in low angle slopes.	Potentially troublesome as fine-grained matrix may be plastic and prone to shrink/swell and creep. Residual (low strength) shear surfaces may be present and may be remobilised upon loading.	Controlled by soil behaviour though adversely oriented bedding fabric may initiate planar failures in cut slopes in side long ground.	1:1.5 (<5-15m) 1:1.75 (15-20m) 1:2 (20-30m)	Conventional excavation. Some larger boulders will be encountered.	Masonry or gabion retaining walls likely to be required in cuts >10m to ensure cut slope stability. Controlled slope drainage.
Tv	Talus derived from volcanic debris (from basalt, tuff and breccia rock sources)	Planar talus slopes close to or at limiting slope angle, developed beneath ravelling exposures or from rockfall failures in cliffs formed in volcanic rocks.	Uncemented basalt cobbles and boulders with a low clay/silt content	Subject to creep and shallow circular or planar failures through fine-grained components. Potentially subject to further rockfall and rock avalanche.	Full cut in steep slopes. Cut/fill in shallower natural slope angles.	Poor and unreliable due to variable materials on steep slopes close to their limiting angle of stability, potentially subject to creep.	Controlled by soil behaviour. Troublesome due to loose, unconsolidated deposits. Excavation may initiate new shallow plane failures which regress upslope.	1:1.5 (<5m) 1:1.75 (5-10m) Reference condition not expected beyond 5m depth. Retaining structures required if cut slopes need to be steepened to daylight.	Generally conventional excavation.	Masonry road retaining wall and cut slope retaining walls founded into underlying bedrock. Ditches and gabion barriers on upslope side of road to contain rockfalls.
Fa	Alluvium	Translational/ rotational landslides on flanks of alluvial terraces	Uncemented sands, gravels, cobbles and boulders of variable lithologies with a minor silt/clay content.	Base of slope may be subject to river scour, potentially destabilizing slopes and enlarging landslides.	Avoid or cross in full cut or balanced cut and fill.	Not recommended for embankment as additional loading may reactivate movements along residual shear surfaces leading to gradual creep or sudden failure.	Variable ground conditions possible. High groundwater table may be encountered. Stability controlled by residual shear strengths, groundwater, fines content and plasticity.	Site specific assessment and design required for excavations into this Reference Condition.	Conventional excavation.	Gabion retaining walls to support failing slopes. Scour protection. Controlled slope drainage.

Chapter 6 Hydrology

6.1 Introduction

This chapter considers the influence of river crossings and hydrology on route selection. Key hydrological issues for route selection are identified with guidance on how they can be determined; either from remotely sensed images or by inspection on the ground if that is possible. The influence of hydrology and drainage considerations on route selection relates primarily to:

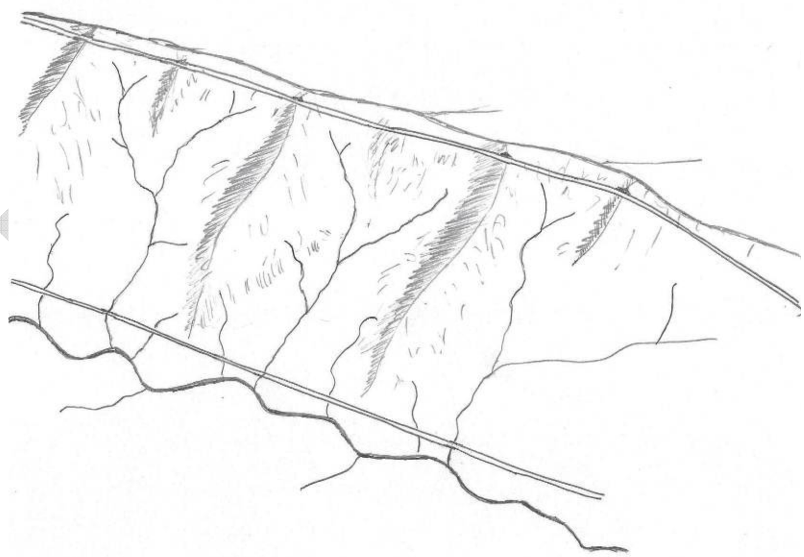
- The implications of routes located on ridge tops, valley floors (including flood plain routes), valley sides and flat to rolling terrain
- The location of major bridges as potential fixed points in a route selection exercise
- Anticipated levels of flooding, scour and sediment accretion where there factors control feasibility and significantly influence route option cost comparison.

6.2 Broad Drainage Implications of Different Route Options

6.2.1 Ridge Routes and Valley Floor Routes

Ridge routes typically cross only small watercourses fed by small catchments whereas valley floor routes usually encounter a smaller number of much larger rivers and watercourses, supplied by large catchments, with the requirement for bridges. It is the cost of the additional large watercourse crossings that makes selection between ridge and valley floor routes on drainage grounds an important issue for route selection (Figure 6.1).

Figure 6.1 Ridge and Valley Floor Routes



Valley floor routes encounter one or a combination of the following:

- A 'V-shaped' valley floor without river terraces and sometimes without flood plain – an incised channel
- A valley floor that comprises a river channel and its flood plain only

- A valley floor that comprises a river channel, its flood plain and flanking river terraces

a) Incised Valleys

Incised channels (Figure 6.2) are those where the valley sides extend to the banks of the watercourse to form a V-shaped profile with no flood plain. The watercourse is constrained to flow in a single channel. Typically this type of channel occurs at higher elevations in catchments where the river is geomorphologically young and actively downcutting, though there are exceptions (Figure 6.2).

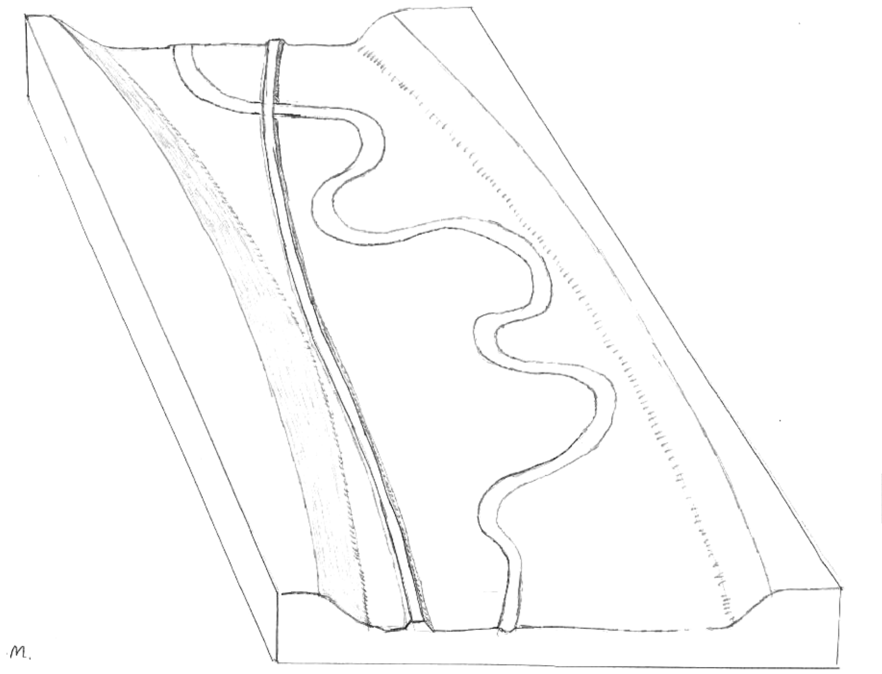
Figure 6.2 Incised Gorge of the Abay River

Generally this type of channel poses relatively few hydrological/hydraulic problems for bridge crossings, though scour will need to be considered. Key concerns will relate to alignment selection on the valley sides and the stability of steep valley side slopes potentially undermined by river erosion. Such situations can require extensive erosion protection works and should be considered and cost estimates provided for route selection.

b) Flood Plains

Flood plains exist on more mature rivers (Figure 6.3) and may be crossed or followed by routes. Three potential factors may influence route selection on flood plains: the extreme flood level, the level of the road needed to avoid being flooded; migration of meanders which can outflank bridges or erode embankments; and the potential for loss of flood plain storage or conveyance either under a road embankment or cut off behind an embankment.

Figure 6.3 Flood Plain Routes



Whilst flood plains may provide an inviting level alignment three factors should be assessed when considering locating a route along or across a flood plain:

- flood level;
- loss of flood plain storage and conveyance;
- meander migration.

It is on flood plains where an assessment of potential flooding is likely to be most relevant. If local rainfall and/or river flow data is available this should be used to calculate an initial estimate of flood levels. In the absence of that data and if a clearly defined natural channel exists in the flood plain the depth to the channel invert from the flood plain level is likely to be approximately equal to the depth of water over the flood plain during a flood event with an annual exceedance probability of 1%.

The route will need to be located at a level that avoids flooding, typical above the flood event with an annual exceedance probability of 1%, the 1 in 100 year return period flood, plus freeboard. It may be possible to build a route on embankment to raise it above the flood level but this will cause loss of flood plain storage and may need erosion protection at the toe to prevent meander migration from undermining it.

Loss of flood plain can have two causes: firstly the footprint of any embankment constructed in the floodplain and secondly where an embankment isolates a section of flood plain and prevents flood water from flowing into it. Any loss of flood plain storage will tend to increase peak flood flows downstream and the loss of conveyance will tend to increase flood levels locally. Isolation of sections of the flood plain can be mitigated by inclusion of flood relief culverts to maintain flood flow paths. Losses of storage caused by embankment footprints are more difficult to mitigate and whilst the effect may be small when a route crosses a flood plain it can be significant where a route is aligned alongside a flood plain. In either case the cost of mitigation should be estimated for route comparison purposes.

Braided and anabranching rivers are often found on flood plains where the sediment yield of catchments is very high. These rivers comprise more than one channel. Anabranching rivers typically have two channels: at any time one channel will tend to be dominant though the dominant channel may vary over time. Braided rivers have a number of criss-crossing channels as shown in Figure 6.4.

Figure 6.4 Examples of Braided River Channels

	
Satellite image of a braided river	Braided river viewed from a helicopter

Both anabranching and braided types of channel raise issues for bridges as the channel is unstable in location and wider than necessary to pass the flood flow. Any bridge is likely to require extensive river training to stabilise the channel location and to reduce the bridge span to an economical design.

Meandering channels predominate where a river has a floodplain. Figure 6.5 shows a meandering channel. The processes of erosion and deposition around bends means that meanders tend to migrate downstream. As they do so the location of the channel will move across the flood plain. If maps or images are available from different dates it may be possible to see how rapidly meanders are moving. Meander progression can require extensive river training at bridges or erosion protection at the toe of embankments or both and is thus an important consideration for route selection.

Figure 6.5 Meandering Channel on the Addis Ababa – Debre Markos Road

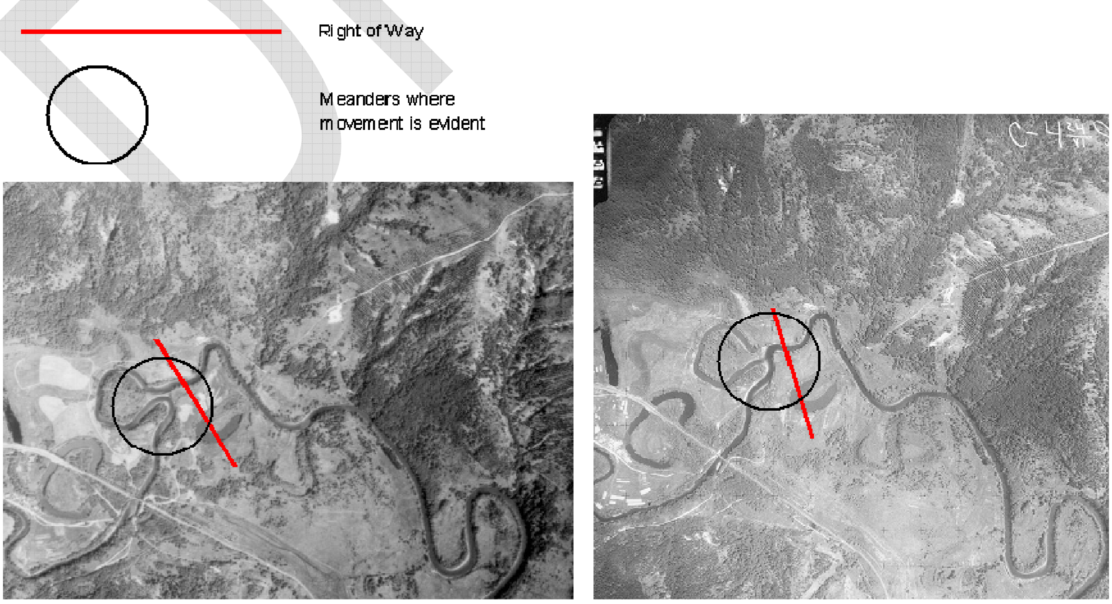
Figures 6.6 and 6.7 show locations where meander migration has led to the channel moving relative to a bridge. In both cases the channel is now eroding the toe of the approach embankment and slope failure can be seen on the embankment slope.

Figure 6.6 Meandering Channel on the Adwa-Adigrat Road

Figure 6.7 A Bridge where Meander Migration has Caused the Channel to Shift Laterally, Eroding the Adjacent Embankment, on the old Adwa-Adigrat Road

If sufficiently accurate topographic data is available to determine the location of the channel at the present and at least once in the past it may be possible to see where migration has occurred and even to estimate the average rate of migration. An example is shown in Figure 6.8. However, past rates of movement should be treated with care if they are used to predict future change, as they are likely to be influenced by factors such as climate change, deforestation and underlying geology.

Figure 6.8 Meander Migration and Cut-off on Aerial Photographs



Accretion can also be an issue for bridges located on flood plains. Figure 6.9 shows a bridge in Ethiopia, where accretion has almost filled the waterway opening in the 60 to 70 years between construction and when the photograph was taken.

Figure 6.9 Accretion at a Bridge on a Valley Route

Alluvial fans occur where a sudden reduction in bed gradient causes sediment to be deposited, most commonly where a relatively steep and active tributary flows out onto the flat floodplain of a larger river. These are always difficult locations as sediment will deposit in the main channel: this accretion will cause changes in channel level and sudden shifts to new channels. Where possible, routes should be selected to avoid crossing such features.

If an alluvial fan has to be crossed, it is preferable to cross near the apex of the fan where the location of the upstream channel is stable. However even at this location accretion may occur. Further away from the apex extensive training works will be required to confine the watercourse to the desired single channel and regular maintenance will be need to keep this waterway clear.

C) River Terraces

High level terraces, above the level of flooding in the main river can easy terrain for route engineering. The advantage offered will depend on terrace continuity and width and the presence of side tributaries posing bridging requirements and potential active fan crossings. Scour may also be a significant cost consideration on valley meander bends high level terraces tend to be absent and the river scours the adjacent valley side.

6.2.2 Valley Side Routes

Valley sides are often drained by eroding gullies which may require extensive works to stabilise. Figure 6.10 shows gully erosion encroaching upstream to threaten a road. The erosion protection downstream of the culvert had not been taken sufficiently far and has not been adequately founded. The steepest stream gradients are found on valley sides and affect alignments constructed in side-long ground. The actual erosion potential will depend upon flow velocities and the resistance of channel beds and banks to withstand scour. These considerations can be assessed in general terms during walk-over surveys (Section 6.4.3). Channels formed in weaker rock or soil may erode rapidly forming gullies.

Figure 6.10 Gully Erosion on the Adwa-Adigrat Road

The presence of existing eroding gullies will be visible either on aerial photographs or during a walkover survey. They can occur either on valley sides or on more gently-sloping ground in terrace deposits or residual soils, and are typically the result of past changes to the catchment such as deforestation. The presence of even limited gully erosion should be taken as an indication that the whole topographic unit in which it is occurring may be susceptible to erosion. Whether or not this is significant enough to influence route selection will depend upon severity and the anticipated cost of stabilisation. In some instances stabilisation can require extensive channel protection works for considerable distances above, and particularly below, a road in order to ensure long-term stability. In these instances, while it may be economically expedient to consider the inclusion of just two or three scour checks immediately downstream of a road these would be liable to undermining by gully development from below and would only provide a short term solution.

6.2.3 Flat and Rolling Terrain

Rolling and flat terrain are areas where neither drainage nor erosion are generally problematic (Figure 6.11). Therefore hydrology is unlikely to be a key issue for route selection in these types of terrain, except where larger streams or rivers require crossing, posing meander migration and scour potential. Adequate provision for scour protection will need to be included in route option cost estimates to deal with these hazards.

Figure 6.11 A simple culvert in essentially flat terrain

6.3 Bridge Locations

Bridges are relatively expensive to construct and can be prone to scour damage. Selection of appropriate locations for bridges where the span and need for river training works are minimised will reduce both capital and maintenance costs. Such locations will be fixed points that help to define route options.

The preferred location for a culvert or bridge would be over a straight, stable reach of the river with a single channel and erosion resistant materials on which to found abutments. Such combined conditions are rarely encountered. The best available site is selected based on the following factors:

- Channel stability;
- Channel width;
- Potential for scour.

A stable channel will require less training works to ensure the watercourse flows through the waterway efficiently. Unstable channels include braided and anabranching channels (where the location of the main channel can vary chaotically) and meandering channels (where progressive meander migration can cause the channel to move over time). Whilst unstable channels can be controlled through the use of training works these may need to be extensive and are likely to be costly.

Figure 6.12 shows a bridge in Guinea that has been located on a stable reach of the river and dense vegetation can be seen on the banks. There is also rock present within the foundation. Inspection of the channel about 2km upstream revealed eroding banks, gravel bars and cut off meanders. This bridge had been built at a good location and the road alignment adapted to match.

Photo 6.12 Bridge on a stable reach of channel in Guinea

Within an otherwise unstable channel there may be locations that are more stable. The reason may be obvious, for example where a rock outcrop provides natural river training, or less obvious, for example where underlying changes in geology or faulting control the channel geometry. Such locations are likely to be preferred if they can be found. Alternatively locations where the channel is located against a stable valley side may be more suitable than where the channel is freely meandering.

Usually, the most significant factor in the cost of a bridge is its span. For that reason a single narrow channel would be preferred as a crossing location to either a broader channel or a reach where there are multiple channels. Training the river to reduce the width or number of channels is possible but is likely to be costly. Similarly, a location where the route crosses a river at right angles will minimise the skew and hence the length and cost of the bridge. Realigning the river to suit the road alignment may be possible but again is likely to need costly river training works.

Scour at bridges may be exacerbated by a variety of factors, and these should be avoided where possible:

- Severe scour can occur at the confluence of two streams. It can also be difficult to estimate extreme flood flows and hence flood levels at such locations. The reaches upstream and downstream of any confluence should be avoided if possible.
- Scour and bank erosion will occur at bends. They should be avoided unless the outside of the bend is against an erosion resistant valley side.
- Bridge piers cause local scour, so a location that does not need any piers in the river channel would be preferred over a location where a central pier is required.

- Existing structures, such as an earlier bridge, will alter the channel hydraulics. If two bridges have to be located close to each other their effects on each other will need to be considered and may require uneconomic spans to be selected to minimise interaction of scour effects.

For larger bridges a preliminary estimate of flood flows will usually be needed at route selection stage to improve the accuracy of estimation of both the waterway required and potential for scour if these factors are considered likely to have a significant effect on the overall cost estimate for each route option. These preliminary estimates should be based on readily available information such as catchment characteristics and design rainfall. Any flow estimates should be compared with data from physical inspection of the potential bridge location to ensure at least a basic level of calibration.

Further information on the location of bridges including requirements for minimum freeboard above design flood level can be found in the ERA Bridge Design Manual.

6.4 Data Sources for Route Assessment and Comparison

There is a range of data sources available that can assist in route selection as far as hydrology and drainage patterns are concerned. These include published topographic maps, aerial photographs and free to download satellite DEM data. LiDAR and other airborne imagery is unlikely to be available in the majority of cases and is likely to prove too expensive to acquire at route selection stage. Figure 6.8 illustrates the value in using historical aerial photographs to assess changes and rates of change to stream channels over time. Satellite imagery can also offer significant potential in this regard given the frequency and increasing resolution of image data collection.

Specific hydrological information such as gauged rainfall records or river flow data may exist, either within the corridor or from adjacent catchments. Desk study data will almost inevitably have to be supplemented by field observations in order to obtain the required data for route selection.

6.4.1 Topographic Data

In respect of hydrology and drainage issues, there are two types of information that can be extracted from the topographic data to guide route selection:

- The contributory catchment areas, especially with regard to the major river crossings
- The type of river channels (incised, braided, meandering etc) of each route option.

6.4.2 Hydrological Data

24-hour maximum rainfall data can be obtained from National Meteorological Services Agency (NMSA) if there are rainfall stations present in the route corridor. In addition, the ERA Drainage Design Manual divides the country into different rainfall regions. The daily maximum rainfall data from NMSA can be analysed to derive design rainfalls for various return periods to be applied to the determination of design discharges. The maximum rainfall values derived from data analysis should be compared with the ERA regionalized rainfall values provided in the Drainage Design Manual.

River flow data can be obtained from the Ministry of Water and Energy Resources of Ethiopia. The use of rainfall and flow data at route selection stage will vary according to each project. As a minimum it is recommended that this data is reviewed to identify any hydrological feasibility constraints on route selection and any requirements for major investments to accommodate drainage patterns and anticipated flood events.

6.4.3 Field Observations

Although the presence of erosion resistant features or zones can, to an extent, be determined from aerial photograph interpretation, walkover surveys will be required to assess ground conditions. Furthermore, flood marks can only be ascertained from field observations and consultation with local inhabitants can often provide valuable historical information that cannot be ascertained from other sources.

Field inspections will be needed at major bridge sites to confirm their viability, particularly with regard to identifying erosion resistant locations either for use as foundations or as a point at which river training works can be tied in. Field inspection also provides an opportunity to collect information on the flood channel: its size, any evidence, physical or anecdotal, of past flood levels and information on the type of material in the channel bed and banks. If existing bridges are located on the same reach they should be inspected as their performance will give an indication of channel stability and scour risk.

6.5 Route Selection Preferences

The selection of a route will typically be based on a trade off between very different factors for which no direct quantitative assessment is possible. For example, a route that crosses an alluvial fan at its apex may need to cross unstable ground to reach that point. The table below sets out a weighting for the various hydrological factors noted in this chapter to aid in route comparison.

Factor	Weighting				
	Avoid	**Very poor**	**Poor**	**Neutral**	**Preferred**
Topography					
Ridge					✓
Eroding valley side		✓			
Stable valley side				✓	
High level terraces on valley floor					✓
Flat or rolling					✓
Bridge Locations					
River straight and stable					✓
Locally stable reach					✓
Narrow or avoids piers in the channel					✓
River confluence		✓			
Active meander migration			✓		
Alluvial Fans					
Any alluvial fan	✓				
Alluvial fan apex		✓			
Flood Plains					
Embankment on flood plain			✓		
Anabranching or active meander migration		✓			

Chapter 7 Environmental and Social issues

7.1 Introduction

There is a growing awareness that road development can have major environmental impacts, including damage to sensitive ecosystems, loss of productive agricultural lands, resettlement of large numbers of people, permanent disruption of local economic activities, demographic change, accelerated urbanization, and introduction of disease.

Route selection differs fundamentally from other types of development in two ways:

- Road projects occur over long distances that typically cross through a number of different environmental settings.
  Identification of significant environmental resources and avoidance of environmental impacts is achieved during constraint mapping and route selection stage. A constraint map summarizes the most critical features identified in the inventory and analysis stage and presents them, where possible, in relation to the physical layout of an area. The constraints cap includes features which are the basis for the development of the future land use plan. Historic Features, Forest Resources, Agriculture, Road System, Recreation Facilities, Very Low Soil Potential Areas, wetlands areas, Visual and Scenic Parcel Resources, Transportation Facilities, Natural Resource Preservation, Future Commercial and Light Industrial Development, Public Access.
- An environmental impact statement for a road scheme needs to allow sufficient scope to cater for procurement methods that sometimes provide scope for design input by the contractor after development consent has been obtained. This may often involve the use of innovative methods by the contractor to mitigate significant environmental impacts.

The process to identify route corridors can be divided into five main stages

- Identification of issues
- Collection of data on environmental and socio economic issues that are sensitive to the construction and operation of road and creation of constraint mapping
- Assigning sensitivity value for each environmental and social issue.
- Selection of least impact corridor option derived from the constraint mapping and
- Field investigation to verify broad suitability of corridors developed

Route corridor selection is rigorous process which requires careful and detailed description of the physical, biological, social and economic situations prevailing in an area under investigation and speculation of potential changes that may be induced in all the variables mentioned above due to the proposed route corridor development. Route corridor selection process follows a seven stage approach (but not limited to), including the following:

1) Establish start and end points for the route
2) Establish corridor selection criteria
3) Undertake desktop studies to determine broad constraints
4) Develop potential corridor route options
5) Select a preferred corridor option
6) Undertake field investigations based on desktop studies

7) Further refine the preferred corridor option

This Chapter includes four appendices (Appendices 3.1 to 3.4).

Appendix 3.1 sets out the institutional and legal framework. In this part, national and international laws, regulations and guidelines which are relevant to route corridor selection are reviewed.

Appendix 3.2 discusses the environmental issues that should be considered in route corridor selection. This part of the document attempts to show the varied environmental resources and issues that should be taken, but the list is by no means exhaustive. Some of the resources, for example the protected areas, are protected by proclamations and regulations and some are not. Whenever route corridor selection is planned it is very important to consult the relevant public sectoral and regional agencies, the private sector, education and research institutes and the community. Information should be obtained on the resource under question as the data included in this part may change over time, new areas may be added into the protected areas by new regulations, new archaeological, cultural, natural and historical heritages may be found. Apart from this, one may encounter some archaeological evidences and heritages of considerable importance during the route corridor selection that may not have been known previously. When such cases occur, the relevant authorities must be informed before further steps are taken.

Appendix 3.3 comprises the social and economic issues that should be taken into account. The social issues listed may not be exhaustive but it is important to make detailed analysis of the socio-economic situation of the area and an assessment of potential changes that could occur due to the route corridor.

Appendix 3.4 discusses the valuation of ecological resources.

7.2 Identification of Key Environmental Components and Issues

A number of national and international environmental policies and multilateral lending agencies regulations require the description of existing environment that might be affected by potential development. The study process entails a scoping exercise by multi-disciplinary group of experienced specialists for the key environmental issues. Based on the valued ecosystem components, the study scope should cover, but not limited to issues such as climatic conditions, drainage and water resources, soils, flora, fauna, air quality, noise, land use, land tenure and socioeconomic aspects.

7.3 Techniques for Assessing Baseline Conditions

The term “baseline” refers to conditions existing before development against which subsequent changes can be referenced.

Environmental Baseline Studies” generally include an entire range of pre-project studies and are carried out to:

- Identify key environmental factors, which may influence project design decisions (site lay- out, etc);
- Identify sensitive issues or areas requiring mitigation or compensation;
- Provide input data to impact prediction models; and
- Provide baseline data against which the results of future monitoring programs can be compared

Baseline data for the study area is generated using a combination of:

- Field studies
- Analysis of maps, plans, aerial photos
- Review of engineer's reports and drawings
- Review of background project documents
- Structured Interviews
- Social Surveys
- Laboratory analyses
- Internet Searches
- Public agency requests and document searches

7.4 Environmental Baseline study

7.4.1 Scoping

The early environmental baseline study process starts with a scoping exercise for the key environmental issues. A multidisciplinary group of experienced specialists (Environmentalist, Meteorologist/Air Pollution Specialist, Geologist/Soil Engineer, Chemist/Water Pollution Specialist, Forester/Ecologist, and Social Scientist/Geographer etc) define:

- the key environmental factors
- baselines for the key factors, and
- project alternatives, including "no project" option.
- Inputs from consultations with other public stakeholders and statutory institutions e.g.

a) Climatic conditions – Information on local meteorological conditions is important in future for assessing the dispersion of gaseous emissions from sources associated with the route corridor development. This entails review of data on wind, temperature, humidity, rainfall and evaporation.

b) Drainage and water resources – This entails description of major water bodies (lakes), rivers, springs and swamps. These can be further categorized into surface (lakes, rivers, dams, water pans, swamps) and groundwater sources (boreholes).

c) Soils- Data collection on soil physical properties is very useful in explaining the prevalence of erosion and the principles of its control. The chemical properties of the soil are vital in determining the potential impacts on soil fertility associated with route selection development.

d) Flora – Description of existing vegetation of the area. This involves use of ecological checklists that will show the distribution of plant species over the proposed route corridor prospect area. It also involves characterization of vegetation and description of the major vegetation types, composition and associations.

e) Faunal studies - This entail description of the fauna in the area. Acquisition of quantitative data and information with an aim of identifying unique and important habitats together with the spatial and temporal patterns of habitat use by the animals.

f) Air quality issues – involves identification of matters, which are important in assessing the air quality impacts arising from the proposed route corridor development. Assessing the existing air quality by determination of ambient concentration of the main gas emission from the route corridor development project.

g) Noise quality – the potential for a noise to annoy depends on the loudness of the noise relative to the existing noise levels. Thus to undertake an impact assessment it is necessary to determine the existing noise environment in the absence of noise emissions from the proposed developments. Data on background noise levels are important from the point of view of noise impact assessment because it is the difference between the background noise and the proposed route corridor development related noise that most closely correlates with the perceived annoyance of noise.

h) Land use and Tenure systems – It is the use of a stretch of land and involves interaction between the land and its user, which encompasses the relationship between biophysical features (geology, topography, soil, climate, flora and fauna) and socio-economic issues (land tenure, culture, community organization, income etc). Thus land use in any given area is always dynamic in any given time. Land tenure is the type of ownership i.e. freehold (individuals with title deeds), leasehold (for a given period of time) and communal ownership (community ownership).

i) Socio economic aspects – administrative boundaries, demography (population estimate & projections), economic structure and labour, commercial sector, agriculture, tourism, community infrastructure (education & training, health services, housing, recreational facilities, security), transport, perceptions of local over the project, aesthetic/historical, cultural & archaeological sites, energy sources, natural resources (economic minerals) and utilities (power, communication, water supply & quality etc).

A comprehensive work plan is then drawn outlining details of the key environmental aspects to be considered, methods to be used for baseline data collection, the various stakeholders to be consulted, estimated human and financial resources required and time allocation for the various components of the Environmental Baseline Studies.

7.4.2 Methods of Baseline Data Collection

Baseline environmental information is assembled using 3 methods
1 Collection and analysis of existing data;
2 Carrying out specific field studies to acquire supplementary data to help in prediction of impacts of the proposed development project and its alternatives, and to identify potential tradeoffs in an Environmental Impact Assessment studies; and
3 Community consultation programmes.

a) Review of existing data and sources

Before embarking on field studies, maximum effort should be directed at determining the numerical and spatial data that already exist and can be used in describing the baseline environmental conditions in the proposed route corridor project area.

Existing data sources include:

- Government databases and routine monitoring programs – review scope and extent of these programs and re-focus studies to include areas and parameters relevant to Environmental Baseline Studies.
- Historical environmental studies in the area – review all available scientific and technical literature including unpublished information from academic and

non-governmental organization groups active in the area of study for use in the Environmental Baseline Studies

- Experience gained from similar route corridor projects – useful in focusing baseline studies on key issues of concern.
- Aerial photographs and satellite images – useful in determining the historical land use changes, which have occurred in the area and prediction of additional cumulative impacts of the proposed route corridor development on various features of the landscape.
- Traditional knowledge – local communities possess profound and refined knowledge of the spatial and temporal distribution of wildlife and their ecological relations often lacking in scientific literature. This is useful in understanding socio-cultural impacts of route corridor developments, which affect the subsistence economy and continuous relationship of the indigenous people to land.

b) Field studies

Field studies are required to fill in data gaps realized from review of the existing information or to provide more focused information for the Environmental Baseline Studies. Field sampling programs for baseline studies is designed with an aim of providing sufficient information to assist in impact predictions and developing a reference base to guide and test future route corridor development project monitoring programs. The level of detail and scope are tailored to meet the needs of the proposed route corridor development.

c) Community consultation programmes

The community consultation programs are aimed at creating awareness and ensuring early involvement and active participation of the local communities living in the precincts of the proposed route corridor development project area and other stakeholders, which may be directly affected on implementation of the proposed route corridor development project.

The consultations between community leaders and representatives of the route corridor development project proponent should be confined to key issues of concern. The local people including administration, elders, women and the youth, should be consulted and given a chance to articulate their concerns, fears and offer environmental solutions for consideration in the project planning, design, and implementation. An appropriate feedback mechanism on issues raised should be established and maintained to avoid suspicions and ensure smooth implementation of the proposed project.

7.4.3 Impact Predictions

a) Impact Types

The potential impacts of route corridor development may fall in broad categories that include: physical, chemical, biological, and socio- economic impacts. The physical impacts may vary from soil erosion due to civil works, noise emissions, visual quality impairment, etc. The Chemical impacts may arise from the chemical discharges from development works. The biological impacts may include loss of sensitive habitats and interference with animal migration routes. The socio-economic issues may range from provision of employment opportunities and constraints on available social amenities.

Impact prediction is therefore fundamental to Environmental Baseline Studies as well as Environmental Impact Assessments (EIAs) and should consider *direct or primary impacts* as a result of the route corridor project implementation*, indirect or secondary impacts*, which have knock-on effects in the same project location or other adjacent areas, *cumulative impacts* that accrue over time and space from many developments, and possible *impact interactions* between different impacts of a proposed project. In general, impacts may be *positive (beneficial) or negative (adverse)*, short-term or long-term, reversible or irreversible, permanent or temporary.

To be able to make logical impact predictions, a good understanding of the nature of the proposed route corridor project, similar projects including effectiveness of impact mitigation measures, and other projects that may cause interactive or cumulative impacts, is required.

b) Methods of impact prediction and significance evaluation

Impact prediction is not an exact science irrespective of the method used. The uncertainties should therefore be clearly stated in the final Environmental Baseline Studies document. Direct impacts are often easy to predict unlike indirect or cumulative impacts.

Several standard techniques to aid in impact predictions are available and include: *Checklists, Matrices, Networks and Flowcharts, Mathematical/Statistical Models, Maps and Geographical Information System (GIS) and Environmental Risk Assessment (ERA)*. *Checklists and Matrices* are commonly used for most of the Environmental Baseline Studies conducted during geothermal exploration. Statistical weightings of *impact magnitude, sensitivity and recoverability of relevant receptor* are used to quantitatively derive *impact significance*.

Impacts on certain ecological resources may have financial implications. Whilst it is not intended that economic value be subsumed within the valuation of ecological resources, it is important to recognise, within the ecology and nature conservation topic, these financial implications and to ensure effective integration with other related topic areas.
The likely impacts on some species and groups need to inform project design and mitigation as a result of potential road safety and animal welfare issues, even when these are not selected as key receptors and/or the impacts upon their populations are not assessed as significant.

Chapter 8 Route Option Engineering

8.1 Introduction

This chapter is concerned with the route engineering process that follows the initial route option identification described in Chapter 3. Having determined in broad terms the location of up to three or more alternative routes, it is then necessary to progress the engineering of each route in sufficient detail to enable feasibility and costs to be determined within +/- 30 per cent.

Route option engineering must take into account:

- Topography (see Chapter 4)
- Engineering geology (see Chapter 5)
- Hydrology (see Chapter 6)
- Environmental and Social Considerations (see Chapter 8)
- Traffic
- Road geometry
- Road pavement
- Cost estimation

The first four topics are covered in the earlier chapters of this manual, although the outcome of each must feed directly into the route engineering in order to ensure that important considerations are taken into account. The final four topics are dealt with in the following sections.

8.2 Traffic

At this stage, historical traffic data from the ERA database can be used as the basis for estimating future traffic demand on the road. It is unlikely that the route options will vary to the extent that traffic demand will vary significantly between them but the possibility of this should still be considered.

Future development of the road network and general development plans for the area and region must also be taken into consideration on a percentage basis similar to the treatment of traffic generated from the new road. While these issues are also considered at project identification and route corridor selection stage by ERA (Chapter 2) they should also form part of the route option engineering study.

One issue which requires consideration is that of traffic composition and its impact. As can be seen in Figure 8.1, a wide variation in traffic composition can be observed even on trunk roads in Ethiopia.

Figure 8.1 Typical Traffic Mix on Ethiopian Roads

(a) Pedestrians

(b) Wide Load

(c) Herds (camel)

(d) Herds (cattle)

(e) Mixed Traffic (small town)

(f) Mixed Traffic (rural)

The ERA Geometric Design Manual 2011 (GmDM) allows for the widening of shoulders or for increasing the design standard where high numbers of Passenger Car Units (PCUs) operate on category DC 2 to DC 6 roads (see GmDM Chapter 2) or where the percentage of heavy vehicles is excessive. PCU values are defined in the GmDM and reproduced here in Table 8.1.

Table 8.1 PCU Values

Vehicle	PCU value
Pedestrian	0.15
Bicycle	0.2
Motor cycle	0.25
Bicycle with trailer	0.35
Motor cycle taxi (bajaj)	0.4
Motor cycle with trailer	0.45
Small animal-drawn cart	0.7
Bullock cart	2.0
All based on a passenger car = 1.0	

Source: ERA Draft Geometric Design Manual 2011

The equivalence factors listed in the table do not include those for the normal range of motorized vehicles (cars, buses and trucks etc). However, for consistency, when PCUs are used for capacity calculations, equivalence factors for all types of traffic must be adopted.

The vehicle equivalence factors for motorized vehicles used for design in the East African Community are given in Table 8.2.

Table 8.2 Vehicle Equivalence Values

Vehicle type	Terrain		
	Level	Rolling	Mountainous
	pcu		
Passenger cars	1.0	1.0	1.5
Light goods vehicles	1.0	1.5	3.0
Medium goods vehicles	2.5	5.0	10.0
Heavy goods vehicles	3.5	8.0	20.0
Buses	2.0	4.0	6.0
Motor cycles, scooters	1.0	1.0	1.5
Pedal cycles	0.5	0.5	NA

Source: Preparation of the East African Transport Facilitation Strategy

Similar factors given in the Highway Capacity Manual (Transportation Research Board – 2004) are much lower (see Table 8.3) and may reflect the more developed nature of the road network in the USA.

Table 8.3 USA Vehicle Equivalence Values

Factor	Type of Terrain		
	Level	Rolling	Mountainous
E_T (trucks and buses)	1.5	2.5	4.5
E_R (RVs)	1.2	2.0	4.0

Source: Highway Capacity Manual (2004)

The equivalence factors developed for East Africa are probably more appropriate for use in Ethiopia.

8.3 Road Geometry

Based on the result of the traffic forecasts, the appropriate design standard is selected from those summarized in Chapter 2 of the GmDM. The standard adopted is based on the projected AADT in the case of new roads and on the percentage of heavy vehicles operating on an existing road if the project involves road improvement by road realignment.

The design standard for any project must also remain consistent with that of the remainder of the route of which it forms a part. This particularly applies to those sections of the route immediately adjacent to the project. The design standard adopted for a project should not vary from that of an adjacent project by more than a single standard unless dictated by ERA.

Information on these adjacent sections must be obtained from ERA records and their network analysis before being confirmed on the ground during a walk-over reconnaissance of each route option.

8.3.1 Alignment

As described in Chapter 4, the selection of a design standard must also be related to the terrain classification through which the route option passes and the type of alignment selected – ridge, escarpment, valley etc. Chapter 2 of the GmDM specifically permits variations of a design standard for difficult terrain, for traffic composition where the percentage of heavy vehicles exceeds a specified amount and for other variations in traffic composition such as pedestrian and animal and herd movements in particular locations.

Because the population is still predominantly rural, pedestrian movements along rural roads, including trunk roads, remains significant. This is particularly the case on market days when large numbers of pedestrians, often with domestic animal and other goods for sale or barter, utilise the road. Movements of animals and herds to and from water also remain normal practice in Ethiopia.

Neither practice appears likely to change in the foreseeable future. However, both conditions are rarely considered when assessing road capacity. The timing of markets can be determined from local administrations but any movements of animal and herds must be observed in the field. If a project is impacted by either condition this should be noted and any impact on road capacity taken into account. The impact of pedestrian movements can be estimated by using the PCU factors given in the GmDM.

No advice is given in the GmDM and no values of PCU are known for herding by road. The impact of such herding will depend on the size and numbers of herds being moved and their frequency of movement. The effects of herds on traffic movement will also vary with the design standard of the road. This is best assessed by field observations.

The geometric design standard adopted for a road project is therefore determined by:

- the road classification assigned to the route as part of the road network,

- the traffic volume and composition on the particular section under consideration,
- the design standards of adjacent sections of the route of which the project forms a part.

A summary of design standards and criteria is given in Table 2-1 of the GmDM. For each class of road the GmDM provides for a range of acceptable design standards with varying road widths and design speeds. The latter varies according to the type of terrain. Using Table 2-1 of the GmDM, selection of the design standard for a particular section of road is made mainly on the basis of traffic volume.

Uniformity in driving conditions will normally be reflected in lower accident rates. To provide such uniformity, the most desirable condition is if the design standard selected for a project is the same as that for the adjacent sections of the same route. Because of the changes in traffic conditions with distance from urban population centres and differences in terrain, this may not be possible.

Chapter 4 describes the possible variations in topography for different topographic regions in Ethiopia and the engineering and other considerations which must be catered for when comparing route options through the different terrains. Typical issues and possible mitigation measures when reviewing route options through difficult terrain are summarized in Table 8.4. Note that the majority of mitigation options shown in Table 8.4 are dealt with during detailed design and not route selection. However, they need to be scoped in to the route selection process in order to confirm feasibility and derive a realistic cost estimate.

Table 8.4 Route Selection Issues and Possible Mitigation for different Route Types

Alignment Type	Topography/ Engineering	Typical Issue	Possible Mitigation (see the ERA Geotechnical Design Manual for further guidance)
Ridge Top	Earthworks	Weathered soil - variable depth	Cut/fill – protect exposed faces by vegetation
		Exposed rock	Bench and /or raise profile
		Variation in elevation – excessive rise & fall	Balance cut/fill, or fill sags constructing embankments or retaining walls, see Chapter 5
	Stability	Dipping strata – unfavourable jointing	Bench, rock bolt or realign
		Seismicity	Minimize cuttings and structures
	Drainage	Rainfall	Seal carriageway & shoulders, protect side slopes, particularly in sags.
		Few channels	
		Road run off damage to side slopes	
	Erosion	Weathered soils may erode	Bio-engineering protection of exposed soils
		Scree may be unstable	Realign road, provide rock netting and rockfall catch ditch
Valley Side	Earthworks	Rock face –variable dip / bedding	Cut, bench, rock bolt, netting – depends on local condition
		Steep slope (35^o – 40^o) – shallow unstable surface material over rock	Remove surface material and treat rock as above
		Steep slope (25^o – 35^o) –	Minimize cutting, retaining

Alignment Type	Topography/ Engineering	Typical Issue	Possible Mitigation (see the ERA Geotechnical Design Manual for further guidance)
		deep unstable surface material	walls, drainage
		Spurs – rock or residual soil	Adjust profile, minimize cutting, consider tunnel
	Stability	Talluvium and colluvium deposits	Minimize cutting, retaining walls, drainage
		Landslide or potential slope instability	Realign road, minimize cut/fill, see Chapter 4
		Thin soil over rock	Remove soil, minimize cut/fill, bench cut face, catch ditch
		Forested areas	Remove soil, minimize cut/fill, bench cut face, catch ditch
	Erosion	Channels	Drainage, stabilize slopes with vegetation
Valley Floor	Earthworks	Soil saturation	Raise embankment, drainage, surcharge & settlement period
	Stability	Steep valley slopes adjacent	Bench or retain cuttings, stabilize side slopes
		River channel subject to scour	Bank protection
	Drainage	Proximity to river and meanders, including migration and avulsion	River diversion & protect embankment or realign road
		Tributary crossing, including active fans	Drainage structures
		Flood risk	Raise embankment, hard & soft protection
		Accretion	Provide extra clearance to cater for accretion, provide catch-pits at small structures, ensure maintenance in future.
	Erosion	Main and tributary channels	Bank & bed protection

As noted in Chapter 4, four terrain classifications are defined in the GmDM - flat, rolling, mountainous and escarpment. In all topographic regions of the country any route selection process will probably require to cater for several of the terrain classes although the typical challenges may vary between topographic regions.

In some circumstances the design standard for an intermediate section of new road may be required to vary from that of adjacent sections. Such locations are where terrain types differ significantly.

As described in Chapters 4 and 5, topographic and engineering geological factors can be crucial determinants of route selection. These include not only areas with sensitive soils and those prone to landsliding but also steeply sloping ground, ridge and marshy terrain. Some consideration of these factors will have been included during the corridor definition process where local information and other engineering considerations will have helped locate the road corridor away from unsuitable areas. The process will have been refined further during route option identification (Chapter 3).

Other than in flat terrain, the preferred road alignment is curvilinear. By avoiding straights to the greatest extent possible this type of alignment provides the best opportunity for fitting the road to the terrain. The phasing and mis-phasing of road alignment elements is described in Chapter 10 of the GmDM. The most critical combination has been found to be the placing of a sharp horizontal curve at the end of a long straight.

Curvilinear alignments eliminate such situations. They have been found most suitable in the design of dual carriageway roads in rolling terrain. They are also suitable for single carriageway two-lane roads in similar terrain where overtaking provisions are not impaired, as these may help to reduce headlight glare and in judging the approach of oncoming vehicles. These are largely detailed design issues, but nevertheless may be of relevance during route selection.

Once a design standard has been selected for a section of road, the full design standards should be adhered to unless adverse terrain (Chapter 4), engineering geology (Chapter 5) or environmental factors (Chapter 7) dictate otherwise.

Unless located on sloping ground towards the toe of an escarpment, marshy areas will usually be on flat topography and can be avoided. Such areas may contain sensitive soils which can be identified from desk study interpretation and field observations (Chapter 5). There would normally be no necessity of compromising design standards in this case although soil treatment could be costly (see also the Geotechnical Design Manual).

Alignments in flat and rolling terrain are much preferred to alignments in mountainous or escarpment terrain. Typically construction costs for a new road in a heavily mountainous area can be two to five times greater than a road of the same design standard in rolling and flat terrain. In addition, for the same length of road, vehicle operating costs will be significantly higher.

8.3.2 Departure from Standard

In steep, mountainous and escarpment terrain, the design standard may be compromised by terrain and geotechnical factors. Chapter 2 of the GmDM provides for departures from standards under such conditions by:

- reducing the design speed as terrain becomes more extreme,
- permitting hairpin bends on very steep escarpment faces,
- modifying shoulder width to minimize earthworks.

A departure from standards may also be permitted where large numbers of heavy vehicles are expected to operate on the road.

a) Hairpin Bends and Switchback Roads

These are often required on roads climbing escarpments and valley sides. A combination of high gradients and tight radii effectively reduces the operating speed, capacity and level of service of such roads. Road sections linking hairpins should be compliant with design standards. Exceptionally, shoulder widths are frequently reduced to minimise earthworks. Ditches on the inner face are often adjacent to a cutting which might remain a source of rock fall for many years. Rock-fall catch areas and structures should be provided if possible to avoid rockfall debris being deposited on the carriageway and shoulders.

In locations where a contoured road in side-long ground has been proposed a possible alternative may be to provide a tunnel and /or a viaduct. A viaduct must comply with ERA bridge design standards. No tunnel standards are included in the ERA manual series at present.

b) Difficult Terrain Conditions Generally

As noted in Chapter 4, severe terrain includes most escarpment, mountainous and some ridge alignments. Departure from standards is not uncommon in such conditions but will vary from case to case. Most departures in difficult terrain will compromise shoulder width reductions and the provision of climbing lanes. Depending on the terrain and traffic composition the average operating speed may be considerably reduced because of slow moving vehicles. This affects road capacity and level of service but for geometric design the design speed applicable to the selected design standard should be retained (with the exception of hairpin bends) to provide acceptable visibility. Additional safety measures may need to be included such as warning signs and road markings. Where the appropriate design standard must be reduced, the reduction should be by a single design standard only.

The extent to which these considerations are likely to affect route selection will vary from project to project, and they will only apply in critical circumstances. In many, if not most, situations the accuracy of topographic data used to compare different route options may be insufficient to be able to fix any details of an alignment, including especially the detailed locations of hairpin bends.

According to Chapter 2 of the GmDM, any proposed departure from standard must be submitted to ERA's Design and Research Division manager for evaluation and if acceptable this is forwarded to the Director General for approval. The "Departure from Standards" application format is included in the GDM. For route selection, such prior approvals are unnecessary. However, the engineer must remain aware of the procedures that will have to be followed should such an alignment become the preferred option.

On ridge top alignments, in order to keep to standard aligning the road to the side of the crest is sometimes called for to maintain the design standard. This may affect the selection of the preferred route. Typically such roads are sinuous and phasing of horizontal and vertical alignments can prove problematic. The vertical alignment of a ridge crest road will often be in cut but where embankment is required this may require the construction of retaining structures on both sides of the ridge. Again, these are design considerations, but they may need to be assessed in general terms for route selection if they are expected to significantly affect feasibility or cost.

8.3.3 Rural Intersections

Most accidents on rural roads occur at intersections. The numbers of intersections should be minimized with rural intersections closer than about 2km being avoided if possible.

8.3.4 Alignment Design for Route Selection Purposes

For route selection purposes it is current practice in Ethiopia to utilise free to download SRTM data (Chapter 4) in conjunction with road design software to develop a nominal alignment for each option. This allows an approximation to be made regarding route length and earthworks quantities. If a suitable cross section template is used, it should also be possible to determine lengths and heights of retaining walls supporting the road, and therefore derive retaining wall quantities as well.

At route selection stage, road construction costs should be estimated within +/- 30% of the final design figure. In order to achieve this, the initial route alignments and quantities need to be as accurate as possible. In relatively flat terrain, with an absence of retaining walls, the earthworks can be determined with reasonable accuracy. In an exercise to compare earthwork quantities using SRTM data with those determined in a design that utilised topographic survey data in terrain that meets the 'flat' criteria given in Sections 4.1 and 4.2 of Chapter 4, cut and fill quantities from SRTM data were within X per cent of the design quantities. However, when this exercise was repeated for sections of road in 'mountainous' terrain, cut, fill, and retaining wall quantities from SRTM data were only within Y per cent of the design quantities. This is unsurprising given the horizontal and vertical accuracy of the data and where the terrain itself can vary considerably within the 90m resolution provided by SRTM.

Consequently, where all route option alignments can be described as passing over 'flat', or to a lesser extent, 'rolling' terrain, the use of SRTM data is likely to produce earthwork quantities suitable for comparison of the route options. However, if any or all route options pass over 'mountainous' or 'escarpment' terrain, then the use of SRTM data cannot be recommended. In such cases, particularly for low category roads, it is suggested that the route option are determined using SRTM data and suitable road design software, but checked and adjusted from field observations, and that average per km quantities from other designed and constructed projects in similar terrain are used to estimate overall earthwork and retaining wall quantities. For high classification roads, it is recommended that other sources of digital data are considered, and that the advice of the Ethiopian Mapping Agency (EMA) is sought in this regard.

8.4 Road Pavement

A significant proportion of the cost estimate will arise from the type of pavement to be adopted. Pavement design is covered in detail in the Flexible Pavement Design Manual, the Rigid Pavement Design Manual and the Low Volume Roads Manual. Aspects that need to be considered insofar as route selection is concerned are the estimated strength of the subgrade (which will control the required pavement thickness), the cumulative traffic load over the lifetime of the pavement, the types of materials most likely to be used (taking due account of any naturally occurring materials available locally), and the required width of the pavement and shoulders.

If the quality of the subgrade soils is likely to vary significantly along the length of a route option, consideration should be given to utilising more than one pavement thickness.

8.5 Reconnaissance Survey

After completion of desk study activities, the route selection team should carry out a reconnaissance surveys and field investigations for each of the route options and their environs. This is intended to confirm, amplify and supplement the information collected during earlier stages and enable team members to test their inferences, assumptions and proposals before finalizing input to the route selection process. It also allows team members to integrate their individual proposals, discuss constraints and agree on how to proceed. The clarity provided by this process will be reflected in the selection of the routes and will ensure an consistent approach. Chapters 4-7 provide further information on the information and observations that are required from field investigations.

8.6 Cost Estimation

In view of the potential discrepancies inherent in using free-to-download satellite DEM data, any route option alignment must be deemed to require modification during later detailed design activities following a ground survey. As a consequence, although cost estimates based on such satellite imagery can be used for the comparison of selected options, they will be prone to error, sometimes significantly.

A second option is to derive global costs for road construction in different types of terrain (i.e. flat, rolling, mountainous and escarpment) from ERA's construction database. Major drainage can be estimated on the basis of estimated square metres of deck and minor drainage on estimated linear metres of each culvert cross-section type.

The initial cost estimate should be broken down as summarized in Table 8.5.

Table 8.5 Sample layout for initial cost estimate

Bill / Description	**Remarks**
General Items	Consider as 10% of works costs at this stage
Earthworks	Cut, fill, sub-grade & treatment of sensitive soils
Pavement	Carriageway & shoulders
Drainage	Culverts & ditches
Structures	Bridges, retaining walls & special geotechnical structures
Miscellaneous Construction	Safety, environmental & complementary measures etc.
Contingencies etc	Consider 30% of works costs at this stage
Land & Resettlement	Base on crop areas &current values + resettlement rate/ household.

Land acquisition and resettlement costs are best separated from other social costs as the latter are not direct construction costs.

Chapter 9 Route Selection Techniques

9.1 Introduction

This chapter describes the manner in which the various studies undertaken concerning topography, engineering geology, hydrology, environmental and social impact assessment and route engineering are incorporated into the selection of the preferred route option. In route selection many factors have to be taken into consideration and of these the majority have been covered in the preceding chapters. It is therefore, necessary, for each of these factors to be brought together including, as far as possible, those factors, not covered to date, which specifically relate to road scheme evaluation.

Previous chapters have covered:

- Road network and strategy
- Topography
- Engineering Geology
- Hydrology
- Environmental & Social Issues
- Route Option Engineering

To these factors it is necessary to add a review of traffic data as part of the overall scheme evaluation and economic aspects. Traffic has already been discussed in Chapter 8 with regard to Route Option Engineering and the outcome of these analyses regarding confirmation of expected traffic volumes and composition and the confirmation of design standards accordingly. In this chapter the emphasis is placed upon the role that these traffic studies play in the evaluation of road projects as a whole and, in some cases this may influence the overall selection of route options.

Economic factors are themselves implicit within much of the engineering and environmental/social studies. Cost acts as a controlling factor in road planning, particularly when a full economic evaluation is to be carried out.

Chapter 2 covering the network and strategic aspects of route selection has looked at route corridor selection which is principally the domain of ERA. This chapter, following sections covering the detailed assessment of engineering, environmental and social factors affecting the comparison of route options examines the techniques available for the evaluation and selection of the preferred route.

9.2 Traffic studies

Traffic represents the users or consumers of road provision and provide the justification for construction and subsequent maintenance, usually regardless of the route option finally selected. As discussed in Chapter 8, in any road study it will be necessary to develop as robust an estimate of average daily traffic usage as available resources allow. The ERA Pavement Design Manual Vol. 1 and the Design Manual for Low Volume Roads provide guidance in this regard.

Traffic assessment is essential at the corridor selection phase of a project to determine the potential usage of the corridor. However, while not always decisive at route selection stage because of the limited scope for variation between alternatives, traffic still forms a standard component of the evaluation.

Road sections of approximately homogeneous traffic characteristics need to be identified and traffic estimates assigned to each. Where alternative route alignments are very finely distinguished[4], a single set of traffic data may be collected and applied. However, traffic characteristics may vary between alternative routes in the following circumstances:

- where routes provide different network connections, for example meeting another road on different sides of a settlement, with a local impact on traffic diversion.
- where alignments have very different vertical and/or horizontal alignments with an impact on traffic volumes and composition
- where alignments provide different access connections, for example direct access to major properties or significant land-uses, with an impact on traffic generation.

The first two of these exceptions are exemplified by the Wozeka – Gato road in the Southern Region of Ethiopia where the adopted alignment via Gedole involves both a change to the set of network connections and a radically different vertical and horizontal alignment to the direct route.

The third exception is at a fine level of detail where alternative routes may provide direct access to different sets of properties or land-users. In most cases, this is unlikely to have a significant impact on road usage but can have an effect on the direct beneficiaries of the road, for example in the potential for traffic generation or agricultural surplus. It is therefore of more relevance to this analysis than to the engineering studies for road classification described in Chapter 8.

In such cases, traffic data collection has to be subtly adjusted to account for the different configurations of the alternative routes. The methods used (traffic counts, roadside interviews, travel time surveys, axle-load surveys) will remain the same but their precise specifications (number and locations and possibly type) will need to be carefully adjusted.

9.3 Economic Studies

Alongside traffic studies road scheme evaluation requires a component of economic data collection to prepare the ground for the economic assessment. Much of this work, for example economic growth rates and vehicle fleet characteristics, will be at a network and national or regional scale and where it impacts on route selection it will be at the corridor level, as referred to in Chapter 2, rather than at route alignment level.

As mentioned above the economic evaluation is implicitly linked to the engineering and environmental/social factors discussed in Chapters 4 to 8. While costs have a guiding and limiting impact on road planning, the engineering, environmental and social investigations are reflected in some detail in economic evaluation, in the modelling of the benefits as well as in the cost inputs.

Only in certain cases, as referred to above, will micro-scale socio-economic factors, such as agricultural surplus, come into play and potentially differentiate between alternative route options. Again, in general these factors will be very similar between alternatives but in certain cases where alternatives provide different degrees of

[4] such that the traffic sections are essentially the same in terms of location, length and function and consequently there is no expectation of differences in traffic characteristics between alternatives

access to particular properties, estates or land-uses a careful comparison will be required (Table 9.1).

9.3.1 Cost Benefit Analysis

The following subjects are covered under this heading:

- Description & Methodology
- Inputs and Outputs
- Contribution to Route Selection including examples

a) Description

Cost Benefit Analysis (CBA) is a well established technique for comparing the costs and benefits of a project in monetary terms.

In brief, CBA compares the costs (capital and recurrent) of road investment with the resultant benefits to road users. These benefits primarily comprise vehicle operating cost savings, travel time savings, reductions in accident costs and future maintenance expenditure.

Time savings, vehicle operating costs and accident costs result from combinations of improvements in road standard/design, alignment and surface condition (notably roughness), future maintenance savings from improvements in road surface condition and structural strength.

The improvement scheme(s) are compared to a base or do minimum situation in which the unimproved road or lack of access continues to be maintained in line with established practice.

All costs and benefits are quantified in monetary terms to a specified price base. In this way, the net benefit of a project or project alternative can be measured over a specified period (the evaluation period) which should include at least one complete life span of the proposed scheme (that is, prior to road reconstruction or a full repeat of the proposed measures at some stage in the future).

It is acknowledged that not all costs and benefits of a road project can be satisfactorily monetised and thus included within CBA. The following costs/benefits cannot be covered, either to some degree or entirely, within CBA:

- certain environmental impacts, for example visual intrusion and severance
- certain social impacts, for example access to education and medicine
- strategic, policy and administrative impacts
- sustainability

b) Inputs and Outputs of Cost-Benefit Analysis

The principal inputs to CBA for road schemes can be summarised as follows:

- Road network data: inventory, structure, condition by road section
- Vehicle fleet data: types, characteristics, usage and costs
- Traffic data: volume, composition and traffic growth by road section
- Road maintenance regime: without and with proposed scheme
- Road improvement regime, as proposed including timing
- Road maintenance costs, by works type
- Road improvement costs, by unit rate and road section

- Background economic parameters including evaluation period, discount rate, value of time, accident costs, etc

It is to be noted that many economic evaluation methodologies and tools, notably HDM-4, are as much, if not more, based on engineering data and factors than on traffic and economic factors. The engineering data required to run HDM-4 successfully is extensive. There is a case to be made for its greater direct use by highway engineers.

Of those groups of factors discussed in previous chapters, namely Topography (Chapter 4), Engineering Geology (Chapter 5) and Hydrology (Chapter 6) are represented indirectly. Environmental/social factors (Chapter 7) are, as stated above, only partially covered in the evaluation process and, although progress has been made in incorporating their impacts in economic assessment, they require the wider coverage provided by Multi-Criteria Analysis (MCA, see below) to be fully represented. The Engineering factors (Chapter 8) are represented directly in the road network, road maintenance and improvement inputs.

c) Costs and benefits

The more significant costs and benefits covered by CBA can be summarised as in Table 9.1 with an indication of their significance to the route selection process.

Table 9.1 Significant Costs and benefits Covered by CBA

Cost/Benefit	Significance in CBA	Significance in RS
Capital investment	High	High
Maintenance	Low-Medium	Medium
Vehicle Operation	High	Medium
Time (Passenger/Cargo)	Medium-High	Low
Accidents	Medium	Low
Fuel Efficiency	Low	Low
Air Pollution	Low	Low
Agricultural Surplus	Low	Medium

Capital investment represents the engineering operations entailed by a project or alternative. Similarly, vehicle operation, time and accidents reflect traffic volumes and characteristics. The significance in CBA shows the general impact of each element on the CBA results as revealed in sensitivity tests. The significance in route selection emphasises the pre-eminence of engineering factors, as represented by capital investment and maintenance, at this detailed level of assessment.

The principal output parameters of CBA for road schemes can be summarised as follows:

- Net Present Value (NPV) of proposed scheme: total discounted benefits – total discounted costs
- Net Present Value/Costs (NPV/C) – NPV divided by discounted costs
- Benefit/Cost Ratio (BCR) – ratio of discounted benefits to discounted costs [an alternative parameter to NPV/C]
- Economic Internal Rate of Return (%) (EIRR) – discount rate at which NPV = 0
- First Year Rate of Return (%) (FYRR) – benefits in first year of operation as % of costs

These values each indicate the economic viability of the proposed scheme under evaluation.

Overseas Road Note 5 “A Guide to Road Project Appraisal” by the TRL assesses the strengths and weaknesses of the principal economic viability parameters as shown in Table 9.2.

Table 9.2 Strengths and Weaknesses of Economic Viability Parameters

Criteria	NPV	IRR	NPV/C	FYRR
Economic validity of project	Good	Good	Good	Good
Mutually exclusive projects	Very good	Poor	Good	Poor
Project timing	Fair	Poor	Poor	Good
Robustness to changes in assumptions	Poor	Good	Very good	Poor
Project screening	Poor	Good	Very good	Poor
For use with budget constraint	Fair	Poor	Very good	Poor

Source: TRL

The robustness and reliability of the economic results as shown by NPV, EIRR, etc are tested through the use of sensitivity analysis which commonly consists of changes in key project variables such as capital costs and base traffic by +/-20%.

d) Contribution to Route Selection

Cost Benefit Analysis can, and is, used in both corridor selection and route selection. It is appropriate wherever a road scheme, either as a single option or a number of alternatives is being evaluated in terms of economic viability against a base or do minimum scenario in which the proposed scheme is not developed.

At the level of route selection where alternative routes are being compared to identify the preferred solution, CBA is useful in quantifying in monetary terms many, but not all, of the impacts of the road scheme. The quantification provides a mechanism which allows a broader comparison of competing alternatives. In many cases, where the differences between alternatives are finely drawn, for example a variation in alignment of less than 500m, the CBA results will be very similar and probably not decisive in terms of economic viability. However, the CBA methodology, with its use of precise monetary values, always allows for a ranking of alternatives in economic terms such that small differences in net benefits can be revealed. This puts the emphasis on reliable data collection and an understanding of the key parameters in CBA in general and the software tool being used in particular.

In the overall comparison between alternative routes the economic results will often be small in absolute terms but nevertheless it has two qualities that make it a highly suitable component of this process:

- its quantification in monetary terms
- its inherent use of comparisons, between base and scheme and between alternative schemes

The principal limitation of CBA, with regard to route selection, is, as indicated above, that it does not cover all of the impacts, positive or negative, of a road scheme. Factors can be broadly classified as follows in respect of applicability to the CBA process:

1. Central to economic evaluation and entirely modelled within CBA

2. Peripheral to economic evaluation and partially or indirectly modelled within CBA (much of its analysis conducted outside CBA)
3. Outside economic evaluation and not modelled by CBA

In route selection additional techniques are, therefore, required to provide a comparison including all factors relevant to a road scheme. CBA should be used as an intermediate technique whose outputs provide some of the inputs to these further techniques.

Project Example (High Traffic): Addis – Nazaret Road

The Addis Ababa – Nazaret Road Project is an example of a high level, high traffic study which involved extensive traffic and economic studies. Addis Ababa and Nazaret are the first and third most populous cities of Ethiopia respectively and approximately 100km apart. The route between the two passes the significant urban settlements of Akaki, Debre Zeit and Modjo giving a total population served by the Addis – Nazaret road of 3.5m in 2005. The route passes through predominantly rolling terrain.

Traffic flows on the Addis Ababa – Nazaret road are exceptional by inter-urban standards for Ethiopia. 2006 traffic counts, carried out over a continuous period of seven days on each of five defined sections (delimited by the major intermediate settlements) produced estimates of Annual Average Daily Traffic (AADT) ranging from 19,000, nearer to Addis, to 5,000 nearer to Nazaret. Heavy goods vehicles comprised between 17% and 27% of total motor vehicles.

Three alternative improvements were considered for Addis Ababa – Nazaret:

(1) upgrading the existing road through widening
(2) construction of a new road with a new alignment
(3) upgrading the existing road with construction of bypasses at densely populated areas

The study also included the possible application of tolls to an upgraded Addis Ababa – Nazaret road.

In addition to the manual classified counts of one week, two origin-destination surveys, covering the higher and lower trafficked ends of the road, travel time and willingness to pay (for the proposed tolling) surveys were conducted. Estimates of AADT by section were calculated by the application of appropriate seasonality factors.

Origin-destination survey data was used to produce 16 zone trip matrices which assisted, in conjunction with the willingness to pay data, the modelling of traffic diversion (to and from the upgraded road). The potential traffic impact of a high speed rail link between Akaki and Nazaret was also modelled.

Traffic forecasts for the road under the various scenarios were developed, on the basis of trend analysis, for each of the main sections of the road, for three broad vehicle categories (car, bus, truck) and for four growth periods up to 2030. This enabled capacity analysis to be carried out based on Level of Service, as laid out in the Highways Capacity Manual, to reveal the required number of lanes by scenario, road section and year.

The traffic studies comprised a major input to the economic evaluation which used the HDM-4 (Highway Development and Management) software. HDM-4 was used in the conventional project analysis mode comparing alternative improvement options against a do minimum or without project case.

Vehicle fleet and operating cost data research was carried out and input to HDM-4 together with highway engineering and cost data. HDM-4 was then run for a number of scenarios; three road improvement options (with combinations of upgraded existing road and new road sections), with and without toll collection, five toll charge options, with and without high speed *rail link and for each of the road sections. NPV, EIRR and Benefit Cost Ratio were produced for each option evaluated. The analysis included toll revenue forecasts under each of the with toll options.*

Sensitivity tests covered capital costs (+20%), benefits (-20%), the two combined, and traffic growth rates (-50%, +50%).

The economic results were robustly positive with all scenarios, including the increased cost/reduced benefit sensitivity test, comfortably exceeding the required 10% rate of return.

An analysis of benefits showed that vehicle operating cost (voc) benefits comprised 78-83% of the total, varying between options, toll revenues 14-19% and time savings 3%.

In conclusion, it was recommended that a new toll road be constructed between Addis Ababa and Nazaret together with the upgrading of specific sections of the existing road.

Addis Ababa – Nazaret Road Study: Summary of Costs/Benefits Evaluated

Cost/Benefit	Included in Study	Quantified
Capital costs	Yes	Yes
Maintenance	Yes	Yes
VOC	Yes	Yes
Time	Yes	Yes
Accidents	Yes	Yes
Toll revenues	Yes	Yes
Employment opportunities	Yes	No
Social	Yes	No
Environmental	Yes?	No
Administrative	No	No

9.3.2 Multi-Criteria Analysis and Cost-Effectiveness Analysis

The following subjects are covered under this heading:

- Description
- MCA Criteria for Ethiopian Roads
- MCA Weightings for Ethiopian Roads

a) Description

Overseas Road Note 5 “A Guide to Road Project Appraisal” by the TRL states:

“For many low-volume roads, the level of traffic is often insufficient to justify any improvements using conventional CBA as the analytical tool. That is to say, the benefits that can be measured in monetary terms are insufficient to outweigh the costs of the project. However, there may well be other benefits that cannot be measured in monetary terms but which need to be considered in the appraisal process. Cost-Effectiveness or Multi-Criteria Analysis has been developed in order to try to address this problem of combining both quantified and non-quantifiable benefits.”

Multi-Criteria Analysis (MCA) involves the ranking of route alternatives on the basis of their performance against a set of criteria. Methods such as MCA which involve ranking of alternatives are dependent upon the subjective values of those involved in the process of developing the criteria. As a result there is a very wide variation in the formulation and characteristics of ranking criteria.

The principal advantages of ranking procedures, as highlighted by ORN5, are:

- Speed and simplicity
- Transparency
- Potential inclusion of social benefits (see Chapter 7)
- Potential inclusion of popular preference

The main disadvantages are:

- Totalling and weighting of very different characteristics
- Weightings are unlikely to be stable in the longer run
- Limited assistance/connection to project timing, alternative designs, combinations with other investments and maintenance options
- Solution indicated may be sub-optimal

Social benefits and ranking criteria are used to a much greater extent for rural access and feeder road programmes because the case for inclusion of social benefits is strongest when roads become impassable to motorised traffic thus undermining the central relationship in CBA which depends on a regular flow of vehicular traffic. Conventional CBA is more generally used for main and secondary road projects.

Multi-Criteria Analysis brings together ranking procedures to combine economic, social, environmental and other considerations in the final choice of route alternative.

For each characteristic the different alternatives are assessed and put into rank order. This process is then repeated for the other characteristics. Weights are then assigned to each characteristic and an overall score is obtained. (The score for each criterion is the product of the rank and the weight).

The process is demonstrated below (Table 9.3) in an example from Overseas Road Note 5. The highest number rank refers to the best. The overall score gives a measure of the overall desirability of the project. In the example it can be seen that Alternative 1 has the highest overall score while Alternative 2 is the least desirable. In the example, the high weight given to the economic evaluation (50%) is a reflection that the economic analysis is a combined analysis of engineering, traffic, travel times, user benefits and identifiable costs associated with resettlement and environmental mitigation (for example, as modelled using HDM-4 or RED).

Table 9.3 Example of Multi-Criteria Analysis from Overseas Road Note 5

Analysis criteria	**Alternative 1**			**Alternative 2**			**Alternative 3**		
	Rank	**Weight**	**Score**	**Rank**	**Weight**	**Score**	**Rank**	**Weight**	**Score**
Economic evaluation	3	50	150	1	50	50	2	50	100
Environmental evaluation	2	30	60	3	30	90	3	30	90
Development	3	10	30	2	10	20	1	10	10
Public transport	3	5	15	2	5	10	2	5	10
Accessibility/ Severance	1	5	5	2	5	10	3	5	15
Overall score	-	-	260	-	-	180	-	-	225

Source: TRL - Overseas Road Note 5 “A Guide to Road Project Appraisal”

Note that this is merely an example quoted from a well-established source to give an indication of how MCA works. As already stated, the precise format, both in criteria and weighting, varies considerably between applications. Guidance on the use of MCA in Ethiopian road studies is given in the following sections.

There is a risk of double counting costs and benefits when overlapping components are introduced separately within MCA. Care is required not to allow small differences in one criterion to be given undue prominence within the procedure, thus overriding significant differences in other criteria.

The Framework Approach
In this approach, a variant of MCA, the components are not explicitly weighted; through a process of paired comparisons the reasons behind the alternative routes become transparent. The different effects and characteristics of a road project are summarized in such a way that the advantages and disadvantages of the different alternatives are revealed.

The framework approach may be summarised as follows:

- The key quantifiable and non-quantifiable effects and characteristics of each alternative are summarised giving attention to critical differences between alternatives
- Alternative pairs of ‘project cases’ are compared. Through comparison of the key differences, one alternative of each pair is rejected
- This pair-wise comparison is continued until one ‘project case’ remains. This is recognised as the most desirable investment option

Within the framework procedure, there is a high risk of double counting costs and benefits. However, the process is transparent and the different effects are not weighted and added up (as with MCA), leaving the user in a position to take account of different factors and make necessary adjustments in the final choice.

b) MCA Criteria for Ethiopian Roads
There is a considerable range of criteria from which MCA can be conducted, drawing from available reference sources and from recent road studies in Ethiopia. These criteria can be sub-divided into quantified and non-quantified. The following is effectively a long-list of MCA criteria:

A. Quantified criteria:

- Vehicle operating cost (VOC) savings
- Time savings
- Accident savings
- Construction costs
- Economic viability criteria, e.g. NPV or EIRR
- Noise levels
- No. of properties within a specified distance from the road
- Area of land acquisition covering different land uses
- No. of people affected by resettlement
- Environmental mitigation costs
- Public support for each alternative (from public consultation)
- Air pollution
- Energy efficiency

B. Non-quantifiable criteria:

- Visual intrusion and effect on local amenities
- Impact on public transport
- Differential effects on future development
- Wider effects on the natural environment
- Severance and accessibility impacts on communities
- Administrative and political impacts

It should be noted that the criteria listed are not mutually exclusive and degrees of overlap occur between certain pairs or groups. The potential for overlap and hence double-counting should be careful considered prior to making a final selection.

Examples of the Application of MCA Criteria

1. MCA in HDM-4 (Highway Development and Management)

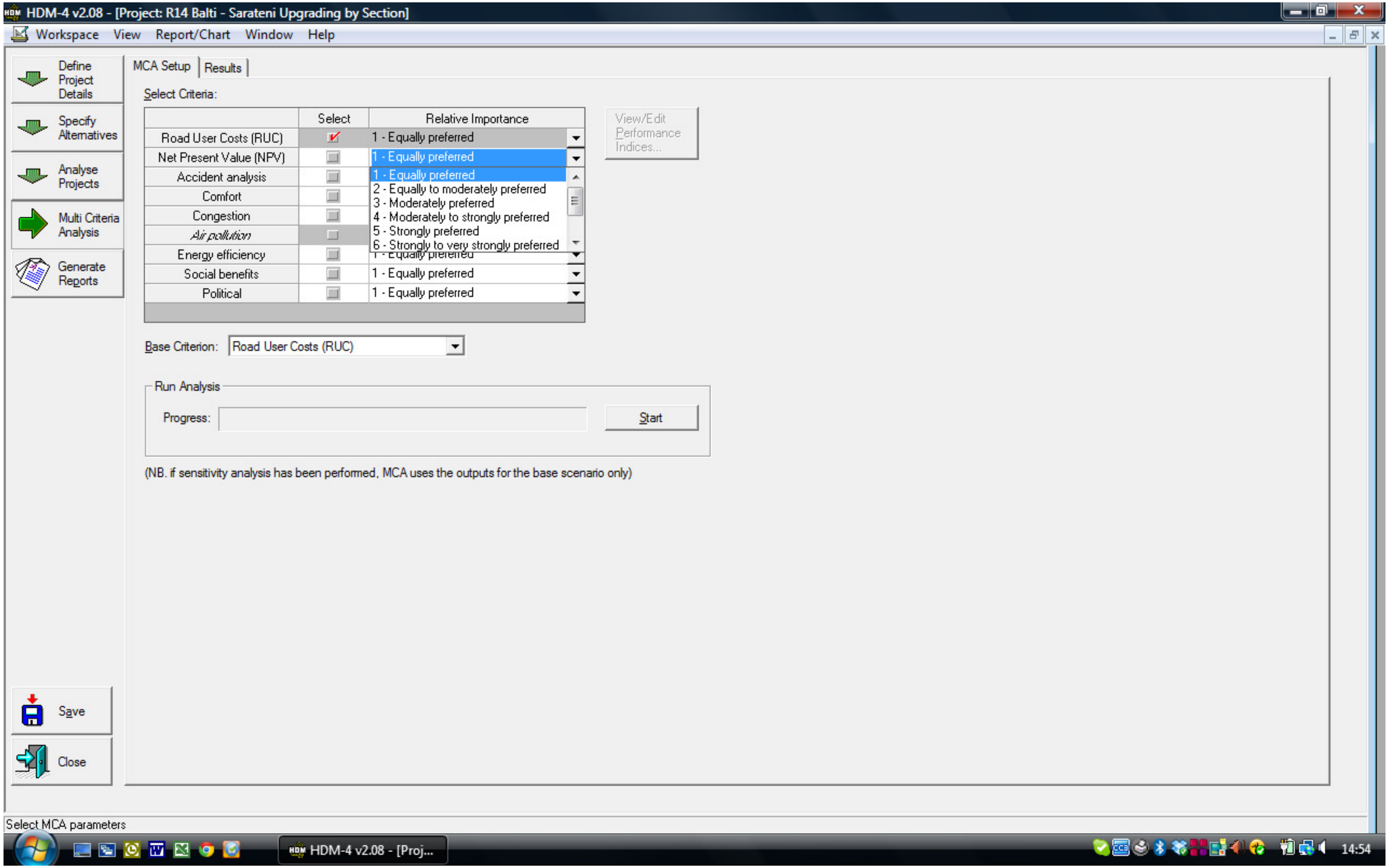
The MCA page within the HDM-4 economic evaluation software (*copyright of World Road Association/PIARC*) is shown below.

HDM-4 uses nine criteria which are then rated in importance relative to a selected base criterion in the manner of the framework approach. The nine criteria which are all represented in the above long-list, either directly or indirectly, are as follows:

- Road User Costs (RUC)
- Net Present Value (NPV)
- Accident analysis
- Comfort
- Congestion
- Air pollution
- Energy efficiency
- Social benefits
- Political

The user selects which of the above is to be used as the base criterion and then compares each of the other selected criteria with the base criterion in one of the following terms:

- Equally preferred
- Equally to moderately preferred
- Moderately preferred
- Moderately to strongly preferred
- Strongly preferred
- Strongly to very strongly preferred.


HDM-4 v2.08 - [Project: R14 Balti - Sarateni Upgrading by Section]
Workspace View Report/Chart Window Help
Define Project Details
Specify Alternatives
Analyse Projects
Multi Criteria Analysis
Generate Reports
Save
Close
MCA Setup
Results
Select Criteria:
Select
Relative Importance
Road User Costs (RUC)
Net Present Value (NPV)
Accident analysis
Comfort
Congestion
Air pollution
Energy efficiency
Social benefits
Political
1 - Equally preferred
2 - Equally to moderately preferred
3 - Moderately preferred
4 - Moderately to strongly preferred
5 - Strongly preferred
6 - Strongly to very strongly preferred
View/Edit Performance Indices...
Base Criterion:
Road User Costs (RUC)
Run Analysis
Progress:
Start
(NB. if sensitivity analysis has been performed, MCA uses the outputs for the base scenario only)
Select MCA parameters
HDM-4 v2.08 - [Proj...
14:54

2. MCA in Ethiopia (1)

Certain studies have used as a basis the example given in Overseas Road Note 5 which, as revealed above, gathers the criteria into five broad classes:

- Economic
- Environmental
- Development
- Public transport
- Accessibility/severance

3. MCA in Ethiopia (2)

Where the differences between alternatives are fine, as is often the case in route selection, MCA needs to reflect this greater level of detail in the criteria used. As indicated in the section on CBA the traffic and economic components of MCA tend to become less significant as the focus on alternatives becomes narrower and more precise. There is usually limited variation between alignment alternatives with regard to traffic and economics and these aspects may be represented, at least indirectly, by socio-economic criteria.

An example of route option MCA is given by the Omorate – Kangaken road project (boxed text below) for ERA which compared three alternatives using the following principal criteria:

- Engineering
- Socio-Economic
- Environmental
- Administrative

Note, no economic criteria, as such were used.

In turn, each of these principal criteria was sub-divided into a series of secondary criteria to enable precise comparisons to be made:

1. Engineering
1.1 Length of the road
1.2 Topography (Gradient, Curvatures, and cross section)
1.3 Sub grade Soil type
1.4 Availability of construction materials
1.4.1 Borrow material
1.4.2 Natural Gravel
1.4.3 Quarry
1.4.4 Water
1.4.5 Sand
1.5 Drainage structures
1.5.1. No. of Major Drainage and/ estimated Span
1.5.2. Minor Drainage

2. Socio-Economic
2.1 Intermediate control towns, villages and important sites
2.2 Settlement along each route
2.3 Right of way problems and land acquisition

2.4 Overall project cost
3 Environmental
3.1 Sensitive Archaeological Heritage site
3.2 Flooding risk
3.3 Vegetation cover & Wild life habitat
3.4 Land resources & Soil erosion

4 Administrative
4.1 Improvement on the administrative conditions
4.2 Social Acceptability of the route
4.3 Improvement on security problems of the border conflict among Ethiopian and Kenyan pastoralist communities

This is a highly detailed, and project specific, breakdown which requires much information gathering and, of necessity, many of the secondary categories making very small contributions to the analysis. This level of detail can be difficult to justify in terms of accuracy of available data.

Project Example (Low Traffic): Omorate – Kangaken Road

The Omorate – Omo Bridge - Gynangatom - Kangaken Road Project is an example of a low traffic road which forms part of the Road Sector Development Program (RSDP).The project road is situated in the South Omo zone of the Southern Nations Nationalities and Peoples Regional State (SNSPR) in south and south west Ethiopia. The control points of the project were Omorate, Omo bridge, Gynangatom and Kangaken.

The existing route consists of an non-engineered track or tracks which are impassable in the wet season. The route passes predominantly through flat terrain. The route is approximately 60km in length.

The objective of the project was to investigate three alternative routes serving the specified control points and to select the most viable alternative for upgrading to an all-weather road.

Traffic volumes on the route are currently negligible. Traffic counts were carried out over seven successive days, including two night counts, at two locations. These surveys showed vehicular traffic of less than 20 per day.

The study examined in detail the potential for induced and generated traffic in connection with the provision of an all-weather road in the corridor. Induced traffic represents the impact of agriculture-based development, notably in connection with sugar cane production, following opening of the proposed road. Generated traffic was estimated in relation to the reduction in operating costs for passenger and freight traffic as a result of new road provision.

Traffic forecasts for the road were developed for six vehicle categories (4WD, bus, small, medium, heavy and articulated truck) and for two growth periods up to 2031 on the basis of forecast national economic growth and elasticity of demand for transport.

No conventional CBA was carried out. Each of the three alternatives under consideration was thoroughly costed and a detailed MCA conducted which itself referred to a detailed environmental impact comparison of the alternative alignments.

The MCA consisted of four broad categories of criteria; engineering, socio-economic, environmental and administrative. Below these secondary and, in the case of construction materials and drainage, tertiary criteria were identified. The criteria and weighting adopted were acknowledged to be project specific with archaeological heritage contributing 15% of the total score.

In fact, this particular weighting proved decisive because the selected alternative alignment *was that with the least impact on the archaeological site. It was also the longest of the three alignments.*

Omorate – Kangaken *Road Study: Summary of Costs/Benefits Evaluated*

Cost/Benefit	*Included in Study*	*Quantified*
Capital costs	*Yes*	*Yes*
Maintenance	*Yes*	*Yes*
VOC	*No*	*No*
Time	*No*	*No*
Accidents	*No*	*No*
Employment opportunities	*Yes*	*Yes*
Social	*Yes*	*Yes*
Environmental	*Yes*	*Yes*
Administrative	*Yes*	*No*

For the purposes of wider usage in the Ethiopian road sector at the route alignment selection stage a more generic and flexible set of criteria is necessary. After reference to existing international sources, Ethiopian road studies and the particular issues and objectives of road development in Ethiopia, the set of criteria shown in Table 9.4 is proposed as a guideline for MCA.

Table 9.4 Proposed Criteria for MCA at Route Alignment Selection Stage

No.	Primary Criteria	Secondary Criteria	RSM ref (Ch)
1	Engineering	Road Length	8
		Topography	4
		Earthworks	4/5/8
		Pavement	8
		Drainage	6
		Structures	6/8
		Materials	5/8
		Geo-hazards	5/6
		Cost	8
2	Social	Access	7
		Development	7
		Public Transport	7
		Resettlement	7
		Severance	7
		Popular Support	7
		Cultural Heritage	7
3	Environmental	Air Pollution	7
		Water	7
		Land Take	7
		Ecology	7
		Mitigation	7
4	Economic	Viability	9
		Road Users	9
		Road Safety	9
5	Administrative	Sustainability	7
		Policy Integration	2
		Strategic Impact	2

This set of criteria is proposed for use by all roads at route selection stage. Variations in road status and location (region, topography) can be allowed for by use of appropriate weightings. In very specific instances where it is agreed that certain criteria or sub-criteria are not relevant to a project consideration could be given to setting their weighting to zero.

c) MCA Weightings for Ethiopian Roads

Overseas Road Note 5 states:

"it is ….difficult to develop the weighting procedure. This is very subjective and best carried out through a process of wide consultation of different experts. It is important to remember that the weighting procedure should only relate to making a comparison between choices. The absolute value of any characteristic is not being assessed."

The proposed set of weightings shown below is, therefore, initially for discussion purposes to trigger the consultation process.

A clear starting point for the development of weightings for MCA is cost as used in CBA. However, as previously stated certain factors cannot easily be quantified in monetary terms. This is a major factor behind the development of MCA. In addition, engineering costs cannot always be defined with sufficient accuracy. In many cases a significant degree of fieldwork is required to derive credible cost data.

Cost estimates also vary considerably depending on terrain and engineering geology complexity. An estimate on flat straight forward terrain might be within 10-15%. In mountainous and complex geology it could be as coarse as 50%.

One example uses the following assumptions to derive engineering weightings for cost distribution in mountainous terrain:

- Earthworks – 60%
- Minor drainage structures for surface drainage – 12%
- Major drainage structures for surface drainage – 5%
- Minor drainage structures for sub-surface drainage – 12%
- Retaining walls – 4%
- Pavement works – 14%

Given that certain of the non-engineering and non-economic factors cannot be readily monetised it is reasonable to assume that, as typically represented in CBA, their significance in the wider evaluation of MCA is underestimated. As such, their contribution to CBA effectively forms the lower end of possible weightings.

Economic criteria weightings are likely to be of secondary significance in route selection. In most cases, the differences between alternative alignments will not be significant in traffic and economic terms such that the benefits accruing to one will be similar to those for another. However, their exclusion altogether is not recommended because of the risks associated with the selection of an economically weak option. Economics should always act as a brake on the more fanciful options.

If MCA is to be applied over a wide range of road projects economic weightings need to be included because of their significance in decision making on medium-high traffic projects where, because of the number of road users, minor adjustments in alignment can have noticeable effects on the economic results.

Administrative criteria weightings need to be handled with sensitivity. It is generally advisable that their significance within MCA be carefully delimited. However, there are good reasons for their inclusion; all road projects are developed within a wider context and in conjunction, and competition, with other projects. The administrative criteria represent the wider impact and suitability of the project. Such wider objectives of a project are very difficult to quantify and MCA, or the like, is the most appropriate place for their inclusion in scheme appraisal.

Low weightings for administrative criteria are justified when considering projects, for example the Wozeka – Gedole - Gato road, where alignment has been primarily driven by non-technical factors. In such cases substantial technical and cost problems have been encountered which could readily have been avoided by a more thorough and balanced decision making process. Good practice demands that administrative criteria remain relatively low in the route selection process.

9.4 Route Selection Summary

1. Engineering: highest weighting at route selection stage, based as far as possible on project cost ratios
2. Social impact: inclusion with weightings based on uplifted ratios from CBA
3. Environmental impact: inclusion with weightings based on uplifted ratios from CBA
4. Economic analysis: inclusion with low weightings for route selection stage
5. Administrative issues: inclusion with low weightings

Ranges have been indicated in Table 9.5 for the weightings to allow for their application as widely as possible to route selection studies. It is recommended that the weightings can be adjusted between road classes to reflect their different status, function and standard. The application of different weightings for specific terrain types also merits consideration.

The precise weighting used for a particular project should be determined during the course of the project evaluation but should reflect the following:

- The primary objectives of the project: engineering, social, environmental, etc; these should be given higher range values, others taking lower range values
- The scale of costs and benefits, as far as they are known, for each of the criteria such that those with generally higher costs/benefits taking higher range values, others taking lower range values
- The technical judgement of the project manager and senior staff should confirm the values adopted after comprehensive discussion.

Table 9.5 Proposed Weightings for MCA at Route Selection Stage

No.	Primary Criteria	Weightings		Secondary Criteria	Weightings	
		from	to		from	To
1	Engineering	30	50	Road Length	4	6
				Topography	4	7
				Earthworks	4	7
				Pavement	3	4
				Drainage	4	6

No.	Primary Criteria	Weightings		Secondary Criteria	Weightings	
				Materials	3	4
				Geo-hazards	4	10
				Cost	4	6
2	Social	25	35	Access	4	5
				Development	4	5
				Public Transport	3	4
				Resettlement	4	7
				Popular Support	3	4
				Severance	3	4
				Cultural Heritage	4	6
3	Environmental	20	30	Air Pollution	3	4
				Water	4	4
				Land Take	4	6
				Ecology	5	8
				Mitigation	4	6
4	Economic	10	15	Viability	4	5
				Road Users	3	5
				Road Safety	3	5
5	Administrative	10	15	Sustainability	4	5
				Policy Integration	3	5
				Strategic Impact	3	5

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Appendices

Appendix 1

Terrain Models

Appendix 2

Geological Setting of Ethiopia

Ethiopia is a country with diverse geological formations. According to literature (Kazmin, 1972; Mengesha et al., 1996) rocks that occur in the country are:

- Precambrian basement (metamorphic) rocks
- Paleozoic and Mesozoic sedimentary rocks
- Tertiary volcanic and Cenozoic sedimentary rocks
- Quaternary volcanic rocks and recent sediment cover

The oldest rocks in the country are metamorphic rocks of the Precambrian age, which contains a wide variety of sedimentary, volcanic and intrusive rocks that have been subjected to varying degrees of metamorphism and deformation. The Precambrian basement rocks are classified into lower, middle and upper complexes each representing varying grades of metamorphism from high to moderate and low grades respectively. The Precambrian rocks have been subjected to several orogenic episodes since their formation. Crystalline rocks forming the Precambrian basement consist of gneisses (orthogneiss and paragneiss), various schists (mainly micaceous, chloritic, sericitic, feldspathic and amphibolitic), slates, phyllites, marbles, meta-conglomerates, as well as various generations of intrusions (granites, granodiorites, diorites, dikes or lenses of aplites and pegmatites, gabbros, pyroxenites and peridotites). These rocks are exposed in the southern and southwestern (Sidamo), western (Wollega and Gojam), northern (Tigray) and smaller areas in the eastern (Harar and Dire Dawa) parts of the country. The metamorphic rocks in the southern and western Ethiopia represent high grade metamorphism. Despite being frequently and strongly folded and foliated, the rocks in the northern parts of the country represent a lower grade metamorphism. In the south and west, gneisses and granitic rocks dominate, while in the north, slate and phylite are abundant.

At the end of the Precambrian, uplift occurred resulting in very few Paleozoic sediment deposits. The Paleozoic was marked by an intense period of erosion followed by subsidence and sea transgression during the Mesozoic allowing deposition of a variety of sediments, which nowadays are called sedimentary rocks. The Paleozoic and Mesozoic sedimentary rocks include sandstone, conglomerates, variety of shale, marl, siltstones, clay stones, limestone, dolomite, gypsum and anhydrite. These rocks lie unconformably on the metamorphic rocks filling channels in the Precambrian basement rocks, and are exposed in eastern Ogaden, parts of Dire Dawa and Harar, central dissected plateaus (such as in the Blue Nile gorge) and Tigray. Cenozoic sedimentary rocks, which contain sandstone, limestone, gypsum, anhydrite and lacustrine deposits occur in the eastern Ogaden, Afar depression, and lower Omo Valley. In the early Tertiary to Quaternary, related to the occurrence of several volcanic episodes, sedimentary and volcano-sedimentary rocks are found intercalated in various proportions. These include clay, silt, sand, gravel, tuffs, marls, limestone, siltstone and conglomerates, which are common in the Rift Valley and lower Omo basin.

Extensive fracturing, widespread volcanic activity and faulting occurred in the Cenozoic resulting in the most conspicuous feature of the regional geology of Ethiopia, which is the occurrence of a significant amount of volcanic rock formations in great variability and the development of the main Ethiopian Rift Valley. High scarps built up by faults border the Rift Valley and the western and eastern highland plateau. Numerous faults and fault systems crossing the highlands resulted in the formation of horsts, grabens and fault scarps. Extensive areas of the Ethiopian highlands on both parts of the Rift Valley and the Rift Valley floors are covered with intrusive, extrusive and pyroclastic rocks. On the highland plateaus, the volcanic rock formations rest unconformably on the Mesozoic strata. The quaternary volcanic sequence is mainly associated with the Rift Valley. Isolated and series of plugs, bosses, domes and cones are common in the volcanic terrains. The Rift Valley is characterized by numerous faults that are widely believed to be historically active and active. Recent activities are evidenced by displacements of Tertiary-Quaternary volcanics and Quaternary alluvial deposits (Korme, 2004).

Recent sediment covers of alluvial (fluvial and lacustrine origins), residual, eolian, and colluvial origins are widely spread all over Ethiopia. Extensive areas within the Rift Valley, major river basins and floodplains, fault bound grabens, depressions and lowlands are covered with alluvial sediments. Residual soils are abundant in many parts of the country covering the highland plateau, ridge tops and gently sloping grounds. Eolian deposits are found within the Rift Valley, Afar and Somali regions, and the lower Omo valley in the southern Ethiopia. Colluvial deposits are common at mountains and hills foot, valleys and major river basins.

Various geological structures such as faults, folds, beddings, joints and fractures, foliations, schistosity, cleavage etc. formed as a result of powerful tectonic activities, mode of depositions, successive eruptions, metamorphism etc. (Figure A2.1 shows few examples) are highly relevant with respect to road infrastructure development.

Figure A2.1 geological structures showing fault (surface rupture), fold in metamorphic rock, columnar jointing in basalt, bedding planes in sedimentary rocks respectively

Problematic Soils

Expansive soils

The occurrence of expansive soils is wide spread in Ethiopia. They are common on flat and gently sloping landscapes such as on the highland plateau, low lands, flood plains, Rift Valley, and locally in river basins and valley floors, waterlogged and drainage restricted grounds. Broad ranges of difficulties were experienced in the road construction sector (Fig. 8), which are challenging reminders of the requirement of careful consideration of these soils particularly at the early stages of road infrastructure development.

Expansive soils can be either residual or transported soils containing active clay minerals such as smectities, allophane and immogolite, illites and halloysite. Micaceous soils also expand upon unloading, and exhibit low strength at high moisture contents.

The presence of expansive soils is commonly anticipated based on knowledge of local geology, soil types, climate, topography and drainage conditions. Black cotton soils are the easiest to identify. In general the following features are useful during field survey:

- Wide shrinkage cracks are common in dry state (such desiccation cracks are often polygonal).
- Strong angular structure and popcorn texture.
- Slickensides, wedge shaped parallelepiped structural aggregates with grooved surfaces.
- An array of micro-knolls and depressions or wavy micro-topography (gilgai micro-relief), localized waterlogged depressions.
- Erosion gullies and fine dendritic drainage pattern

Optical remote sensing can significantly assist identification as expansive soils show characteristic tone, texture, reflectance and absorption features coupled with the aforementioned typical micro-topographic expressions. Susceptibility mapping using several factors could be an important addition. Field and laboratory tests are detailed in the previous ERA site investigation manuals (ERA, 2002, 2011).

Figure 1 subgrade failure due to soil expansiveness resulting in road surface deformation and formation of potholes, and slope instability on colluvium with expansive (black cotton) soil matrix.

Dispersive soils

Dispersive soils are those with high amount of dissolved exchangeable sodium (up to 12 %) in their pore water (Bell, 1999). These soils deflocculate easily and rapidly in the presence of relatively pure water, thus are highly susceptible to erosion, piping and subsequent settlement and failure (Fig. 9). Slopes in dispersive soils often suffer from runoff erosion, as well as internal erosions when subjected to localized seepage making them prone to instabilities. Erosion of drainage channels (both lined and unlined) is also a significant problem.

Dispersive soils occur in semi-arid regions and are mostly associated with parent materials, which upon weathering yield active clay minerals. In Ethiopia, such soils are common in the Rift Valley, lowland areas, and some places of the volcanic terrain highlands.

Figure 2 slope erosion, sedimentation of drainage structure and road side ditch (lined and unlined) erosion on dispersive soils (an example from a road project in the Rift Valley).

Erosion susceptible areas and materials should be identified and avoided to the extent possible.

Identification: the presence of dispersive soils could be anticipated based on knowledge of local geology climate, topography, soil types and to some extent vegetation cover. Optical remote sensing can significantly assist their identification. Field survey involves looking for signs of severe erosion manifestations such as gullies and piping. Laboratory testing is required for positive identification (for details of laboratory testing reference should be made to the ERA site investigation manual (ERA, 2011).

Collapsible soils

Collapsible soils or meta-stable structured soil are susceptible to sudden large volumetric strains upon saturation (Fig. 10 right). Collapse may be triggered by water alone (hydro-compaction), or water coupled with mechanical manipulation and loading. Major problem is sudden collapse affecting foundation, embankment and slope stabilities. Collapsible soils could be of residual, alluvial and eolain origin.

Identification: the presence of collapsible soils could be anticipated based on knowledge of local geology, soil types and climatic conditions. Loess and sand dunes are the easiest to identify in the field; laboratory testing is required for positive identification (for details of laboratory testing reference should be made to the ERA site investigation manual (ERA, 2011).

Compressible soils

Compressible soils are those that are susceptible to large settlements and deformations upon loading. They are typically soft, porous and highly permeable; and provide poor subgrade and foundations conditions. Formations of large depressions accompanied with random cracking on pavement surfaces are characteristic failures, which may severely affect road serviceability. Compressible soils are usually of alluvial, eolian and colluvial origin. In Ethiopia, their occurrence is common in the Rift Valley, lowlands, floodplains, river basins, and locally water logged or marshy grounds, mountains and hill bottoms etc. Micaceous soils are also highly compressible.

Identification: the presence of compressible soils could be anticipated based on knowledge of local geology soil types, topographic setting and drainage conditions. Optical remote sensing can significantly assist identification mainly based on associations. Laboratory testing is required for positive identification as detailed in the previous ERA site investigation manual (ERA, 2011).

Saline soils

Saline soils are rich in salts such as chlorides and sulfates. They are particularly troublesome in relation to their deleterious impacts on concrete and steel structures. Saline soils can be encountered in places where precipitation is too low to maintain enough percolation of rainwater through soils. These soils are found in Afar (mainly in Dallol, Afdera, Dobi) and Somali regions, and small amounts in the southern part of Ethiopia near Kenya border.

Identification: the presence of saline soils could be anticipated based on knowledge of local geology, climate and soil types. Optical remote sensing can greatly assist identification as saline soils show characteristic tone, reflectance and absorption features. Laboratory identification is detailed in the previous ERA manuals (ERA, 2011).

Hydrogeological regime

As a mountainous country, Ethiopia receives a large amount of rainfall particularly in the highlands. The country has different climatic zones, which appeared to be controlled by altitudinal variations. The regional hydrogeology of Ethiopia is summarized by the Geological Survey of Ethiopia (Cherinet, 1985) in a 1:2,000,000 map and accompanying explanatory note. Larger scale maps (1:250,000) are also available for most parts of the country.

Most of the Precambrian basement rocks are relatively impermeable. Ground water is associated with fracture zones, deeply weathered parts and alluvial covers in river valleys. It is largely low yield, localized and mainly at shallow reaches.

In the Mesozoic sequence, springs are common especially at the contact between Adigrat sandstone and the Precambrian basement rocks. The Antalo limestone is in particular rich in groundwater due to prominent secondary permeability in the form of solution cavities.

Due to excellent vertical permeability of jointed and fractured basalt (e.g. columnar jointing), seepage lines and springs are abundant at the contact between Tertiary flood basalts and Mesozoic sedimentary sequence. Auto-brecciated contacts between individual lava flows also have great water holding potential.

Aquifers in the Cenozoic volcanic sequence dominated by ignimbrites and tuffs, are largely inconsistent.

Groundwater of high yield are common in the cenozioc sedimentary units, quaternary volcanics and recent covers. Alluvium-filled fault bound grabens, channel fills, coarse sandstone and conglomerate layers interbedded with shales, contacts between clastic and chemical sediments, contacts between clastic sediments and interbedded volcanic rocks, lava flows interbedded within lacustrine sedimentary sequences are aquifers that are typically charcterised by shallow water tables.

Seismicity

A considerable portion of the great East African Rift system, which contains a number of active and historically active faults, is located in Ethiopia. In addition, Ethiopia is located close to seismically active major tectonic plates. Therefore, the country has a pertaining significant seismic hazard (Fig. A2.2).

Notable destructive earthquake events include the Kara Kore earthquake in 1961 of magnitude, M~6.5 that destroyed the town of Majete, the Serdo earthquake in 1969 of M~6.5 that destroyed Serdo town and its surroundings, and the Dobi graben earthquake in 1989 of M~6.5 that destroyed several bridges between Assab and Addis Ababa etc. (Asfaw, 1993).

The Afar region shows a large concentration of seismic activities. Localized seismic activities are common close to major volcanoes and associated eruptions (e.g., the Dabbahu volcano eruption in 2005 was associated with an earthquake of M~5.5).

Figure A3.2 Spatial distributions and magnitudes of major earthquakes in Ethiopia (Courtesy: USGS)

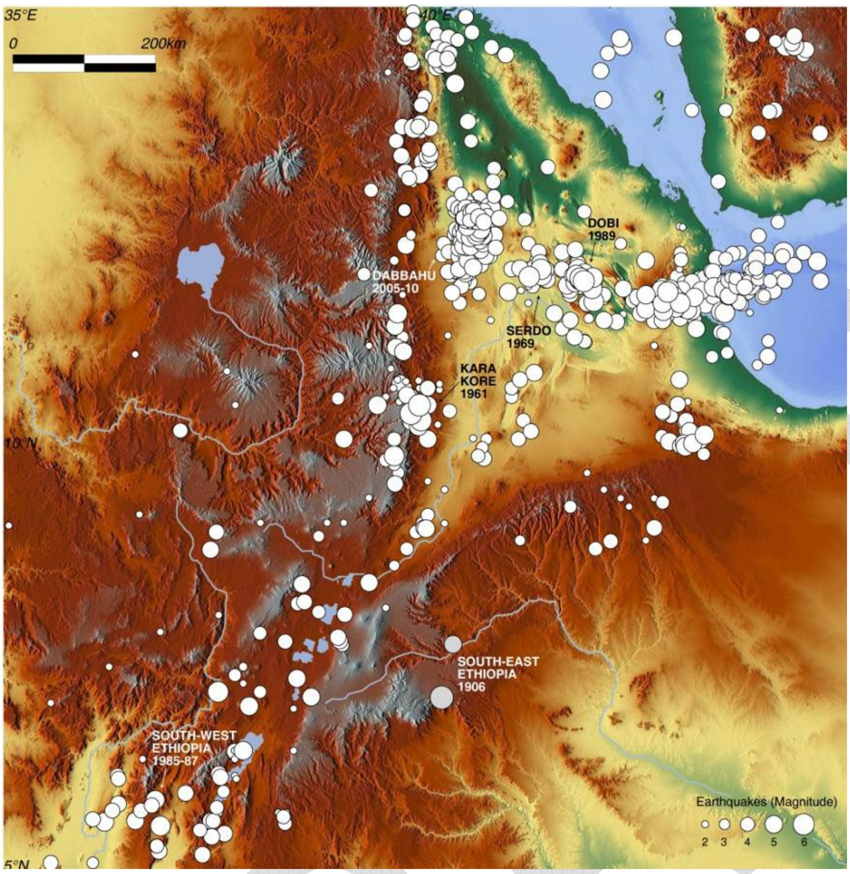

Table A2.1 Soil map units and relevant engineering characteristics that can be derived from available pedological or agricultural soil maps.

Soil map units	Relevant characteristics
Vertisols	smectite-rich highly expanding soils that swell and shrink with changes in moisture content
Andosols[5]	young soils in volcanic regions that are usually associated with pyroclastic parent materials (could be allophanic/ immogolitic or halloysitic)
Luvisols	soils that usually exhibit a high cation exchange capacity (CEC) and water retention potential due to accumulation of active clay minerals
Fluvisols	young soils of alluvial and lacustrine origin
Leptosols	shallow soils over hard rock or unconsolidated gravely material, and are common in mountainous areas
Nitosols	deeply weathered, mostly gravelly and kaolinitic soils characterized by low CEC
Cambisols	moderately developed soils derived from a wide range of parent

[5] Andosols are susceptible to heave and dispersion.

	materials, and are common in areas where there is active erosion
Phaeozems	soils that are predominantly derived from basic parent materials, and are rich in organic matter
oxisols	red residual soils with high contents of kaolinite clay minerals, iron and aluminum oxides (lateritic soils)
Solonetz[6]	soils that are rich in sodium (large concentration of exchangeable sodium in the upper horizon)
Gypsisols[7]	gypsum rich soils, typically develop in arid regions associated with unconsolidated alluvial , colluvial and eolian deposits
Solonchaks	Saline soils

[6] Solonetz are potentially dispersive soil types.
[7] Gypsisols are prone to collapse upon wetting as their gypsum cementation is soluble.

Excavation considerations

Excavation concerns arise primarily in relation to hardness of rock and soil constituent minerals and their subsequent abrasiveness. Hardness defines the ability of one mineral to scratch another. The Mohs' scale of hardness (from 1 to 10) is based on this criterion. Mineral hardness in rocks and soils is directly related to ease of excavatability and drillability. Each mineral in a scale is capable of scratching those of a lower order. That means higher order minerals in the Moh's hardness scale are more abrasive than those at the lower scale. Abrasiveness, on the other hand, describes the ability of rock and soil forming minerals to wear away and polish earth moving machines blades, cutting edges, tips and drill bit materials etc. Rocks and soils composed essentially of quartz are highly abrasive in drilling, excavation and mucking activities (McGregor, 1967). Figure II-1 illustrates the relationship among commonly occurring rock-forming and soil constituent minerals, and earth moving machines cutting edge and drilling materials. Table II-1 presents abrasion potential of common igneous, sedimentary and metamorphic rocks.

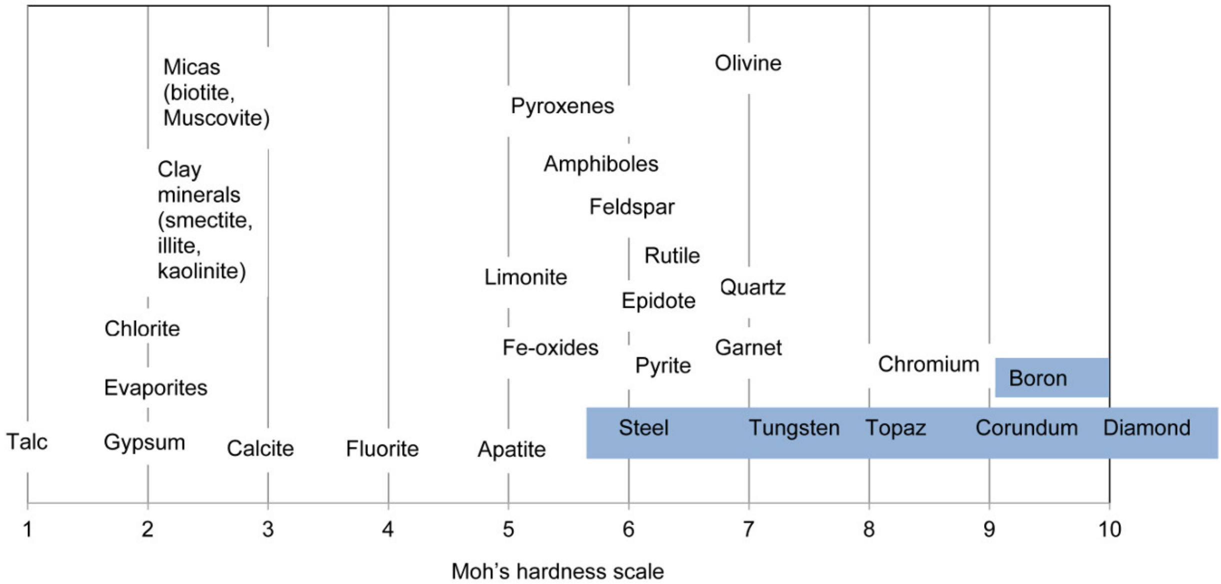

Figure II-1 Relative hardness (in Moh's hardness scale) of earth moving machines cutting edges, blades and drilling bit materials (highlighted) with respect to some commonly occurring rock and soil constituent minerals.

Table II-1 Common rocks and their abrasiveness (after McGregor, 1967).

Igneous:
Highly abrasive: rhyolite, granite, pegmatite, welded tuffs
Less abrasive: basalt, dolerite, gabbro
Least abrasive: weathered intrusive rocks and lavas
Metamorphic:
Highly abrasive: quartzite*, hornfels, gneiss, granitoids
Less abrasive: schist
Least abrasive: phyllite, slate, marble
Sedimenatry:
Abrasive: flint, chert, sandstone, quartz-conglomerate, siltstone, siliceous limestone
Non-abrasive: limestone, shale, mudstone, marl, dolomite, gypsum, chalk, coal

* Quartzite is the most difficult of all common rocks to drill and excavate.

Claims and large amount of variations related to “unforeseen ground conditions” earthwork activities, rapid and unexpected wear rate of cutting edges, blades, tips, packets etc. of earth moving machines incurring high replacement and maintenance costs are common. Even if excavation concerns may not affect route selection processes very much, it should be regarded as construction need to consider its critical cost implication related to the requirement of using blades, cutting edges and tips manufactured to achieve an extended wear life.

Appendix III: General and specific Criteria for identifying active faults (after (Cluff et al., 1972)).

General criteria	Specific criteria
Geological	Young geomorphic features: fault scarps, triangular facets, fault scarplets, fault rifts, fault slice ridges, shutter ridges, offset streams, enclosed depressions, fault valleys, fault troughs, side-hill ridges, fault saddles Ground features: open fissures, "mole tracks" and furrows, rejuvenated streams Subsurface features: stratigraphic offset of Quaternary deposits, folding or warping of young deposits, en echelon faults in alluvium, groundwater barriers in recent alluvium
Historical	Description of past earthquakes, surface faulting, landsliding, fissuring, and other phenomena from historical manuscripts, news accounts, and other publications. Indications of fault creep or geodetic monument movements may be indicated in recent reports, and literature.
Seismological	High-magnitude earthquakes and micro earthquakes, when instrumentally well-located, may indicate an active fault. A lack of known earthquakes cannot be used to indicate that a fault is inactive

Appendix IV: Morphologic, vegetation and drainage features characteristic of slope instabilities and their photographic characteristics (after (Soeters and van Westen, 1996)).

Terrain Features	Relation to Slope Instability	Photographic Characteristics
Morphology		
Concave/convex slope features	Landslide niche and associated deposit	Concave/convex anomalies in stereo model
Steplike morphology	Retrogressive sliding	Steplike appearance of slope
Semicircular backscarp and steps	Head part of slide with outcrop of failure plane	Light-toned scarp, associated with small, slightly curved lineaments
Back-tilting of slope facets	Rotational movement of slide blocks	Oval or elongated depressions with imperfect drainage conditions
Hummocky and irregular slope morphology	Microrelief associated with shallow movements or small retrogressive slide blocks	Coarse surface texture, contrasting with smooth surroundings
Infilled valleys with slight convex bottom, where V-shaped valleys are normal	Mass movement deposit of flow-type form	Anomaly in valley morphology, often with lobate form and flow pattern on body
Vegetation		
Vegetational clearances on steep scarps, coinciding with morphological steps	Absence of vegetation on headscarp or on steps in slide body	Light-toned elongated areas at crown of mass movement or on body
Irregular linear clearances along slope	Slip surface of translational slides and track of flows and avalanches	Denuded areas showing light tones, often with linear pattern in direction of moveme
Disrupted, disordered, and partly dead vegetation	Slide blocks and differential movements in body	Irregular, sometimes mottled grey tones
Differential vegetation associated with changing drainage conditions	Stagnated drainage on back-tilting blocks, seepage at frontal lobe, and differential conditions on body	Tonal differences displayed in pattern associated with morphological anomalies in stereo model
Drainage		
Areas with stagnated drainage	Landslide niche, back-tilting landslide blocks, and hummocky internal relief on landslide body	Tonal differences with darker tones associated with wetter areas
Excessively drained areas	Outbulging landslide body (with differential vegetation and some soil erosion)	Light-toned zones in association with convex relief forms
Seepage and spring levels	Springs along frontal lobe and at places where failure plane outcrops	Dark patches sometimes in slightly curved pattern and enhanced by differential vegetation
Interruption of drainage lines	Drainage anomaly caused by head scarp	Drainage line abruptly broken off on slope by steeper relief
Anomalous drainage pattern	Streams curving around frontal lobe or streams on both sides of body	Curved drainage pattern upstream with sedimentation or meandering in (asymmetric) valley

Appendix 3.1

Institutional and legal framework for route corridor selection

Institutional and legal frame work	**Main Objectives of the proclamation/regulation /strategy**
Overarching laws	
The Constitution of FDRE	The Constitution provides the basic and comprehensive principles and guidelines for environmental protection and management. The main articles related to the route selection are ❖ Government shall endeavour to ensure that all Ethiopians live in a clean and healthy environment (Article 44 states that all persons have the right to a clean and healthy environment) ❖ Development projects shall not damage or destroy the environment ❖ People have the right to full consultation and the expression of views in the planning and implementation of environmental policies and projects that affect them directly ❖ Government and citizens shall have the duty to protect the environment
Conservation Strategy of Ethiopia (CSE)	❖ This strategic document provides a strategic framework for integrating environmental planning into new and existing policies, programs and projects ❖ Provides national and regional strategies, sectoral and cross-sectoral policies, action plans and programmes, as well as providing the basis for development of appropriate institutional and legal frameworks for implementation. ❖ recognizes the importance of incorporating environmental factors into development activities from the outset, so that planners may take into account environmental protection as an essential component of economic, social and cultural development
Environmental Policy of Ethiopia (EPE)	❖ The EPE's overall policy goal may be summarized in terms of the improvement and enhancement of the health and quality of life of all Ethiopians, and the promotion of

	sustainable social and economic development through the adoption of sound environmental management principles. ❖ Recognition of the need for EIA to address social, socio-economic, political and cultural impacts, in addition to physical and biological impacts, and for public consultation to be integrated within EIA procedures ❖ Incorporation of impact containment measures within the design process for both public and private sector development projects, and for mitigation measures and accident contingency plans to be incorporated within environmental impact statements (EISs) ❖ Creation of a legal framework for the EIA process, together with a suitable and coordinated institutional framework for the execution and approval of EIAs and environmental audits ❖ Development of detailed technical sectoral guidelines for EIA and environmental auditing ❖ Development of EIA and environmental auditing capacity and capabilities within the Environmental Protection Authority, sectoral ministries and agencies, as well as in the regions
World Bank Polices on Environmental Assessment	❖ According to the World Bank Operational Policies (OP 4.01) issued in 1999 and revised in 2004, the Bank requires environmental assessment (EA) of projects proposed for Bank financing to help ensure that they are environmentally sound and sustainable, and thus to improve decision making. ❖ The borrower is responsible for carrying out the EA.
African Development Bank (ADB) Environmental Policy	❖ A strong and diversified economy shall be recognized as a just means to enhance the capacity for environmental protection; however, all development-related decision-making processes shall integrate economic, social and environmental considerations. Nonetheless, lack of financial resources shall not constitute an impediment to the promotion of community-based natural

	resource protection and management. ❖ Environmental management tools, like environmental assessments, shall systematically be used to ensure that economic activities are environmentally sustainable, and to systematically monitor their environmental performance. ❖ Community involvement, specifically including women, in natural resource management decisions that affect the most marginalized and vulnerable groups shall be provided for, and the value of traditional knowledge shall be recognized and preserved. ❖ Transparency, accountability of governance structures and institutions, which are more responsive to the needs and priorities of affected communities in general, and poor people, women, and vulnerable groups in particular, shall be encouraged. ❖ A coordinated approach to effective environmental interventions in the region shall be pursued by building partnerships with development partners, including other Multilateral Development Banks (MDBs), bilateral organizations, UN agencies, research institutions and NGOs.
African Development Bank (ADB) Gender Policy	ensure equal access to women and men of all Bank resources and opportunities ❖ Gender analysis will be an integral part of all Banks 'policies, programmes and projects ❖ Attention will be paid to the co-operative relations between women and men. ❖ Women's economic empowerment will be considered as key to sustainable development. ❖ Women will not be considered to be a homogeneous group ❖ A strategic choice will be made on the use of the mainstreaming strategy/targeted inputs.
Environmental Framework Legislation	

Proclamation on Environmental Organs Establishment	❖ The objective of this Proclamation (No. 295/2002) is to assign responsibilities to separate organizations for environmental development and management activities on one hand, and environmental protection, regulations and monitoring on the other, in order to ensure sustainable use of environmental resources, thereby avoiding possible conflicts of interest and duplication of effort. ❖ It is also intended to establish a system that fosters coordinated but differentiated responsibilities among environmental protection agencies at federal and regional levels. ❖ This Proclamation re-established the EPA as an autonomous public institution of the Federal Government of Ethiopia. It also empowers every competent agency to establish or designate an environmental unit (Sectoral Environmental Unit) that shall be responsible for coordination and follow-up so that the activities of the competent agency are in harmony with this Proclamation and with other environmental protection requirements.
Proclamation on Environmental Impact Assessment	❖ The aim of this Proclamation (Proc. No. 299/2002) is to make an EIA mandatory for specified categories of activities undertaken either by the public or private sectors and is the legal tool for environmental planning, management and monitoring. ❖ The Proclamation elaborates on considerations with respect to the assessment of positive and negative impacts and states that the impact of a project shall be assessed on the basis of the size, location, nature, cumulative effect with other concurrent impacts or phenomena, trans-regional context, duration, reversibility or irreversibility or other related effects of a project. ❖ Categories of projects that will require full EIA, not full EIA or no EIA are provided. To effect the requirements of this Proclamation, the EPA has issued a Procedural and Technical EIA Guidelines, which provide details of the EIA process and its requirements.
Proclamation on Environmental	❖ This Proclamation, Proc. No. 300/2002,

Pollution Control	is mainly based on the right of each citizen to have a healthy environment, as well as on the obligation to protect the environment of the Country and its primary objective is to provide the basis from which the relevant ambient environmental standards applicable to Ethiopia can be developed, and to make the violation of these standards a punishable act.
Proclamation on Expropriation of Land Holdings and Payment of Compensation Proc. No. 455/2005,	❖ This Proclamation, Proc. No. 455/2005, was issued in July 2005 and deals with appropriation of land for development works carried out by the government and determination of compensation for a person whose landholding has been expropriated. ❖ Part two of the Proclamation deals with expropriation of landholdings comprising articles on power to expropriate landholdings, notification of expropriation order, responsibility for the implementing agency, and procedures for removal of utility lines. According to the Proclamation, the power to expropriate landholdings mainly rests on woreda or urban administration authorities.
Proclamation on Rural Land Administration and Land use, Proc. No. 456/2005	❖ This Proclamation, Proc. No. 456/2005, came into effect in July 2005. The objective of the Proclamation is to conserve and develop natural resources in rural areas by promoting sustainable land use practices. ❖ In order to encourage farmers and pastoralists to implement measures to guard against soil erosion, the Proclamation introduces a Rural Land Holding Certificate, which provides a level of security of tenure. ❖ Proclamation where land, which has already been registered, is to be acquired for public works, compensation commensurate with the improvements made to the land shall be paid to the land use holder or substitute land shall be offered. The Proclamation imposes restrictions on the use of various categories of land, for example wetland areas, steep slopes, land dissected by gullies, etc.
Proclamation No. 209/2000 proclamation for Conservation and Research of Cultural	❖ Proclamation No. 209/2000 provides legal framework for Research and Conservation of Cultural Heritage.

Heritage.	❖ The Proclamation establishes the Authority for Research and Conservation of Cultural Heritage (ARCCH) as a government institution with a juridical personality. In addition, it has provisions for management, exploration, discovery and study of Cultural Heritage and miscellaneous provisions. ❖ As defined in the Proclamation, the objectives of the Authority (ARCCH) are to carry out a scientific registration and supervision of Cultural Heritage; protect Cultural Heritage against man-made and natural disasters; enable the benefits of Cultural Heritage assist in the economic and social development of the country; and discover and study Cultural Heritage. ❖ Any person who discovers any cultural heritage in the course of an excavation connected with mining explorations, building works, road/rail way construction or other similar activities or in the course of any other fortuitous event, shall forthwith report same to the Authority , and shall protect and keep same intact, until the Authority takes delivery thereof. ❖ The Authority shall ,upon receipt of a report submitted pursuant to Sub-Article (1) hereof, take all appropriate measures to examine ,take delivery of ,and register the cultural heritage so discovered. ❖ Where the Authority fails to take appropriate measures within six month in accordance with Sub-Article (2) of this Article, the person who has discovered the cultural heritage may be released from his responsibility by submitting, a written notification with a full description of the situation, to the Regional government officials. ❖ The Authority shall ensure that the appropriate reward is granted to the person who has handed over a cultural heritage discovered fortuitously in accordance with Sub-Articles (1) and (2) of this Article.
Civil Code, Proclamation NO.65/1960	❖ In Ethiopia, involuntary displacement due to expropriation is governed mainly by the Civil Code, proclamation No.

	65/1960. In this code reasons and objectives of expropriation are clearly specified. ❖ According to articles 1460-1488 of the Civil Code, expropriation is possible only for projects of public utility and only immovable assets could be expropriated. These regulations of the Civil Code are designed to protect private property and in the case of expropriation necessitated by public utility are unavoidable to make sure that it is co-ordinate with payment of legally sufficient compensation and proper communication with those whose immovable assets are to be dispossessed.
Sectoral proclamations and policies	
Proclamation on Forest Development, Conservation and Utilisation	❖ Proclamation No. 542/2007, issued in September 2007, provides for the development, conservation and sustainable utilization of forests in satisfying the needs of the society for forest products and in the enhancement of national economy in general. ❖ It provides the basis for sustainable utilization of the country's forest resources. The Proclamation categories types of forest ownership as private forest and state forest. The Proclamation then goes on to give some specific direction for the development and utilization of private and state forests.
Proclamation on Development, Conservation and Utilization of Wildlife Proclamation No.209/2000	❖ This Proclamation (No. 541/2007) came into effect in August 2007 and its major objectives are to conserve, manage, develop and properly utilize the wildlife resources of Ethiopia; to create conditions necessary for discharging government obligations assumed under treaties regarding the conservation, development and utilization of wildlife; and to promote wildlife-based tourism and to encourage private investment. Under its Part two, the Proclamation provides the categories of Wildlife Conservation Areas to be designated and administered by the Federal Government, Regional States, Private Investors, and Local Communities.

Proclamation on Ethiopian Water Resources Management	❖ This Proclamation, Proc. No. 197/2000, was issued in March 2000 and provides legal requirements for Ethiopian water resources management, protection and utilization. ❖ The aim of the Proclamation was to ensure that water resources of the country are protected and utilized for the highest social and economic benefits, to follow up and supervise that they are duly conserved, ensure that harmful effects of water use prevented, and that the management of water resources is carried out properly. ❖ The Proclamation defines the ownership of water resources, powers and duties of the Supervising Body, inventory of water resources and registry of actions, permits and professional licenses, fees and water charges. According to the Proclamation, all water resources of the country are the common property of the Ethiopian people and the State.
Proclamation on public health Proclamation No.200/2000	❖ The public health proclamation, proclamation No. 200/2000 is promulgated in order to participate the society for the implementation of the countries health policy. It is believed that the altitudinal change of the society through primary health care approach can solve most of the health problem of the country. ❖ Proclamation No.200/2000, article 10 sub-article 3 states that, it is prohibited to discharge untreated liquid waste generated from septic tanks, seepage pits, and industries in to water bodies, or water convergence. ❖ In the same proclamation of article 11 on occupational health control and use of machinery sub- article 1, it is stated that, any employer shall ensure the availability of occupational health services to his employees and in the same article sub-article 2 it is stated that the use of any machinery or instrument which generate excessive noise is prohibited and any person who uses such machinery or instrument shall install noise reducing apparatus or instrument.
Land Tenure proclamations.	❖ Land is the property of the state/public

proclamations on rural land No. 31/1975 Proclamation of urban land No. 47/1975	and does not require compensation. ❖ The land proclamations 31/1975 of rural land and 47/1975 of urban land state that the Government holds the ownership of land it is the property of the Ethiopian People. ❖ Article 7(72) of proclamation 47/1975 states that the Government shall pay fair compensation for property found on the land, but the amount of compensation shall not take any value of the land into account, because land is owned by state. ❖ Proclamation No.80/1997, Article 6 (18) states that ERA shall use, free of charge, land and such other resources and quarry substances for the purpose of construction of highways, camps, storage of equipment and other required services, provided, however, that it shall pay compensation in accordance with the law for properties on the land it uses. ❖ The Right-of-Way (ROW) is the land allocated and preserved by the law for the public use in road construction, rehabilitation and maintenance work. The property within the ROW limits could be removed/ demolished by the road authority.
Water Resource Policy	❖ Enhance and promote all national efforts towards the efficient and optimum utilization of the available water resources for socio-economic development on sustainable bases. ❖ The policies are to establish and institutionalize environment conservation and protection requirements as integral parts of water resources planning and project development. ❖ Conserving, protecting and enhancing water resources and the overall aquatic environment on sustainable basis.
Wildlife Policy	❖ The major objective of the policy is to create a conducive environment whereby the country's wildlife and their habitats are protected and developed in a sustainable manner, and to enable the sector to play an important role in the economic development of the country. ❖ Preservation, development and sustainable utilization of Ethiopia's wildlife resources for social and economic development and for the integrity of the biosphere.

	❖ Protecting the wildlife resources and their habitats, maintaining the balance of nature for posterity in accordance with international wildlife conventions and agreements to which the country is a signatory.
National Population Policy	❖ Making population and economic growth compatible and the over-exploitation of natural resources unnecessary. ❖ Ensuring spatially balanced population distribution patterns, with a view to maintaining environmental security and extending the scope of development activities. ❖ Improving productivity of agriculture and introducing off-farm non-agricultural activities for the purpose of employment diversification.
National Policy of Women	❖ All economic and social programs and activities should ensure equal access of men and women to the country's resources and in the decision making process so that they can benefit equally from all activities carried out by the Federal and Regional institutions.
Environmental guide lines	
EPA's Environmental Impact Assessment Guidelines	❖ They are intended to guide developers, competent agencies and other stakeholders in carrying out EIAs. The procedural guideline details the required procedures for conducting an EIA, the permit requirements, the stages and procedures involved in EIA process, and the roles and responsibilities of parties involved in the EIA process. ❖ It also includes the categories of projects (schedule of activities) concerning the requirement of EIA, and list of project types under each category.
Environmental impact assessment procedural guideline	The EA procedural guideline series aim at in particular towards: ❖ ensuring the implementation of the EPE and compliance of EA related legal and technical requirements, ❖ providing a consistent and good practice approach to EA administration in Ethiopia, ❖ assisting proponents and consultants in carrying out their environmental assessment related tasks,

	❖ assisting Interested and Affected Parties, especially communities in realizing their environmental rights and roles, ❖ assisting Environmental Protection Organs, Competent and Licensing agencies in discharging their roles and responsibilities, and ❖ establishing partnership and networking among and between key stakeholders in EA administration.
EIA guide line for road and railway	❖ In order to standardize environmental procedures for design of new roads and rehabilitation of existing roads, the ERA, in consultation with the EPA, has prepared an Environmental Procedures Manual for the use and technical guidance of design personnel of the ERA and consultants preparing projects for the Authority.
Administrative and Institutional Framework	
Federal and Regional Administration	❖ The Federal Democratic Republic of Ethiopia (FDRE) was formally established on August 21, 1995. The FDRE comprises of the Federal states with nine Regional State members. The new government structure takes power from the centre to regions and localities. ❖ The relative roles of government at the different levels (Federal, Regional and Local) in terms of power and duties, including on fiscal matters, have been defined by the Constitution, Proclamations Nos. 33 of 1992, 41 of 1993, and 4 of 1995. Under these proclamations, duties and responsibilities of Regional States include planning, directing and developing social and economic programs, as well as the administration, development and protection of natural resources of their respective regions.
Environmental Protection Authority	❖ The National Environmental Protection Authority (EPA) was re-established under Proclamation No. 295/2002 as an autonomous public institution of the Federal Government of Ethiopia entrusted with the protection and conservation of natural resources in Ethiopia. ❖ The general role of the EPA is to provide

	for the protection and conservation of the broad environment, through formulation of policies, strategies, laws and standards, which foster social and economic development in a manner that enhance the welfare of humans and the safety of the environment sustainable.
Environmental Protection Unit	❖ Proclamation No. 295/2002 requires at the Federal level each sectoral ministry to establish in-house Environmental Protection Unit to ensure harmony with respect to implementation of the environmental proclamations and other environmental protection requirements. This Unit will form a lower level inter-sectoral co-ordination structure.
Regional Environmental Agency	❖ In accordance with the principles of government decentralization and the Proclamation No. 295/2002, each National Regional State shall establish an independent regional environmental agency or designate an existing agency that shall, based on the Ethiopian Environmental Policy and Conservation strategy and ensuring public participation in the decision making process. These are expected to reflect the environmental management requirements at local level.
Multilateral Agreement Convention concerning the Protection of World Cultural and Natural Heritage ratified 1972. International Plant Protection Convention. Convention on International Trade in Endangered Species (CITES), ratified in 1989. Vienna Convention on Ozone Layer Protection (1990); Montreal Protocol for Substances Depleting the Ozone Layer (1990); United Nations Convention on the Law of the Sea. Framework Convention on the Law of the Sea.	

Framework Convention on Climate, ratified in 1994. Convention on Biological Diversity, ratified in 1994. African Convention on the Conservation on Natural Resources. Convention on desertification ratified 1997. Convention on Biodiversity (Rio convention) (1997); Framework Convention of United Nations on Climate Change (1997); Convention on the Control of Trans-boundary Movement of Hazardous Substance	

Appendix 2.2

Environmental issues to be considered in route selection

A.2.2.1 Land degradation

One of the most important environmental resources of Ethiopia is land and the most serious environmental problem of the country is land degradation which refers to deterioration in the quality of the environment for man, vegetation, animals and aquatic life. Land degradation includes all forms of soil degradation processes, sheet and rill erosion and the interrelated physical degradation process, which are the dominant degradation processes, in term of both their extent and their influence on land degradation. (Ethiopian environmental outlook) Soil degradation may be manifested by a reduction in the actual or potential productivity of soil to produce food, fodder, fiber, building materials and fuel.

Substantial proportion of the country's land mass exhibit moderately steep to very steep topography that covers about 67 percent of the country's total area, highlighting the high potential erosion risk.

Inappropriate land use practices, which often expose the soil to erosive agents, not only devoid the soil's protective cover, but also affect soil erodability and slope. Ethiopia is one of the seriously affected countries in terms of desertification and persistently recurring drought**.** The key driving force behind land degradation in Ethiopia is a nexus of poverty, rapid population growth, and inadequate progress in increasing agricultural productivity. Poor rural people in their quest for food and other livelihood needs are (1) expanding cultivation into remaining forest, hillsides and other fragile areas that are easily degraded; (2) reducing fallow periods to the point where soils are inadequately rejuvenated, (3) Pursuing land management and cultivation practices that deplete soil of their nutrient and organic matter content and promote erosion. : (iv) overgrazing pasture areas: and (v) cutting but not replanting sufficient trees and bushes for fuel wood and other purposes which accelerate the process of land degradation.

In a highly degraded area a minimal human intervention may bring about unprecedented result such as land slide, high erosion and total or partial destruction of flora and fauna. Route corridor selection should always give due attention to the level of land degradation of the area under question and try to either totally avoid or minimize through selecting among alternative activities, that may lead to further intensify the land degradation, or make adequate preparation to protect the environment.

A3.2.2 Ecosystem deterioration

An ecosystem is a natural system consisting of all plants, animals and microorganisms (biotic factors) in an area functioning together with all the non-living physical (abiotic) factors of the environment (Christopherson 1997). Road development if undertaken without proper understanding of the various components of the natural biophysical environments can be accompanied by serious disruption to the ecosystem. Major adverse impacts include damage terrestrial and aquatic habitats, habitats fragmentation or loss, deforestation, loss of biodiversity, disappearance of reproduction and food zones for fish, aquatic and migrating birds, corridor restrictions, ecological disequilibria, contamination of biota, transmission of diseases and increase in poaching and hunting.

The ecosystem classification of Ethiopia is done based on vegetation which is found to be the best way to explain the ecosystems in the country.The vegetation of the country falls into five recognized biomes: Sudanian, Congo- Guinean, Sahel arid zone, Somali-Maasai, and the Afro-tropical and montane. These can be further sub-divided into ten broad ecosystems:

- Afro-alpine and sub-alpine ecosystem

The ecosystem includes areas, which on the average are higher than 3200 m. The sub afro-alpine areas occur between 3200 and 3500 m, while the afro-alpine areas occur between 3500 m and 4620 m. The ecosystem is characterised by the most conspicuous giant Lobelia, *Lobelia rhynchopetalum*, and evergreen shrubs including the heather, *Erica arborea* and perennial herbs such as *Helichrysum* species.

The endemic mammals in this ecosystem include Walia Ibex, Mountain Nyala, Starck's Hare, Ethiopian Wolf and Gelada Baboon. The Giant Mole Rat is also a characteristic species to this ecosystem. Of the 199 species of birds that have so far also been recorded, the characteristic birds include Chough, Ruddy Sheld Duck, Spot-breasted Plover, Bluewinged
Goose, Wattled Crane, Lammergeyer, and Golden Eagle.

- Dry evergreen montane forest and grassland ecosystem

This ecosystem represents a complex system of successions involving extensive grasslands rich in legumes, shrubs and small to large-sized trees to closed forest with a canopy of several strata occurring between (1600-) 1900-3300 m. This ecosystem covers much of highland areas and mountainous chains of Ethiopia in Oromia region (Shewa, Arsi, northern Bale and western Hararge), Amhara Region (Gojam, Welo, Gonder), Tigray Region (Tigray) and SNNP region (Shewa, Sidamo and Gamo Gofa). See (Annex 1 Tables 3 and 4). The areas with Dry Evergreen Afromontane forest have canopies usually dominated by Tid/Gatira (*Juniperus procera)* as a dominant species, followed by Weira/Ejersa (*Olea europaea* subsp. *cuspidata*), etc. Zigba/Birbirsa (*Podocarpus falcatus)* is also found in sheltered valleys.

The areas with Afromontane woodland, wooded grassland and grassland include the natural woodlands and wooded grasslands of the plateau with *Acacia abyssinica* and *A. negrii.* The grasslands occur in the areas where human activity has been largest and most intense, and found at altitudes between 1500 and 3000 m. The montane grassland in most places is derived from forest and other woody vegetation types. There exists also some edaphic grassland.

The endemic species in this ecosystem include Mountain Nyala is considered rare as well as globally threatened. The characteristic birds include Black-headed Forest Oriole, Abyssinian Woodpecker, White-backed Black Tit, Rouget's Rail, Abyssinian Longclaw, Yellow-fronted Parrot, Wattled Ibis, and Abyssinian Catbird. Erlanger's House snake, Bale Mountains Two-horned Chameleon, Arena Heather Chameleon, Ethiopian Mountain Viper, Stripped Ethiopian Mountain Snake and Ethiopian House Snake are representatives of the reptilian group.

- Moist evergreen montane forest ecosystem

This ecosystem is in most cases characterised by one or more closed strata of evergreen trees, which may reach a height of 30 to 40 m. The vegetation type in this ecosystem can be further divided into two (Friis, 1992; Sebsebe Demissew et al. 2004). One type includes what is traditionally referred as the Afro-montane rainforest. These forests occur in the south-western part of the Ethiopian Highlands at between

1500 and 2600-mm elevation and the Harenna Forest on the southern slopes of the Bale Mountains. The forests characteristically contain a mixture of Zigba (*Podocarpus falcatus*) and broadleaved species as emergent trees in the canopy including Kerero (*Pouteria (Aningeria) adolfi-friederici*). Kerkha (the mountain bamboo- *Arundinaria alpina*) is also one of the characteristic species, although not uncommon is found locally. There are also a number of medium-sized trees, and large shrubs. The second type includes the Transitional Rainforest, which includes forests known from the western escarpment of the Ethiopian Highlands, in Wellega, Illubabor and Kefa. The forest type occurs between 500 and 1500 m elevation. The characteristic species in the canopy includes *Pouteria (Aningeria) altissima, Anthocleista schweinfurthii, Ficus mucuso* and species of *Garcinia, Manilkara* and *Trilepisium* .
Although this ecosystem is rich in floristic composition, its importance for reptiles, mammals and avian fauna is very minimal. The larger mammals that are characteristic include the Blue Monkey, De Brazza's Monkey, Leopard and, Guereza. The characteristic birds that occur in this ecosystem include African Hill Babbler, Banded Barbet, Abyssinian Woodpecker, abyssinian Crimsonwing, Sthulman's Starling, Grey Cukoo Shrike, Narina's Trogon, crowned Eagle and Silvery-cheeked Hornbill. It is important to note that the Harena Forest includes wild dogs and lions, which characteristically are found in, open *Acacia* woodland ecosystems.

- *Acacia-Comiphora* Woodland Ecosystem

This ecosystem is characterised by drought resistant trees and shrubs, either deciduous or with small, evergreen leaves occurring between 900 and 1900 m. This vegetation type occurs in the northern, eastern, central and southern part of the country mainly in Oromia, Afar, Harari, Somali, and Southern Nations, Nationalities and Peoples Regional States. The trees and shrubs form an almost complete stratum and include species of Grar/Lafto (*Acacia senegal, A. seyal, A. tortilis*), Bedeno (*Balanites aegyptiaca*), Kerbe (*Commiphora africana, C. boranensis, C. cilliata, C. monoica and C. serrulata*). The ground cover is rich in sub-shrubs, including species of *Acalypha, Barleria, Aerva*, and succulents with a number of Ret/Argessa (*Aloe*) species.

The characteristic mammals include African Wild Ass, Grevy's Zebra and Black Rhinoceros. The characteristic birds include Hunter's Sunbird, Shining Sunbird, Somali Golden-breasted Bunting, Salvadori's Seedeater, Yellow-throated Serin, Ruppell's Weaver, White-headed Buffalo Weaver Golden-breasted Starling and Abyssinian Bush Crow.

The three characteristic mammals known in this ecosystem namely, the African Wild Ass
(Endemic), Grevy's Zebra and Black Rhinoceros are globally threatened. In addition, of the bird species known in this ecosystem, the endemics, Abyssinian Woodpecker, Yellow-fronted Parrot and Abyssinian Bush Crow and the near-endemics, Lappet-faced Vulture, Imperial Eagle, Lesser Kestrel, Wattled Crane, Abyssinian Bush Crow, White-tailed Swallow and Nechisar Night Jar, are categorised as vulnerable.

Most of the National Parks in the country are found in this ecosystem. Of these parks, only the Awash National Park is gazetted. All the other conservation areas (Abijata-Shala Lakes National Park, Nechisar National Park, Omo National Park, Mago National Park, and Yangudirassa National Park.) attempt to function without proper legal recognition.

- Lowland, Semi-evergreen Forest Ecosystem

This ecosystem includes forests that are restricted to the Lowlands of eastern Gambella Region in Abobo and Gog Weredas. They occur between 450 and 650 m on sandy soils. They are semi-deciduous, with a 15-20 m tall, more or less continuous canopy in which *Baphia abyssinica* is dominant, mixed with less common species including *Celtis toka, Diospyros abyssinica, Malacantha alnifolia*, and *Zanha golungensis* and species of *Lecaniodiscus, Trichilia* and *Zanthoxylum*.

The characteristic mammal species of this ecosystem include White-eared Kob, Nile Lechwe and Lesser Canerat, also found in the neighbouring Sudan. Of these, the Nile Lechwe, Giant Forest Hog, Bush Elephant and Leopard are subjected to serious threats.

The characteristic birds include Yellow-fronted Parrot, Swallow-tailed Bee-eater, White throated Bee-eater, Red-throated Bee-eater, Red-tailed Buzzard, Grasshopper Buzzard, Lizard Buzzard, Yellow-fronted Canary and Basra Reed Warbler. Even though Abobo-Gog forest is recognised as priority forest for conservation, nothing was done so far to protect the forest from ruthless exploitation. The villagers and other users pose threats to the forest in general and to some species in particular.

- *Combretum-Terminalia* Woodland Ecosystem

This ecosystem is characterised by small to moderate-sized trees with fairly large deciduous leaves. These include Yetan Zaf (*Boswellia papyrifera*), *Anogeissus leiocarpa* and *Stereospermum kunthianum* and species of Weyba (*Terminalia*), *Combretum* and *Lannea*. The solid-stemmed lowland bamboo, Shimel (*Oxytenanthera abyssinica*) is prominent in river valleys [and locally on the escarpment] of western Ethiopia.

The vegetation type occurs along the western escarpment of the Ethiopian Plateau, from the border region between Ethiopia and Eritrea to western Kefa and the Omo Zone (in the SNNP Region); it is the dominant vegetation in Benshangul-Gumuz and Gambella Regions, and the Dedessa Valley in Wellega in Oromia Region, where it occurs between 500 and 1900 m. The vegetation in this ecosystem has developed under the influence of fire. The soil erosion rate is very high especially at the onset of rains.

The characteristic birds include Fox Kestrel, Red-throated Serin, Red-pate Cisticola, Green-backed Eremomela, Bush Petronia and Black-rumped Waxbill. Although it is not demarcated, the Gambella National Park is the only protected area in this ecosystem.

- Desert and Semi-desert Scrubland Ecosystem

This ecosystem is characterised by highly drought tolerant species of Grar/Lafto (*Acacia brichettiana, A. stuhlmanii* and *A. walawlensis*), Etan (*Boswellia ogadenenesis*) Kerbe (*Commiphora longipedicillata* and *C. staphyleifolia),* as well as succulents, including species of *Euphorbia* and *Aloe.* The doum palm (*Hyphaene thebaica*), grasses such as *Dactyloctenium aegyptim* and *Panicum turgidum* are also characteristic species.

The characteristic birds include Kori Bustard, Arabian Bustard, Blackhead Plover, Temminck's Courser, Two-banded Courser, Tawny Pipit, Chestnut-bellied Sandgrouse, Lichstenstien's Sandgrouse, Singing Bush Lark and Masked Lark. This ecosystem type occurs in the Afar Depression, the Ogaden, around Lake Chew Bahir and the Omo Delta below an altitude of 500 m.

The semi-desert parts are found in the northern western and North eastern parts of the country (Amhara, Tigray and Afar), Southern (Oromia and Southern Nations and Nationalities and Peoples Region) and the South eastern and eastern (Somali) parts. The northern parts of Afar and north eastern Tigray are predominantly desert Fragmentation and overgrazing of the rangeland has also affected wild animals. In this ecosystem, Wild Ass is critically endangered and has appeared in the 1996 IUCN list of threatened animals.

- Lakes, wetlands & river systems ecosystem

This ecosystem consists of both running (lotic) and standing (lentic) inland water bodies, including rivers, lakes, reservoirs, swamps, wetlands and aquatic bodies with transient water contents during some time of the year. The strict IUCN definition of wetlands has been slightly modified to include all types of lakes in this document (See Annex 1, Table 7).
Although the floristic composition of the riverine vegetation varies depending on altitude and geographical location, in general it is mainly characterised by species of *Celtis africana*,*imusops kummel*, *Tamarindus indica*, etc. The swamps, reservoirs and shores of lakes are dominated by species of sedges and grasses.

Aquatic resources in this ecosystem include over 180 fish species of which some 30 to 50 are endemic. In addition several invertebrates groups with variable endemicity are listed in annex 1, Table 8 (Golubstov and Mina, 2003). In the rivers and lakes, numerous species of lanktonic and bentic fauna have been reported. Moreover, the aquatic ecosystem harbours over 200 species of phytoplankton, including many important Bluegreen algal species such as *Spirulina* (*Arthrospira*). Studies of the planktonc life forms started only recently. These diverse aquatic habitats serves as breeding, feeding and roosting sites for a large number of resident and migrant birds including the endemics such as Spot-breasted Plover, Blue-winged Goose and Rouget's Rail and about 10 species that are globally threatened. Aquatic mammals that frequently use this ecosystem include Hippopotamus, Nile Lechwe, Common Waterbuck and Bush Elephant. The habitat is also used by considerable species of reptiles such as the Nile crocodile.

Some of the lakes harbour endemic fish species; for example Lake Tana is unique for its Barbus flock. This is the only remaining stock after the demise of similar population in Lake Lanao (Philippines). Thus this lake has international significance and serves as a natural laboratory for evolutionary investigation. Baro and Akobo are also 'hotspot' of aquatic biodiversity.

Ethiopian streams and rivers, and lakes are much influenced by various development activities. Land and water development, pollution, introduction of exotic species, over exploitation of fish stocks, etc are some of these activities. The effects of these activities have resulted to the demise of some aquatic biota that cannot tolerate conditions created by human activity, an increase in others cultured by human beings or favoured by human-induced alterations in this aquatic environment (McClanahan et al., 1966).

The varied ecosystem found in the country support different biotic and abiotic resources among which some are endangered plant and animal species and several of these species are near to extinction. There fore route corridor selection should always take the necessary steps to accomplish the following:

- inventory of biotic and abiotic resources,

- Estimation of the productivity of the ecosystem components (terrestrial and aquatic),
- Description of flora and fauna,
- Estimation of the ecological significance of the fauna and flora, wildlife and water bodies and ecosystem variables which are expected to experience changes;
- listing of physical, biological and chemical indicators to determine quantitatively ecosystem function and health;
- listing of rare or vulnerable species of fauna and flora;

And obtain detailed information by consulting the relevant public institutions, identify sensitive areas of the ecosystem early in the planning stage so that alternate routes and designs are considered; In all the ecosystems mentioned earlier very sensitive and vulnerable parts of the environment are indicated and therefore it very important to handle these hot spots with maximum care and as the list is not exhaustive one, in the process of environmental study the pertinent public agencies, educational and research institutes, private sector, communities and concerned individuals must be consulted.

A3.2.3 Slope and Topography

Slope and topography describe the shape and relief of the land. Topography is a measurement of elevation and slope is the percent change in that elevation over a certain distance. Topography may be measured with lines that connect points representing the same elevation; these are called topographic contours. Slope is measured by calculating the difference in the elevation from one point to another divided by the internal distance between those points.
Topography and slope should be considered in route corridor selection. Consideration of the slope of the land is important to reduce construction costs, minimize risks from natural hazards such as flooding and landslides, and to minimize the impacts of proposed development on natural resources such as soils, vegetation and water system. Steep slopes are vulnerable to land slide, gully formation and heavy soil erosion associated with loss of vegetation cover. Route corridor selection must avoid steep slopes as much as possible.

A3.2.4 Water

Ethiopia is naturally endowed with water resources that could easily satisfy its domestic requirements for irrigation and hydropower, if sufficient financial resources were made available. The geographical location of Ethiopia and its favorable climate provide a relatively high amount of rainfall for the sub-Saharan African region. Annual surface runoff, excluding groundwater, is estimated to be about 122 billion m^3 of water. Groundwater resources are estimated to be around 2.6 billion m^3. Ethiopia is also blessed with major rivers, although between 80 and 90 per cent of the water resources are found in the 4 river basins of Abay (Blue Nile), Tekeze, Baro Akobo, and Omo Gibe in western parts of Ethiopia where no more than 30 to 40 per cent of Ethiopia's population live.

The country has abundant surface and ground water resources potential of which groundwater has a lion-share. The preliminary estimated amount of yearly groundwater recharge of the country is about 28,000 Mm 3. Recent studies indicated that the potential is much greater than this amount. Most of the developed groundwater resources are mainly used for domestic and industrial water supply. So far, only 20.4% of the Ethiopian landmass has been mapped at 1:250,000, 36.8% at one million scales and the whole country at two million scales (Ethiopian Geological Survey).

However, the water resources are exposed to various environmental problems, including land based, water-based and natural threats. The degradation and loss of inland water ecosystems is driven by population and consumption growth, infrastructure development (reservoirs, dams, dikes, diversions, etc.), deforestation, land conversion, exploitation and over-harvesting, introduction of exotic species, pollution and eutrophication, and climate change. From the total run off of the 12 major river basins, about 91 percent flows to the neighboring countries. The remaining small amount (which is not exceeding 9 percent), along with the other inland water resources, is facing serious threats due to the above-mentioned problems.

Because of un controlled human activities for different purposes the water resources of the country is exposed to interruption of surface water flows, variation in the level of ground water table resulting from changes in the drainage, contamination of surface and underground water quality by hazardous materials, change in water resource availability and Water pollution due to the use of different chemicals. The ministry of water and energy and the geological survey of the ministry of mines have detailed information on water resources of the country and the route corridor selection have to obtain from these and other relevant and reliable sources data on the ground and surface water of the area under question and which particular area needs special attention.

A3.2.5 Wetlands

Wetlands, comprising 2% of the country's total area, are one of the most productive ecosystems which have significant functions including recharging groundwater; retaining and purifying agro-chemicals, toxicants and sediments; reducing the greenhouse effect (through their capacity for sequestering and retaining carbon); minimizing natural disasters such as drought and floods; stabilizing micro-climates; and providing tourism/recreation and water transport opportunities.

They also generate various products such as water supply, fisheries, wildlife, forest and agricultural resources which are vital for ensuring food security and reduce poverty. In addition, wetland ecosystems house a range of biological diversity (microbial, animal, and plant species) and cultural uniqueness/heritage. However; the wetlands are exposed to man-made impacts that deplete their potential to perform well i.e. disruption of natural processes. Rapid population growth coupled with lack of alternative livelihood and shortage of cultivable land intensified wetland degradation.

The major types of wetlands that are found within the country are summarised as follows based on information compiled from different sources (Laykun 2000, Afework 1998, FAO 1984). The list provided here focuses only on the major types of wetlands and is by no means exhaustive. Numerous unrecorded wetlands exist all over the country.

- Lake Tana and Associated wetlands (Lake Tana, Fogera Floodplain, Dembia Floodplain, Dangela and the surrounding wetlands)
- The Ashenge, Hayk and Ardibbo Lakes
- Wetlands of the Bale Highlands (Numerous alpine lakes including Gerba Gurecha, swamps and floodplains)

- Wetlands of the Western Highlands (Keffa, Benchi Maji and Sheka including Ghibe and Gojeb floodplains, Illubababor, Jimma and Wollega valley bottom wetlands, dominated by marsh and swamps)
- Lakes of Bisoftu (Crater lakes – Hora, Bishoftu Guda and Zukala, Grean, Babogaya, Bishoftu Lakes, etc.)
- Lakes and associated wetlands of the SW Rift Valley (Lake Ziway, Langano, Abjiyata, Shalla, Awassa Lake and Chelekleka wetland system, Lake Abaya, Chamo, Chew Bahir, Lake Turkana)
- Lakes and Swamps of the Awash River System (The upper Awash Valley – Dillu Meda, Aba Samuel, the Lake Beda Sector, the Gewane Lakes/Swamp Complex, the Dubti, Afambo and Gemari Lakes/Swamp complex, Lake Abe and delta)
- Lakes of the Afar Depression (Lake Afera, lake Asale, Dallol depression)
- Western River Floodplains (Alwero, Baro, Akobo, Gilo, Chomen, Fincha swamps, Dabos swamp, Beles floodplain).

The above mentioned wet lands are not the only wet land resources in the country there are several others which are not registered but are as equally important as the ones mentioned here. Each one of the mentioned and the not mentioned here have special importance with regard to their local ecosystems and whenever route corridor selection happen to come across such wetland resource have to make a detailed data collection and analysis and know all about the details of the resources. The ministry of water and energy, the environmental protection authority and the Ethiopian wetlands and natural resources association are some of the major institutions relevant to wetlands.

A3.2.6 Wildlife conservation area

Falling under the NRCDMD (*Natural Resources Conservation and Development Main Department*) is the *Ethiopian Wildlife Conservation Organization* (EWCO), which is directly responsible for the establishment, administration and management of national parks, sanctuaries, wildlife reserves and controlled hunting areas. According to the official document found from this organization there are 8 national parks, 58 national forest priority areas, 8 wild life reserves, 4 sanctuaries and 18 controlled hunting areas. These areas are one of the most vulnerable areas which are continuously invaded by people from elsewhere for search of land either for crop production or for grazing land. “Wildlife conservation area” means an area designated for the conservation of wildlife and includes national wildlife conservation parks, wildlife sanctuaries, wildlife reserves and wildlife controlled hunting areas;

According to the Wildlife Development, Conservation and Utilization Council of Ministers Regulations No. 163/2008,article 5, No person shall carry out any activity in a national park, wildlife sanctuary or wildlife reserve unless otherwise provided in these Regulations:

- **National wildlife conservation parks**

“National Park” means an area designated to conserve wildlife and associated natural resources to preserve the scenic and scientific value of the area which may include lakes and other aquatic areas;
Kafta Shiraro, Semien Mountain, Alatish, Bahir Dar Blue Nile River Millennium, Borena Sayut, Yagudi-Rassa, Awash, Dati Wolel, Bale Mountains, Yabello, Abjata

Shala, Arsi Mountains, Geralle, Gambella, Nechsar, Omo, Mago Maze, Gibe Sheleka, Lake Abaya, Chebra Churchura.

- **Wildlife Reserves**

“Wildlife Reserve” means an area designated to conserve wildlife where indigenous local communities are allowed to live together with and conserve the wildlife; Alledeghi,Awash West, Bale,Chelbi, Gewane, Mille-Sardo, Shire, Tama.

- **Sanctuaries**

“Wildlife sanctuary” means an area designated to conserve one or more species of wildlife that require high conservation priority;
Babile Elephant, Kuni-Muktar, Mountain Nyala, Senkelle Swayne's Hartebeest, Yabello

- **Controlled Hunting Areas**

“Wildlife controlled hunting area” means an area designated to conserve wildlife and to carry out legal and controlled hunting;
Afdem-Gewane, Akobo, Arsi, Awash West, Bale ,Borana ,Boyo Swamp, Chercher, and Arba Gugu, Dabus Valley, Eastern Hararghe (Harar-Wabi Shebelle), Erer-Gota, Jikao, Maze ,Mizan-Teferi ,Murle ,Omo West ,Segen Valley, Tedo.
According to the proclamation No. 541/2007.” development conservation and utilization of wildlife in Ethiopia
The following wildlife conservation areas shall be designated and administered by the Federal Government:

- National parks those are nationally and globally significant and known to have representative ecological zones and embrace immense diversity of wildlife;
- National parks and wildlife sanctuaries that are inhabited by the country’s endemic and endangered species;
- Any wildlife conservation areas geographically situated within two or more regions;
- Any trans-boundary wildlife conservation areas that may be established in accordance with agreements with neighbouring countries;

When a route corridor selection is required the above mentioned natural resources should be avoided as much as possible or interventions should be done in consultation with the relevant institutions and with maximum care and should have a permit from the concerned authority to carry out any kind of activity within the delineated area.

A3.2.7 Biodiversity hot spots

According to the Ethiopian biodiversity conservation and research authority, with its dramatic geological history, broad latitudinal spread and immense altitudinal range, Ethiopia spans a remarkable number of the world's broad ecological regions. These range from the depressions in the Afar (115 m below sea level) to the spectacular mountain tops of Ras Dashen in the north and the Bale Mountains in the southeast. This variety of habitats also supports a rich variety of different species, which contributes to the overall biological diversity (or “biodiversity”) of the country. Ethiopia has some of the world’s rarest animals and plants but these are now in danger of disappearing forever due to overuse and loss of natural habitat.

The country's biodiversity is also vital for ensuring ongoing provision of ecosystem services such as production of clean water through good catchments management,

soil formation and protection, carbon storage, clean air, diseases/ pests control, invasive alien species control, provision of wild foods, energy, power, irrigation and provides job opportunity.
There are 97 biodiversity hotspots identified, distributed in all the regional states including the two special city administrations namely Addis Ababa and Dire Dawa. The current Ethiopian Biodiversity Strategy and Action Plan (EBSAP) will address inter linked issues comprising biodiversity protection and management for food security (poverty reduction), health and livelihood improvement of the Ethiopian population especially the rural communities (farmers and pastoralists) whose survival depends on the use of natural resources.

In Ethiopia, information about the components of biodiversity is very incomplete. There is no biodiversity information and monitoring centre to maintain, store, and organise data or to analyse, evaluate and disseminate data in a usable form. Data derived from the identification and monitoring of biological diversity are scattered among a large number of organisations. Data on the flora of Ethiopia, for example are available at the National Herbarium, Addis Ababa University. Additional data are also available at IBC and EARO, Herbaria and Museums in Europe and North America.

Annex 1 of CBD gives guidelines to the parties on identifying the component of biodiversity, which should be the target of attention. They are described as:
1) Ecosystems and habitats: containing high diversity, large numbers of endemic or threatened species, or wilderness; required by migratory species; of social, economic, cultural or scientific importance; or, which are representative, unique or associated with key evolutionary or other biological processes;
2) Species and communities which are threatened; wild relatives of domesticated or cultivated species of medicinal, agricultural or other economic value; of social, scientific or cultural importance; or of importance for research into the conservation and sustainable use of biological diversity, should be given maximum attention during the route corridor selection.

A3.2.8 Natural, Cultural and historical heritage.

Ethiopia is well known for its natural, cultural and historical heritages which are the major destinations for tourists from abroad. These can include sites that consist of buildings, objects, artifacts, aesthetics, significant sites and places with regard to the history in districts, town and cities. The route corridor selection study shall consider these historical sites and places and other similar cultural aspects. The major problem associated with heritages in general is loss of cultural, religious and historical heritage as well as aesthetic resources and breach in agreements with traditional authorities concerning cultural, religious, historical and aesthetic sites and resources.

- Aksum(1980)
- Fasil GIbbi, Gondar region (1979)
- Harar jegol, the fortified city (2006)
- Konso Cultural Landscape (2011)
- Lower Valley of the Awash (1980)
- Lower Valley of the Omo(1980)
- Rock Hewn Church, Lalibela(1978)

- Tiya (1980)
- Ongoing registration process with UNESCO
- Bale Mountain National Park (2008)
- Dirre Shiek Hussein Religious, Cultural and Historical Site (2011)
- Holqa Sof Omar Natural and Cultural Heritage (Sof Omar Caves of mystery) (2011)

There are also several natural and cultural heritage sites which are not registered and it is these sites, even though they are not registered by the UNESCO, are of huge importance to the country and to the world. The ministry of tourism and culture, the natural history society of Ethiopia, the regional bureau of culture and tourism and many others are the source of data concerning these heritages. Sometimes the route selection may come across unidentified heritages which may be of invaluable importance to the country and such cases should be immediately reported to the concerned authority.

A3.2.9 Archaeological sites

The geological formation and characteristic situation of the Ethiopian- rift valley has its own contribution to the archaeological history of Ethiopia. The rift valley region is the home of various lakes and rivers, and varieties of plants and animals. In addition, it is a known site for paleontological collection. As a result various research projects in archaeology, palaeontology, Palo anthropology, ethnology and related filed of studies are undergoing in different parts of the country.

Some of the major of the archaeological findings include:
The lower valley of the Awash, which is located in the Afar Regional State, cover a large area including Hadar, where the most important partial skeleton known as "Lucy" (3.2 million years old) was discovered. This site was included on UNESCO's World Heritage List in September 1980. In addition to Lucy, there are also various exciting findings such as Ramidus 4.4 million years old, Ardipithecus Ramidus Kadaba 5.8 million years old, and Australopithecus Garahi 2.5 million years old. These have contributed to the advancement of the research in origin of human kind.
The prehistoric site of the lower valley of the Omo, which was discovered in 1902 was registered in the World Heritage List on the 5th of September 1980.
The Tiya site which is located at about 90.5 km south of the capital, Addis Ababa, contains about 36 monuments. Out of these 32 are carved stelae having symbols inscribed on them. Tiya is one of the 160 archaeological sites discovered so far in SNNPRS. The site was registered in the world heritage list on September 1980.
The Melka Kuntre prehistoric site located in upper Awash Valley, and the Konso-Guduala paleo-antropological sites in the SNNPRS are also some of the important archaeological sites.
Axum town and its environs are also one of the known archaeological sites in Ethiopia.
Heritages forms the identity of each society and nation. So people should try to preserve and enhance their place and conditions in the environment. To create a map about the heritage, documents and existing maps were studied. Apart from the above mentioned areas where archaeological evidences were found the whole area of the country is considered archeologically important and care must always be taken not to destroy these globally important evidences.

A3.2.10 Flora

Ethiopia has over 6,000 species of vascular plant (with 625 endemic species and 669 near-endemic species, and one endemic plant genus). The country is well known for its field crop diversity, horticultural crop diversity Pasture and forage plants biodiversity and Medicinal plants biodiversity. The government is trying to conserve these important biodiversity resources in-situ and ex-situ. Below are indicated some of the priority areas delineated for conservation. Data on the flora of Ethiopia are available at the National Herbarium, Addis Ababa University. Additional data are also available at IBC and EARO, Herbaria and Museums in Europe and North America.

National Forest Priority Areas

The Forestry Proclamation (Proclamation No.94/1994) was enacted with a view to consolidate existing forestry laws and provide for the inclusion of new provisions that enhance better conservation, development and utilisation of forests. However, in practice, there is no clear jurisdiction over the forests, and different government agencies use this resource for their purposes through the mandates provided by their own pieces of sectoral legislation. Conservation of forest biodiversity therefore goes by default.

Abelti Gibie, Abey-Albasa, Abobo-Gog, Aloshie-Batu, Anferara-Wadera, Arba-Minch, Arero, Babiya-Fola, Belete Gera, Bonga, Bore-Anferara, Bulki-Melakoza, Butajira, Chato-Sengi-Dengeb, Chilalo-Gallema, Chilimo-Gaji, Deme-Laha, Dengego-Melka jedbu, Denkoro, Desa-A, Dindin-Arbagugu, Dire-Gerbicha, Dodola-Adaba-Lajo, Gara muleta, Gebre Dima, Gedo, Gergeda, Gidole-Kemba, Godere, Goro-Bele, Gumburda-Grakaso, Gura Ferda, Harena-Kokosa, Jalo-Addes, Jarso-Gursum, Jibat, Jorgo-Wato, Kahatasa-Guangua, Komto-Waga-Tsige, Konchi, Kubayo, Megada, Mena-Angetu,Menagesha-Suba, Munesa-Shashemene, Negele (Mankubssa), Sekela Mariam, Sele Anderacha, Shako, Sibu-Tole-Kobo, Sigmo-Geba, Tiro-Boter-Becho, Wof-Washa,Yabelo, Yayu, Yegof-Erike, Yeki, Yerer.

Permanent and temporary loss of forest and other plant products (feed, fodder, fiber, construction material, medicinal plants, fuel wood, timber, and non-timber forest products) are the main issues of environment. The above mentioned forest priority areas should be, if possible avoided or care must be taken not to destroy the already endangered species. It is important to note the species which are endangered in every forest priority area and take the maximum care in choosing the route corridor selection.

A3.2.11 Fauna

860 avian species (16 endemic species and two endemic genera), 279 species of mammal (35 endemic species and six endemic genera), 201 species of reptile (14 endemic species), 23 species of amphibians (23 endemic species), 150 freshwater fish (6 endemic species). There are a number of charismatic flagship species, most notably the gelada (an endemic genus, *Theropithecus*, and the world's only grazing primate), the mountain nyala, the Ethiopian wolf, the walia ibex and the giant lobelia.

The major concerns associated with fauna are Perturbation of wildlife habitats, fragmentation of habitats and isolation of animal populations, perturbation of wildlife migrations, increase in animal mortality disruption in animal traction increase in poaching due to non-resident workers and better access to wildlife habitats. The data on endemic and near extinction species which should be considered with maximum care can be obtained from the wildlife conservation agency and other higher learning institutions and research organizations.

A3.2.12 Landscape

Landscape comprises the visible features of an area of land, including the physical elements of landforms such as (ice-capped) mountains, hills, water bodies such as rivers, lakes ponds and the sea, living elements of land cover including indigenous vegetation, human elements including different forms of land use, buildings and structures, and transitory elements such as lightning and weather conditions.

Combining both their physical origins and the cultural overlay of human presence, often created over millennia, landscapes reflect the living synthesis of people and place vital to local and national identity. Landscapes, their character and quality, help define the self-image of a region, its sense of place that differentiates it from other regions. It is the dynamic backdrop to people's lives. The World Heritage Committee has identified and adopted three categories of cultural landscape.

Roads project involves cutting of trees, soil filling and cutting operation. This disturbs the natural aesthetic of the environment (scenic value). Some express way components like large bridges and interchanges will create visual impacts and detract from the natural beauty of the area. The lack of resurfacing/ replanting of exposed areas are also the leading factor to aesthetic reduction.

The three categories extracted from the Committee's Operational Guidelines, are as follows:

1. A landscape designed and created intentionally by man.
2. An organically evolved landscape which may be a "relict" (or fossil) landscape" or a "continuing landscape".
3. An "associative cultural landscape" which may be valued because of the "religious, artistic or cultural associations of the natural element"

Major issues associated with landscape of the country are degradation of the landscape by land clearing, embankments, cuttings, fillings and quarries, roadside litter.

A3.2.13 Geology and Soil

Soil is by far the most important environmental resource for the very existence of living organism. The development of soils depends primarily on geologic and climatic conditions. In Ethiopia, seventeen major soil units have been identified (EMA, 1988). The FAO Soil Map of Ethiopia (1998) classifies 19 soil units, which do not all coincide spatially with the EMA soil map. For this research, the FAO classification system has been selected and is used in the following descriptions and analyses (FAO, 1998).
Runoff erosion resulting in sedimentation problems, change in the local topography, contamination of soils from spilling of hazardous materials, Landslides and other types of soil movements in the cutting areas, Soil compaction are the major problems associated with soil.
The wearing away, detachment and transportation of soil from one place to another place and its deposition by moving water, blowing wind or other causes is called soil erosion. Large numbers of trees and plantation has to be removed for construction of highway. This leads to loosing of the soil, soil disturbance, and exposure of bare soil surface. This causes problem of soil erosion and siltation during rain or heavy wind. The most severe problems will be associated with embankment construction in the plain area, road sections with heavy cuts and fills, borrow and spoil sites, as well as bridge and culvert construction sites, particularly on rainy days. Soil pollution resulting from release of pollutants (e.g. oil, greases) of the construction machineries and Soil instability which can lead to landslides is also issues to be considered.

When route corridor selection is made it is very important to identify the type of soils and their associated characteristics, their ability to withstand natural and manmade interventions.

A3.2.14 Climate change

Climate change is expected to hit developing countries the hardest. Its effects—higher temperatures, changes in precipitation patterns, rising sea levels, and more frequent weather-related disasters—pose risks for agriculture, food, and water supplies. At stake are recent gains in the fight against poverty, hunger and disease, and the lives and livelihoods of billions of people in developing countries. Tackling this immense challenge must involve both mitigation—to avoid the unmanageable—and adaptation—to manage the unavoidable—all while maintaining a focus on its social dimensions.

Climate change have inflicted heavy damage to the road infrastructure in the country, particularly in recent years heavy rain have destroyed roads due to land slide, closed path ways due to flood, damage and siltation of drainage structures, damage or collapse of bridges. Besides this, high temperature has also damaged the asphalt roads; asphalt road when exposed to high temperature will melt and rubbed away by vehicles.
Climate change has inflicted a heavy damage to the infrastructure of transport sector. According to the climate change adaptation action plan of the ministry of transport, flood associated with heavy rain and extreme heat has destroyed roads, bridges and sewerage canals in many part of the country. According to the report, In 2006 EC heavy rain damaged the asphalt road and road side structures in Diredewa and Gamogofa. Extreme heat also have melted the tar on asphalt road and damaged the road in law lands of the country where extreme heat is prevalent.

In the climate resilient green economy document the transport sector is given high emphasis to employ modern technology that reduces emission particular emphasis given to construction machineries. In addition to this to extend the use life of roads and railways it is required to make these infrastructures adapt to climate change. In the process of selecting route corridor it is compulsory to assess the extreme events of climate change and make the necessary preparation for adaptation including emergency exit roads in case of climate hazards.

Appendix A3.3

Social issues to be considered in route selection

A3.3.1 Displacement or relocation

Displacement and resettlement of residents is significant and can lead to further impacts on the community. Residents displaced for the construction of a road may experience additional impacts such as: economic impact resulting from acquiring new housing at a new location; social and psychological impacts due to the disruption of social relationships and establishing relationships in a new social environment; and, changes in type and tenure of housing. For some projects, businesses and community services (e.g., churches, community centres, and parks) experience a significant impact when they are removed or relocated.

The businesses and community services may have difficulty in obtaining suitable relocation sites; they may lose clients, and, upon relocation, may incur additional costs to re-establish. Apart from these involuntary displaced people may face Decreased standard of living , inappropriate living conditions for non-resident workers and their families, constraints in adjusting to resettlement and changes in productive activities, population pressure due to the arrival of non-resident workers and migrants attracted by new economic opportunities, unplanned human settlements.

According to the World Bank and African Development bank policy displacement and resettlement must be the last option among other alternatives and any development program, project or policy should try to avoid displacing people as much as possible. Involuntary resettlement can have a dramatic impact on the lives of the people living in an area of influence of development projects. It can cause a sudden break in social continuity and can result in impoverishment of the people who are relocated. The resettlement may provoke changes, which could dismantle settlement patterns and modes of production, disrupt social networks, cause environmental damage, and diminish people's sense of control over their lives. It can threaten their cultural identity and create profound health problems.

When people must be displaced they are treated equitably, and that they share in the benefits of the project that involves their resettlement. The objectives of the policy are to ensure that the disruption of the livelihood of people in the project's area is minimized, ensure that the displaced persons receive resettlement assistance so as to improve their living standards, provide explicit guidance to Bank staff and to borrowers, and set up a mechanism for monitoring the performance of the resettlement programs. Most importantly, the resettlement plan (RP) should be prepared and based on a development approach that addresses issues of the livelihood and living standards of the displaced person as well as compensation for loss of assets, using a participatory approach at all stages of project design and implementation.
There for route corridor selection should, as much as possible, try to avoid dislocation of people or if dislocation is found to be unavoidable has to try to resort to unalternative which minimizes the number of displaced.

A3.3.2 Land use

One of the most important social issues that should be taken seriously during route corridor selection is the land use plan of the area. The land tenure system may differ from community to community or different land tenure system may be found in the same community. The current land use or utilization of land for different purposes including land utilized for crop production and fallow land, grazing land, land occupied by perennial crops, land occupied by residence and farm stead structures, land used for fuel wood collection and land utilized for any other use should be described. Who owns the land as related to gender the community and any change in land use should be studied in detail.

A3.3.3 Institutional setups

These are issues of government and private services such as housing, schools, police, justice, etc. To obtain data inquiries to be placed are: how are communities are linked with regional and national organizations? How are power and authority distributed in the community? What is the current structure and organization of the potentially affected population? Who are the relevant stakeholders? How do they organize and exercise power internally and externality? How do they react?

A3.3.4 Conflict

Usually there have been ethnic conflicts (tensions) to exist elsewhere in Ethiopia along the borders separating different ethnic groups. This sort of problem often occurs more frequently in the pastoralist area than the sedentary agriculturalists and it is common to observe while different pastoral groups often resort to blood shade competition for grazing and water resources. Route corridor selection should always take in to consideration how resources are owned and controlled by different ethnic groups and make fair decision not to escalate the conflicts.
Religion may sometimes become cause of conflict in some areas where different religions found in the same area and care must be taken when it comes to the resource they own.

A3.3.5 Religious and worship places, burial sites

The route corridor selection should always give due emphasis for the religious, cultural and ritual values of communities and respect them without reservations and when it comes to the places occupied by these entities care must be taken not to harass the communities.

A3.3.6 Existing infrastructure

Existing physical and social infrastructure found in the area particularly road, electric power, potable water and telecommunication access should be assessed with regard to their capacity to satisfy current and future needs of the community. Issues to be considered in here are development of new infrastructures or improvement to existing ones, changes in water supply, easier access to social services (education, medical care, etc.), increased pressures on existing social services due to migration and better access and increase in prices of social services (housing, water, electricity, etc.)

A3.3.7 Population of the project areas/Population and Settlement

Demographic issues include the number of currently existing and new permanent residents or seasonal residents associated with the development, the density and distribution of people and any changes in the composition of the population, (e.g., age, gender, ethnicity, wealth, income, occupational characteristics, educational level, health status).

Development invites growth in new jobs in a community and draws new workers and their families into the community, either as permanent or temporary residents. When this occurs, the incoming population affects the social environment in various ways including increased demand for housing and social services (e.g., health care, day care, education, recreational facilities). Because residents' needs depend on a wide range of variables (e.g., age, gender, employment status, income level and health status), the diversity of service needs are determined not only by the absolute size of the incoming population but also by the old and new populations' demographic and employment profiles.

As a result, a proposed development may have a significant impact on the community's ability to accommodate new residents and adapt to changes in the social environment for existing residents. Assessing the magnitude and rate of population change has important implications for community infrastructure and service requirements and can play a major role in determining social impacts associated with the proposed development.

The following question may help to identify the dynamics of population characteristics. What is the estimated population change with the proposed development? Of the population change, what percentage are under the age of 18, over 65, minority, female, male? What is the ethnic breakdown of the new population? Is there an influx or out flux of temporary workers (e.g., construction of development)? How many children per housing unit?

A3.3.8 Gender

The implications of development projects on women's role in society are, income generating opportunities, access to resources and employment opportunities. To get information question to be asked are, what is the role of low income women (reproductive, productive and community managing role)? How men and women participate in benefit from and control project resources and activities? What is the gap between men and women in terms of how they benefit from the built environment?

- Who are the target beneficiaries?
- Disaggregate the beneficiaries according to gender.
- Talk to women as well as men.
- Are women visible in the sector?
- Determine the gender division of labour in general.
- Are women's needs in the sector the same as those of men?
- Identify if possible, the main sources of income for women and men.
- How might the project affect women? Is the project likely to have the same positive and negative effects on women and men?
- Can a gender-inclusive design be drawn up for the project, and could it effectively and equitably target women?
- Identify, if possible, legal, cultural, or religious constraints on women's potential participation in the project.
- Does the executing/implementing agency have the capacity to deliver benefits to or involve women?
- Will the project preparatory technical assistance (PPTA) fact finding and PPTA study require the services of a consultant with specialized gender and development expertise to assist in developing a gender inclusive design?

A3.3.9 Livelihood and Economic Practices

The detailed analysis of means of lively hood and economic practices of an area or community is important in deciding how to compensate for lost income and disturbed livelihood. There are important issues to be looked in to in detail such as Development of agricultural and pastoral land due to an easier access, disturbance or change in land uses which can lead to social conflicts, loss of productive land needed for the road/ railway or for work purposes, loss of territory for local people, decrease in the quantity and quality of natural resources due to population pressures and change in land prices and ownership along roads.

Improvement in quality of life due to new economic opportunities and adequate compensations for losses better access to goods and services, degradation of the quality of life due to nuisances such as noise, dust, vibrations and traffic deterioration of the visual quality of the landscape due to land clearing, construction works, new infrastructures, disruption of non-motorised transport changes in way of life, jeopardising traditional cultural values, social conflicts due to the venue of non-resident workers and new settlers (divorces, ethnic tension, etc.), increased waste along roadsides.

To know in detail, the livelihood base of a community one may require data on the following economic variables.

- Economic activity, employment and incomes.
- Standard of living.
- Compensation for losses.
- Access to benefits, particularly for the poor and other vulnerable groups.
- Awareness on project implications and opportunities.
- Access to markets and social services.
- Change in prices of retail prices of consumables.

A3.3.10 Socioeconomic Characteristics

The socio-economic issues includes effects on farm land and land use patterns, effects of prices of goods and services, incomes, employment rates and taxation effects, etc. To obtain information on socio-economic question to be asked are, what factors influence the daily lives of potentially affected members of a community? Are they concerned about what the proposed action would do to their way of life? What attitudes do peoples have toward risk, health, safety and the proposed alternative? How do people use the land, whether urban or rural? How do they use the natural environment? How available are housing and community services like police protection, water, sewer services, and electricity, schools and libraries

A3.3.11 Ethnic Minorities and Tribal People

Ethiopia is known to have more than 80 ethnic groups with diversified culture, religion, beliefs, values and norms. Within these ethnic diversity there are ethnic minorities and tribal people whose interest may be overlooked unless given due emphasis. In several regions ethnic groups with fewer members live with big nations and nationalities with very big number of members. In many parts of the country particularly in remote areas traditional cultures or practices are prevalent where sometimes group of people are marginalized based on what they do for living.

For example weavers, metal ware works and skin and hide processors are considered inferior. It is important to identify what major ethic groups are there in the area under question and what minority groups and tribal people are living in the same area and how they are treated particularly with regard to resource ownership, the roles they have in local and regional administrations, whether they are consulted in the development activities of the area and the like.

A3.3.12 Non-Farm Livelihood Activities

Non-farm activities are very important income generating activities particularly in rural areas which are mostly done during slack times (when on farm activities are at their minimum). Farmers do nonfarm activities as means of additional income generating activity. These may include working as a daily laborer, charcoal and fuel wood and construction material selling. These nonfarm activities should be identified and the route selection process should look for alternatives to compensate for lost income. In most cases the compensation process include the tangible assets and overlook those which are done as additional activities and are not related to ownership rights.

A3.3.13 Social services (Education Health Services)

The new residents and their associated activities will require a variety of services provided by the areas public and private institutions. A social impact assessment must determine the quantity and variety of anticipated needs. The goods and services most commonly included in a social evaluation are open space and parks; cultural and recreation facilities; education; health care; special care for the elderly, the disabled, the indigent and preschool-age children; police and fire protection; and a variety of administrative support functions. The optimum amount of resources that would be required for the satisfaction of needs is based on either planning standards, which are guidelines established by professional organizations and government agencies, or service levels, which are observed national (or regional) average amounts of resources expended per capita or some unit of size.

Service resources are objective indicators of the level of resources available for the satisfaction of society's needs. For example, the number of physicians, dentists, acute-care hospital beds, and psychiatric care hospital beds are indicators of the level of health care resources. Square feet of parkland, picnic areas, tot lots, etc., are indicators of facilities for recreation needs. The Appendix includes worksheets designed to assist you in assessing the specific current and future needs of a variety of public services based on commonly applied planning standards. Once the tables are complete with information about the community's current service level and current and future needs, you can begin to deter-mine the feasibility of the proposed development and how it may affect the quality of services provided to residents.

A3.3.14 Rural mobility and livelihood

Many inhabitants of rural areas in developing countries lack adequate and affordable access to transport infrastructure and services. Poor access to transport constrains economic and social development and contributes to poverty. Better transport services can stimulate economic activity and social improvement, leading to easier access and a virtuous circle that reduces poverty and improves the lives of poor rural residents.

Improving rural people's access to essential services requires better mobility through transport infrastructure and services as well as the location, price, and quality of facilities. Rural poverty is pervasive and difficult to address. Improving mobility can reduce rural poverty by facilitating women, men, and children to more easy access to services (education, health, finance, markets), obtain goods and income, and participate in social, political and community activities. Mobility requires a combination of appropriate transport infrastructure, improved transport services, and affordable means of transport, both motorized and non-motorized.

According to the rural Transport and Poverty Observatory study, improvement of rural mobility improves lively hood through Roads improve access to better market so that farmers will sell their products for higher prices and buy consumable items and agricultural inputs for lower prices, roads ease travel to Health Care Facilities, Improve Household Income and enhance ability to pay for health care and educational services, roads facilitate Establishment and operation of health care facilities in rural areas, roads ease travel to health care facilities and also facilitate commencement of health care services in rural areas, particularly to women

Road ease the burden of travel on women:

- Village level travel study in Ethiopia shows women spend a lot of time on:
- Fetching water
- Fire wood collection;
- Travel to grinding mill;
- Travelling to market

Child delivery in health care facility significantly increased, number of women receiving regular family planning services also increased, and access to Roads enables women to use animal drawn carts and hand driven carts to:

Route corridor selection should always take in to account rural mobility and lively-hood analysis and try to maximize the benefit to the community and take care not to compromise the mobility of the community.

A3.3.15 Public consultation

Public consultation and field level investigation should be carried to incorporate the interest of all stakeholders. The primary purpose of public consultation is to make the stakeholders at different level and the community at large participate in the whole process of development which is the right of any citizen as mentioned in the constitution, from design to implementation phase. It also gives opportunity for the affected people to influence the project to reduce adverse impacts, maximize additional benefits, and ensure that they receive appropriate compensation. Public consultation was carried out through formal meetings & public gatherings, focused group discussions, meeting with women groups, meeting with teachers and health professionals, and also through informal meetings held with different sections of the community

The main purposes of public consultation are

• To inform the public on the potential impacts and seek the participation and contribution of the public during the construction of the railway project;

• To ensure that acceptance of the project by the stakeholders and the community along the route corridor;

• Identifying the potential social impacts (positive and negative); and agree on the implementation of the proposed mitigation measures for the negative impacts and on measures of reinforcement for the positive impacts;

A3.3.16 Priority areas for consultation

• Providing adequate documentation of the consultation process

• Ensuring that minority/disadvantaged communities or groups are involved

• Ensuring involvement of communities at the early planning (scoping) stages of the EA

• Ensuring that expertise in effective consultation techniques is employed
• Using systematic approaches to identify and include all stakeholders
• Providing effective and timely disclosure of information to all stakeholders
• Ensuring that the concerns of stakeholders are reflected in the design of the project
• Ensuring that separate consultations are held on resettlement vs. Environmental issues

To provide quality engagement and genuine opportunities for feedback

- Design and construct the project with the stakeholder in mind, in particular land owners along the project corridor
- To be responsible to stakeholders and the local community
- To ensure issues are effectively managed within a timely manner and to the satisfaction of stakeholders
- Ensure potential stakeholder community issues are identified early and appropriate mitigation strategies are implemented to address these and the local community
- To ensure issues are effectively managed within a timely manner and to the satisfaction of stakeholders
- Ensure potential stakeholder community issues are identified early and appropriate mitigation strategies are implemented to address these.

Appendix A3.4

Valuing Ecological Resources

Valuing environmental **or** ecological resources is not practiced adequately in Ethiopia but is very important in grading, comparing and selecting among alternative resources. In general there are several ways of valuing but the most used is the geographic context for determining value.

A3.4.1 Geographic context for determining value

The following geographic frame of reference should be used when determining value:

- International importance
- National importance
- County importance (or vice-county in the case of plant or insect species)
- Local importance (higher value)
- Local importance (lower value)

The collection of adequate contextual information is crucial in determining the value of ecological resources at the lower end of the geographic scale. For example, when dealing with locally important resources, it is often not possible to rely on or refer to designated sites or equivalent criteria. So, to value a site, area of habitat, or species population in a meaningful way, it is necessary to have some understanding of the distribution and abundance of that resource on a local and county basis.

This part of the process culminates in the selection of those 'key ecological receptors' for which detailed assessment is required and the design of any further surveys that may be necessary to underpin this assessment. Further advice on the scope, detail, techniques and boundaries of ecological surveys should be reviewed**.**

A3.4.2 Designated sites and features

In the case of designated sites or features, it is appropriate to recognise the level of ecological value accorded by that designation and value the site or feature accordingly within the subsequent assessment; the reasons for the designation then need to be taken fully into account within the impact assessment process. In addition, sites for which the process of designation has commenced should be valued equivalently. In the event that surveys reveal that designated sites no longer meet their criteria for designation, the potential for them to be re-established should be assessed and their current value interpreted in consultation with the relevant designating authority.

A3.4.3 Un-designated sites and features that meet the relevant criteria for designation

The network of site designation in Ethiopia is not exhaustive and it is important that the valuation process does not overly rely on existing site designation. Surveys may reveal sites and features that appear to meet the criteria for designation at a particular level. In this case, the resources should be valued accordingly and their importance confirmed with the potential designating authority.

A3.4.4 Other resources of nature conservation value

Where areas of a particular habitat do not obviously meet criteria for selection as a designated site, or where it is appropriate to value an assembled species or population, it is important to consider the features that tend to characterise valuable ecological resources.
These include:

- Species that are rare at a particular geographic scale, and the habitats or features upon which they depend;
- species undergoing substantial declines in abundance and distribution;
- endemic species;
- species on the edge of their natural range or distribution, particularly where this is contracting;
- large populations of uncommon species;
- species-rich assemblages;
- features exhibiting a high degree of habitat diversity, structural diversity, connectivity and/or valuable juxtapositions of otherwise less intrinsically valuable habitats, that create conditions favourable for rare or protected species.

Wherever possible, values should be assigned to ecological resources on the basis of their known (or perceived) rarity, status and distribution, and hence collating contextual information for the resource at different geographic 'levels' is particularly relevant. In many cases it is appropriate to assign a value to assemblages of species, and these can be of greater value than their constituent parts.

A3.4.5 Other considerations

For sites, features, habitats and populations that are currently below favourable conservation status, their potential to be restored and the potential value they could reasonably attain should be taken into account, and described, in the valuation process. In addition, some features that are of limited intrinsic ecological value may perform important ecological functions for adjacent designated sites (e.g. buffer zones). This should also be taken into account, and explained, in the valuation process.

A3.4.6 Other attributes of ecological resources

People derive benefits from ecological resources in a variety of ways. Some elements of social value are likely to have formed part of the designation criteria for sites identified as important at a county level. For other, non-designated sites, it is also appropriate to take account of considerations of social value, as far as this relates to ecology and nature conservation. For example, a local nature reserve or site of value for conservation education should be taken into account. It is important to ensure appropriate integration with the other relevant topic areas with regard to this issue.

A3.4.7 Examples of important ecological resources

International Importance:

- 'international Site' including Special Area of Conservation, Site of Community Importance (SCI), Special Protection Area, or proposed Special Area of Conservation.
- Proposed Special Protection Area
- Site that fulfils the criteria for designation as a 'international Site'
- Features essential to maintaining the coherence of the Natural environment

- Site containing ‘best examples’ of the habitat types
- Resident or regularly occurring populations
- Species of bird, and/or Species of animal and plants
- Ramsar Site (Convention on Wetlands of International Importance)
- World Heritage Site
- Biosphere Reserve
- Site hosting significant species populations under the Bonn Convention
- Site hosting significant populations under the Berne Convention Biogenetic Reserve

National Importance:

- Site designated or proposed as a Natural Heritage Area (NHA).
- Statutory Nature Reserve.
- Refuge for Fauna and Flora protected under the Wildlife Acts.
- National Park.
- Undesignated site fulfilling the criteria for designation as a Natural Heritage Area (NHA);

  Statutory Nature Reserve; Refuge for Fauna and Flora protected under the Wildlife Act; and/or a National Park.
- Resident or regularly occurring populations (assessed to be important at the national level)
- Species protected under the Wild life Acts; and/or
- Species listed on the relevant Red Data list.
- Site containing ‘viable areas’8 of the habitat types listed in Annex I of the Habitats Directive.

County Importance:

- Area of Special Amenity.
- Area subject to a Tree Preservation Order.
- Area of High Amenity, or equivalent, designated under the County Development Plan.
- Resident or regularly occurring populations
- Species of bird,
- Species of animal and plants
- Species protected under the Wildlife Acts; and/or
- Species listed on the relevant Red Data list.
- Site containing area or areas of the habitat types
- Directive that do not fulfil the criteria for valuation as of International or National importance.
- County important populations of species, or viable areas of semi-natural habitats or natural heritage features identified in the National or Local Sites containing semi-natural habitat types with high biodiversity in a county context and a high degree of naturalness, or populations of species that are uncommon within the county.
- Sites containing habitats and species that are rare or are undergoing a decline in quality or extent at a national level.

Local Importance (higher value):

- Locally important populations of priority species or habitats or natural heritage features identified

- Resident or regularly occurring populations (assessed to be important at the Local level)
- Species of bird,
- Species of animal and plants
- Species protected under the Wild life Acts; and/or Species listed on the relevant Red Data list.
- Sites containing semi-natural habitat types with high biodiversity in a local context and a high degree of naturalness, or populations of species that are uncommon in the locality;
- Sites or features containing common or lower value habitats, including naturalised species that are nevertheless essential in maintaining links and ecological corridors between features of higher ecological value.

Local Importance (lower value):

- Sites containing small areas of semi-natural habitat that are of some local importance for wild life;
- Sites or features containing non-native species that is of some importance in maintaining habitat links.