Review of the Road Design and Pavement Standards Manual in Bangladesh

Progress Report

J. Rolt

BAN2143A

January 2019

For further information, please contact: John Rolt, j.rolt@sky.com

Cardno Emerging Markets (UK) nLd
ReCAP Project Management Unit
Clarendon Business Centre
Meriden House
42, Upper Berkeley Street
London W1H5QL

The views in this document are those of the authors and they do not necessarily reflect the views of the Research for Community Access Partnership (ReCAP) or Cardno Emerging Markets (UK) Ltd for whom the document was prepared

Cover photo: Rural road in Bangladesh near Dhaka, Abedin. M, 2018

Quality assurance and review table

<table>
<thead>
<tr>
<th>Version</th>
<th>Author(s)</th>
<th>Reviewer(s)</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>J. Rolt</td>
<td>M. Abedin N Leta</td>
<td>29 January 2019</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>01 February 2019</td>
</tr>
<tr>
<td>2</td>
<td>J. Rolt</td>
<td>M. Abedin</td>
<td>13 February 2019</td>
</tr>
<tr>
<td>3</td>
<td>J. Rolt</td>
<td>M. Abedin</td>
<td>14 February 2019</td>
</tr>
</tbody>
</table>

ReCAP Database Details: Review of the Road design and Pavement Standards Manual in Bangladesh

<table>
<thead>
<tr>
<th>Reference No:</th>
<th>Location</th>
<th>Source of Proposal</th>
<th>Procurement Method</th>
<th>Theme</th>
<th>Sub-Theme</th>
<th>Lead Implementation Organisation</th>
<th>Partner Organisation</th>
<th>Total Approved Budget</th>
<th>Total Used Budget</th>
<th>Start Date</th>
<th>End Date</th>
<th>Report Due Date</th>
<th>Date Received</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAN2143A</td>
<td>Bangladesh</td>
<td>N/A</td>
<td>Sole Source</td>
<td>Infrastructure</td>
<td>Optimised use of material resources and environment</td>
<td>John Rolt</td>
<td>N/A</td>
<td>£62,293.80</td>
<td>£6,722.30</td>
<td>19/02/2018</td>
<td>30/06/2019</td>
<td>04/01/2019</td>
<td>11/01/19</td>
</tr>
</tbody>
</table>
# Contents

Abstract ........................................................................................................................................ 4  
Key Words .................................................................................................................................... 4  
Acknowledgements ....................................................................................................................... 4  
1 Introduction and Background to the Project .................................................................................. 5  
2 Stakeholder Consultation and Field Visits, 14-19th December 2018 ............................................. 5  
2.1 Personnel met at LGED Meetings ............................................................................................... 5  
3 Site Visit on 17th December 2018, at Narsingdi and Narayanganj District ....................................... 6  
4 Methodology .................................................................................................................................. 7  
4.1 General ...................................................................................................................................... 7  
4.2 Universal Information .................................................................................................................. 7  
4.3 Country Specific Information ..................................................................................................... 7  
5 Comments on the Terms of Reference ............................................................................................ 8  
5.1 Clarifications and Decisions Required from LGED ..................................................................... 9  
Feedback Process ........................................................................................................................... 10  
6 Revised Programme ....................................................................................................................... 10  
ANNEX 1 Geometric Design (Draft) ................................................................................................. 11  
Extract from the geometric design chapter (draft) ......................................................................... 11  
7.1 Basic Methodology .................................................................................................................... 11  
7.2 Selection of Design Standards for Rural Roads .......................................................................... 12  
7.3 Option B Design Standards ....................................................................................................... 14  
ANNEX 2 Original Proposed Contents of Manual .......................................................................... 18
Abstract

The Bangladesh University of Engineering and Technology (BUET) and the Bureau of Research and Testing (BRTC) were commissioned to update the existing road design manual used by the Bangladesh Local Government Engineering Department (LGED). A Review of the draft was completed in March 2018 and missing topics and topics that had not been dealt with satisfactorily were identified. This project is concerned with updating and improving the manual and began on 1st December 2018. A first visit was made to Bangladesh between 14th and 19th December to meet the staff of the LGED, to discuss the required work in more detail and to make a site visit for familiarisation and to observe at first hand some of the problems with the rural road network. Copies of current LGED manuals were obtained and a timetable for carrying out the work was proposed. The report describes the work done so far including an update on the status of the original review work, and the recommended methodology, strategy and work plan for the remaining activities.

Abstract

Key Words

Low volume rural roads, road design, pavement design.

Acknowledgements

The cooperation of the LGED staff listed in Chapter 2 as participators in the meetings and in the site visits is gratefully acknowledged.
1 Introduction and Background to the Project

The Bangladesh University of Engineering and Technology (BUET) and the Bureau of Research and Testing (BRTC) were commissioned to update the existing road design manual used by the Bangladesh Local Government Engineering Department (LGED). Several reports were submitted in early 2018 including a final report entitled *Final Report on the Assessment of Road Design and Pavement Standards*. However, there were concerns that the report was incomplete and did not cover the full scope required. LGED therefore requested an independent review and recommendations for its improvement. A Review was completed in March 2018 and over 175 comments with action points were made. The original document was also edited to improve sentence structure and corrections were made to the text where necessary. Missing topics and topics that had not been dealt with satisfactorily were identified. A further report was produced by BUET and BRTC in October 2018 entitled *Final Report of Consultancy Services for Assessment of Road Design and Pavement Standards* but this document did not adequately address many of the issues identified in the Review hence LGED initiated this project to correct the deficiencies identified in the Review. The project began in December 2018 with the visit of Dr Rolt to Bangladesh.

2 Stakeholder Consultation and Field Visits, 14-19th December 2018

One of the primary purposes of the visit was to meet the LGED staff who were to be involved in the project and to engage in technical discussions emanating from the Review of the draft pavement design manual prepared by the Bangladesh University of Engineering and Technology.

Some of the key findings from that Review are summarised in this report. Many of the outstanding queries emanating from the Review were resolved but some remain to be discussed and resolved as indicated below.

2.1 Personnel met at LGED Meetings

A Meeting on 15th December 2018, at LGED Office (Level-4), Dhaka

1. Md. Khalilur Rahman - Additional Chief Engineer (Implementation), LGED
2. Md. Ali Akhtar Hossain - Superintending Engineer (Planning), LGED
3. Md. Enamul Haque - Project Director, Second Rural Transport Improvement Project (RTIP-II), LGED
4. Abul Monzur Mohammed Sadeque - Executive Engineer (Planning), LGED
5. Md. Golam Mowla - Executive Engineer, Second Rural Transport Improvement Project (RTIP-II), LGED
6. Mir Tanweer Husain - Senior Assistant Engineer, Second Rural Transport Improvement Project (RTIP-II), LGED
7. Md. Abul Bashar – Ex. Superintending Engineer, LGED
8. Shahzad Khan – Hydrologist, ReCAP
9. Muhammad Khalid Bin Siddique – Hydrologist, Coastal Climate Resilient Infrastructure Project (CCRIP), LGED
10. Md. Abu Raihan – Assistant Engineer, Research & Development Unit, LGED
11. Sharmila Afsha – Assistant Engineer, Research & Development Unit, LGED.

The meeting was essentially concerned with meeting all the staff, summarising the aims of the project and discussing the arrangements for the site visit and timetable. Little detailed technical discussion occurred at this stage.
B Meeting on 18th December 2018, at LGED Office (Level-5 & 4), Dhaka

1. Md. Abul Kalam Azad, Chief Engineer, LGED
2. Md. Khalilur Rahman - Additional Chief Engineer (Implementation), LGED
3. Abul Monzur Mohammed Sadeque - Executive Engineer (Planning), LGED
4. Mir Tanweer Husain - Senior Assistant Engineer, Second Rural Transport Improvement Project (RTIP-II), LGED
5. Tapas Chowdhury - Senior Assistant Engineer, Design Unit, LGED
7. Shahzad Khan – Hydrologist, ReCAP
8. Muhammad Khalid Bin Siddique – Hydrologist, Coastal Climate Resilient Infrastructure Project (CCRIP), LGED
9. Sarthak Halder - Assistant Engineer, Project Monitoring & Evaluation Unit, LGED
10. G.M. Iftekhar - Assistant Engineer, Project Monitoring & Evaluation Unit, LGED
11. Md. Abu Raihan – Assistant Engineer, Research & Development Unit, LGED
12. Sharmila Afsha – Assistant Engineer, Research & Development Unit, LGED.

The discussions centred around the role of LGED and the scope and range of their activities. It was chaired by the Chief Engineer who was desirous that the project proceed quickly, requesting a completion date in February, some 4 months before the planned date. Dr Rolt was pleased to say that he would try to advance the completion date but could not promise such an early completion.

3 Site Visit on 17th December 2018, at Narsingdi and Narayanganj District.

A site visit was made to a number of Upazila roads, Union Roads, and Village Roads with the following LGED staff to review some of the technical problems and to discuss possible solutions. However it was essentially a familiarisation and brainstorming session.

1. Abul Monzur Mohammed Sadeque - Executive Engineer (Planning), LGED
2. Md. Rayhan Shiddique - Executive Engineer, LGED Narsingdi District
3. Md. Mafiz Uddin - Senior Assistant Engineer, Narsingdi District
4. Shahzad Khan – Hydrologist, ReCAP
5. Muhammad Khalid Bin Siddique – Hydrologist, Coastal Climate Resilient Infrastructure Project (CCRIP), LGED
6. Md. Ridwanur Rahman - Assistant Engineer (Planning), LGED

The types of vehicles were noted (registered, unregistered-local). Several fully loaded 3-axle lorries were encountered and their likely loads estimated from the goods carried and from discussion with the drivers. The estimated load on the rear tandem axle was clearly in the range 10 -15 tonnes giving a typical esa of about 4. It was concluded that on many of these rural roads typical truck traffic may be exerting greater loads on the pavement than has been assumed in the past, hence the need for some axle load surveys by LGED was identified, preferably on a regular basis. (Incidentally the esa values quoted for different vehicle types in the BUET report appear to be rather high; possibly they are for fully loaded vehicles only or for legally loaded vehicles, but this is not clear in the report). The geometry of the roads and typical travel speeds were noted bearing in mind the fact that we were observing only a small sample.

1 One of the main problems is concerned with the width of the roads and their capacity to provide an acceptable level of service for the future traffic that is likely to grow quite quickly given the economic growth estimates and the likely increases in motor cycle-based transport.
A second common problem is the flat nature of much of the terrain, at least in the area visited, leading to problems of drainage and frequent flooding of shops and houses.

Brainstorming these problems together with the LGED staff produced several ideas to be explored later in the project. For example, it is possible on many roads that additional passing places can be constructed to provide a considerably better service by decreasing journey times without affecting safety to any great extent.

4 Methodology

4.1 General

Rural roads must fulfil a range of tasks and functions to satisfy the requirements of an extremely wide range of road users under a wide range of conditions. Fortunately, the geometric design of rural roads depends on many factors (see Annex 2) which can be varied so that many different requirements can be catered for. The geometric designs can therefore be tailored to the precise requirements of each road, within practical engineering limits. This flexibility is essential if LGED is to continue to provide the best rural roads commensurate with the budgets provided.

It is generally accepted that the appropriate standards of roads, or service level, should increase with traffic level. Service level is measured by average speed or travel time. Both are closely linked to the costs of travel. Thus improving service level also has a direct influence on economy and can often be justified from both an economic and social perspective. However, increased travel speed is also associated with increased accidents and therefore methods to control speed where necessary are also vital.

There are two aspects of such an engineering manual, namely the universal engineering information that is not country specific, and the information that differs from country to country. For efficiency each has to be dealt with separately. Clearly the sources of the information are different. The lead author can deal with the universal engineering details from a base anywhere in the world but the second type, namely the country specific information, requires input from LGED staff. Obtaining and incorporating it in a manual is probably more time consuming and should begin as soon as possible.

4.2 Universal Information

Engineering information based on the laws of physics for example do not differ from country to country. In the last ten years or so, as part of the SEACAP, AFCAP and now RECAP programmes of DFID, road design manuals for roads have been written (many by the current author) for at least nine countries in South East Asia and in Africa. Thus there are many examples of chapters about the ‘universal information’. The task here is to select from what has gone before and to choose the ‘best’ by amalgamating and combining the best written versions. Most of the first drafts of these components of the various chapters have already been completed (see Table below). These are the Phase 1 drafts.

4.3 Country Specific Information

Country specific information requires the input of the LGED technical group and access to existing manuals and documentation specifically focussed on the issues relevant to Bangladesh. Compiling these aspects of each chapter is Phase 2 and requires a longer active input, probably another visit to Bangladesh by the lead author and considerable coordination of contributions. Table 1 below is a summary of these requirements for each chapter. The full, originally proposed contents list is shown in the Annex.
5 Comments on the Terms of Reference

In the previous report entitled ‘Peer Review of the Updated Road Design and Pavement Standards Manual in Bangladesh’ (BAN2143A) there was a section that said

‘The scope of work for the authors of the proposed manual is summarised in Table 2 taken from the introduction to the manual. The extent to which the tasks have been achieved is also summarised in the Table but may be inaccurate if other reports have been written but not referenced in the manual.’

Followed by a summary Table 2 entitled Author’s Scope of Work and Review of Accomplishments

This paragraph refers to the scope of work that formed the Terms of Reference for the BUET authors of the Final Report on the Assessment of Road Design and Pavement Standards i.e. the document that was being reviewing. It pointed out that there were no results quoted from some of the tasks that were supposed to have been completed (including the rather important performance analysis of existing roads amongst other things).

It was not a list of tasks that was assessed to be necessary for the new project or that should have been included in this ToR (for the extended phase). This misunderstanding should have been spotted sooner. However, the work has been based so far so far on the need for all the topics in the contents list to be improved based on the sentence in the ToR that states the following:

‘In addition, the original peer review prescribed a typical contents list in Section 8 of the report. However certain sections are missing or weakly addressed and LGED would like including in the report. This will form a substantial part of the service provider’s tasks’.

This is the basis of Table 1 below.

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Short Title</th>
<th>Mainly Universal</th>
<th>Mainly local Bangladesh (Input to add any details for completeness and accuracy concerning local methods).</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Planning and feasibility</td>
<td>Draft 75% complete(^1)</td>
<td>25% local inputs required</td>
</tr>
<tr>
<td>3</td>
<td>Site Investigation and Route Selection</td>
<td>50% completed</td>
<td>Local inputs required</td>
</tr>
<tr>
<td>4</td>
<td>Traffic</td>
<td>Draft attached and almost complete (^2)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Geometric Design</td>
<td>75% complete(^4)</td>
<td>Minor inputs needed</td>
</tr>
<tr>
<td>6</td>
<td>Hydrology and drainage design</td>
<td>40% complete</td>
<td>Dr Shahzad Khan commissioned by Recap concentrating on this chapter</td>
</tr>
</tbody>
</table>

Review of the Road Design and Pavement Standards Manual in Bangladesh
<table>
<thead>
<tr>
<th>Section</th>
<th>Topic</th>
<th>Drafted</th>
<th>To Be Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Design of unpaved roads</td>
<td>75%</td>
<td>25%</td>
</tr>
<tr>
<td>8</td>
<td>Design of paved roads</td>
<td>75% (2, 5)</td>
<td>25% to be completed</td>
</tr>
<tr>
<td>9</td>
<td>Bitumen surfacings</td>
<td>75%</td>
<td>25%</td>
</tr>
<tr>
<td>10</td>
<td>Recycling</td>
<td>75%</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Drainage structures</td>
<td>50% complete</td>
<td>50% to be completed</td>
</tr>
<tr>
<td>12</td>
<td>Borrow pits and Quality Control</td>
<td>50%</td>
<td>50% to be completed</td>
</tr>
<tr>
<td>13A</td>
<td>Maintenance of unpaved roads</td>
<td>50%</td>
<td>50% to be completed</td>
</tr>
<tr>
<td>13B</td>
<td>Maintenance of paved roads</td>
<td>70%</td>
<td>30% to be completed</td>
</tr>
<tr>
<td>14</td>
<td>Environmental issues and social</td>
<td>25%</td>
<td>75% local input required</td>
</tr>
</tbody>
</table>

Notes

1. **Planning:** Planning methods are very country specific. Considerable input is required from LGED for this Chapter.

2. **Traffic:** One of the queries that has not been resolved is the question of the scope of the manual in terms of traffic levels. The original BUET report proposed road designs for what was described as ‘light and medium’ traffic up to 500 commercial vehicles per day (CVD) and also for designs for cumulative traffic up to 150 million equivalent standard axles. Such a road would be 4-lane major trunk road. Also roads for 500 CVD would typically carry 10 times this in non-commercial traffic or typically 5000 ADT. These are not low volume roads.

3. **Maintenance:** Is maintenance required in this manual or is there another manual for this topic?

4. **Geometric design:** Example attached (summary only).

5. **Structural Design:** The BUET document defines only 3 subgrade strengths for design. However there are quite substantial differences in pavement thickness design between them and so it is more usual to define more than 3 categories to save over-design costs. Nevertheless using only 3 does recognise the practical problem of subgrade variability and problems of defining uniform lengths of subgrade.

### 5.1 Clarifications and Decisions Required from LGED

A decision is required from LGED to confirm the required traffic levels for the manual. It is considered that LGED roads are normally genuine low volume roads. The international definition of a low volume road is variously set at less than 300 AADT, 500 AADT or 1000 AADT. The traffic level that LGED wishes to include in the manual needs to be decided. It is suggested that a maximum of 500 or 1000 ADT is used.

In terms of structural design the traffic range for true low volume roads is normally below about 0.5 million equivalent standards axles of cumulative traffic over 10 or 15-year period. It is up to this level that a relaxation of the specifications for road base and sub-base materials can be used to reduce construction costs.

However there are many rural roads that will exceed this value hence a range up to 3.0 million (or 5.0 million) standard axles is often used. Assuming typical values of average esas per commercial vehicle this is equivalent to up to 200 CVD. These figures need to be verified using actual data from rural roads in Bangladesh.

Review of the Road Design and Pavement Standards Manual in Bangladesh
The number of traffic classes depends on the range that is to be covered. Usually, and based on the sensitivity of thickness design to traffic in esa, each traffic class typically covers a factor of two or three. The number of subgrade classes should also be taken into account because if the number of subgrade classes is low based on the conditions of subgrades in Bangladesh, this indicates more uniformity. Fewer traffic classes can then be chosen. This appears to have been the policy in the original BUET proposals where there are only 3 subgrade classes, 3 geometric classes and many structural classes. It is suggested at this stage that five subgrade classes are used (for example CBRs 2-3; 4-6; 7-10; 10-15; 15+) and 4 traffic classes for geometry (AADT 0-25; 25-75; 75-200; 200-600) and six traffic classes for structure. In esa; 0-0.1; 0.1-0.25; 0.25-0.5; 0.5-1.0; 1.0-3.0 or also 2.5-5).

Feedback Process

One of the problems associated with feedback in the past is simply that the local technical group steering a project are often expected to review a large draft document in a short period of time towards the latter stages of the project. This is usually difficult for busy people and results in delays and last minute haste. It is proposed that chapters or small groups of chapters are submitted to LGED when they have been drafted to allow more time for review by LGED. Thus dividing the task into several smaller ones and giving more time can only benefit the project.

6 Revised Programme

The original timetable has slipped because of the delayed start from the initial plan.

A revised programme is as follows:

<table>
<thead>
<tr>
<th>Deliverable</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Progress Report second draft</td>
<td>4th February 2019</td>
</tr>
<tr>
<td>Draft Technical Memorandum detailing updates to the LGED Road Design and Pavement Standards and Manual in Bangladesh (consistent with the outputs specified in the Terms of Reference)</td>
<td>01 April 2019</td>
</tr>
<tr>
<td>Final Technical Memorandum detailing updates to the LGED Road Design and Pavement Standards and Manual in Bangladesh (consistent with the outputs specified in the Terms of Reference) and incorporating LGED review comments</td>
<td>31 May 2019</td>
</tr>
<tr>
<td>Finalised Road Design and Pavement Standards and Manual in Bangladesh</td>
<td>30 June 2019</td>
</tr>
</tbody>
</table>

Note that every effort will be made to provide the deliverables earlier than these deadline.
Annex 1: Geometric Design (Draft)

One of the most important outcomes of the meetings and discussions was LGED’s need for the manual to allow flexibility in design to cater for the wide range of road functions. This process is often called ‘context sensitive design’ and allows the designer to match the road accurately to its precise function. As indicated in the new draft chapter on geometric design, the precise design is affected by about thirteen factors as follows:

- Cost and level of service
- Alignment and route controls
- Design vehicle
- Administrative and functional considerations
- Traffic volume and composition
- Terrain
- Design speed
- Roadside population (open country or populated areas)
- Pavement type
- Land use
- Environmental considerations
- Construction technology
- Soil type and climate
- Safety

Each of these is discussed in detail in the appropriate chapter.

Extract from the geometric design chapter (draft).

7.1 Basic Methodology

The preferred Option A design method for upgrading an existing LVR or track is recommended for traffic classes LVR1 to LVR4. It can also be used for higher traffic classes but these fall outside the scope of this Manual. Option A utilises the existing alignment as much as possible and therefore also the effective existing operating speeds. These may vary along the road and so it is important to identify any sections of the road that are sufficiently unsafe to warrant either improvement or modification. Such improvements include

- ensuring adequate sight distances along the entire road;
- controlling traffic speeds using traffic calming methods;
- minor alignment to ensure a more uniform traffic speed;
- controlling traffic by means of warning signs.

However, since we are considering Option A, these improvements are only required when the components of the existing alignment differ by a significant amount from an extremely safe alignment designed for higher traffic levels. Given that the number of vehicle interactions on a LVR will be very small (Table 2.2), a LVR is inherently very safe provided that vulnerable road users are protected, especially by controlling traffic speeds.
At present there are no golden rules for identifying and ranking areas of poor safety on LVRs because road accident data is insufficient for such a detailed analysis but it is suggested that if the new road parameters differ by more than 30% from the values that would be obtained using a full Option B engineering design then consideration should be given to either improvement or modification locally as listed above. Clearly this also requires engineering judgement and experience that will be enhanced by future research.

7.1.1 Large vehicles

In the specification Tables ‘large vehicles’ are defined as trucks with three or more axles and gross vehicle weights greater than 10 tonnes.

7.1.2 Flexibility

Sometimes there will be cases where it is impossible to meet some of the standards, mainly due to severe terrain conditions. Under such circumstances the standards must be relaxed at the discretion of the Engineer and suitable permanent signage used to warn road users.

For example, alignment design in severe mountainous terrain can sometimes be difficult. A minimum curve radius of 70m to 85m suitable for a design speed of 50km/hr might not be possible without massive earthworks and potential problems of slope instability, disposal of spoil and environmental damage. In such terrain the design speed can be reduced with the associated alterations in the alignment standards that can be achieved more easily and less expensively. Each situation should be treated on its merits. The Tables provide specifications for design speeds from 20 to 80km/h but if the specifications for the proper design class need to be changed, approval of the client is usually required.

7.2 Selection of Design Standards for Rural Roads

It is important to note that there is no reason why a higher standard than the standard appropriate to the traffic and conditions should not be used in specific circumstances. For example, for reasons of national and international prestige or for strategic or military reasons, a road may be built to a higher standard than would normally be justified e.g. a road to an international sports facility (where the traffic is very low for most of the time but can be quite high for short periods), the road to an airport, and roads to military establishments. Thus, higher standards can be used if required but lower standards should not be used except in exceptional circumstances, for example, in particularly difficult terrain.

Figure 7.1 shows how the appropriate geometric standard is selected.
Step 1: The first step is to determine the basic traffic level because this defines the road class (Chapter 2). This in turn determines possible design speeds and overall level of service, but subject to modification depending on the other controlling factors. At this point, the proportion of heavy vehicles in the traffic stream is also determined. This step is not specific to the geometric design and will usually have been done by the time it is necessary to determine the geometric characteristics of the road. However, more details of the traffic are required for the geometric design in terms of the other road users such as pedestrians, bicycles, motor cycles, motor cycle taxis and animal drawn vehicles. These are taken into account in Step 5.

Step 2: The numbers and characteristics of all the other road users are considered (Section 4.6). It is here that the road layout may be altered and additional widths provided for safety and to improve serviceability for all road users (e.g. reduce congestion caused by slow moving vehicles).

Step 3: The terrain class; flat, rolling, mountainous and escarpment is determined (Section 3.8).

Step 4: The ‘size’ of the villages through which the road passes is evaluated to determine whether they are large enough to require parking areas and areas for traders (Section 3.10).

Step 5: For most road classes there are options for road type and therefore the next step is to decide which type will be built. In many cases the adoption of an EOD policy will mean that different parts of the road may
be designed with a different surfacing. The choice of road type is described in Chapters 3 and the detail are discussed in subsequent chapters.

**Step 6:** From the available data the widths of the travelled way and shoulders should be determined (Chapter 5). At this stage additional factors that affect the geometric standards are also considered such as additional road safety features and the construction technology to be employed. Opportunities for the relaxation of standards have also been identified.

**Step 7:** The initial stage in selecting an alignment for a new road is to sketch a route on a contoured map or aerial photograph. A similar process can be carried out when investigating the upgrading of an existing road. By reference to the standards, the designer will have some knowledge of appropriate minimum radii for the scale of the map or photograph. Consideration will be given to gradient by reference to the contours of a map, or by relief when using stereo photographs. Several alternative alignments should be tried. The design process should be carried out in conjunction with on-site inspections and surveys. One or two of the alignments should be chosen for further design and assessment prior to possible construction.

On two-lane roads, the horizontal alignments should be designed to maximise overtaking opportunities by avoiding long, continuous curves. Instead, relatively short curves at, or approaching, the minimum radius for the design speed should be used in conjunction with straights or gentle, very large radius curves. This is the safest option for LVRs. An alignment of flowing curves may reduce real overtaking opportunities, thus encouraging injudicious driver behaviour. On two-lane roads the provision of adequate overtaking opportunities may be particularly important because of the proportions of slow-moving vehicles.

Often a new road will be built to replace an existing facility. The structural features of the existing road, including bridges, embankments and cuttings may have substantial residual value and influence alignment choice.

The geometric standard of individual elements of the road will vary with the terrain. It is necessary that elements of lower geometric standard are identified to ensure that they will not result in unacceptable hazards to approaching vehicles. These elements will be readily identifiable from the preliminary horizontal and vertical curvature profiles. The tests for the necessary consistency are simple, as described below, and should be carried out if there is any doubt as to the acceptability of an element.

### 7.3 Option B Design Standards

Tables 7-1 and 7-2 summarise the values of all the alignment design variables that can be used to check whether the actual values on the redesigned road are of acceptable value. It is suggested that differences of greater than 30% should be looked at carefully to check whether such a difference may represent a significant safety problem. Not all of the parameters are equally important but stopping sight distances are probably the most significant.

For greenfield sites and when fully engineered designs are required the detailed design standards for each design class are shown in Table 7-3 (LVR5), Table 7-4 (LVR4), Table 7-5 (LVR3), Table 7-6 (LV 2). For unpaved roads the detailed design standards for each design class are shown in Table 7-7 (LVR5), Table 7-8 (LVR4), Table 7-9 (LVR3), Table 7-10 (LVR2) and Table 7-11 LVR1)
The traffic levels have yet to be decided but the following classes are suggested.

<table>
<thead>
<tr>
<th>Class</th>
<th>AADT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>0-25</td>
</tr>
<tr>
<td>Class 2</td>
<td>25-75</td>
</tr>
<tr>
<td>Class 3</td>
<td>75-200</td>
</tr>
<tr>
<td>Class 4</td>
<td>200-600-</td>
</tr>
<tr>
<td>Class 5</td>
<td>600-1000</td>
</tr>
</tbody>
</table>
### Table 0-1: General design variables - Paved Roads

<table>
<thead>
<tr>
<th>Design Speed</th>
<th>km/h</th>
<th>100</th>
<th>90</th>
<th>80</th>
<th>70</th>
<th>60</th>
<th>50</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum. Stopping Sight Distance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g = 0%</td>
<td>m</td>
<td>205</td>
<td>170</td>
<td>140</td>
<td>110</td>
<td>85</td>
<td>64</td>
<td>45</td>
</tr>
<tr>
<td>g = 5%</td>
<td>m</td>
<td>235</td>
<td>195</td>
<td>155</td>
<td>120</td>
<td>95</td>
<td>68</td>
<td>47</td>
</tr>
<tr>
<td>g = 10%</td>
<td>m</td>
<td>280</td>
<td>230</td>
<td>182</td>
<td>140</td>
<td>105</td>
<td>75</td>
<td>50</td>
</tr>
<tr>
<td>Min. Passing Sight Distance to abort</td>
<td>m</td>
<td>310</td>
<td>275</td>
<td>240</td>
<td>210</td>
<td>180</td>
<td>155</td>
<td>135</td>
</tr>
<tr>
<td>% Passing Opportunity</td>
<td>%</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>33</td>
<td>33</td>
<td>25</td>
</tr>
<tr>
<td>Minimum Horizontal Curve Radius(^{(2)})</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE = 4%</td>
<td>m</td>
<td>520</td>
<td>400</td>
<td>300</td>
<td>220</td>
<td>150</td>
<td>95</td>
<td>55</td>
</tr>
<tr>
<td>SE = 6%</td>
<td>m</td>
<td>455</td>
<td>350</td>
<td>265</td>
<td>190</td>
<td>135</td>
<td>85</td>
<td>50</td>
</tr>
<tr>
<td>SE = 8%</td>
<td>m</td>
<td>415</td>
<td>320</td>
<td>240</td>
<td>175</td>
<td>120</td>
<td>80</td>
<td>50</td>
</tr>
<tr>
<td>Transition curves required</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Max. Gradient (desirable)</td>
<td>%</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Max. Gradient (absolute)</td>
<td>%</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>8</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Minimum Gradient</td>
<td>%</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Maximum Super-elevation</td>
<td>%</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Min Crest Vertical Curve - K</td>
<td>m/%</td>
<td>100</td>
<td>67</td>
<td>45</td>
<td>30</td>
<td>17</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Min. Sag Vertical Curve - K, Comfort criterion</td>
<td>m/%</td>
<td>25</td>
<td>20</td>
<td>16</td>
<td>12</td>
<td>9</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Min. Sag Vertical Curve - K, Headlights criterion</td>
<td>m/%</td>
<td>50</td>
<td>40</td>
<td>32</td>
<td>25</td>
<td>19</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>Normal Camber/Crossfall</td>
<td>%</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>
Table 0-2: General design variables - Unpaved Roads

<table>
<thead>
<tr>
<th>Design Speed</th>
<th>km/h</th>
<th>80</th>
<th>70</th>
<th>60</th>
<th>50</th>
<th>40</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum. Stopping Sight Distance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g = 0%</td>
<td>m</td>
<td>160</td>
<td>125</td>
<td>95</td>
<td>70</td>
<td>50</td>
<td>32</td>
</tr>
<tr>
<td>g = 5%</td>
<td>m</td>
<td>190</td>
<td>145</td>
<td>110</td>
<td>80</td>
<td>55</td>
<td>35</td>
</tr>
<tr>
<td>g = 10%</td>
<td>m</td>
<td>235</td>
<td>175</td>
<td>130</td>
<td>90</td>
<td>60</td>
<td>37</td>
</tr>
<tr>
<td>Min. Passing Sight Distance to abort</td>
<td>m</td>
<td>240</td>
<td>210</td>
<td>180</td>
<td>155</td>
<td>135</td>
<td>115</td>
</tr>
<tr>
<td>Min. Horizontal Radius</td>
<td>m</td>
<td>355</td>
<td>255</td>
<td>175</td>
<td>115</td>
<td>65</td>
<td>35</td>
</tr>
<tr>
<td>4 % SE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. Gradient (desirable)</td>
<td>%</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Max. Gradient (absolute)</td>
<td>%</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Minimum Gradient (4)</td>
<td>%</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Max. Super-elevation</td>
<td>%</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Min. Crest Vertical Curve K</td>
<td>m/%</td>
<td>58</td>
<td>35</td>
<td>20</td>
<td>11</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Min. Sag Vertical Curve - K, Comfort criterion</td>
<td>m/%</td>
<td>16</td>
<td>12</td>
<td>9</td>
<td>7</td>
<td>4</td>
<td>2.5</td>
</tr>
<tr>
<td>Min. Sag Vertical Curve - K, Headlights criterion</td>
<td>m/%</td>
<td>32</td>
<td>25</td>
<td>19</td>
<td>14</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Normal Camber/Cross-fall</td>
<td>%</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

If statistics are applied, depending on the number of different levels of choice for each factor, there are potentially over 50,000 combinations. This is, of course, an exaggeration because not all are different but the potential range is very broad and should be sufficient to meet every specific requirement.
ANNEX 2 Original Proposed Contents of Manual

The red italics indicate topics that are not included in the original BUET proposed manual or included with insufficient detail.

1 Introduction
2 Planning
2.1 Rural Accessibility Planning
2.2 Scope
2.3.1 Basic access
2.3.1 Full access
2.3.3 Accessibility
2.4 Prioritising Investment
2.5 Community level planning
2.6 Network level planning
2.7 Integrated accessibility planning
2.8 Traffic
2.8.1 Traffic surveys
2.8.2 Traffic growth
2.8.3 Axle load surveys
2.9 Material Prospecting
2.10 Planning and resourcing for materials prospecting
2.11 Recording – materials database.

3 Site Investigation and Route Selection
3.1 Introduction and Scope
3.2 Investigations for a Completely New Road
3.2.1 Socio-economic:
3.2.2 Engineering:
3.2.3 Other
3.2.4 Site investigation components
3.2.5 Site investigation procedures
3.2.6 Investigations for the project phases
3.2.7 Identification and general planning
3.2.8 Pre-feasibility study
3.2.9 Feasibility study or preliminary engineering design
3.2.10 Final engineering design
3.2.11 Subgrade characterisation
3.2.12 Earthworks
3.2.13 Construction materials
3.3 Special Considerations in Hilly and Mountainous Areas
3.3.1 General principles:
3.3.2 Unstable terrain:
3.3.3 Erosion potential:

3.4 Site Investigation for a New Road that Follows an Existing Track/Trail

3.5 Site Investigation for Upgrading a Lower Class Road to a Higher Class

3.5.1 General

3.5.2 Assessing problem areas

3.5.3 Strength of existing gravel layers

3.5.4 Existing road in very poor condition

3.5.5 Subgrade strength assessment

3.6 Investigations for Small Structures

3.6.1 Assessment of the problem or need

3.6.2 Assessment of potential structures

3.6.3 Desk Study

3.6.4 Field study

3.6.5 Collection of initial design data

3.6.6 Field assessment practicalities

3.6.7 Foundation bearing capacity

4 Traffic for Design

4.1 Geometric Design

4.2 Structural design

4.2.1 Equivalent standard axles per vehicle class

5 Geometric Design

5.1 Introduction

5.2 Principal Factors Affecting Geometric Standards

5.2.1 Traffic volume and composition

5.2.2 Terrain/Topography

5.2.3 Roadside population

5.2.4 Road surface type

5.2.5 Land use and physical features

5.2.6 Construction technology

5.2.7 Safety

5.3 Design Situations

5.3.1 Upgrading an existing road

5.3.2 Designing a new road where none existed before

5.4 Geometric Design Standards for LVRs

5.5 Single Lane Roads and Passing Places

5.6 Adverse Cross-fall and Super-elevation

5.7 Curve Widening

5.8 Curve Length

5.9 Cross Sections

5.10 Junctions, Intersections, Roundabouts
6 Hydrology and Drainage Design
6.1 The Direct Observation Method
6.2 The Rational Method
6.3 The SCS Method
6.3.1 Catchment area
6.3.2 Rainfall
6.3.3 Runoff and curve numbers
6.3.4 Time of concentration
6.3.5 Steps in the SCS procedure
6.4 Hydraulics and Design of Drainage Structures
6.4.1 Design of culverts
6.4.2 Design of drifts and fords
6.4.3 Side drains
6.4.4 Erosion control in the side drain
6.4.5 Mitre drains or turnouts
6.4.6 Water crossings and associated structures
6.5 Design for Climate Resilience
6.6 Other Drainage Considerations
6.6.1 Wet lands
6.6.2 Subsoil drains
6.6.3 Filters
6.6.4 Interceptor, cut-off or catch-water drains.
6.6.5 Chutes

7 Design of Unpaved Roads
7.1 Pavement Design for Engineered Natural Surfaced Roads
7.2 Pavement Design for Gravel Surfaced Roads
7.2.1 Traffic classes for structural design
7.2.2 Natural gravel roads
7.3 Assessing the Subgrade Strength
7.3.1 Specifying the design subgrade class
7.3.2 Material depth
7.3.3 Improved subgrade layers
7.4 Minor Gravel Roads
7.5 Material Design Requirements for Gravel Wearing Course
7.5.1 Gravel roads in areas of material scarcity
7.5.2 Material requirements for gravel roads in rural roads:
7.6 Design of Major Gravel Roads
7.7 Design of Unsealed Macadam Roads

8 Design of Paved Roads
8.1 Materials Design for Paved Roads
  8.1.1 Materials requirements for unbound roadbases
  8.1.2 Stabilisation of Bases
  8.1.3 Material requirements for sub-bases
8.2 Structural Design of Paved Roads
  8.2.1 Introduction
  8.2.2 The catalogue method
  8.2.3 Design method for upgrading and rehabilitation
  8.2.4 The DCP DN design method
  8.2.5 Design of roads with stabilised roadbases
  8.2.6 Design of roads with semi-structural surfacings (SSS)
  8.2.7 Design of roads with discrete element surfacings
  8.2.8 Design of roads with structural surfaces

9 Design of Bituminous and Discrete Surfacings
  9.1 Surfacing Options
  9.2 Factors affecting choice of bituminous surface treatments
  9.3 Design Principles for Bituminous Surfacing
  9.4 Prime Coat
  9.5 Sand Seals
  9.6 Slurry Seal
  9.7 Chip Seal/ Surface Dressing
    9.7.1 Design procedure
  9.8 Design of Double Surface Dressing
    9.8.1 Adhesion agents:
    9.8.2 Pre-coating agents:
  9.9 Surface Dressing Using Emulsion
  9.10 Single Surface Dressing with Sand Capping
  9.11 Cape Seal
  9.12 Otta Seal
    9.12.1 Bitumen binder
    9.12.2 Bitumen Additives
    9.12.3 Aggregates
  9.13 Emulsion-based Otta Seals/Graded Aggregate Seals
  9.14 Cold Mix Asphalt
  9.15 Penetration Macadam
    9.15.1 Stone Aggregate
    9.15.2 Bitumen
  9.16 Hot Sand Asphalt
  9.17 Amalgamated Surfacings
    9.17.1 Amalgamation of surfacing with the base
    9.17.2 Amalgamation of surfacing layers
9.18 Design of Concrete Surfacing
9.18.1 Unreinforced concrete

10 Recycling

11 Design of Structures
10.1 Structural Elements
10.1.1 Concrete elements
10.1.2 Reinforcement
10.1.3 Masonry
10.2 Types and General Standards of Structures on LVRs
10.2.1 Drains
10.2.2 Pipe culverts
10.2.3 Drifts
10.2.4 Causeways/vented drifts/fords
10.2.5 Box culverts
10.2.6 Small bridges

12 Construction and Quality Assurance
11.1 Scope
11.2 Tendering and Procurement
11.3 Preliminaries and General
11.3.1 Mobilisation and site establishment
11.3.2 Contractor's works and civil obligations
11.3.3 Site clearing
11.4 Roadbed Preparation
11.5 Opening Borrow Pits
11.6 Stockpiling Material
11.7 Sampling and Testing
11.8 Formation
11.9 Siting and Construction of the Drainage Structures
11.10 Sub-bases and Bases
11.11 Blended Bases
11.12 Armoured Bases
11.13 Emulsion Treated Bases
11.14 Surfacings
11.14.2 Priming
11.14.3 Surface dressings
11.14.4 Otta seals
11.14.5 Sand seals
11.14.6 Construction of slurry seals
11.14.7 Construction of Cape seals
11.14.8 Construction of cold mix asphalt
11.14.9 Construction of penetration Macadam
11.15 Final Clearing
11.16 Protection Works
11.17 Placement of Road Signs and Road Markings

13 Maintenance and upgrading of Unpaved Roads
12.1 Types of Maintenance
12.1.1 Routine Maintenance
12.1.2 Periodic maintenance
12.1.3 Urgent maintenance
12.1.4 Emergency maintenance
12.1.5 Rehabilitation
12.1.6 Local improvements
12.3 Routine Maintenance Activities
12.2 Maintenance works – Labour-based activities
12.3 Carriageway Maintenance
12.3.1 Pot-hole filling and repairs
12.3.2 Maintenance works - Equipment based activities
12.3.3 Road condition evaluation
12.3.4 Maintenance planning

13B Maintenance and upgrading of Low Volume Sealed Roads
13.1 Scope
13.2 Road Authorities and Responsibilities
13.3 Traffic Volumes and Loading
13.4 Deterioration Characteristics of LVSR
13.5 Deterioration Factors and Maintenance Remedies
13.6 Deterioration Data and Collection of Information
13.7 Maintenance Planning, Design and Budgeting for LVSRs
13.7.1 Desk study
13.7.2 Deterioration characteristics for different surfacing options
13.7.3 Road Condition Assessment
13.7.4 Visual Condition Surveys
13.7.5 Pavement strength tests
13.7.6 Analysis of road condition data and information
13.7.7 Maintenance design
13.7.8 Maintenance budgeting
13.7.9 Database of maintenance activities
13.8 Selection of Appropriate Maintenance Regimes
13.8.1 Level of service
13.8.2 Measurement contracts

Review of the Road Design and Pavement Standards Manual in Bangladesh
13.8.3 Area-based maintenance
13.9 Selection of Appropriate Work Methods
13.9.1 Labour-based methods
13.9.2 Community participation
13.9.3 Labour-based Force Account operations
13.9.4 Labour-based contracting
13.9.5 Machine-based maintenance operations
13.10 Maintenance Operations
13.10.1 Packaging works and project delivery
13.10.2 Resources and work outputs

14 Environmental and Social Issues
14.1 Environmental Issues
14.1.1 Responsible authorities
14.1.2 EIA process and legislative framework
14.1.3 Analysis of impacts
14.1.4 Environmental measures
14.1.5 Environmental monitoring, evaluation and auditing
14.2 Social issues
14.2.1 Child protection and HIV Aids considerations
14.2.2 Participation of women and children
14.2.3 Employment creation
14.2.4 Restrictions on using personnel in the permanent employ of the contractor
14.2.5 Implementation

15 References

Appendix A: The Rational Method of Computing Water Flows for Drainage Design
Appendix B: The SCS Method of Computing Water Flows for Drainage Design
Appendix C: Coping with Climate Change
Appendix D: Traffic Engineering
Appendix E: Theoretical Methods
E2 Mechanistic or Analytic Methods
E3 Elastic Theory
E4 Design Criteria
E5 Model Assumptions
Appendix F: The Structural Number Method of Pavement Design.