FOREWORD

The road network in Ethiopia provides the dominant mode of freight and passenger transport and thus plays a vital role in the economy of the country. The network comprises a huge national asset that requires adherence to appropriate standards for design, construction and maintenance in order to provide a high level of service. As the length of the road network is increasing, appropriate choice of methods to preserve this investment becomes increasingly important.

In 2002 the Ethiopian Roads Authority (ERA) published road design manuals to provide a standardized approach for the design, construction and maintenance of roads in the country. Due to technological development and change, these manuals require periodic updating and expanding. The new series of manuals has particular reference to the prevailing conditions in Ethiopia and reflects the experience gained through activities within the road sector during the last 10 years. The updating of existing manuals and preparation of new manuals was undertaken in close consultation with the federal and regional roads authorities and stakeholders in the road sector.

Most importantly, a series of thematic peer review panels was established that comprised local experts from the public and private sector who provided guidance and review for the project team.

The Route Selection Manual is a new addition to the ERA series of manuals. The standards set out shall be adhered to unless otherwise directed by ERA. However, I should emphasize that careful consideration to sound engineering practice shall be observed in the use of the manual, and under no circumstances shall the manual waive professional judgment in applied engineering. For simplification in reference this manual may be cited as ERA’s Route Selection Manual – 2013.

On behalf of ERA I would like to thank DFID, Crown Agents and the AFCAP management team for their cooperation, contribution and support in the development of the manual. I would also like to extend my gratitude and appreciation to all of the industry stakeholders and participants who contributed their time, knowledge and effort during the development of the documents. Special thanks are extended to the members of the various Peer Review Panels, whose active support and involvement guided the authors of the manual and the process.

It is my sincere hope that this manual will provide all users with a standard reference and a ready source of good practice for the geotechnical design of roads, and will assist in a cost effective operation, and environmentally sustainable development of our road network. I look forward to the practices contained in this manual being quickly adopted into our operations, thereby making a sustainable contribution to the improved infrastructure of our country.

Comments and suggestions on all aspects from any concerned body, group or individual as feedback during its implementation is expected and will be highly appreciated.

Addis Ababa, 2013

Zaid Wolde Gebriel
Director General, Ethiopian Roads Authority
**Preface**

The Ethiopian Roads Authority is the custodian of the series of technical manuals, standard specifications and bidding documents that are written for the practicing engineer in Ethiopia. The series describes current and recommended practice and sets out the national standards for roads and bridges. The documents are based on national experience and international practice and are approved by the Director General of the Ethiopian Roads Authority.

The *Route Selection Manual – 2013* forms part of the Ethiopian Roads Authority series of Road and Bridge Design documents. The complete series of documents, covering all roads and bridges in Ethiopia, is as follows:

1. Route Selection Manual
2. Site Investigation Manual
5. Pavement Design Manual Volume I Flexible Pavements
7. Pavement Rehabilitation and Asphalt Overlay Design Manual
8. Drainage Design Manual
10. Low Volume Roads Design Manual
13. Standard Drawings
14. Best Practice Manual for Thin Bituminous Surfacings
15. Standard Bidding Documents for Road Work Contracts – A series of Bidding Documents covering a full range from large scale projects unlimited in value to minor works with an upper threshold of $300,000. The higher level documents have both Local Competitive Bidding and International Competitive Bidding versions.

These documents are available to registered users through the ERA website: www.era.gov.et

**Manual Updates**

Significant changes to criteria, procedures or any other relevant issues related to new policies or revised laws of the land or that are mandated by the relevant Federal Government Ministry or Agency should be incorporated into the manual from their date of effectiveness.

Other minor changes that will not significantly affect the whole nature of the manual may be accumulated and made periodically. When changes are made and approved, new page(s) incorporating the revision, together with the revision date, will be issued and inserted into the relevant chapter.
All suggestions to improve the manual should be made in accordance with the following procedures:

1. Users of the manual must register on the ERA website: www.era.gov.et
2. Proposed changes should be outlined on the Manual Change Form and forwarded with a covering letter of its need and purpose to the Director General of the Ethiopian Roads Authority.
3. Agreed changes will be approved by the Director General of the Ethiopian Roads Authority on recommendation from the Deputy Director General (Engineering Operations).
4. The release date will be notified to all registered users and authorities.

Addis Ababa, 2013

Zaid Wolde Gebriel
Director General, Ethiopian Roads Authority
# ETHIOPIAN ROADS AUTHORITY
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Registration
Director Quality Assurance
Deputy Director General Eng. Ops

Approval / Provisional Approval / Rejection of Change:

Director General ERA: ____________________ Date: ____________________
ACKNOWLEDGEMENTS

The Ethiopian Roads Authority (ERA) wishes to thank the UK Government’s Department for International Development (DFID) through the Africa Community Access Programme (AFCAP) for their support in developing this manual. It will be used by all authorities and organisations responsible for the provision of roads in Ethiopia.

From the outset, the approach to the development of the manual was to include all sectors and stakeholders in Ethiopia. Our own extensive local experience and expertise was supplemented by inputs from an international team of experts and shared through review workshops to discuss and debate the contents of the draft manual. ERA wishes to thank all the individuals who gave their time to attend the workshops and provide valuable inputs to the compilation of the manual.

In addition to the workshops, Peer Review Groups comprising specialists drawn from within the local industry were established to provide advice and comments in their respective areas of expertise. The contribution of the Peer Review Group participants is gratefully acknowledged.

Finally, ERA would like to thank Crown Agents for their overall management of the project.

As with the other manuals of this series, the intent was, where possible, and in the interests of uniformity, to use those tests and specifications included in the AASHTO and/or ASTM Materials references. Where no such reference exists for tests and specifications mentioned in this document, other references are used.

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Addis Ababa, 2013

Zaid Wolde Gebriel
Director General, Ethiopian Roads Authority
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1 INTRODUCTION

1.1 Definition and Scope of Route Selection Studies

The Ethiopian Roads Authority (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. ERA is the pre-eminent road authority in Ethiopia and although certain highway functions are decentralised and Regional and Local road authorities are beginning to play an increasingly important role, issues relating to route selection, even for relatively low status roads, are mainly dealt with centrally by ERA.

This manual primarily 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.

This Route Selection Manual is the first of its kind in Ethiopia, although other documents, including the Low Volume Roads Manual, include relevant discussion.

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

- project identification
- selection of the corridor
- identification of route options within the corridor
- 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.
Table 1-1 shows how corridor and route selection activities fit into the overall project cycle. The tendency in Ethiopia has been to carry out too much design as part of the route selection phase, thereby incurring additional costs in the development of designs for route options that later become rejected. However, the selected route should not be one that is either economically unviable, or unacceptable from an environmental, social or engineering perspective. To resolve this, the feasibility study phase may be made redundant when the route selection is followed by a preliminary design: the route selection allows the viability of the preferred option to be confirmed while the preliminary design provides a more detailed cost estimate to yield the required level of confidence in the economic analysis.
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<td>Identification of the need for a new road, based on strategic, economic and/or social/rural mobility considerations. Definition of route corridor and identification of fixed points through which route options must pass.</td>
<td>Project Planning and Procurement Manual (Volume 1)</td>
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<td>Route Selection</td>
<td>Identification of route options, desk &amp; field studies to yield comparisons of length, cost, stability and geo-hazard, environmental and social considerations, preliminary economic analysis. Selection of preferred option.</td>
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<td>Feasibility Study/ Preliminary Design</td>
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<td>Detailed Design</td>
<td>Detailed design involves geometric design, design of earthworks, drainage, geo-hazard control, environmental mitigation, land acquisition and compensation, detailed BoQ and cost estimate.</td>
<td>Low Volume Roads, Geometric Design, Bridge Design, Drainage Design, Geotechnical Design, Site Investigation, Rigid Pavement, Flexible Pavement, Environmental and Social Management (Manual)</td>
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<td>Construction</td>
<td>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 unforeseen environmental effects.</td>
<td>All, except Route Selection</td>
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<tr>
<td>Improvement/ Upgrading</td>
<td>This may require road realignment, either locally or over longer distances, to allow for a higher geometric specification. This could involve pre-feasibility level studies as well as Feasibility Study and Design.</td>
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### 1.1.1 Corridor Definition and Identification

For the purpose of this manual, a route corridor is defined as the length and width of an area of terrain that needs to be studied in order to be able to identify route options within it. There are no minimum or maximum dimensions to the width of the corridor, as this is determined usually by the geographical structure of the existing road network, intended road purpose, or road category, topography and the envisaged constraints imposed by social and environmental factors.

The data resources available for identifying a corridor are:
- existing topographic and other specialized mapping, including those for national parks and other protected areas
- satellite imagery
- site reconnaissance
- local information
- government and regional development plans.
The identification of route corridors is covered in 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 programmes.

The outcome of this corridor identification process is:

- the definition of the start and end points of the project corridor
- the identification of any other defined intermediate control points (e.g. towns and villages) through which various route options are required to pass
- the definition of any constraints (topographical, environmental or administrative) that might dictate where route options cannot be located.

The selection of the corridor is usually 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.

### 1.1.2 Route Definition and Identification of Options

Route options are defined as approximate alignments within the route corridor that are compared in order to select the preferred route. The ‘footprint’ of each route option should be defined sufficiently to allow its feasibility (engineering, social and environmental) and approximate cost to be assessed taking into account the topography and geometric constraints. In addition to intermediate towns and other nodal points to be connected, other control points may occur as a result of geographical considerations (e.g. a major river crossing point or a col that will serve as a mountain pass). When the detailed design of the preferred route is carried out during the next project phase (see Table 1-1), the designer is expected to follow the same alignment to the extent practicable, but is permitted to make minor changes where there are engineering and environmental imperatives for doing so.

The ERA Geometric Design Manual 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 ToR for road design consultants define 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 usually required to identify at least three possible alignment options which satisfy the requirements of connecting the stated start and end points via any specified control points, as well as satisfying the required geometric design standards. Where the project involves the upgrading of an existing track or road, the identification of three alignment options may be unnecessary, but selected realignments may be appropriate and, in these cases, more than one route should be examined.

Ordinarily, the order of activity for route option identification is:
• Locate the control points through which route options must pass, such as towns or villages and road network interchanges, where applicable
• Identify topographical and environmental constraints that control route options, such as low points in mountain terrain in order to minimise rise and fall, or sites of environmental protection through which route options cannot pass
• Identify the most suitable locations for major river crossings or fan crossings
• Once these constraints and controls are satisfied, identify three initial route options from topographical maps or suitable satellite imagery, plus broad consideration of environmental, engineering geological and hydrological factors.

1.2 Procedure for Route Selection

The preferred route option is usually selected through the following activities:

• carry out desk study with selected field investigations of the options, considering all relevant factors
• combine all assessments of individual factors into an overall assessment for final route selection.

Chapter 4 gives the recommended contents of a Route Selection Report for submission to ERA.

1.3 Criteria for Route Selection

Table 1-2 lists the criteria most commonly taken into consideration during route selection and also lists the chapters in this manual where guidance and illustration is provided on each.

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<td>Minimum cumulative rise and fall</td>
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<tr>
<td>Minimum length of steep gradients</td>
<td>5 and 9</td>
</tr>
<tr>
<td>Minimum length of reduced horizontal standard due to topographic and other constraints</td>
<td>5 and 9</td>
</tr>
<tr>
<td>Minimum number and span of required bridges (though ordinarily covered in cost)</td>
<td>7 and 9</td>
</tr>
<tr>
<td>Ease of construction and required construction technology</td>
<td>9</td>
</tr>
<tr>
<td>Minimal environmental, social impact and cultural constraints – though most of the major constraints should have been avoided during corridor selection</td>
<td>8</td>
</tr>
<tr>
<td>Socio-economic benefits to be accrued</td>
<td>8 and 10</td>
</tr>
<tr>
<td>Minimal unfavourable geological conditions and geo-hazards</td>
<td>6 and 7</td>
</tr>
<tr>
<td>Construction materials availability</td>
<td>6</td>
</tr>
</tbody>
</table>
1.4 Related ERA Guidelines

The ERA design manuals 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>
<thead>
<tr>
<th>Manual title</th>
<th>Relevance to route selection</th>
<th>Relevant chapter in this manual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality Manual</td>
<td>Provides a summary of what is to be included in route selection studies and reporting for RSDP IV Projects (Ch 2)</td>
<td>All</td>
</tr>
<tr>
<td>Low Volume Roads Design Manual</td>
<td>Very useful all-round manual for low volume roads, but of limited value to route selection.</td>
<td>All</td>
</tr>
<tr>
<td>Geometric Design Manual</td>
<td>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.</td>
<td>9</td>
</tr>
<tr>
<td>Bridge Design Manual</td>
<td>Relates specifically to the design of bridges, limited discussion on site selection for river crossings, of limited value for route selection.</td>
<td>7</td>
</tr>
<tr>
<td>Geotechnical Design Manual</td>
<td>Relates specifically to the description and mitigation of problematic soils and slopes, design of earthworks and foundations for structures, limited value for route selection.</td>
<td>6</td>
</tr>
<tr>
<td>Site Investigation Manual</td>
<td>Useful description of regional variation in geography and geology, ground conditions, geo-hazards and sources of published data – useful for route selection.</td>
<td>6</td>
</tr>
<tr>
<td>Drainage Design Manual</td>
<td>Relates specifically to the design of road cross drainage, of limited value for route selection.</td>
<td>7</td>
</tr>
<tr>
<td>ERA Project Planning and Procurement Manual (Volume 1)</td>
<td>Provides very useful background to the strategic, network planning and economic basis for project identification, though not route selection.</td>
<td>2</td>
</tr>
<tr>
<td>ERA Environmental and Social Management Manual</td>
<td>Provides outline description of environmental and social issues relating to infrastructure development, impact assessment procedures, as well as planning applications, roles and responsibilities. No guidance on route selection specifically.</td>
<td>8</td>
</tr>
</tbody>
</table>

It is important to ensure that the latest editions of the manuals are consulted.

1.5 Contents of this Manual

Chapter 2 of this manual provides a review of the factors normally considered in corridor selection 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 Chapter 4 gives details of a typical Route Selection Report. The remainder of the manual (Chapters 5-10) deals with the studies and processes required to complete a Route Selection Report and the identification of the preferred route.
2 CORRIDOR SELECTION

2.1 Introduction

This chapter deals with the process of corridor definition and identification. 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 involves a range of traffic forecasting, connectivity, economic and strategic environmental and engineering issues and should take into account the 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 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 existing Ethiopian road network 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 borders.

From this, 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, and Classes D and E as Regional Roads which were to be looked after by the Regions or local administrative bodies. However, in reality, the current role of ERA sometimes requires it to become involved in the lower two classes of road (Classes D and E) as well. Through District Maintenance Offices (DMO), ERA maintains some Class C, D and E roads plus some that are unclassified.
For any new road it is important to determine its required standard in general terms at an early stage, 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 is then confirmed or modified once preliminary traffic data are obtained and analysed. Generally, the design standard adopted for a project should not vary from that of an adjoining project by more than a single standard.

2.3 Strategic Decision Making

ERA and the regional road authorities face a number of interlinked issues and challenges in the development of the national road network:

- the size of the country (1.1 million km$^2$)
- the considerable diversity of terrain and altitude with a significant proportion of land area classified as mountainous/escarpment
- low levels of disposable income and vehicle ownership
- road network density and accessibility, which are 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 areas of agricultural surplus and areas of food insecurity, including those prone to drought
- connections between trunk roads.

2.4.1 Road Sector Development Program

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 and 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 RSDP phases to date have covered:

- RSDP I (1997-2002): restoration of the road network
- RSDP II (2002-2007): increased network connectivity and provision of a sustainable road infrastructure to rural areas
• RSDP III (2007-2010): management of the road network and strengthening development of the domestic construction industry
• RSDP IV (2010 – 2015): improved transport operating efficiency, provision of access to Kebele centres, development of technical capacity.

2.5 Corridor Identification

2.5.1 Introduction

Potential road projects are initially identified in a number of ways:

• through ERA’s strategic road network planning analysis
• via the initiatives of other ministries
• from proposals by regional governments
• from requests by community representatives.

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

• economic investment development criteria
• socio-economic development criteria
• areas of environmental sensitivity.

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 carries 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
• likelihood of the anticipated project benefits being achieved.

The process is illustrated in Figure 2-1, modified from ERA’s “Project Planning and Procurement Manual Volume 1 – Planning”. Of considerable importance to 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 result in the identification of the required start, finish and intermediate control points, such as villages, towns and network connections that help define the corridor. In defining the areal extent of the corridor, including those areas in which route options should not be considered, the following should be avoided as part of a Strategic Environmental Assessment (see also Chapter 8):

- protected, or otherwise sensitive, environmental and cultural areas or monuments, including areas of outstanding natural beauty and/or ecological value
- areas of geological and hydrological hazard, especially areas prone to landslides and flooding.

Although these considerations are usually more relevant to route option identification and selection, they can also be relevant to corridor identification and definition.
2.5.2 Application of Multi-Criteria Analysis in Corridor Selection

Where more than one corridor option can be identified, multi-criteria analysis can be used to assist in selection, based on factors that cover the objectives of road network development policy.

Socio-economic return on investment:
- level of transport demand - the relative level of traffic using the infrastructure, determined according to ranges of existing traffic
- 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
- degree of urgency - whether a project has to be implemented as soon as possible or whether its implementation may be delayed
- relative importance of investment cost - whether the project is expensive or inexpensive given its type and size and the costs of similar projects
- environmental effects - whether or not the project conflicts with social safeguards and any other environmental and conservation issues
- 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.

Functionality and coherency of the network:
- international importance of the link associated with the project, politically as well as economically
- relative importance of the international demand of traffic – passengers and goods - indicates the amount of international transport (by passenger and goods) in the total transport demand for the project
- likelihood of the project generating the anticipated development potential, i.e. are the expected project benefits likely to be achieved bearing in mind economic, social, political or environmental factors?
- interconnection of existing networks - extent to which the project improves communications between one regional/national network and another
- meeting ERA standards of service - whether the proposed link allows the network to be able to provide a level of service at or close to the standards defined by ERA in terms of comfort, speed or safety.

These criteria can be used in conjunction with ERA’s five road network development priorities outlined at the beginning of Section 2-4. The ERA 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 Multi-Criteria Analysis (MCA) at a wider level under ERA:

- environmental status
- right of way status
- road pavement condition.
3 IDENTIFICATION OF ROUTE OPTIONS

3.1 Introduction

Once the corridor is defined (Chapter 2), there is a requirement to identify route options within that corridor. The assessment of each of these options (Chapters 5 to 9) needs to be at a sufficient level of detail to allow objective and confident comparisons between them to be made, leading to the Route Selection Report (Chapter 4) and the selection of the preferred option for later detailed design.

In Ethiopia, for a road on a completely new alignment, a minimum of three options is required to be considered. Previous practice has been 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 9 and 10). 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 identification stage (Chapter 2), but a greater level of detail will be required for route option identification. In fact, in some cases, the process of route option identification is equally, if not more, important than route comparison (Chapters 5 to 9) and ultimately route selection itself (Chapter 10).

Route option identification is usually undertaken by consultants on behalf of ERA, and should take into account:

- ease of topography
- practicality of designing an alignment according to the required geometric standard within the topography
- avoidance (or mitigation) of areas of known geo-hazard, including landslides, flooding and problematic soils
- avoidance of environmentally protected areas and other sensitive habitats
- avoidance of the location or areas of cultural heritage value (including archaeological sites, sites of historical importance, religious sites and other locations of ethnic or community value)
- the need to maximise connectivity of villages and towns and improve rural mobility
- the need to maximise traffic connectivity and access to economic resources and markets
- the need to select the shortest distance alignment, bearing in mind the factors given above.

This list is not necessarily 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, at least 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 factors are discussed in more detail in Chapters 6 and 8, but are critically important to the identification of options in the first place.
3.2 Road Geometry

The determination of a road design standard (see ERA Geometric Design Manual) will normally be undertaken during project identification stage (Chapter 2) and will be an important factor in the identification of route options within the defined corridor. Confirmation of the intended road standard may either rule out or rule in certain route options based on topography. During route option identification stage it is important to ensure that the options will be feasible, considering both the ruling geometry and the constraints imposed by the terrain. This exercise is probably best done using topographical maps and a desk study assessment. However, satellite imagery will also be useful in this exercise (see discussion in Chapter 5). Walkover reconnaissance surveys may be required to confirm any uncertainties from the desk study.

3.3 Other Factors

As mentioned in Section 3.1, other factors may 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 type of information available and its level of detail are likely to be insufficient and so field surveys should also be undertaken. These are designed to collect sufficient information to enable major problem areas to be identified. These might include:

- very steep and complex topography (Chapter 5)
- valley sides or slopes that are prone to extensive and deep-seated landslides (Chapters 5 and 6)
- active fault zones and areas subject to volcanic activity (Chapter 6)
- terrain significantly underlain by problematic soils, such as compressible and collapsing soils (Chapter 6).
- areas liable to frequent inundation by floods (Chapter 7)
- areas of high agricultural value (Chapter 8)
- areas where water resources might be adversely affected (Chapter 8)
- any environmentally protected areas and cultural heritage sites that have not been avoided through corridor selection (Chapter 8)
- areas of forest (Chapter 8)
- urban areas (Chapter 8).

Examples of some of the more common issues concerning route identification are given in Figure 3-1.
Figure 3-1 Examples of Typical Route Identification Issues

Field surveys should ordinarily be undertaken in two phases. The first, reconnaissance-level, survey should be undertaken to gain an overall appreciation of the economy in the region, the overall geology and topography, as well as to identify any of the issues listed above. This reconnaissance survey should be used to help identify the route options and make field observations in terms of:
• comparison between published topographical mapping and actual topography
• most suitable bridge locations
• cols or saddles in mountain terrain that act as alignment control points in defining route options
• rock and soils types in general
• any apparent or locally-reported landslide activity and areas of slope or river/stream erosion
• land use
• the presence of existing infrastructure, such as built up areas, roads, quarries, drainage structures or utility supply structures not identifiable from desk study sources.

For low standard roads it may also be necessary to identify route options that avoid large areas of expansive (typically black cotton), compressive and collapsing soils, as mitigating the effects of these could represent a significant proportion of the overall construction cost.

The second phase of field survey is a more detailed assessment of the route options themselves and is described in Chapters 6 to 8.

The field reconnaissance surveys for route option identification should be undertaken by a multi-disciplinary team, typically comprising:

• Highway Design Engineer
• Engineering Geologist
• Hydrologist/Drainage Engineer
• Environmental/Social Specialist
• Traffic Engineer (if traffic surveys are necessary).

The time period required for this reconnaissance survey will vary according to the road design standard, the size of the area being studied and the extent of data already available from the desk study. Some of the more common factors to be considered during a reconnaissance survey are listed in Table 3-1.
Table 3-1 Route Option Reconnaissance Survey

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub-category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alignment</td>
<td>Terrain classification</td>
</tr>
<tr>
<td></td>
<td>Alignment type</td>
</tr>
<tr>
<td></td>
<td>Design standard</td>
</tr>
<tr>
<td>Structures</td>
<td>Required major river crossings and required spans</td>
</tr>
<tr>
<td>Construction Materials</td>
<td>Sources</td>
</tr>
<tr>
<td></td>
<td>Access arrangements</td>
</tr>
<tr>
<td>Geotechnical</td>
<td>Landslides</td>
</tr>
<tr>
<td></td>
<td>Problematic soils</td>
</tr>
<tr>
<td></td>
<td>General founding conditions</td>
</tr>
<tr>
<td></td>
<td>Slope materials</td>
</tr>
<tr>
<td>Hydrology/drainage</td>
<td>Natural drainage pattern</td>
</tr>
<tr>
<td></td>
<td>High water levels</td>
</tr>
<tr>
<td></td>
<td>Bridge locations (see above)</td>
</tr>
<tr>
<td>Environmental/Social</td>
<td>Land use</td>
</tr>
<tr>
<td></td>
<td>Population distribution</td>
</tr>
<tr>
<td></td>
<td>Water resources</td>
</tr>
<tr>
<td></td>
<td>Sensitive habitats</td>
</tr>
<tr>
<td></td>
<td>Protected/reserved areas</td>
</tr>
</tbody>
</table>

3.4 Illustration from the Arba Minch – Konso Road

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 Gato 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 should have included:

1. An upgrade of the existing road between Wozeka and Gato, with the additional construction of a new spur road to Gedole from Wozeka (an elevation difference of approximately 1,000m)
2. As 1 but with a new spur road to Gedole from Gato rather than Wozeka
3. Construction of a new road from Wozeka to Gedole and from Gedole to Gato.

Option 3 was selected due to administrative reasons 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 3-2 and 3-3). There are possibly two fault scarps and large down-faulted blocks that affect the stability of the area. Some of these failed masses have become reactivated by road construction excavation. A route option following the existing track between Wozeka and Gedole should never have been identified on geotechnical and environmental grounds, although it is conceivable that an alternative, more circuitous alignment might have been able to avoid some of the instability. This emphasises the importance of considering geology, hydrology and
geomorphology in an assessment of potential geo-hazards at the route option identification stage (Box 3-1).

Figure 3-2 Landslides Triggered by Construction of the Section of Road Between Wozeka and Gedole

Figure 3-3 Geomorphological Interpretation of the Wozeka – Gedole Area
Geology of the area
There is presently no large-scale geological map of the area and therefore a tentative geological interpretation has been made based on the 1:2,000,000 scale Geographical Map of Ethiopia (2005) and satellite imagery. This interpretation is shown opposite. The section of road where problems have occurred appears to be within the late Eocene Jimma Basalts stratigraphical unit (Pjb). These rocks were subjected to at least 20 million years of humid tropical weathering prior to commencement of rifting in the middle Miocene. Most of the lineaments identified in the map opposite are probably extensional faults that have been active within the last 10,000 years, i.e. during the Holocene. They generally trend either NNW-SSE, reflecting the orientation of the Main Ethiopian Rift (MER) and its border faults, or NNE-SSW, possibly guided by ancient fractures in the underlying Precambrian basement. There are also N-S and E-W lineaments representing a change in the tectonic regime at the southern end of the MER. Gedole is in the highest seismic risk area (zone 4) of EBCS-8: 1995. Five shallow (10km) earthquakes of magnitude 4.1-5.2 have been recorded over the last 25 years.

Box 3-1 Geology of the Arba Minch – Wozeka – Gedole Area
4 ROUTE SELECTION REPORT

4.1 Introduction

This section deals with the recommended contents of a Route Selection Report so that the reader can fully appreciate the context of the chapters that follow.

The contents of a Route Selection Report will vary from project to project, and may have to deal with specific issues that are contained in the route selection Terms of Reference provided by ERA. For example, a Route Selection Report for a 100km length toll road will have to be far more comprehensive than one for a minor single carriageway road; a report for a completely new alignment over mountainous and escarpment terrain will differ considerably from a report for the upgrading of an existing road on flat or rolling terrain. Consequently, the contents that follow present an idealised situation, and will need to be adjusted for the particular project for which the report is being prepared.

4.2 Recommended Contents

A recommended contents list is given below, together with a brief explanation, sometimes as a list of questions, of what each item might cover. Where topics are described in more detail elsewhere in this manual, chapter references have also been given. Finally, a Route Selection Report flow chart is given in Figure 4-1. Note that the Initial Environmental Examination carried out for social and environmental assessment (Chapter 8) should be included as an appendix to the Route Selection Report, and reference made to it where required in the main text.

1. Introduction
   • Project background: What is the background to the project? What decisions have already been taken prior to the requirement of this study?
   • Study objectives and key considerations: What are the objectives and key considerations of the study? Are these listed in the Terms of Reference?
   • Project location: Where is the project located within Ethiopia? A map (minimum scale 1:250,000) of the project location should be included showing all the relevant features.
   • Fixed points: What control points have been specified in the Terms of Reference? These will include the start and end points and may include some intermediate points (e.g. towns or villages). There may also be some no-go areas specified in the Terms of Reference, such as National Parks or other environmentally sensitive areas. Have others been identified during the course of the study?
   • Options: What options and alternatives have been considered in the study?

2. Desk Studies, Reconnaissance Surveys and Stakeholder Consultations
   • Desk studies (Chapters 2, 3, 5-9): Fully describe the desk study work undertaken throughout the assignment and the sources of information used. Discuss the results of the desk studies and how successful they were in yielding the information required.
   • Reconnaissance and detailed surveys (Chapters 3 and 6-8): What field reconnaissance and detailed surveys were carried out; when and for how long? Which members of the project team were involved? What were the purposes of the surveys and how successful were they in yielding the information required? The
outcome of these surveys will need to be described in each of the relevant sections outlined below.

- Stakeholder consultations: Summarise the stakeholder consultations undertaken and their findings, using information contained in the IEE appendix.

3. **The Project Area**

   Section 3 is concerned with the project area as a whole.

3.1 **Socio-economics (Chapter 8)**

   - Location: The location of the corridor may have a large influence on the surrounding area, and it is the location of this entire project area that needs to be described here. A map will be required showing population centres and other geographical features.
   - Population: What is the total population within the project area? How does this vary within the area? What are the main ethnic groups?
   - Economy: What are the main drivers of the local economy within the project area?
   - Natural resources: What natural resources are located within the project area? These might include rivers for irrigation or power development, forested areas, agricultural areas, minerals.
   - Factors that could affect future economic growth: these might include some of the items mentioned under natural resources; some factors might be reliant on the new road being constructed; population growth, tourism potential. Climate change could also be a factor. Reference should also be made to any federal, regional and local development plans that might affect the project area.

3.2 **Environment (Chapter 8)**

   A map or a series of maps will be required to show the location of the environmental constraints given below.

   - National Parks and other protected areas: National Park boundaries, boundaries of other protected areas and their status. How have they been avoided?
   - Forested areas: Where are the forested areas located and will they impact on the route options? Are they legally protected? Can they be avoided?
   - Land use: What is the land use in the project area (e.g. urban housing, commercial development, forest, agricultural crops, grazing land, scrub) and what impact will the route options have on these land uses?

3.3 **Physical Characteristics**

   A map or series of maps will be required to show the physical characteristics listed below together with the locations of each route option.

   - Terrain (Chapter 5): Describe the overall terrain within the project area, particularly with respect to topography.
   - Climate: Describe the climate within the project area, particularly with respect to the rainfall and rainfall variation.
   - Geology (Chapter 6): Describe the geology within the project area, particularly with respect to the location and trend of the various geological formations, faults and other structures, and how they impact on the route options.
• Soils and construction materials (Chapter 6): This is an immediate follow-on from the previous topic and should describe the soils and availability of naturally occurring construction materials (e.g. rock, gravel, sand, water) that can be found within the project area.
• Hydrology (Chapter 7): Describe the overall hydrology of the project area with particular regard to the major drainage courses and overall catchment areas.

4. Route Options

Section 4 is concerned with the individual route options and each sub-section should cover all the options that have been considered.

4.1 Socio-economics (Chapter 8)
• Population centres: What are the environmental constraints on the development of the route options in terms of population centres? These might include some relatively minor villages and other settlements. What are the requirements of each option in terms of approximate number of households to be resettled?
• Socio-economic benefits: Are there any major positive (i.e. beneficial) socio-economic factors that control the selection of the preferred route? If so, explain.
• Economic development: Which option provides the greatest potential in terms of economic development, both locally and regionally?
• Community access: Which of the route options provides the greatest transport opportunities for rural communities, including access to schools, health facilities, places of work?
• Cultural heritage sites: Where are the cultural heritage sites located? Have they been avoided? How do route options impact on them?
• Public/traffic safety and health: How do the route options compare in terms of traffic safety and the safety of pedestrians? Would road construction and operation adversely affect neighbouring populations in terms of air pollution, noise and water quality?
• Socio-economic constraints: Are there any major socio-economic constraints that prevent one or more of the options from being selected, i.e. impacts cannot be mitigated?
• Requirements for impact mitigation: Outline the anticipated requirements for impact mitigation, including provision of cost estimates.

4.2 Environment (Chapter 8)
• National Parks and other protected/sensitive areas: Where are these and have they been avoided? How do route options impact on them?
• Areas of high Landscape Value: Describe these in relation to each option. What other landscape impacts is each option likely to have?
• Aquifers and water resources: Are there any protected aquifers or other potable water sources that are likely to be impacted by each option?
• Land use: What are the lengths/areas of different land use categories (for example forest/prime agricultural land, grazing land, urban, industrial) affected by each route option and how will each option affect land use management?
• Erosion and desertification: Is either of the route options more prone to erosion and desertification, either in its existing ‘natural’ state or as a result of road construction? Can this be managed with effective mitigation?
Environmental constraints: Are there any major environmental constraints that prevent one or more of the options from being selected, i.e. impacts cannot be mitigated?

Requirements for impact mitigation: Outline the anticipated requirements for impact mitigation, including provision of cost estimates.

4.3 Engineering

Road design standard (Chapter 9): The road design standard adopted must be stated, and the reasons for adopting such a classification given. This should have been specified by ERA in the Terms of Reference, but may require verification by the route selection consultant. Any likely required departures from the appropriate geometric design standard (perhaps due to mountainous terrain, for instance) should also be described.

Traffic survey and forecast (Chapter 9): A traffic survey may be specified in the Terms of Reference, or it may be necessary to confirm the adopted road design standard. Full details of the survey must be given, including traffic count locations, the duration and findings of the survey. Details of the existing traffic, induced and generated traffic, and forecast traffic must also be given. The survey and forecast must take account of any variations that may occur between the route options.

Terrain (Chapter 5): Describe the overall terrain for each route option, followed by a breakdown of the length of each route in flat, rolling, mountain and escarpment terrain.

Geology (Chapter 6): Describe the geological formations traversed by each route option, together with any implications these might have on the scope of the future requirements for detailed design and the cost of construction. Specific geo-hazards (e.g. landslides and other unstable slopes) should be described later.

Soils (Chapter 6): Describe the soils found along each route option, together with any implications these might have on the scope of the future requirements for detailed design and the cost of construction. Specific geo-hazards (e.g. problem soils) should be described later.

Materials (Chapter 6): Describe the availability of naturally occurring construction materials within a few km of each route option.

Hydrology and major river crossings (Chapter 7): Describe the hydrology traversed by each route option, together with any implications (e.g. flooding, necessity for closely spaced cross culverts) these might have on the scope of the future requirements for detailed design and the cost of construction. Describe each major river crossing, including the overall required span, the difficulty or ease of foundation construction, the need or otherwise for river training/protection works.

Geo-hazards (Chapters 5 and 6): These are hazards that could, or will, arise as a result of siting the road at a particular geographic location. They could include problem soils (expansive soils, compressible or dispersive soils) and potential or actual unstable slopes. The hazards should be fully described and outline solutions given as to how they should be overcome in the detailed design. The implications of these on the cost of construction must also be discussed. Geo-hazards will also include seismicity, and the implications of seismic activity on the scope of the future requirements for detailed design must also be stated.

Engineering constraints: Are there any engineering reasons why a particular route option has been rejected? If so, explain.
4.4 **Cost estimate** (Chapter 9)

- Cost estimate methodology: Describe the methodology adopted for the cost estimate, e.g. the cost items used and the allowance made for contingencies and VAT. State the precise sources for the prices used in the cost estimate.
- Cost items adopted: Describe the various cost items adopted and the basis upon which each item has actually been costed.
- Cost estimate: Produce in tabular format a summary BQ in which it is clear how the cost and quantity for each item (e.g. earthworks) has been derived for each route option. Show how the environmental mitigation costs, any other contingencies and VAT have been added to produce the final amount.

4.5 **Economic Evaluation** (Chapter 10)

- Economic viability: Which of the options is preferable in terms of CBA, EIRR% and traffic volumes?

5. **Preferred Route Option** (Chapter 10)

- Evaluation criteria: Describe the evaluation criteria utilised. Give clear details in tabular format of the evaluation weightings used in the multi-criteria analysis and reasons for adopting each weighting.
- Evaluation of route options: Clearly indicate in tabular format the results of the multi-criteria analysis and how the allotted ranking has produced the final scoring for each route option. The process leading to the final scoring should also be described.
- Conclusions and recommendations: Discuss the results of the evaluation and list the conclusions and recommendations for the preferred route option. Identify any areas of uncertainty that might lead to a significant change in feasibility or outturn cost, and the measures that might be required to resolve this uncertainty (e.g. ground investigation).
Figure 4-1 Route Selection Report Flow Chart
5  TOPOGRAPHY

5.1  Topography of Ethiopia

The general topography of Ethiopia is shown on Figure 5-1. Within a region of elevated plateaux between the valley of the Upper Nile and Ethiopia’s border with Eritrea rise the various tablelands and mountains that constitute the Ethiopian Highlands. On nearly every side, the walls of the plateaux rise abruptly from the plains, constituting outer mountain chains. The eastern wall of this plateau follows closely the 40° E longitude 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 - within which are a series of lakes - to about 3° N. The outer (eastern) spurs of the plateau still maintaining the 40° E longitude. 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 within which is Lake Turkana and, east of that lake, the southern Debub Omo Zone.

\footnote{Some of this text is based on a Wikipedia entry found under ‘Geography of Ethiopia’}
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 the northern face, the plateau drops 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 valleys, through which descend mountain rapids that dissipate in the sandy soil of the Eritrean coast, provide means of reaching the plateau, alternatively 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 deep gorges which divide it. Some of these gorges 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 distinct chasms in Ethiopia. The highest peaks of the Bale Mountains rise to 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.

The ERA design manuals divide the topography of Ethiopia into four types of terrain (Figure 5.2):

- **Flat** terrain without horizontal and vertical restrictions on route selection, with 0-10 five-metre contours per km (0-5% grade equivalent). The natural ground slopes perpendicular to the ground contours are generally below 3% (2° 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 (5.5-12.5% grade equivalent). The natural ground slopes perpendicular to the ground contours are generally between 3 and 25% (2° to 14° 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 (13-25% grade equivalent). The natural ground slopes perpendicular to the ground contours are generally above 25% but below 75% (14° to 37° slope).
- **Escarpment** terrain that is steep topography requiring switchback sections and side hill traverses; transverse terrain slopes are greater than 75% (37° slope).
In some circumstances it can be difficult to decide absolutely which type of terrain a particular topography is located, and over what length the terrain changes from one type to another. The transition between rolling and mountain terrain can be progressive, with elements of both rolling and mountainous terrain persisting over tens of kilometres in some circumstances. In theory at least, mountainous and escarpment terrain are more easily distinguishable because the ascent or descent through escarpment terrain is usually continuous, i.e. from the base of the escarpment to the top of it or vice versa, whereas the vertical profile through mountain terrain can combine both rise and fall as spurs, ridges and valleys are crossed. However, in terms of slope steepness, there is so much overlap between mountainous and escarpment terrain that it may be more convenient to combine these two terrain types.

Figure 5-3 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 and shows the proposed road substantially following a ridge alignment before descending into the gorge in a series of switchbacks. Significantly, the alignment has to descend two limestone cliffs and the locations of these descents were a critical factor in route selection. Figure 5-4 illustrates some of the terrain depicted in this model. Appendix 1 contains terrain models developed for other parts of Ethiopia, emphasising the importance of topography and geology in the identification and selection of road alignments. Further discussion of landscape modelling as an aid to route selection is given in Chapter 6.
5.2 Topography and Route Selection Implications

The type of topography encountered in the route selection process will normally have a profound influence on the choice of alignment (see Tables 5-1 to 5-3).
### Table 5-1 Flat Terrain

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

* See Chapter 6 for further details on problem soils

### Table 5-2 Rolling Terrain

<table>
<thead>
<tr>
<th>Geographic feature</th>
<th>Facet</th>
<th>Typical problems encountered</th>
<th>Likelihood of existing instability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low hill</td>
<td>Rounded relief</td>
<td>Deeply weathered soils likely; some erosion potential</td>
<td>Unlikely</td>
</tr>
<tr>
<td>Shallow valley</td>
<td>Rounded relief</td>
<td>Deeply weathered soils likely; some erosion potential; possibility of expansive soils</td>
<td>Unlikely</td>
</tr>
<tr>
<td></td>
<td>Streams and minor rivers</td>
<td>Possible compressive alluvial soils. High water tables, flooding hazards</td>
<td>Unlikely</td>
</tr>
</tbody>
</table>

### Table 5-3 Mountainous and Escarpment Terrain

<table>
<thead>
<tr>
<th>Geographic feature</th>
<th>Facet</th>
<th>Typical problems encountered</th>
<th>Likelihood of existing instability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ridge top</td>
<td>Rounded relief</td>
<td>Deeply weathered soils likely; some erosion potential</td>
<td>Unlikely</td>
</tr>
<tr>
<td></td>
<td>Sharp relief</td>
<td>Rock at surface; costly and difficult rock excavation possible</td>
<td>Unlikely</td>
</tr>
<tr>
<td></td>
<td>Irregular relief</td>
<td>Difficult alignment along ridge top between high points and low points</td>
<td>Possibly</td>
</tr>
<tr>
<td></td>
<td>Asymmetric relief</td>
<td>Joint-controlled slopes will influence stability of alignments and cut slopes</td>
<td>Possibly - check for evidence of back scarps and failed material</td>
</tr>
<tr>
<td></td>
<td>Ridge lines generally</td>
<td>May be subject to greater rainfall than valley sides</td>
<td>Possibly</td>
</tr>
<tr>
<td>Geographic feature</td>
<td>Facet</td>
<td>Typical problems encountered</td>
<td>Likelihood of existing instability</td>
</tr>
<tr>
<td>--------------------</td>
<td>-------</td>
<td>-----------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>Ridge lines generally</td>
<td>May be more affected by seismicity (topographic amplification)</td>
<td>Possibly</td>
<td></td>
</tr>
<tr>
<td>Stepped escarpment</td>
<td>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</td>
<td>Possibly – check for debris mass on intermediate benches and rock fall hazards from cliff faces</td>
<td></td>
</tr>
<tr>
<td>Failed escarpment</td>
<td>Deep tension cracks behind cliff faces, very difficult topography for alignment design, seepage zones and highly variable rocks and chaotic boulder/debris deposits within cut slopes, failed/failing slopes and materials, poor founding conditions (Fig 5-5)</td>
<td>Definitely – check for widespread instability, including failed cliffs</td>
<td></td>
</tr>
<tr>
<td>Slopes are steeper than 40°</td>
<td>Probably underlain by rock; therefore likely to be more costly to construct but less costly to maintain</td>
<td>Unlikely</td>
<td></td>
</tr>
<tr>
<td>Slopes 35° to 40°</td>
<td>Potential to be shallow taluvium on rock</td>
<td>Possibly</td>
<td></td>
</tr>
<tr>
<td>Slopes 20° to 35°</td>
<td>Potential to be deep taluvium, colluvium or failed slope</td>
<td>Possibly</td>
<td></td>
</tr>
<tr>
<td>Continuous rock slopes with persistent jointing approximately parallel to slope</td>
<td>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</td>
<td>Possibly - check for back scarps and failed debris downslope</td>
<td></td>
</tr>
<tr>
<td>Embayments</td>
<td>Either erosional in origin or formed by landslide(s)</td>
<td>Probably</td>
<td></td>
</tr>
<tr>
<td>Areas of irrigated farmland</td>
<td>Drainage problems likely; soils possibly taluvial/colluvial in origin and potentially unstable locally, depending on slope</td>
<td>Possibly, but mass as a whole may be stable</td>
<td></td>
</tr>
<tr>
<td>Forested areas on otherwise cultivated hillside</td>
<td>Possibly areas of wet ground, steep slopes, instability that cannot be cultivated</td>
<td>Possibly</td>
<td></td>
</tr>
<tr>
<td>Rounded spurs</td>
<td>Probably formed in residual soils and stable</td>
<td>Unlikely</td>
<td></td>
</tr>
<tr>
<td>Elongated mid-slope benches</td>
<td>Either ancient river terraces or rock benches; both stable and ‘easy’ for road construction, though may contain expansive soils</td>
<td>Unlikely</td>
<td></td>
</tr>
<tr>
<td>Local mid-slope benches</td>
<td>Could be as above, or part of deep seated landslide</td>
<td>Possibly</td>
<td></td>
</tr>
<tr>
<td>Geographic feature</td>
<td>Facet</td>
<td>Typical problems encountered</td>
<td>Likelihood of existing instability</td>
</tr>
<tr>
<td>--------------------</td>
<td>----------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td><strong>Valley floor</strong></td>
<td>Steep slopes forming margins of river channel (i.e. no river terrace)</td>
<td>Possibly unstable; difficult for road alignments, especially on meander bends; possible flood risk and high water table</td>
<td>Likely</td>
</tr>
<tr>
<td></td>
<td>Steep slopes forming valley side margins to river terrace</td>
<td>Possible ancient landslides and high water table</td>
<td>Possibly</td>
</tr>
<tr>
<td></td>
<td>River terrace</td>
<td>Possible flood risk, soft/loose soils and terrace edge scour; high water table</td>
<td>Unlikely, except at terrace edges</td>
</tr>
<tr>
<td></td>
<td>Tributary streams</td>
<td>Possibly active debris flows and debris fan deposition causing scour and blockage/damage to road structures; possible flood risk and high water table</td>
<td>Debris flows only</td>
</tr>
</tbody>
</table>

Modified from Hearn and Hunt 2011

Figure 5-5 Failed Sections of Cliff on Escarpment Slopes

### 5.3 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, and these considerations are therefore required at route selection stage.

Figure 5-6 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° (roughly approximating to the definition of flat terrain), 5° to 10° (rolling terrain), 10° to 35° (mountainous terrain) and 35° to 50° (escarpment terrain). Up to 10°, the ground profile is assumed only to comprise soil; from 10° to 45° the profile is assumed to comprise 2m of soil overlying 1.5m of rippable rock overlying rock requiring blasting. From 50° and above the profile is
assumed only to comprise rock requiring blasting. When the hillside slopes exceed 25°, a below-road cemented masonry retaining wall is assumed to be necessary to retain any fill.

From Hearn & Hunt, 2011

**Figure 5-6 Typical Road Cross-Sections**

Unit rates were obtained from a number of recent road construction projects in Ethiopia for bulk and foundation excavation in soil, in rippable/excavatable rock, blasting in rock, soil fill and compaction in embankments and as backfill to structures, and surplus spoil disposal. 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 5-7.
Although the costs undoubtedly represent a simplification in absolute terms, there are nonetheless a number of important observations:

- Apart from the full fill case, 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.

Table 5-4 compares the various advantages and disadvantages of the road cross-sections.
Table 5-4 Comparison between Road Cross-Sections

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

* 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. If any exposed rock face has jointing adverse to stability, then the face may have to be cut at a shallower angle, leading to higher volumes of rock than that assumed in Figure 5-7.

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.
Figure 5-8a shows the extensive use of a retaining wall on the outer edge of a road in escarpment terrain to avoid the need for a major rock cut in the natural slope above the road. Figure 5-8b shows a road located in very steep terrain predominantly utilising cut with short sections of retaining wall to cross re-entrants and natural drainage courses.

5.4 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. Table 5-5 summarises the main factors involved and Figure 5-9 gives some potential methods of traversing difficult and unstable terrain.

<table>
<thead>
<tr>
<th>Instability type</th>
<th>Alignment location</th>
<th>Preferred section</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing unstable ground, taluvium/colluvium (circular or quasi-circular slip surfaces)(^1)</td>
<td>Close to ridge crest</td>
<td>Full cut</td>
<td>Will reduce destabilising forces but locally may still require below-road retaining wall founded beneath any failure surfaces</td>
</tr>
<tr>
<td></td>
<td>Middle slope</td>
<td>Balanced cut and fill(^2)</td>
<td>If existing ground cannot be stabilised economically, then preference is for least disturbance, with reduced road width and flexible(^4) retaining structures on either side of road. Failures can be anticipated in cut slopes</td>
</tr>
<tr>
<td></td>
<td>Foot of slope</td>
<td>Full fill(^3)</td>
<td>Will increase stabilising forces, but may require frequent and sizeable culverts and larger roadside drains. Scour protection required in riverside locations</td>
</tr>
<tr>
<td>Adversely orientated discontinuities in rock</td>
<td>Applies to all cases</td>
<td>Full fill</td>
<td>Avoids excavation and undercutting of rock strata. Below-road retaining walls will need to be keyed and dowelled into a benched rock surface</td>
</tr>
</tbody>
</table>

\(^1\) Removal of load from head and addition of load at toe or foot of slope has negligible influence on (infinite) slope stability for planar failures.

\(^2\) Locally, full cut or full fill may be necessary depending upon ground conditions.

\(^3\) Due attention needs to be taken in placing embankments on black cotton soil, potentially unstable colluvium or fluvial outwash fans. Drainage, including groundwater control, is also very important.

\(^4\) Flexible in the sense that some movement can be tolerated without structural failure.
It will be necessary to deploy engineering geological and geomorphological techniques of data collection and assessment to determine the location of preferred routes through existing or potentially unstable ground (Section 6.6).

5.5 Source Information

Source information on topography includes existing topographic mapping, stereo aerial photographs, and some satellite and airborne imagery. Topographic ground survey is not a practical option for route selection. See Section 9.3.4 for further discussion on the comparison of road construction quantities derived from remote sensing and terrestrial-based sources.

Figure 5-9 Methods to Traverse Difficult and Potentially Unstable Ground

From Hearn & Hunt, 2011
5.5.1 **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. However, some suburban areas (e.g. Addis Ababa) have been mapped at 1:20,000 and 1:25,000 scale.

5.5.2 **Aerial Photography**

EMA can also provide existing (mostly from the 1980s-1990s) stereo imagery at 1:50,000 scale with some areas available at a larger scale. When viewed through a stereoscope, stereo aerial photography can give a very good three-dimensional image in which the user can identify topographical features (including cliffs and escarpments, steep slopes and flat areas), landslides, areas of erosion, river catchments, alluvial fans, river terraces and flood plains, but there will be no digital information on elevation, gradients or side slopes. New aerial photography can be commissioned and combined with ground control to yield photogrammetry, but this is expensive and time-consuming and would be subject to military permission.

5.5.3 **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 for drainage and catchment area mapping. The digital elevation model (DEM) can also be used as a base layer upon which other satellite imagery can be draped in order to enhance three-dimensional visualisation. Table 5-6 lists the main sources and accuracy of satellite-derived and airborne digital mapping.

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Resolution</th>
<th>Horizontal Accuracy</th>
<th>Vertical Accuracy</th>
<th>Availability/Archive length</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRTM</td>
<td>3 arc seconds (90 m)</td>
<td>30 m</td>
<td>5-15 m (terrain dependent)</td>
<td>Global Coverage</td>
</tr>
<tr>
<td>ASTER</td>
<td>30 m</td>
<td>30 m</td>
<td>15-30 m</td>
<td>Global Coverage</td>
</tr>
<tr>
<td>SPOT HRS DEM (SPOT5)</td>
<td>20-30 m</td>
<td>15 m</td>
<td>5-10 m (terrain dependent)</td>
<td>Off the shelf product</td>
</tr>
<tr>
<td>Elevation10 (TerraSAR-X)</td>
<td>10 m</td>
<td>5-10 m</td>
<td>5-10 m</td>
<td>2007-</td>
</tr>
<tr>
<td>PRISM DEM</td>
<td>5m</td>
<td>5-10m</td>
<td>5-1-0m</td>
<td>2006-2011</td>
</tr>
<tr>
<td>Elevation4 (Pléiades)</td>
<td>4 m</td>
<td>3 m</td>
<td>2 m</td>
<td>2012-</td>
</tr>
<tr>
<td>Elevation1 (Pléiades)</td>
<td>1 m</td>
<td>1.5 m</td>
<td>1 m</td>
<td>2012-</td>
</tr>
<tr>
<td>Worldview 1 &amp; 2</td>
<td>1 m</td>
<td>1-2m (with GCPs, terrain dependent)</td>
<td>1-2m (with GCPs, terrain dependent)</td>
<td>2008-</td>
</tr>
<tr>
<td>GeoEye-1</td>
<td>1 m</td>
<td>1-2m (with GCPs, terrain dependent)</td>
<td>1-2m (with GCPs, terrain dependent)</td>
<td>2009-</td>
</tr>
<tr>
<td>LiDAR (airborne)</td>
<td>1 m</td>
<td>0.5 m</td>
<td>0.15 m-0.25 m</td>
<td></td>
</tr>
</tbody>
</table>
Free-to-download satellite imagery and DEM data currently comes in two formats, SRTM (Shuttle Radar Topographic Mission) and ASTER (Advanced Space-borne Thermal Emission and Reflection Radiometer). Of these two formats, ASTER is currently favoured for route selection by design consultants working for ERA due to its greater resolution. The main issue is the question of accuracy with respect to terrain type, 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 9.3.4.

High resolution stereo satellite data is likely to be largely unavailable in archive form and therefore very expensive to commission. SPOT DEM (SPOT5), however, does provide ground modelling data and is likely to be of most value to route selection in mountainous and escarpment terrain, being globally available, of reasonably high resolution and vertical accuracy, and available at reasonable cost. It is recommended that ERA obtain this imagery through EMA and make it available to consultants who are commissioned to carry out route selection studies. EMA can provide further advice regarding satellite DEM data and should be contacted in the first instance.

### 5.5.4 Airborne Imagery

This imagery and data is captured from an aircraft and is very unlikely to be available in archive form. A typical format is LiDAR (Light Detection and Ranging) with an accuracy given in Table 5-6. 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 (Figure 5-10) can help considerably in the interpretation of topography for the identification and comparison of route options.

![Figure 5-10 Hill Shade LiDAR Showing Mapped Landslides](image)