REPUBLIC OF KENYA

MINISTRY OF TRANSPORT, INFRASTRUCTURE, HOUSING, URBAN DEVELOPMENT & PUBLIC WORKS

STATE DEPARTMENT FOR INFRASTRUCTURE

Consultancy Services for Review and Updating of Road Design Manuals and Standard Specifications for Kenya
Ref. No. KENHA/PCS/342/2021

DRAFT REVIEW REPORT

November 2022

Report details

Report prepared for:	KeNHA
Project/customer reference:	11226171
Copyright:	© TRL Limited
Report date:	28th November 2022
Report status/version:	Ver 2
Quality approval:	

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Contents amendment record

This report has been amended and issued as follows:

Version	Date	Description	Editor	Technical Reviewer
1.0	13th June 2022	Draft Review Report	Bopoto, C. T.	Workman, R.
2.0	28th November 22	Draft Review Report	Bopoto, C.T.	Workman,R.

Document last saved on:	28-Nov-2022 9:11 AM
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Acronyms

Acronym	Description
AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt Concrete
ACEK	The Association of Consulting Engineers - Kenya
ACWC	Asphalt Concrete Wearing Course
ADMM	Asset Data Management Manual
AfDB	African Development Bank
AG	Austroads Guide
AM	Asset Management
AMI	Asphalt Membrane Interlayer
AMOR	Asset Maintenance and Operation Requirements
ASANRA	Association of National Road Agencies
ATS	Austroads Technical Specifications
BCO	Bonded Concrete Overlay
BS	British Standard
BT	Bridge Technology
BoQ	Bill of Quantities
CBGM	Cement Bound Granular Material
CBP	Concrete Blocks Pavement
CBR	California Bearing Ratio
CE	Compensation Event
CEG	Consulting Engineers Group
COLTO	Committee of Land and Transport Officers
COTO	Committee of Transport Officials
COMESA	Common Market for Eastern and Southern Africa
CPR	Concrete Pavement Rehabilitation
CRCB	Continuously Reinforced Concrete Base
CPCD	Concrete Pavement Contraction Design
CRO	Crack Reseat Overlay
CRCP	Continuously Reinforced Concrete Pavement
DBM	Dense Bitumen Macadam

Acronym	Description
DCP	Dynamic Cone Penetrometer
DMRB	Design Manual for Roads and Bridges
EAC	East African Community
EAT	East African Time
EF	Equivalence Factor
EME	
ETB	Emulsion Treated Base
ERA	Ethiopian Roads Authority
EU	European Union
EVA	Ethylene Vinyl Acetate
EWN	Early Warning Notice
FEM	Finite Element Method
FIDIC	International Federation of Consulting Engineers
FHWA	Federal Highways Administration
FSC	Forest Stewardship Council
FWD	Falling Weight Deflectometer
GCC	General Conditions of Contract
GDP	Gross Domestic Product
GGBFS	Ground Granulated Blast-Furnace Slag
GM	Grading Modulus
GNP	Gross National Product
GPR	Ground Penetrating Radar
HBM	Hydraulically Bound Materials
HDM	Highway Design and Maintenance
HGV	Heavy Goods Vehicle
HIG	Hydraulically Improve Granular Materials
HIPAR	Hot in Place Asphalt Recycling
HMA	Hot Mix Asphalt
HRB	Hydraulic Road Binders
HSE	Health Safety and Environment
IANs	Interim Advice Notes
IMESA	Institute of Municipal Engineers South Africa

Acronym	Description
IRC	Indian Roads Congress
JRC	Jointed Reinforced Concrete
JRCP	Jointed Reinforced Concrete Pavement
JUCP	Jointed Unreinforced Concrete Pavements
KEBS	Kenya Bureau of Standards
KeNHA	Kenya National Highway Authority
KeRRA	Kenya Rural Roads Authority
KRB	Kenya Roads Board
KURA	Kenya Urban Roads Authority
KWS	Kenya Wildlife Services
Ls	Load in kN
LET	Layered Elastic Theory
LVSR	Low Volume Sealed Road
LWD	Light Weight Deflectometer
MCHW	Manual for Contract Documents for Highway Works
MDD	Maximum Dry Density
MEM	Monitoring and Evaluation Manual
MEPDG	Mechanistic-Empirical Pavement Design Guide
MESA	Million Equivalent Standard Axles
MHB	Multi-Head Breaker
MPa	Surface Stiffness Modulus
MOPW&H	Ministry of Public Works and Housing
MORT&H	Ministry of Road Transport and Highways
MTRD	Materials Testing and Research Department
NMM	Network Management Manual
NMT	Non-Motorised Transport
NPM	Network and Project Planning Manual
NSC	National Steering Committee
NTR	National Technical Requirement
NTSA	National Traffic Safety Agency
ODA	Overseas Development Administration
OGA	Open Graded Asphalt

Acronym	Description
OMC	Optimum Moisture Content
OPBRC	Output and Performance-Based Road Contracts
ORN	Overseas Road Note
PAM	Project Appraisal Manual
PCA	Portland Cement Association
PCC	Portland Cement Concrete
PCP	Jointed Plain Concrete
PD	Project Delivery
PID	Project Implementation Department
PLWD	People Living With Disabilities
PP	Plasticity Product
PRODM	Pavement Rehabilitation and Overlay Design Manual
PRR	Preliminary Review Report
PSM	Procedures and Standards Manual
PT	Pavement Technology
RDM	Road Design Manual
RM	Road Manual
RAMM	Road Asset Management Manual
RAN	Roads Authority of Namibia
RCB	Roads Coordinating Body
RCC	Roller Impacted Concrete
RCM	Road Construction Manual
RD	Road Design
ReCAP	Research for Community Access Programme
RDM	Road Design Manual
RM	Road Manual
ROM	Road Operation Manual
RS	Road Safety
RSA	Road Safety Authority
RT	Road Tunnels
RTFOT	Rolling Thin Film Oven Test
RTMC	Roads Traffic Management Corporation

Acronym	Description
RWSC	Routine Winter Service Code
SABITA	South African Bitumen Association
SABS	South African Bureau of Standards
SADC	Southern African Development Community
SANRAL	South African National Roads Agency Limited
SANS	South African National Standards
SAPEM	South African Pavement Engineering Manual
SARSM	South African Road Safety Manual
SARTSM	South African Road Traffic Signs Manual
SFCP	Jointed Steel Fibre Reinforced Concrete Pavements
SMA	Stone Mastic Asphalt
SMCA	Standards, Metrology, and Conformity Assessment
SPT	Standard Penetration Test
SRBC	Specification for Road and Bridge Construction
SSA	Sub-Saharan Africa
TA	Technical Administrator
TBT	Technical Barriers to Trade
TCF	Totally Chlorine Free
TIA	Traffic Impact Assessment
TM	Traffic Management
TMH	Technical Methods for Highways
ToR	Terms of Reference
TRH	Technical Recommendations for Highways
TRL	Transport Research Laboratory
TRRL	Transport Road Research Laboratory
TTF	Technical Task Force
TTM	Temporary Traffic Management
UAE	United Arab Emirates
UK	United Kingdom
URA	Uganda Roads Authority
URC	Unreinforced Jointed Concrete
USA	United States of America

Acronym	Description
USDOT	United States Department of Transport
UTRC	Ultra-Thin Reinforced Concrete
UTRCP	Ultra-Thin Reinforced Concrete Pavements
VCS	Visual Condition Survey
VIM	Voids in Mix
WHO	World Health Organisation
WSCM	Works and Services Contracts Manual

1 Introduction

1.1 Background

The Constitution of Kenya, in the Fourth Schedule, assigns to the National Government the function of setting standards for the construction and maintenance of all public roads.

To fulfil the above-mentioned function, the Ministry of Transport, Infrastructure, Housing, Urban Development and Public Works (Ministry) is charged with the sectorial responsibility for the formulation of all policy and standards for public roads, including development and updating of standards for road design, construction, maintenance and operations.

The management of a large road network requires appropriate manuals that consider modern road construction and maintenance technology, including new construction materials and equipment. Changes in motorized and non-motorized traffic demand levels, recent developments in vehicle specifications, particularly changes in vehicle size, carrying capacity and axle configuration, have put pressure on existing road networks not only in Kenya but the entire Sub-Saharan Africa (SSA) region. All these changing features have a direct effect, in one way or another, on pavement design and road functionality.

The current Kenya road and bridges design manual and construction specifications were proposed and drafted in the 1970s and 1980s and only a few have been finalized and published. To complement the above, other related manuals were drafted on subjects such as low-volume sealed roads, road maintenance, safety and appraisal.

The Ministry, over the years, has sought the services of Consultants to assist with the review and updating of the Road Design Manual (RDM) and the Standard Specification. In 2006, the Ministry, with EU funding, commissioned EGIS International to review and update the entire RDM including the associated standard specifications. The draft submissions by EGIS International, in 2009, were reviewed by a National Steering Committee (NSC) but were not adopted.

In late 2021, Transport Research Laboratory Limited (TRL), in partnership with CEG of India and Norken of Kenya (Consultant), was appointed to undertake the review and update of certain existing/approved and draft components of the RDM as well as the drafts prepared by EGIS International.

1.2 Overall project objective

The main and overall objective of the Consultant's assignment is to assist the Ministry to review and update the Kenya road design manual and construction specification to incorporate best practices, climate change considerations, and recent technologies that enable cost-effective and efficient implementation of road development and maintenance projects and ensure a safe, secure and efficient road transport system.

1.3 Specific project objectives

The specific objectives of the project are as follows:

a) **Objective 1**: Review and establishment of a new structure and coding system for Kenyan road design and construction standards.

b) **Objective 2**: Review and updating of existing pavement design manuals and the standard specification for road and bridge construction.

c) **Objective 3**: Review and finalization of the highway and structural design manuals drafted in 2009 under a European Union (EU) funded exercise by EGIS International.

d) **Objective 4**: Dissemination and training on the updated manuals and specification.

1.4 Purpose and structure of this report

The purpose of this version of the Draft Review Report is to present findings from the technical review of existing and draft manuals ***for approval by the NSC towards fulfilment of Objective 2 and 3 mentioned above.***

The structure of the report is as follows:

Section 1 is an introductory section and presents a summarised background to the entire project of reviewing and updating the RDM and specification.

Section 2 outlines the specific objectives of the review process, the scope, and the methodology followed.

Section 3 is a concise summary of the overall findings of the review process.

Section 4 reviews the existing and currently approved *Materials and Pavement Design for New Roads* published in 1987, focussing on flexible pavement design.

Section 5 reviews same manual mentioned above, that is the 1987 *Road Design Manual for New Roads*, with particular attention to rigid pavements. There is no stand-alone manual for the topic; the review paid attention to a chapter in the manual mentioned above.

Section 6 reviews the *Pavement Rehabilitation and Overlay Design* published in 1988, this is the currently approved manual. The review also touches on the draft manual prepared by EGIS in 2009 on the same subject.

Section 7 is a review of the 2009 EGIS prepared *Roads and Bridges Design Manual – Part 1A: Geometric Design for Rural Roads.*

Section 8 reviews the 2009 2009 EGIS prepared *Roads and Bridges Design Manual – Part 2: Drainage Design.*

Section 9 presents results of the review of the *Roads and Bridges Design Manual – Part 6: Bridge Design* draft manuals produced by EGIS in 2009.

Section 10 reviews how the subject of traffic control facilities and road lighting design was attended to in the *Roads and Bridges Design Manual – Part 5: Traffic Control Devices* prepared by EGIS in 2009.

Section 11 is a review of *Road Safety* and *Road Safety Auditing.* The *Roads and Bridges Design Manual: Part 1B – Road Safety Audits* as produced, again by EGIS in 2009, was the main reference document.

Section 12 reviews the *Standard Specification for Road and Bridge Construction* that is currently in use on Kenyan projects. The document, published in 1986, is need of a complete update and merging the draft specification prepared by EGIS in 2009. The EGIS draft was not approved for use in its current form.

Section 13 is an administrative outline of the next steps following the review and approval of this report by the TTF, TAs and NSC.

2 Objective, Scope of Review and Methodology

2.1 Objectives

The specific objectives of this phase of the project, which are sub-objectives of Objectives 2 and 3 given earlier in sub-section 1.3, are to:

a) *Review* the existing pavement design manuals and the standard specification for road and bridge construction.

b) *Review* the highway and structural design manuals drafted in 2009 under a European Union (EU) funded exercise by EGIS International.

2.2 Scope of review

a) Review of the existing pavement design manuals and the standard specification for road and bridge construction.

The intended scope of review under the above objective is to:

1) Review the existing RDM Part III on Materials and Pavement Design for New Roads and the following documents:
   i) The TRL study reports and the recommendations of the 1997 seminar and any relevant research studies undertaken by MTRD.
   ii) Rigid cement concrete pavement design and construction standards adopted in countries with similar climatic conditions.
   iii) Design and performance monitoring reports for rigid cement pavements constructed in Kenya.
   iv) Pavement Design Guidelines for Low Volume Sealed Roads, 2017.
   v) Construction materials and current materials specifications and testing standards.
   vi) Application software for pavement design for new roads and in particular, the French ALIZE, South African RUBICON and American AASHTO pavement design software.
2) Review the existing RDM Part V on Pavement Rehabilitation and Overlay Design and the following:
   i) The existing road maintenance manuals.
   ii) Maintenance and overlay design manuals in UK, USA and South Africa.
   iii) Application software for pavement management and materials characterization in the existing RDM III and in the Highway Design and Maintenance Standards Model, Volume 1, Description of the HDM-III Model, published in 1987 by the World Bank.
   iv) Application software for pavement surface and structural condition analysis i.e. ALIZE, ROSY, PRIMAX and ELMOD, surface condition data i.e. HAWKEYE, ground penetrating radar (GPR) data i.e. RADAN, and for analysis of DCP

data i.e. TRL DCP and South African WIN DCP.

v) Existing MTRD pavement evaluation reports.

3) Review the existing Standard Specification for Road and Bridge Design and the following:

   i) The draft Standard Specifications developed under the EGIS Review of 2009.

   ii) Rigid cement concrete pavement construction specifications adopted in countries with similar climatic conditions.

   iii) Special specifications under ongoing construction projects for concrete paving blocks and cobblestone surfacing, reinforced fill structures and Superpave asphalt concrete and dense bitumen macadam.

   iv) Specifications of proprietary products in other jurisdictions, particularly UK and USA.

The tasks of the Consultant in covering the mentioned review scopes are as follows:

1) Review the pavement design manuals and the SRBC as indicated above and the respective existing manuals in **Annex 1**.
2) Based on the approved structure of the new RDM and in consultation with Technical Task Force (TTF) and the Technical Administrators (TAs), identify gaps and shortfalls and changes that need to be made to each of the pavement manuals.
3) Prepare a Draft Review Report for the pavement manuals highlighting identified gaps and shortfalls as well as proposed changes.
4) Based on the approved structure of the SRBC and the draft review report under item 3 above, and in consultation with TTF and the TAs, identify gaps, shortfalls and changes that need to be made to the SRBC.
5) Prepare a Draft Review Report for the SRBC highlighting identified gaps and shortfalls as well as proposed changes.
6) In consultation with the NSC, hold and facilitate a First Stakeholders' Workshop to discuss the draft review reports for the pavement manuals and the standard specifications.
7) In consultation with the TTF and the TAs, prepare a Workshop Report for the pavement manuals and the standard specifications which should include the Consultant's evaluation of the workshop's comments and recommendations.
8) Submit the Workshop Report to the NSC for concurrence on the stakeholder recommendations to be incorporated into the Final Review Report.
9) Prepare Final Review Reports for the pavement manuals and for the standard specifications incorporating the agreed recommendations of the Stakeholders' Workshop.
10) Present the Final Review Reports to the NSC for approval and adoption.

b) Review the highway and structural design manuals drafted in 2009 under a European Union (EU) funded review exercise by EGIS International.

The scope of the review under the above objective entailed review of the following highway and structural design manuals (Road Design Manuals) drafted in 2009 under EU funded review:

1) Part 1(a): Geometric Design.
2) Part 1(b): Road Safety Audits.
3) Part 1(c): Traffic Surveys.
4) Part 2: Drainage Design.
5) Part 5: Traffic Control Devices.
6) Part 6: Structural Design
    (a) Bridge and Culvert Design.
    (b) Catalogue of Drawings
        (i) Standard Culverts and Drifts
        (ii) Standard Concrete Box Culverts – Schedules and Quantities
        (iii) Standard Small Span Concrete Bridges
        (iv) Standard Structures.

The tasks of the Consultant under the above-mentioned objective are as follows:

1) Review the highway and structural manuals drafted by EGIS International in 2009 as indicated above.
2) In consultation with the TTF and based on the agreed manual structure, identify gaps and shortfalls of each draft and propose changes to be made.
3) Prepare a Draft Review Report covering all the parts.
4) In consultation with the NSC, hold and facilitate a First Stakeholders' Workshop to discuss the Draft Review Report.
5) Prepare a Workshop Report which should include the Consultant's evaluation of the workshop's comments and recommendations.
6) Submit the Workshop Report to the NSC to discuss and agree on the stakeholders' recommendations to be adopted.
7) Prepare a Final Draft Review Report incorporating agreed stakeholder comments and recommendations.
8) Circulate the Final Review Report amongst stakeholders for comments.
9) Prepare a Final Review Report incorporating agreed stakeholders comments and recommendations.
10) Submit the Final Review Report to the NSC for approval and adoption.

2.3 Methodology

The methodology adopted by the Consultant in reviewing the technical content of the existing manuals and the SRBC was as follows:

1) The existing and draft manuals, and the SRBC were read, reviewed and general observations made based on the Consultant's experience.

2) The Consultant then examined international and regional practice in each of the review areas and compared with the current Kenya situation.
3) The next step, for each of the proposed manual, and the SRBC, was to develop an idealized framework of the contents. The framework included a Table of Contents for the proposed manual and SRBC, and an overview of the ideal contents of each Chapter, or Series in the case of SRBC. The establishment of the ideal contents of each Chapter, or Series in the case of SRBC, was guided by recent experience of the Consultant and Kenyan practitioners and regional and international best-practice.
4) The above-mentioned framework was then be used as a yardstick for objectively assessing the adequacy of the existing manuals and SRBC. The adequacy of existing contents of Chapters, or Series in the case of SRBC, were rated against a standardised scale given in **Table 2-1** below.

Table 2-1-2-2: Manual and SRBC Content Rating Scale

Colour Code	Adequacy Rating	Guiding School Report Scorecard
	Fully developed and adequate	>80%
	Partially developed and partially adequate	40-80%
	Not developed and inadequate	<40%

5) The gaps between the existing documents and the idealised/proposed manuals and SRBC was therefore established.
6) Recommendations on how to address the gaps were then made and, following discussion and approval, will be carried to the next stage of the project that will entail drafting of the updates.

3 Overview of Review Findings

3.1 Background

Prior to the review of the technical content of existing and in-use manuals and SRBC, and EGIS drafts, the Consultant and the TTF undertook a preliminary review exercise to establish a new manual structure and coding system for Kenya. The exercise involved reviewing the structure and coding system of the existing Kenyan road design manuals and specification for road and bridge construction as well as the EGIS 2009 drafts. The practices in the following peer countries were studied: U.S.A, U.K., India, South Africa, Uganda, Namibia, Ethiopia and Australia.

Drawing on the structure of the current Kenya manual structure and coding system and practices in other countries, a manual structure and coding system for Kenya was then formulated by the Consultant for discussion with the TTF/TAs. A lean and simple system that mimics and improves the current system and would be largely similar to those in use in the SSA was targeted. An appropriate coding of the manual system was then recommended that constantly points the user to the design subject.

A gap analysis process between the proposed system and the existing system was then undertaken to reveal areas that needed attention. The TTF, TAs and the Consultant's deliberated on several version of the road design manual and SRBC system and coding and eventually settled on the final proposals that were presented to the NSC for approval. The final recommended manual and SRBC structures and coding are presented below.

3.2 New Roads Manuals Structure for Kenya

The preliminary review process recommended that Kenya adopts a roads manual system that recognises the various stages of the project cycle.

The Road Design Manual, which is the main subject of the review and update exercise, will then be part of a Roads Manual system made up of various manuals, some of which have a bearing on road design. The Road Manual system will consist of manuals listed in **Table 3-1** below.

Table 3-1: Proposed new Road Manual (RM) system for Kenya

Project Cycle Stage	Manual: Volume or Part/Chapter	Code	Status
A. General	**Procedures and Standards Manual**	**PSM**	
	1. General		Not developed
	2. Policies		Not developed
	3. Procedures Guidance		Not developed
	4. Codes of Practice		Not developed
	5. Guidelines		Not developed
	6. Product/Testing Standards		Partially developed
B. Planning	**Network and Project Planning Manual**	**NPM**	

Project Cycle Stage	Manual: Volume or Part/Chapter	Code	Status
	1. Road Classification		Partially developed
	2. Route/Corridor Planning		Not developed
	3. Roadside Development and Control		Not developed
	4. Highway Capacity		Not developed
	5. Project Planning		Not developed
C. Appraisal	**Project Appraisal Manual**	**PAM**	
	1. Environmental Impact Assessment and Audit		Not developed
	2. Social Impact Assessment		Not developed
	3. Traffic Impact Assessment		Not developed
	4. Road Safety Audits		Partially developed
	5. Project Appraisal		Partially developed
	6. Feasibility Studies		Partially developed
D. Design	**Road Design Manual**	**RDM**	
	1. Geometric Design		Partially developed
	2. Hydrology and Drainage Design		Partially developed
	3. Materials and Pavement Design for New Roads		Partially developed
	4. Bridges and Retaining Structures Design		Partially developed
	5. Pavement Maintenance, Rehabilitation and Overlay Design		Partially developed
	6. Traffic Control Facilities and Communication Systems Design		Partially developed
	7. Road Lighting Design		Partially developed
E. Contracts	**Works and Services Contracts Manual**	**WSCM**	
	1. Forms of Contracts		Partially developed
	2. Standard Specification for Road and Bridge Construction		Partially developed
	3. Bills of Quantities		Partially developed
	4. Standard/Typical Drawings		Partially developed
F. Construction	**Road Construction Manual**	**RCM**	
	1. Construction Management		Not developed
	2. Project Management		Partially developed
	3. Site Supervision		Not developed
	4. Quality Assurance		Not developed
	5. Quality Control		Not developed
G. Maintenance	**Road Asset Management Manual**	**RAMM**	
	1. Maintenance Management		Partially developed
	2. General Maintenance		Partially developed

Project Cycle Stage	Manual: Volume or Part/Chapter	Code	Status
	3. Pavement Maintenance		Partially developed
	4. Bridges and Structures Maintenance		Partially developed
H. Operations	**Road Operation Manual**	**ROM**	
	1. Traffic Management		Partially developed
	2. Vehicle Load Control		Not developed
	3. Emergency Services		Not developed
	4. Tolling		Not developed
I. Monitoring and Evaluation	**Monitoring and Evaluation Manual**	**MEM**	
	1. Performance Monitoring Manual		Not developed
	2. Technical Audits		Not developed
	3. Poverty, Gender Equality and Social Inclusion Monitoring		Not developed

3.3 New Kenya Road Design Manual Structure and Coding

Following the deliberations between the Consultant and the TTF during the preliminary review stage, the Road Design Manual structure and coding given in **Table 3-2** below was recommended to the NSC.

Table 3-2: Proposed new road design manual system for Kenya

Vol	Manual Title	Part Name	Part/Code
1	Road Design Manual: Vol. 1 - Geometric Design	Part 1 – Topographic Survey Part 2 – Traffic Surveys Part 3 – Geometric Design for Highways and Rural and Urban Roads	RDM 1.1 RDM 1.2 RDM 1.3
2	Road Design Manual: Vol 2 - Hydrology and Drainage Design	Part 1 – Hydrological Surveys Part 2 – Drainage Design	RDM 2.1 RDM 2.1
3	Road Design Manual: Vol. 3 - Materials and Pavement Design for New Roads	Part 1 – Material Prospecting and Alignment Survey Manual Part 2 – Materials Field and Laboratory Testing Manual Part 3 – Pavement Foundation Design Part 4 – Flexible Pavement Design Part 5 – Rigid Pavement Design	RDM 3.1 RDM 3.2 RDM 3.3 RDM 3.4 RDM 3.5
4	Road Design Manual: Vol. 4 - Bridges and Retaining Structures Design	Part 1 – Bridge and Culvert Design Part 2 – Retaining Structures Design Part 3 – Bridge Condition Survey Part 4 – Bridge Maintenance Design	RDM 4.1 RDM 4.2 RDM 4.3 RDM 4.4
5	Road Design Manual: Vol 5 – Pavement Maintenance,	Part 1 – Pavement Condition Survey Part 2 – Pavement Maintenance, Rehabilitation and Overlay Design	RDM 5.1 RDM 5.2

Vol	Manual Title	Part Name	Part/Code
	Rehabilitation and Overlay Design		
6	Road Design Manual: Vol. 6 - Traffic Control Facilities and Communication Systems Design	Part 1 – Road Marking Part 2 – Traffic Signs Part 3 – Traffic Signals and Communication System Part 4 – Other Traffic Control Devices	RDM 6.1 RDM 6.2 RDM 6.3 RDM 6.4
7	Road Design Manual: Vol. 7 - Road Lighting Design	Part 1 – Grid-connected Road Lighting Part 2 – Solar Road Lighting	RDM 7.1 RDM 7.2

3.4 New Kenya SRBC Structure

As for the Road Design Manual, deliberations between the Consultant, the TTF and TAs yielded the structure and content of the new SRBC as outlined in **Table 3-3** below. This structure was readied for presentation to the NSC for approval at the time of preparation of this report.

Table 3-3: Proposed new SRBC structure for Kenya

Series	Title	Remarks
1000	General	
2000	Drainage	
3000	Earthworks	To include: • Ground improvement.
4000	Natural, Crushes Stone and Stabilized Materials Pavement Layers	To include: • Hand-packed stone. • Bitumen stabilised material.
5000	Bituminous Surface Treatments, Seals and Pavement Layers	
6000	Concrete Layers and Modular Paving	To be more comprehensive and cater for: • Paver laid concrete. • Formwork laid concrete.
7000	Structures	To include: • Non-intrusive bridge inspections. • Structural repairs. • Earth-reinforced structures. • Prestressed and post-tensioned concrete.
8000	Ancillary Roadworks	
9000	Environmental, Health, Safety and Social Aspects	Will be a new stand-alone section to emphasize the importance of the matters related to preservation of the environment, enhancement of health and safety and attention to poverty, gender equality and social inclusion.

3.5 Findings – existing and draft manuals and SRBC compared to idealised new system

An overview of the results of the process outlined in **Section 2.3** are given in **Tables 3-4** and **Table 3-5** below for the road and bridges design manual and the SRBC respectively.

The process sought to assess the adequacy of the content of the existing and draft manuals and SRBC against the proposed new system given in the fore-going sections.

3.6 Consultant, TTF and TA Consultations on the Draft Review Report

In accordance with the objectives of the project, the Consultant engaged the TTF and the TAs following submission of the first draft of the Draft Review Report.

Based on the agreed manual structure, the various meetings held deliberated on the identified gaps and shortfalls of currents approved and/or draft manuals, as well as the SRBC, and further refined the proposed changes that had been recommended by the Consultant. The Draft Review Report was submitted by the Consultant in June 2022 and made available to the TTF members well before the deliberations.

The deliberations were undertaken during the TTF's Meeting Nr 5 held over the period from 9th to 17th November 2022.

The meeting consisted of the following sessions:

a) Plenary session Nr 1 of 9th November, 2022.

b) Geometrics Sub-committee meeting of 11th November, 2022.

c) Bridges Sub-committee meeting of 14th November, 2022.

d) Pavements Sub-committee meeting of 14th and 15th November, 2022.

e) Plenary session Nr 2 of 17th November, 2022.

Technical proceedings of the above-mentioned meeting sessions are given in **Appendix B** to this report.

3.7 Recommendations of how the gap will be addressed

On approval of this Draft Review Report, the Consultant will use the existing content in the current manuals as well as new and well-researched content to prepare the first drafts of manuals that are covered under the scope of this project. The Consultant will draw on their recent experience, and regional and international best practice, to formulate up-to-date manuals for Kenya.

The Consultant will seek to conduct working meetings with practitioners to enhance the drafting process and reflect local content. In addition, in order to take the TTF's invaluable guidance on board, the Consultant will seek to meet with designated TTF members informally within four weeks of commencement of the drafting process. The meetings will focus on the Consultant's proposals of the technical content of each manual, or part of a manual, as well as the SRBC.

At the end of the above outlined process, the Consultant will prepare the 1st drafts of the manual volumes based on the proposed manual structure and coding. The 1st drafts of the manuals will be accompanied by the proposed improvements to the SRBC as well as a concise administrative report on the drafting process, as per ToR.

The drafts will be submitted to the Client for review by the TTF and TAs.

Table 3-4: Summary of review of existing and draft manuals compared to proposed new manual contents

Code	Vol	Proposed Manual	Current Title of Approved Manual or Part applicable to new manual structure	Current Title of Draft Manual or Part applicable to new manual structure	Summary of Review of, and Remarks on, the Adequacy of Existing/Approved Manuals and Drafts
PSM		**Procedure and Standards Manual**: 1. General 2. Policies 3. Procedures Guidance 4. Codes of Practice 5. Guidelines 6. Product/Testing Standards	1. Code of practice and materials testing standards (KEBS) 2. RDM Part III, Chapter 14: Material Testing and sampling Program; and, 3. RDM Part III, Chapter 15: Standard Methods of Testing	None	Stand-alone manual does not exist. Available contributory documents are limited in content and will need signification augmentation with new material. The proposed new manual will guide users on road provision policies, manuals, guidelines, procedures, processes and standards; will be a quick reference document. Sketchy information exists for incorporation into the new proposed manual.
NPM		**Network and Project Panning Manual**: 1. Road Classification 2. Route/Corridor Planning 3. Roadside Development and Control 4. Highway Capacity 5. Project Planning	1. RDM Part I, Chapter 2: Road Classification	None	Stand-alone manual does not exist. Available contributory document is limited in content and will need signification augmentation with new material. Available content indicated in this table will assist in formulation of new manual that will attend to corridor planning, control of roadside development, catering for third party services along roads, network and project level planning, and determination of capacity of highways.
PAM		**Project Appraisal Manual**: 1. Environmental Impact Assessment and Audit	1. Feasibility Study Guideline (2016) 2. Project Appraisal Guideline (2016)	None	Stand-alone manual does not exist. Available contributory documents are also limited in content and will need

Code	Vol	Proposed Manual	Current Title of Approved Manual or Part applicable to new manual structure	Current Title of Draft Manual or Part applicable to new manual structure	Summary of Review of, and Remarks on, the Adequacy of Existing/Approved Manuals and Drafts
		2. Social Impact Assessment 3. Traffic Impact Assessment 4. Road Safety Audits 5. Project Appraisal 6. Feasibility Studies			signification augmentation with new material. Proposed new manual will include a part that provides guidance on how road projects should apply and comply with NEMA guidelines and standards and OSHA regulations in Kenya. Will provide guidance tailor-made for roads on environmental impact assessment as well as social impact assessment. ESIA management processes will also be defined. The new manual will also cover the entire process of undertaking feasibility studies. It will include project and programme and project appraisal procedures in economic and financial terms.
RDM	1	**Road Design Manual: Vol. 1 - Geometric Design**: 1. Topographic Survey 2. Traffic Surveys 3. Geometric Design for Highways and Rural Roads 4. Geometric Design for Urban Roads	1. RDM Part I: Geometric Design of Rural Roads (1979)	1. RDM Part 1a): Geometric Design (2009) 2. RDM Part 1c): Traffic Surveys (2009) 3. Road Design Guidelines for Urban Roads (Geometric Design of Urban Roads) (2001) 4. Street Design Manual for Urban Areas in Kenya (2019)	Substantial information available in approved and draft formats will feed into manual update. Manual is viewed as partially developed.

Code	Vol	Proposed Manual	Current Title of Approved Manual or Part applicable to new manual structure	Current Title of Draft Manual or Part applicable to new manual structure	Summary of Review of, and Remarks on, the Adequacy of Existing/Approved Manuals and Drafts
RDM	2	**Road Design Manual: Vol 2 - Hydrology and Drainage Design**: 1. Hydrological Surveys 2. Drainage Design	None	1. RDM Part 2: Drainage Design (2009) 2. Hydraulic Design of Drainage Structures (1983)	Substantial information available in draft form produced by EGIS to feed into manual update process.
RDM	3	**Road Design Manual: Vol. 3 - Materials and Pavement Design for New Roads**: 1. Material Prospecting and Alignment Survey Manual 2. Materials Field and Laboratory Testing Manual 3. Pavement Foundation Design 4. Flexible Pavement Design 5. Rigid Pavement Design	1. RDM Part III: Materials and Pavement Design for New Roads (1987) 2. Pavement Design Guideline for Low Volume Sealed Roads (2017)	1. RDM Part 3: Materials and Pavement Design - New Gravel, Bituminous and Concrete Roads (2009)	Substantial information available in draft to feed into manual update of design of flexible pavements. However, information of rigid pavements is inadequate and will call for new drafting.
RDM	4	**Road Design Manual: Vol. 4 - Bridges and Retaining Structures Design**: 1. Bridges and Culvert Design 2. Retaining Structure Design 3. Bridge Condition Surveys 4. Bridge Maintenance Design	1. RDM Part IV: Bridges Design (1993) 2. Eurocode 3. Standard Designs for Small Concrete Drainage 4. Structures (1987): 5. Part I: Standard Small Span Concrete Bridges 6. Part II: Standard concrete box culverts	1. RDM Part 6: Structural Design– (i) RDM Part 6a): Bridge and Culvert Design (ii) Bridge Design (1982) 2. RDM Part 6b): Structural Design – Catalogue of Drawings (2009) (i) Standard Culverts and Drifts (ii) Standard Concrete Box Culverts – Schedules and Quantities (iii) Standard Small Span Concrete Bridges	Relatively useful content is available in the document listed as approved or draft manuals. There will be need to include design of high embankments and deep cuts, slope stability analysis and design, design of bridge foundations, design of retaining walls. Careful rationalization will be required in adoption of international standards as Kenyan standards. E.g. adoption of the Eurocode and AASHTO standards.

Code	Vol	Proposed Manual	Current Title of Approved Manual or Part applicable to new manual structure	Current Title of Draft Manual or Part applicable to new manual structure	Summary of Review of, and Remarks on, the Adequacy of Existing/Approved Manuals and Drafts
				iv) Standard Structures	
RDM	5	**Road Design Manual: Vol. 5 – Pavement Maintenance, Rehabilitation and Overlay Design**: 1. Pavement Condition Survey 2. Pavement Maintenance, Rehabilitation and Overlay Design	1. Road Maintenance Manual (2014) 2. Minor Roads Programme Technical and Maintenance Manual (1989) 3. Roads 2000 Operations Manual (2008)	1. RDM Part V: Pavement Rehabilitation and Overlay Design (1988) 2. RDM Part 4: Materials and Pavement Design - Overlay and Asphalt Pavement Rehabilitation (2009)	The EGIS draft on the subject is relatively inadequate and will call for a complete re-write. The Consultant has flagged this manual as requiring increased input.
RDM	6	**Road Design Manual: Vol. 6 - Traffic Control Facilities and Communication Systems Design**: 1. Road Marking 2. Traffic Signs 3. Traffic Signals and Communication Systems 4. Other Traffic Control Devices	Traffic Management Toolkit	1. RDM Part 5: Traffic Control Devices (2009) (i) RDM Part 5a): Traffic Signs (ii) RDM Part 5b): Road Marking (iii) RDM Part 5c): Traffic Signals 2. Road Marking (1972) 3. Traffic Signs in Kenya (1975)	Significant information available in the existing documentation for incorporation into updates. Some high level modernization will be necessary. The Consultant will include a chapter on Intelligent Transport Systems under Part 3 – Traffic Signals and Communication Systems.
RDM	7	**Road Design Manual: Vol. 7 - Road Lighting Manual**: 1. Grid-connected Road Lighting 2. Solar Road Lighting	None	1. RDM Part 5: Traffic Control Devices (2009) (i) RDM Part 5d): Street Lighting	Some limited information is available in the draft for incorporation into the update and/or drafting of new content. Solar powered street lighting is viewed as a sustainable solution and will be given special attention.

Table 3-5: Summary of review of existing and draft SRBC compared to proposed new SRBC contents

Series	Proposed Series Title	Series Exist in current speci-fication (1984)	Series Exist in EGIS 2009 Draft?	Summary of Review Findings on Adequacy of Existing and Draft SRBCs	Remarks
1000	General	Yes	Yes	General guidance on the specification not given.	Substantial improvements will be required. Information in current specification and EGIS drafts in sketchy. Series partially developed.
2000	Drainage	Yes	Yes		Series partially developed.
3000	Earthworks	Yes	Yes	Ground improvement not comprehensively covered.	Series partially developed. Ground improvement will be catered for under this series.
4000	Natural, Crushed Stone and Stabilized Materials Pavement Layers	Yes	Yes	Current and EGIS draft do no cover the following: • Hand-packed stone. • Use of bitumen emulsions to improve granular materials.	Series partially developed. To now include: • Hand-packed stone. • Bitumen stabilized material.
5000	Bituminous Surface Treatments, Seals and Pavement Layers	Yes	Yes		Series partially developed.
6000	Concrete Layers and Modular Paving	Yes	Yes	Specification does not full cater for paver laid concrete.	Series partially developed. Series to be made more comprehensive and cater for: • Paver laid concrete. • Formwork laid concrete.
7000	Structures	Yes	Yes	Specification does not cover: • Non-intrusive bridge inspections. • Bridge repairs. • Pre-stressed concrete.	Series partially developed. To include: • Non-intrusive bridge inspections. • Structural repairs. • Earth-reinforced structures. • Prestressed and post-tensioned concrete.

Series	Proposed Series Title	Series Exist in current speci-fication (1984)	Series Exist in EGIS 2009 Draft?	Summary of Review Findings on Adequacy of Existing and Draft SRBCs	Remarks
8000	Ancillary Roadworks	Yes	Yes		Series partially developed.
9000	Environmental, Health, Safety and Social Aspects	No	No	Huge gap identified. This is a new area for the Kenya system and must be updated to comply with local laws and regulations, international laws, norms and practices.	Series not developed. Will be a new stand-alone section to emphasize the importance of the following matters: • Preservation of the environment. • Enhancement of health and safety at work and in project affected communities. • Attention to poverty, gender equality and social inclusion.

4 Review of Materials and Pavement Design Manuals for New Roads – Flexible Pavements

4.1 Review of Materials and Pavement Design for New Roads, 1987 Manual

4.1.1 General

The manual is obviously quite old and is therefore not digital in nature. That made quick search for items time-consuming. The good aspects of this manual are that it is concise and therefore easy to read. Each topic is dealt with in the style of a manual and not a textbook.

The manual could benefit from several sketches, for example on treatment of expansive clay subgrades. However, values of some parameters need to be changed in light of recent research; new parameters and their values need to be included; obsolete parameters need to be excluded; and finally the document needs a minimal level of restructuring.

4.1.2 Chapter 2 - Traffic

This chapter describes the determination of axle loads, vehicle equivalence factors, estimation of traffic volume for design, the determination of design traffic, and the classification. It needs a significant rewrite. Since 1987, there has been a revision included in the traffic act that designates different vehicle classes. These have to be synchronised with traffic enumeration forms. A debate is also required as to whether the classes in the enumeration forms should deviate from the vehicle classes in the traffic act.

It is noted that the legal limits presented in the manual were valid in 1987 and there is a need for the limits to be updated in line with the current legal limits being enforced in Kenya. It currently refers to axle loads measured on major roads in Kenya. Currently, it is relatively easy for designers to measure axle loads on their project roads or nearby roads. Therefore, instructions on how to carry out axle load surveys accurately, estimating generated traffic and diverted traffic should be included. Additionally, there are now new vehicle classifications (Table 4-1) and design traffic classes (Table 4-2) as included in the LVSR 2017 which should be retained.

Table 4-1: Vehicle Classification System

Vehicle Category	Vehicle Class	Description based on Road Design Manual and the Traffic Act (Cap 403)	Class by Axle Configuration
Passenger Vehicles	Pedal Cycle (PC)	Non-motorised bicycle or tricycle.	
	Motor Cycle (MC)	Self-propelled vehicle with less than 4 wheels.	
	Cars (C)	Passenger motor vehicle with seating capacity of not more than nine persons including the driver.	2-Axle Rigid

Vehicle Category	Vehicle Class	Description based on Road Design Manual and the Traffic Act (Cap 403)	Class by Axle Configuration
	Minibus (MB)	Two axle rigid chassis passenger motor vehicle with seating capacity of 10 to 25 persons including the driver.	2-Axle Rigid
	Bus (B)	Two axle rigid chassis passenger motor vehicle with seating capacity of 26 to 53 persons including the driver.	2-Axle Rigid
	Omnibus (OB)	Three or four axle passenger motor vehicle with seating capacity of more than 53 persons including driver	3 or 4-Axle rigid or articulated
Goods Vehicles	Light Goods Vehicle (LGV)	Two axle rigid chassis goods vehicle of gross vehicle weight not exceeding 3,500 kg.	2-Axle Rigid
	Medium Goods Vehicle (MGV)	Two axle rigid chassis goods vehicle or tractor of gross vehicle weight exceeding 3,500 kg.	2-Axle Rigid
	Heavy Goods Vehicle 1 (HGV 1)	3 or 4 axle rigid chassis, articulated goods vehicle or tractor.	3 or 4-axle rigid or articulated
	Heavy Goods Vehicle 2 (HGV 2)	Goods vehicle having 5 or more axles	5 (or more)-axles articulated

Table 4-2: Design Traffic Classes

Design Traffic Class	Cumulative Equivalent Standard Axles
T5-4	< 25,000
T5-3	25,000 - 100,000
T5-2	100,000 – 250,000
T5-1	250,000 – 500,000
T5-0	500,000 – 1 million
T4	1 million – 3 million
T3	3 million – 10 million
T2	10 million – 25 million
T1	25 million – 60 million
T0	60 million – 150 million
TX	≥ 150 million

The axle damage exponent factor needs to be revised in light of recent research. New research shows that the damage exponent is related to the pavement material and structure configuration. For example, TRH 4 (1996) recommends a damage exponent of 3 for granular base on cemented sub-base. If this is compared with using the value of 4.5 as in RDM III, the design traffic can be one class lower (when axles are greater than the standard axle of 80 kN) – see Table 4-3.

Table 4-3: Comparison of effect of damage exponent

AADT	Axle loads	Damage exponent = 3			Damage exponent = 4.5		
		3	ESA/day	MESA (20 years)	4.5	ESA/day	MESA (20 years)
600	7000	0.63	379	4,571,396	0.50	301	3,632,124
600	9000	1.34	805	9,715,882	1.55	932	11,254,100

Therefore, whereas the value of 4.5 should be used for preliminary estimation of design traffic. A recommendation for the designer to undertake undertake a sensitivity analysis using different exponents for different pavement configurations should be included in the manual.

Elements of compounding the design traffic vis-à-vis the carriageway width are conservative and need to be revised.

Liddle's formula (Equation 1) was adopted for conversion of all single axle loads to equivalent standard axles, taking a regional factor of 1.0 and a terminal serviceability index of 2.0

$$EF = \left(\frac{L_S}{80}\right)^{4.5} \qquad \text{Equation 1}$$

where:

EF is the equivalence factor of the single axle considered, and
Ls is the load in kN on the single axle considered.

The formula however is not applicable to axle weights greater than 130 kN. The effect of pavement strength on the equivalence factor is also noted in the manual but no further guidance is provided. .

The manual recommends the use of portable weighbridges for axle load surveys. Also, it requires that two tentative pavement designs are prepared at the preliminary design stage 1 - Assuming that the traffic carried by the road in future will be within the legal axle load limits of the Traffic Act, and 2 - Considering the axle loads measured at the time of the survey, and where these exceed 130 kN, attempt to design for the damaging power of such axles. Furthermore, average vehicle equivalence factors are provided in Table 2.3.1 of the manual for the different trunk roads and vehicle classes. The East African Community Vehicle Load Control Act 2016 has made changes to permissible axle loads. The tandem load permissible is now 18 tonnes as opposed to 16 tonnes in the RDM III. It is recommended that the maximum permissible axle load to be designed for should be less than 13 tonnes. A policy decision to be made. During surveys and design, excess axle load above 13 tonnes should be converted to generated traffic, because if axle load control is enforced then the excess load will generate traffic. A statement to that effect should be included in the manual.

It is noted that the data presented in Table 2.3.1 is likely to be based on the axle load study conducted in 1976 to 1980 and is therefore outdated and no longer applicable. Thus, it is proposed that: In addition to portable weigh pads, other axle load survey methods (e.g. Weigh-in-Motion, records from fixed weighbridges, and sampling at fixed weighbridges) be considered where these are available for trunk road project or any other project, including secondary road projects. This shall minimise errors arising from using the values presented in Table 2.3.1 for other projects such as secondary road projects whose traffic is likely to differ. The summary of VEFs on Kenya Roads should be included/moved to the appendices and categorised by road classes. MTRD to avail recent axle load data.

Table 2.4.1 of the manual presents the commercial traffic to be considered for design based on the carriageway width and traffic volume. It is proposed that commercial traffic considerations on dual carriageways be revised to reduce the proportion of commercial vehicles utilising the slow lane. The current proportion of 80% to 90% seems high.

It is proposed that a detailed section on how to estimate diverted and generated traffic be included. An appropriate example may be required.

Axle configurations affect the stresses and strains that pavement layers experience. Generally, for simplicity in axle load surveys, each axle shall be weighed independently instead of weighing by axle groups and tyre types. For critical roads, a designer is expected to undertake performance design and will be required to assess the various effects. This will be emphasised in the manual.

Forecasting the annual growth rate

In forecasting the annual growth rate information on how to obtain and/or estimate traffic growth rates is provided. This includes annual trends in traffic growth, national and regional development plans, number of vehicles registered, motor vehicle fuel consumption and the growth rate of Gross National Product (GNP) or Gross Domestic Product (GDP).

While the sources of information for determining traffic growth rates are correct, it is necessary to separate the forecast traffic into the different categories and apply the respective growth rates from the relevant information sources to each traffic category.

Choosing a design period

The definition of design period is provided in Section 1.3.4 of the manual. More detail differentiating between the design period and pavement life is provided in this section. The manual recommends stage construction due to its economic advantages and an initial design period of less than 15 years. This method is applicable for road projects where the information available is associated with a high level of uncertainty. For road projects, where the traffic data has a high level of confidence longer design periods should be considered. Guidelines on choice of design period could also be provided.

Calculating the cumulative number of standard axles

The cumulative number of standard axles, T over the chosen design period N (in years) is obtained following Equation 2.

$$T = 365\, t_1 \frac{(1+i)^N - 1}{i} \qquad \text{Equation 2}$$

Where:

t_1 is the average daily number of standard axles in the first year after opening

i is the annual growth rate expressed as a decimal fraction.

It is proposed that an alternative equation that takes into account the effect of the project life cycle such as design, time to construction, construction period, time of opening to traffic and the design period be considered for determining the cumulative number of standard axles. Emphasis should be made of the fact that Equation 2 should be applied to each traffic class and the results summed to obtain the design traffic class.

The traffic classes need to be extended from a maximum of 60 MESA to at least 100 MESA where principles of long-life pavements come into play. It is proposed that the classes developed during revision of the LVSR Guideline of 2017 be adopted. Principles of long-life pavement must be included in the manual.

4.1.3 Chapter 3 - The Natural Environment

Climate

The manual describes six climatic zones in Kenya, namely:

- Afro-alpine climate
- Equatorial climate
- Wet-tropical climate
- Semi-arid climate
- Arid climate
- Very arid climate.

A definition of these climatic zones in terms of rainfall and temperature distribution is required.

An appendix is included that contains maps of the mean annual rainfall and figures of minimum, mean, and maximum air temperatures. The legend of the map needs to be re-drawn to make it clear, since it is not easily legible. In the map, the six climatic zones are not labelled. The matrix of temperatures, and rainfall in the RDM III should be updated using recent data, and a matrix on evaporation should be included.

Regarding the figures showing the air temperatures in selected parts/towns of Kenya, these would be better represented in tabular format.

Ideally, a map of Kenya showing the maximum and minimum road temperatures would be required, but this requires a major study to be undertaken to measure the road temperatures or to calibrate a suitable model.

At the moment, these rainfall and temperature zones can be updated using meteorological data from the past 50 to 100 years. KeNHA should assist in obtaining and collating this data.

The manual defines Wet Areas as those with mean annual rainfall greater than 500 mm. Other documents such as TRL's Overseas Road Note 31 define Wet Areas as those with greater than 250 mm. This definition should be discussed and reviewed in light of recent climate change. The definition has implications on the design subgrade moisture content to be used, and subsequently the pavement performance. Even in zones with rainfall less than 250 mm, sometimes there is flooding lasting for several days and weeks. All subgrades will be classified on the basis of 4 days' soaked strength. Materials classification will be dealt with separately as has already been initiated in LVSR 2017.

The chapter also discusses the geology and soils of Kenya. A geological map is included in an appendix, but a soils map is not included; this will be required for the update. It also refers to Materials Branch Reports 336 for details of the stone types available in Kenya. It also refers to Materials Branch Reports 343 and 344 for details of the types of gravel available in Kenya, including their engineering properties. These reports will be required during drafting to ensure that materials specified actually exist in Kenya. It may be necessary to corroborate this information with test results of various samples that have been tested by MTRD in recent years.

Lastly, this chapter will require a discussion on how the pavement designs are expected to vary according to the climatic zones and materials availability. For example, the recommended bitumen grades for each major climatic (temperature zone) and the materials choices for unbound pavement layers in the different climatic (rainfall zones). A superimposition of the climatic maps, geology, and soil maps may be required.

4.1.4 Chapter 4 - Earthworks

The chapter discusses the introductory design of cuttings and embankments. Under cuttings, the following topics are covered:

- Type of material to be excavated
- Volume and position of the different materials
- Level and flow of water table and springs
- Stability of slopes
- Drainage and protection against erosion.

These topics will require minor updates, such as emphasis on how materials from cuttings can be re-used as capping or subgrade replacement in other parts of the alignment or even for other adjacent projects.

Under the stability of slopes, reference should be made to other documents (which could be external to Kenya) and software that deals with slope stability analysis in detail. Statements referring to a geotechnical manual or the need to engage a geotechnical specialist for complex situations should be added to the section.

The protection of slopes needs to be enhanced to minimise erosion and the risk of slope failures. Slope protection measures, especially bioengineering, should be emphasised.

For embankments, the following topics are covered:

- Foundation conditions

- Acceptable fill material
- Stability of slopes
- Settlement
- Method and rate of construction.

For embankments, under slope stability, reference should be made to other documents (which could be external to Kenya) and software that deals with slope stability analysis in detail. Statements referring to a geotechnical manual or the need to engage a geotechnical specialist for complex situations should be added to the section.

4.1.5 Chapter 5 - Drainage and Erosion Control

This chapter discusses three main topics:

- Drainage of surface water
- Drainage of ground water
- Erosion control.

Under the drainage of surface water, reference has been made to Part I of the Road Design Manual. This is agreeable and should now be referred to appropriate volume (hydrology and drainage design) of the Road Design Manual. It is also proposed that erosion control should be retained in RDM III, but further cross-referencing to the appropriate volume of the Road Design Manual that deals with hydrology and drainage design and reference can then be made to it in this volume. In the Hydrology and Drainage Manual, consideration should be made for sizing of drainage channels and structures to enhance climate resilience.

It is recommended that this chapter should have more emphasis on sub-surface drainage and the use of geo-textiles. The list of situations where ground water could be encountered and that warrant investigation should be enhanced. Further discussions on the appropriate type of geotextile is required. A cautionary statement should be made on the expected increase in ground water due to climate change effects should be made, together with the appropriate dimension adjustment factors.

4.1.6 Chapter 6 - The Subgrade

This chapter describes the classification of Kenyan soils and subgrades, determination of the subgrade strength, and subgrade requirements for pavement design.

Currently Table 6.3.1 includes materials to be used for subgrade improvement, the minimum thickness required, and the new subgrade class achieved as a result. This would benefit hugely from the introduction of Foundation Classes at this stage. Foundation Classes need to be defined in terms of the design surface modulus. Combinations of capping layers necessary to achieve these moduli need to be expanded.

The compaction density at which the subgrades should be classified needs an extensive debate with practicing engineers in Kenya. It is recommended that instead of classifying the subgrade on the basis of light compaction (100% MDD on 2.5 kg rammer), it should be based on heavy compaction (93% or 95% MDD on the 4.5 kg rammer). With modern compaction equipment, it is now possible to achieve these levels of compaction in situ. Alternatively, materials with plasticity index greater than 20 (or clays and silts) should be classified on the basis of light compaction and any others classified on the basis of heavy compaction. It requires great depth of information on how to identify uniform design sections. In the absence of this switch, then in special cases, a designer should have the liberty to use the modified proctor. In such cases, other aspects such as the use of geofabrics and separators to prevent pumping of fines may be recommended. The Consultant will propose a study for conversion/ correlation of subgrade classification from standard proctor to modified proctor.

It is recommended that the '6-point' CBR test should become the '9-point' test so as to evaluate the strength of the subgrade in a saturated condition (to cater for adverse effects of climate change).

Guidelines have also been provided on choice of subgrade class within a section. However, information on how to determine homogenous sections has not been provided.

The following gaps need to be addressed within the manual in line with current best practice.

1. Other methods for improving subgrade strength such as geotextiles, geogrids and dump rock need to be considered.
2. In cases where fill material is to be used to raise the road level, material properties of suitable fill material need to be included.

4.1.7 Chapter 7 - Pavement Materials

Classification of materials: Currently the RDM III sometimes refers to materials as "base quality" but applied to the sub-base. This includes Cement Improved Gravel and GCS. For ease of use a revision to this system should be made and materials codes should be used. The materials codes adapted (to reflect the strength) from TRH 4 and used in the LVSR Guide 2017 will be amended, expanded, and used in the RDM III. e.g. G80 vs G4., HIG160, HBG2, HMS3. Brief materials description/specification will be presented in a table and linked to traffic class and applicable layers. For hydraulically treated materials, the following codes are proposed:

- HBG 2: Hydraulically Bound Gravel of cylinder UCS 2-6 MPa
- HMS 3: Hydraulically Modified Stone of cylinder UCS 3-6 MPa
- HBS 6: Hydraulically Bound Stone of cylinder UCS 6-12 MPa
- HBS 12: Hydraulically Bound Stone of cylinder UCS 12-20 MPa

The chapter describes and specifies materials for use in sub-base, base, and surfacing. Sub-base materials described include natural gravels, clayey and silty sands, cement and lime-improved materials, graded crushed stone, and soft stone.

Base course materials described include natural gravels, cement and lime-improved materials, cement-stabilised materials, graded crushed stone, sand-bitumen mixes, dense bitumen macadam, dense emulsion macadam, lean concrete, and other materials (e.g. bitumen-treated gravel). Specifications of materials and techniques to be used to enhance climate resilience should be included, for example foamed bitumen bases. Additionally, it is proposed to include the use of dry-bound, wet-bound macadam, Telford bases, and hydraulic road binders (HRBs e.g. cement with additions, GGBFS) in this section. These could largely benefit areas in Kenya that have abundance of stone and also for high traffic stress areas.

For both sub-bases and bases, it is proposed to provide for the use of recycled asphalt pavement materials. Other materials that proposed for this include building waste which could be readily available in urban centres, albeit these may be confined to the capping layer. Guidance on mechanical stabilisation of natural materials for sub-base and base should be included in the update.

There is a need to introduce a section on suitable materials to be used as capping layers in foundation design. Capping materials will have similarity with sub-base materials, but it is proposed that the specification for particle size distribution (Grading Modulus) and plasticity indices be relaxed.

For surfacing materials, the manual describes the use of prime and tack coats, surface dressing and bituminous premixes (ACI, ACII, gap-graded asphalt, and sand asphalt).

There is a need to emphasise the use of materials such as prime emulsion since in the near future the use of cut-back emulsion could be restricted or banned. Likewise, newer types of emulsion currently available in Kenya need to be included in the manual since emulsions will eventually replace cut-backs.

In this respect, the use of polymer modified binders in the wearing course have to be added. Application, specification, and design of SMA (Stone Mastic Asphalt) should also be added.

For the binder course, there is a need to introduce Enrobé à Module Élevé (EME 2) material. Primarily because of its importance in combating effects of climate change and its resilience to high traffic stresses. The SABITA Manual 33 (2019) is a good starting point.

There is a need to include surfacing materials such as stone mastic asphalt, Cape seals, etc.

A decision is to be made as to whether guidance on surface dressing design, and asphalt mix design are to be included (to some extent) in the manual or they should be standalone documents (Guides) to be prepared under a separate project. This is because other countries keep these as separate documents and the level of detail required is large such that inclusion of a partial discussion in the manual could be detrimental. The Consultant proposes that for low volume roads, Marshall mix design will be recommended; for medium and high volume roads, modified Marshall with vibratory hammer and Superpave grading followed by application of surface treatment. If stone crushing during vibratory compaction then change stone spec. For special cases or critical roads, performance design incorporating Superpave (carefully) is recommended.

The procedure of the Bailey method of selection of suitable aggregate grading should be included in detail.

In the meantime, the chapter can benefit by addition of the recommendations that came out of the 1996 studies on the performance of asphalt in Kenya (PR/OSC/567/96) and the review of the RDM III in 1996 (PR/ORC/115/96). These include:

- Emphasis and guidance on Rolling Thin Film Oven Test (RTFOT) in the selection of binders

- The sensitivity of Asphalt Concrete (AC) wearing course mixes to slight changes in composition
- Marshall Mix Design Method supplemented by Refusal Density testing
- Specification of AC designed to 3% Voids in Mix (VIM/ air voids) at refusal density and in-situ compaction specifications
- Specifications for the wheel tracking test
- Sealing of AC wearing courses designed to refusal density specifications
- Minimum asphalt surfacing layer thickness 75 mm?
- The specification of flakiness index versus nominal aggregate size
- The role of modified bitumen, their criteria for use, selection and specifications – especially in combating climate change effects.
- The use of crack-relief layers
- Racked-in surfacings
- The use of hardness probe (ball-penetrometer) in surface dressing design

Regarding the materials charts these are good and should be largely retained. There is however a need to revise the materials nomenclature in line with the Pavement Design Guideline for Low Volume Sealed Roads 2017; G for granular materials, HIG for hydraulically improve granular materials, etc. Other materials charts for materials introduced into the new volume should be included as well.

Lastly, the use of the Hubbard Stabilometer should be removed from the materials specifications since it is no longer in use. The Marshall stability and flow suffices.

Recent research from Australia shows the measured in-service moduli of cement-bound materials. This should be compared with values from pavement evaluation reports in Kenya (if available). In fact, this comparison should be done for other materials in Kenya if the pavement evaluation reports exists.

4.1.8 Chapter 8 - The Structural Design Method

The chapter describes the design principles; practical considerations; stresses, strains, and deflections in pavement layers; and construction principles. This chapter is very well written and should be largely retained with minor edits. Methods (new) of determination/verification of foundation modulus and computation of strains and stresses should be included.

The moduli of any materials new to the RDM III, such as EME2 and SMA should added in.

The foundation classes need to be defined here and the options for achieving the classes on various subgrades should be included. These can be taken from the work that was used for the development of the Pavement Design Guideline for Low Volume Sealed Roads 2017 (Table 4-4). The options to confirm the foundation classes through construction of trial sections should be described. Pavement evaluation reports (if they exist) should be used to confirm the foundation classes. Alternatively, and FWD can be dispatched to ongoing construction trials to confirm this in a matter of weeks; and the results included in the revised manual.

Table 4-4: Foundation Classes

Foundation Class	Surface Stiffness Modulus (MPa)	Minimum CBR (%)	Equivalent Subgrade Class
F1	65	10	S3
F2	90	14	S4
F3	125	23	S5
F4	250	30	S6
F5	400	80	

Source: MoTIHUD, (2017)

The option to design pavements using mechanistic-empirical method should be included; with description of the steps and processes and any software that can be used for this. At the moment, the permissible strain relationships contained in the RDM III (Figure 8.2.1, 8.2.2, and 8.2.3) should be retained and used for mechanistic analysis if necessary, and for extending the range of design catalogues to more than 60 MESA. The figures should be turned into equations for easy use with any mechanistic-empirical design software. In future, it may be necessary to develop more transfer functions for various subgrades, or to further calibrate the existing one.

It must however, be noted that top-down cracking predominates the bottom-up cracking that is modelled in many transfer functions.

Guidance should be provided for the trial and confirmation or rejection of proprietary materials.

4.1.9 Chapter 9 - The Standard Pavement Structures

This chapter presents the standard pavement catalogues using various material combinations; their applicable traffic classes; their economic viability vis-à-vis the traffic classes; and the applicable materials specifications.

This chapter can benefit from the addition of standard structures that makes use of newer materials e.g. EME2 bases, Stone Mastic Asphalt (SMA). The standard structures have to be expanded to cover higher traffic ranges up to the long-life pavements (80 MESA). The transfer functions for the subgrade and asphalt layers should be used for this purpose. Use can be made of the India, Australian, and Brazilian Manuals to rationalise any extended catalogue. For low volume roads, the Kenya subgrade fatigue criterion will be used. For medium and high volume roads, the Shell 50% subgrade criterion will be used. For the asphalt fatigue, the Kenya equations obtained from Figure 8.2.2 in RDM III will be used. Pavement evaluations in Kenya shows that these are representative even for Superpave designed mixes. The materials failure criteria (Figure 8.2.3) for cement treated materials will also be used to check designs containing cemented materials.

Catalogues should be presented for all traffic classes up to 150 MESA. However, above 60 MESA, the catalogues should be used as guide for design. The design above 60 MESA should be performance designs with foundations checked, and in addition mechanistic analysis used to check the design. The Consultant will review the traffic class ranges objectively. The default start position is to retain what is contained in the RDM III. Catalogues for modular units (e.g. stone setts, cobble stones, and block paving) should be added to this chapter since they are highly suitable for urban pavements. Additionally, they promote employment due to their labour-based approaches to construction.

Structures for pedestrian and NMT sidewalks should also be included in this chapter.

4.1.10 Chapter 10 - Shoulders, Pavement Drainage and Cross-sections

Only minor modification is required, but several sketches should be added to illustrate the shoulder and drainage systems. The existing sketches should be enhanced. Additionally, Chapter 5 should be integrated into this chapter and adequately cross-referenced to the Hydrology and Drainage Manual.

Other materials such as cinder (scoria) gravel, that may not be suitable for base course materials of high volume roads, are suitable for their shoulders. Scoria, in particular, possesses very good drainage characteristics.

Recycled pavement materials are also suitable for use in shoulders.

The cross-sections (especially for urban roads) should be cross-referenced with the geometric design manual.

4.1.11 Chapter 11 - Roads on Expansive Clays

This chapter presents the problems associated with expansive clays, and the recommended design and construction procedures. It is proposed that this chapter should be merged with the *Chapter 6 Subgrade*, and expansive clays and other problem subgrades (dispersive, collapsible, etc) should be discussed right at the beginning. Areas in Kenya where the various problems occur in Kenya should be further discussed with emphasis on how to treat them. Materials Research Branch Report 345 offers a good starting point for this.

Nevertheless, this chapter is adequate and requires only a minor addition. That is, the classification of the level of expansivity of the clays. The Tanzania manual (Table 4-5) offers a good criterion for the method of treatment depending on the level of expansivity of the soil.

Table 4-5: Category and Treatment of Expansive Clays

Expansiveness of the soils	Alternative methods for construction over expansive soils	
	Paved trunk roads	**Other paved roads**
Low $\varepsilon_{ex} < 20$	sealed shoulders	
	side slopes 1: 6 or flatter *)	-
Medium ε_{ex} 20 - 50	**Figure 6.2** - sealed shoulders - side slopes 1: 6 or flatter *)	
	min. earthworks cover 1 m	min. earthworks cover 0.6 m
High $\varepsilon_{ex} > 50$	**Figure 6.3** - excavate and replace 0.6 m of clay according to Fig. 6.3. - min. earthworks cover 1 m - sealed shoulders - side slopes 1: 6 or flatter *)	
	min. shoulder width 2 m	
	Alternative: **None**	Alternative: **Figure 6.2** - sealed shoulders - min. shoulder width 2 m - min. earthworks cover 1 m - side slopes 1: 6 or flatter*)

*) Where the earthworks cover is larger than 2 metres the side slopes can be made 1:4 or flatter.

Source: Ministry of Works (1999).

4.1.12 Chapter 12 - Low Standard Bitumen-Surfaced Roads

This chapter should be replaced with excerpts and catalogues from the recently updated *Low Volume Sealed Roads Guidelines 2017*. The words 'Low Standard' insinuates inferiority, the chapter should therefore be renamed to remove the insinuation of inferiority. 'Tertiary Roads' or 'Low-volume Roads' will be more appropriate.

4.1.13 Chapter 13 - Gravel Roads.

This chapter discusses the general materials requirements for gravel roads, the structural design of gravel roads, and the wearing course materials specifications.

The content is largely useful and valid. It could benefit from a few additions and modifications. The traffic limitations need to be revised to reflect recent experience in Kenya. The materials and thickness requirements need to be revised to reflect recent scarcity of gravel, and to reflect maintenance strategies.

It is understood that the gravel roads thicknesses shown in RDM III are not being used for design of gravel roads because they are regarded as too thick. Agencies are using only 150 mm. The RDM III provides a model for estimation of gravel loss but determination of some of the model coefficients is not easy. Additionally, it is better in designing gravel roads to always consider the formation, a foundation/capping layer, and a gravel wearing course. The capping will be beneficial during upgrading of the gravel road to a sealed standard.

It is also important to know what road can be gravelled. The foundation/subgrade should not be less than S2 Class. S4 may not require gravel since the subgrade may already be sufficient.

The thicknesses will be reviewed with foundation approach to equivalent to at least S2 subgrade. Emphasis shall be made on the formation and forming of side drains. Then the wearing course of gravel applied. For problem soils, the methods of treatment of these soils will be applied prior to any gravel thickness design. For the design traffic, it is recommended that the use of commercial vehicles per day should be retained due to its simplicity of use.

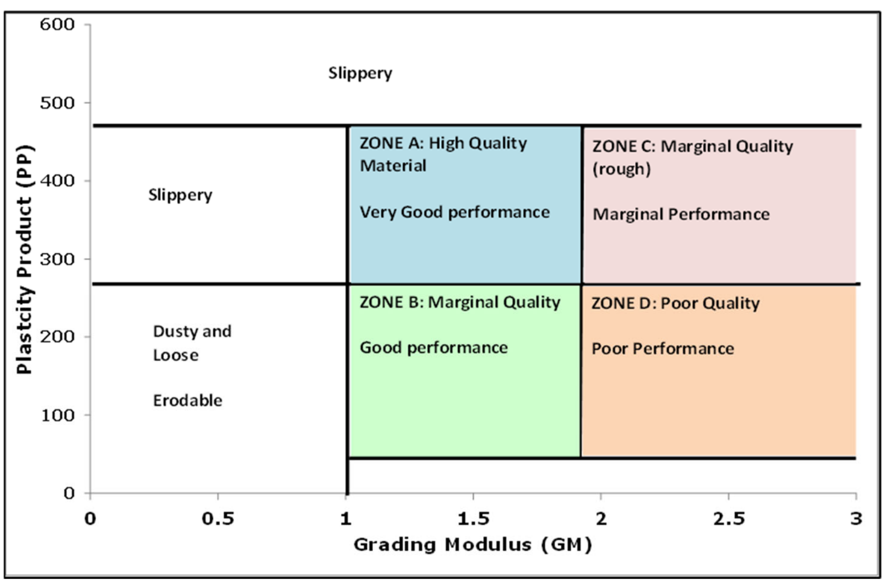
Other methods of wearing course specifications shall be reviewed by the Consultant.

The wearing course specifications could be revised to include the recent research that utilises Grading Modulus and Plasticity Product (Table 4-6 and Figure 4-1).

Table 4-6: Gravel Wearing Course Specifications

Property	Specification
Maximum size (mm)	37.5
Oversize Index (% retained on 37.5mm sieve)	< 5%
Plasticity Product (PP)	50[1] - 480
Grading Modulus (GM)	1.0 – 1.9
Soaked CBR at 95% Mod AASHTO	>15%
Note 1. A minimum PP of 280 is preferred to enhance adhesion of larger particles	

Source: Rolt, et al. (2020)



Source: Rolt, et al. (2020)

Figure 4-1: Gravel Wearing Course Performance Chart

The Australian risk-assessment based approach (Table 4-7) of materials selection could be useful where gravels are scarce, but the road users in Kenya may develop negative connotations if the see gravel of sub-optimal quality being used.

Table 4-7: Risk-based Low-volume Materials Chart

Table A 1: Risk catalogue

Sealed and unsealed roads risk catalogue				
Moisture Probability (X_M) as % of years exceeding 500 mm rainfall p.a.	Risk assessment category			
X ≤ 20% (Low)	S.1 U.1 *Traffic*	S.2 U.2 *Traffic*	S.3 U.3 *Traffic*	
20% ≤ X ≤ 75% (Medium)	S.4 U.4 *Moisture*	S.5 U.5 *Moisture and traffic*	S.6 U.6 *Moisture and traffic*	
X ≥ 75% (High)	S.7 U.7 *Moisture*	S.8 U.8 *Moisture and traffic*	S.9 U.9 *Moisture and traffic*	
	< 0.25 (Low)	0.25–0.75 (Medium)	> 0.75 (High)	**Traffic conditions (cumulative MESA)**

Source: Austroads. (2020a).

4.1.14 Chapter 14 - Materials Sampling and Testing Programme

This chapter discusses the mass of materials samples required for testing, sampling from alignments and borrow-pits, sampling for preliminary design and for detailed design. Tests to which the samples are to be subjected are also listed.

The chapter is very well written and should be largely retained. It however requires additions to the sections on sampling frequency (intervals along alignments, and by quantity for borrow materials).

There is also a need to describe the methods of sampling in deep cuts (along the alignment). The Tanzanian manual offers good options of dealing with this. Tests such as Standard Penetrometer Tests (SPT), and augering need to be added to these options.

There is a need to add aspects of the British Soil Classification System into the chapter.

4.1.15 Chapter 15 - Standard Methods of Testing

This should be retained, but the list of test methods should be updated to include recent modifications and numbers. A decision has to be made as to whether to retain BS test methods or move to the equivalent BS EN test methods or KEBS.

4.2 Review of PR/ORC/115/96: Aspects of road design in Kenya

4.2.1 General

In 1996, the Ministry of Public Works and Housing (MOPW&H) requested the Transport Research Laboratory (TRL) to comment on sections of the RDM III. The review was funded by the Overseas Development Administration (ODA). The chapters of the RDM III that were reviewed included were as follows:

- Chapter 6 - Subgrade
- Chapter 7 - Pavement Materials
- Chapter 9 - Standard Pavement Structures.

The review was undertaken in comparison to the Overseas Road Note 31 (ORN 31). Additionally, Dry Compaction practice in Kenya was reviewed.

A comprehensive Executive Summary of the report (PR/ORC/115/96) was included. The following analysis is based points that the Consultant finds relevant for discussion with stakeholders.

4.2.2 Chapter 6 - Subgrade

Currently the RDM provides two climatic conditions for consideration of the subgrade design moisture content. The first for areas where annual rainfall is greater than 500 mm /year the design is based on soaked conditions, whereas for areas with rainfall less than 500 mm/yr the design is based optimum moisture content (OMC). The report recommends that a third criteria for areas where rainfall is less than 250 mm/yr be introduced. It recommends the subgrade to be assessed at 0.8 OMC to reduced conservativism of pavement design in such areas. Stakeholders should debate this recommendation.

In view of the risks to catastrophic failure due to climate change effects (excessive rainfall and subsequent increase in subgrade moisture), the Consultant proposes that this approach should only be undertaken if the crown height of the pavement is at least 0.75 m (as presented in Rolt et al., 2002) and the road has been triple sealed from the onset. In fact, the design should be based on soaked conditions.

4.2.3 Chapter 7 - Pavement Materials

The review found that for natural sub-base materials, the RDM III specifies materials that are generally of higher plasticity than those specified in ORN 31. The RDM III, however, additionally specifies plasticity modulus.

The Consultant recommends that no adjustments should be made to the current specifications in RDM III unless evidence from performance of roads indicates otherwise. The pavement performance reports requested by the Consultant will be used for this.

Both the RDM III and ORN 31 limit the use of cement or lime-improved sub-bases to 10 MESA. For higher traffic classes, ORN 31 recommends stabilised materials of roadbase quality. For roadbase, the report highlights the main difference between RDM III and ORN 31 as that the RDM III permits for modification of materials containing up to 35% passing 75 µm sieve whereas ORN 31 permits only up to 15%. Austroads (2020b) offers recent research outputs on lightly-bound materials.

For cement or lime-stabilised roadbases, the report found that: In ORN 31 these materials are recommended to have a crushing strength of 3 to 6 MPa after 7 days moist cure and 7 day soak. In comparison the RDM III requirement is 1.8 MPa. In ORN 31 the material is only recommended for the lower layer of composite roadbases allowing the upper layer of crushed rock to counter the possible effects of shrinkage cracking in this high strength material. The RDM III recommends the use of this material for roadbase directly under asphalt surfacings, however, the lower strength requirement should result in less shrinkage cracking.

The Consultant recommends that the traffic limit in RDM III be reviewed upwards since significant developments have been made in low-shrinkage cements and hydraulic road binders. Regarding the stabilised roadbases, a higher strength should now be permitted for use and hence higher traffic levels accommodated. Pavement performance reports will be required to decide whether this is applicable.

For graded crushed stone for sub-bases, the report recommends that the maximum value of 20 for Sodium Sulphate Soundness test and 40-45 for the Los Angeles Abrasion test be reviewed for T1 (25-60 MESA) and T2 (10-25 MESA) traffic classes.

The review found that for natural roadbase materials, both the RDM III and ORN 31 specify the same strength (CBR 80%) but ORN 31 recommends less plastic material (PI ≤ 15 for RDM III and PI < 6 for ORN 31).

Again, the Consultant recommends that no adjustments should be made to the current specifications in RDM III unless evidence from performance of roads indicates otherwise. The pavement performance reports requested by the Consultant will be used for this.

The report found that the dry-bound and wet-bound Macadam bases have not been included in the RDM III. In ORN 31, their use is limited to design traffic levels up to 3 MESA. The report recommends their use in ORN 31 on the basis that they are useful alternative pavement types suitable for machine or more labour-intensive construction methods.

The Consultant agrees with this and recommends that their use be permitted up to even higher design traffic (10 MESA). A study by Moloisane and Wyngaard (2004) in South Africa found that the potential for water-bound Macadam is greater than 10 MESA. The Indian Road Congress (IRC, 2005) can be a starting point for their specifications.

The report highlights the challenges that had been faced with the use of Cold Bitumen-Emulsion mixes in Kenya. It was reported that the material continued moving under roller compaction for several days because of delayed setting of the bitumen-emulsion.

The Consultant is of the opinion that with current variety/types of bitumen emulsions currently available in Kenya, this is no longer a challenge and this technology should be promoted. Moreover, due to environmental concerns, the use of hot-mixes and cut-backs will be scaled down in the coming years. The use of Foamed Bitumen Bases should also be promoted. *Austroads Report (AP-R666-22, 2022) and (AP-T336-18, 2018) offer good characterisation of the strength and design of Foamed Bitumen Materials – these can be used in the Kenya mechanistic design procedure to develop catalogues.*

Regarding surface dressing, the review report recommends that the use of 'racked-in' surface dressings, which are tougher than conventional single seals, should be considered for inclusion in the RDM III. It notes that this seal could be particularly effective when applied to new asphalt surfacings.

The Consultant is in agreement with this. Racked-in surface dressing minimises stone loss and enhances the 'impermeability' of the seal.

Regarding asphalt materials, the report mainly refers to the findings of PR/OSC/567/96. This will be discussed in the next section.

4.2.4 Chapter 9 - Standard Pavement Structures

The report states that *"The comparison of thickness showed that the pavement structures recommended in the RDM were broadly similar to those in ORN 31".* It also points out that pavement Type 8 (Asphalt surfacing on graded crushes stone roadbase, on cement or lime-improved sub-base) in the RDM III is significantly thinner than a similar structure in ORN 31 – in particular for traffic levels 10 MESA and 25 MESA.

It is important that pavement performance data for this type of pavement is obtained and analysed. This could form the basis for adjusting pavement layer thicknesses in the other catalogues.

4.3 Dry compaction

In summary, the report found that dry-compaction was suitable for well-graded granular materials with sufficiently fine particles to fill air voids. High densities may be achieved in many clayey or silty soils (Liquid Limit < 50, percent passing 75 micron sieve < 50). It should be noted that the air voids content in all dry compacted soils can be very high, typically 25%. Despite some soils having lower dry compacted densities, their strengths are relatively high immediately after construction in comparison with the subgrade CBR design categories. Conversely, after wetting up, dry compacted soils can exhibit lower strengths than if they had been compacted at the optimum moisture content. Often, subgrade wetting will occur even in the moist arid climates, and to permit the use of fine soils (non-gravels) the engineer must be satisfied that the subgrade will retain the design strength after wetting. This applies also to other soils and granular materials for earthworks, sub-base, and bases. It should be remembered also that even if the carriageway and shoulders are sealed, run-off water in the rainy season will either erode the embankment side slope or infiltrate into the pavement layers and subgrade through the side-slope.

The Consultant finds that dry compaction is risky and alternative approaches of construction in arid and semi-arid areas should adopted. For example, changing the construction calendar to the short 'rainy' season in these areas; road projects could be combined with complementary interventions such as dam construction or sand dams; and soils and gravels for road construction are spread out loose just before the rainy season, then windrowed and compacted whilst moist.

4.4 Review of PR/OSC/567/96: A Study of Bitumen and Bituminous Mixes for Road Pavements in Kenya

4.4.1 General

In 1995, the Ministry of Public Works and Housing (MOPW&H) and the European Commission for Development commissioned the Transport Research Laboratory (TRL) to identify the causes of premature cracking and, in particular, of plastic deformation in bituminous hot mix surfacings in Kenya and to provide a methodology for mix design which will reduce such failures. This review summarises the main findings and recommendations of the study and the Consultants views on these.

4.4.2 Tyre type and pressures

The report found that it was probable that and increase in the use of radial-ply tyres may have played a role in the failures of bituminous surfacings through plastic deformation. Coupled with this, the tyre pressures in Kenya (measured at Athi River in 1987) were found to be very high compared to that used in the AASHO Road Test (75 psi), on which most mix design criteria are based. The 10th and 90th percentile tyre pressures in Kenya were minimum 80 psi and 120 psi respectively.

The Consultant is of the opinion that the issue of tyre pressures will require a revision of the pavement design catalogues. The issue is now further compounded by the rise in the use of Super Single tyres by heavy vehicles. It would be beneficial to obtain data on tyre characteristics in Kenya to enable this customisation.

4.4.3 Role of climatic factors on the premature failures

The reported concluded that climatic factors were unlikely to be a ***controlling*** factor in determining the onset of plastic deformation. This was because the road from Mombasa to Malaba which used a common AC Wearing Course specification showed plastic deformation in both hot and cool areas. It notes that the section between Timboroa and Eldoret which experiences the lowest temperatures was also experiencing plastic deformation.

The Consultant is of the opinion that much as in this case climatic factors were not a controlling variable, selection of bitumen grades should still be undertaken on the basis of climate. This is because much as in this case it was not the controlling variable, if other controlling variables are solved, climate could become the controlling variable of performance.

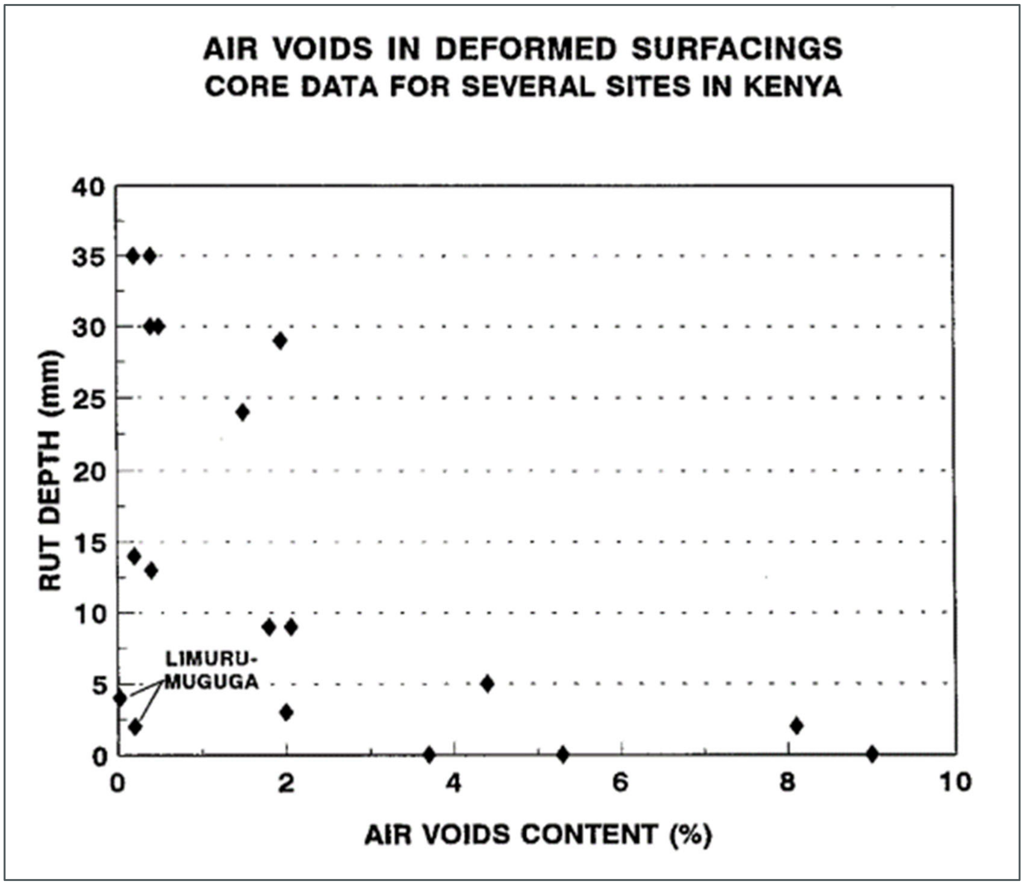
4.4.4 Role of constituent materials on the premature failures

The report concluded that aggregate properties, source of bitumen, and construction plant were unlikely to be factors that contributed to the failures.

The Consultant is of the opinion that current materials specifications are adequate to maintain good quality control over these constituents and may not require any revisions in updating the RDM III.

4.4.5 Role of the asphalt mix properties on the premature failures

The report showed that for severe loading conditions, a minimum residual air voids content of 3 % is required after secondary compaction has taken place. A review of as-built records from five sites exhibiting plastic deformation showed that voids in mix (VIM) of many of the cores were already well below the 8% (at construction before secondary traffic compaction) recommended by the Asphalt Institute. Samples were taken from 11 sites in Kenya and the data showed a strong relationship between the in-situ air voids and the measurement of rut depth or plastic deformation. This confirmed that if the VIM falls to less than 3 % then there is a very high risk that plastic deformation will develop.



Source: Smith and Edwards (1996)

Figure 4-2: Relationship between rut depth and air voids in the mix on Kenya sites

Therefore, the mix designs not appropriate for traffic loading conditions. This could have originated as follows.

In order to combat rapid ageing observed in Kenya, the RDM III recommends the use of the softest grade bitumen and highest bitumen content compatible with the design requirements. Hence it was noted that there was a tendency amongst engineers to use mixes with bitumen content on the higher side of permitted tolerances. In addition to this, the minimum degree of compaction of asphalt concrete wearing course (ACWC) was increased from 96% to 98% of the Marshall density. The report states that the degree of sensitivity of ACWC mixes to small errors in composition had possibly been underestimated.

The report further notes that the Marshall method alone is not enough for design since the level of compaction could not accurately represent the level of secondary compaction in service and the orientation of particles achieved in the Marshall compaction differed from the compaction achieved by construction rollers.

The report noted that some lessons were to be learnt from previous experience in Kenya.

1. Mixes had been laid in Kenya in the past which have given long service lives in a wide range of climatic conditions. These materials carried high traffic loads which included large numbers of overloaded off-tankers.
2. The principal form of failure was cracking in which climatic factors played a dominant part, but mixes which were sealed as part of the construction process have given excellent performance.

The Consultant agrees with this assessment and a revision of the mix design method should be included in the updated RDM III. A comparison should be undertaken between compaction to refusal density and the gyratory compactor.

Another important finding that requires debate on the way forward comes from this statement: "During the MoPW&H and TRL studies samples of ACWC were made up to a range of air voids contents to study the effect of natural weathering on un-trafficked asphalt. A number of the samples were made with 40/50, 60/70 and 80/100 penetration grade bitumen. After two years exposure there was no discernible difference in the viscosities of bitumen recovered from the top 3 mm of samples made with each of the three grades of bitumen. It is therefore arguable that a softer bitumen will be beneficial. In fact if the results mean that the softer bitumen loses more volatile material, then a larger change in volume may be taking place which could increase the likelihood of cracking". ***The question then arises as to whether in the Kenya/Tropical conditions, there is any merit in temperature zoning for binder selection.***

4.4.6 Implications for pavement design

The report states:

"Environmentally induced top-down cracking and not traditional fatigue cracking has generally been observed by TRL in many tropical countries as well as in Kenya. It is possible that the stiffer mixes which will be produced by refusal density design procedures may become susceptible to fatigue cracking. However, evidence from trials at Pala suggests that this is not likely to result in premature failure. Therefore, there is no indication that a radical increase in structural capacity is required although the risk of fatigue cracking can be further decreased by the use of stabilised sub-bases as recommended in Overseas Road Note 31."

The Consultant recommends that the approach of applying as surface treatment (surface dressing, Cape seal, or slurry seal) on stiff asphalt mix surfacings be adopted in RDM III instead of increasing asphalt thickness to combat bottom-up cracking (which is rare).

4.4.7 Main recommendation from the study

The main recommendation from the study reads as follows:

> "A new design procedure has been described which should produce mixes which are resistant to plastic deformation on severely loaded sites. Results show that to prevent plastic deformation on these sites the bituminous surfacing must be designed to retain a minimum of 3 per cent air voids at the refusal density. However, this implies that the air voids of the surfacing material at construction would be in the region of 8 per cent and at this level the surfacing would be vulnerable to oxidation and ingress of water. Although the material in the wheel paths will densify after construction, the high initial air voids content will be retained in untrafficked areas and this is likely to result in premature surface cracking. To prevent this type of cracking it is essential that the surface is sealed at the time of construction."

The Consultant recommends that this criterion be incorporated into the revised RDM III and SRBC as an enhancement to the Marshall method at 75 blows. In addition to this, adopt the Superpave grading, use of Bailey blends, and wheel tracking tests - until a customised approach based on Superpave principles have been developed and successfully trialled for Kenya.

4.4.8 Miscellaneous recommendations

The report recommends a number of other measures necessary for good performance of Kenya roads. These are:

1. Recycling of asphalt that had suffered plastic deformation is possible, but because that asphalt is rich, a large quantity of aggregates would need to be added in, thus resulting in a mix suitable for only binder course.
2. Careful laboratory evaluation and long-term field trials of modified binders. Research conducted elsewhere showed that modified binders containing Ethylene Vinyl Acetate (EVA) were good at enhancing resistance to plastic deformation while not compromising resistance to cracking.
3. Increase the number of blows for Marshall mixes from 50 to 75 which will conform to the AI requirement for design traffic of more than 1 MESA.
4. The total thickness of asphalt mix material laid should not be less than 75mm for mixes designed for severe loading conditions.
5. The draft specifications included in Appendix G should be edited and included in the revised SRBC.
6. Enhanced quality control measures and well-documented quality assurance procedures are necessary to ensure good construction and performance of these proposed mixes.

The Consultant recommends that these should be debated and a position reached as to whether they should be adopted, revised or rejected.

4.5 Review of the Pavement Design Guidelines for Low-Volume Sealed Roads 2017

This is one of the newest document (Guideline) in the Kenya Road Design Manual. It was developed by TRL and the MTRD.

Given that it is one of the newest, it is therefore not surprising that very little update (if any would be required). In fact, the Consultant recommends that several excerpts of this Guideline should be incorporated directly into the updated RDM III (now Volume 7 Part 1). However, during the 1st Stakeholders' Workshop and the site visits/consultation with consultants and contractors, feedback on possible revisions and updates will be gathered.

The following chapters are contained in the Guideline.

- Chapter 1: Introduction
- Chapter 2: Traffic
- Chapter 3: Subgrade Classification
- Chapter 4: Pavement Foundation
- Chapter 5:Pavement Materials
- Chapter 6: Pavement Design Principles and Methods
- Chapter 7: Pavement Cross Sections and Drainage
- Chapter 8: Design Catalogue

This review has identified the following minor changes to the Guideline.

1. Including a paragraph or sub-section on how to rationalise design MESA when axles weighed in the axle load surveys are either mostly significantly below or significantly above the legal load limit.
2. Including another copy of (Table 4.2) all capping options to achieve the foundation classes at the beginning of Chapter 8. The table could be modified to show the resultant foundation class after application of the capping.
3. Emphasising the nominal sizes for the second seal for surface dressing, Otta seal and sand seal.
4. Addressing typographical errors in the document.

These are the changes proposed.

4.6 Review of software

The purpose of this objective is unclear. If the Client wants to mandate or recommend that only certain named software should be used in its network, then the best approach to review software is for the Client to develop a list of requirements (hardware) and outputs required. This then acts as a benchmark against which software is rated. Following this, selected software providers would then be invited to make a presentation on their software. In this way bias and misinterpretation is minimised. The Consultant proposes that a working meeting is conducted with the Client to develop these requirements, and then invite the suppliers of the listed software for presentation.

However, if the purpose is to ensure transparency in understanding how consultants have arrived at certain designs, then the Client should instead specify the information/data that must accompany any report submissions of designs undertaken using a software. This then permits the design to be effectively reviewed – especially beneficial if this is done by other software and methods.

Lastly, the Consultant recommends that pavement design consultants should be given the liberty to select the software that they prefer.

Table 4-8: A preliminary comparison of selected pavement design and overlay software

Software	Description/ Outputs	Data Inputs	Remarks
AASHTO-Ware	For pavement design and rehabilitation of flexible and rigid pavements.	Road classification, level of reliability, design life, local calibration factors, traffic, climate data, materials and characteristics	Based on the AASHTO MEPDG -1 2008. Allows for 3 levels of data input depending on data availability. Allows FWD data from devices: Dynatest®, JILS and KUAB.
ALIZE	For pavement design and rehabilitation of flexible.	Road classification, level, design life, load characteristics, traffic, temperature data, materials and characteristics	Based on the French design method NF P98-086 [1]. Allows for 3 types of 'design standard axles'. Uses FWD and Lacroix Deflectograph deflection data for back-calculation
RUBICON	For pavement design and rehabilitation of flexible.	The toolbox offers several design tools which include: the AASHTO 1986 tool, Pavement Number tool, Layered Elastic Theory (LET) stress-strain calculator tool, the LET standard axle tool and the LET axle spectrum analysis tool. Tools were calibrated to conditions in South Africa.	Based on SAPEM Chapter 10. The LET axle spectrum analysis tool analyses the damage caused by overloaded vehicles. Uses FWD and Benkelman Beam deflection data for backcalculation
HDM-III (Now HDM IV)	For economic analysis of road investments and road network management.	Vehicle fleets, road network data, road works standards and costs, economic rates and costs, works effects, intervention alternatives.	Allows model calibrations. Several reports are output (e.g. economic indicators, sensitivity analysis, works programme, emissions, road

Software	Description/ Outputs	Data Inputs	Remarks
		Climatic data, calibration factors.	deterioration, VOCs, etc). Special prices for LMICS.
ELMOD	Software for analysis of FWD data and overlay design.	Dynatest FWD data and data from other FWDs in compatible file formats. Temperature data is critical.	Analysis of FWD Data can be by LET, MET or FEM.
ROSY	RoSy Design is the software applied for processing data collected by the PRIMAX FWD (with 9-16 geophones).	PRIMAX FWD data and data from other FWDs in compatible file formats.	Allows pavement design using various transfer functions. Defaults are Shell, Asphalt Institute, etc. The software also offers road asset management (RoSy RAMS).
HAWKEYE	This is a visualisation, analysis, graphing and reporting tool for VCS data collected by HAWKEYE machines.	Specialised files collected by Hawkeye machines	Utilises Google Maps to Display data collected: - Roughness - Texture - Cracking - Rutting -Visual defects. On-screen height and width measurement
RADAN	RADAN® is a post-processing software for ground penetrating radar (GPR) data.	GPR data files from various GPR machines: .DZT, .DZX, .DZA, .DZG, .PLT, .TMF, .B3D, .BZX, .S3D	The 3D Module allows the user to view and build 3D visualizations. The RoadScan Module is used to analyze pavement, base, and sub-base layers in roadways. The BridgeScan Module allows users to process bridge deck GPR data and account for skew angles.
UKDCP	Analysis of DCP data	Test point chainage, location on cross-section, weather, removed layers, allows input of various DCP equations. Allows variable input of blows.	Available freely. Structural numbers easily computed and uniform sections identified using various parameters.

Software	Description/ Outputs	Data Inputs	Remarks
WIN DCP	Analysis of DCP data	Test point characteristics. Layers. Fixed set of blows.	Available at a cost.

4.7 Further review to be conducted during the drafting of the manuals

The Terms of Reference 3.2 (a) required the review of the following:

1) Review the existing RDM Part III on Materials and Pavement Design for New Roads and the following:
    a. The TRL study reports mentioned in Section 2.3.1 and the recommendations of the 1997 Seminar and any relevant research studies undertaken by MTRD;
    b. Rigid cement concrete pavement design and construction standards adopted in countries with similar climatic conditions;
    c. Design and performance monitoring reports for rigid cement concrete pavements constructed in Kenya;
    d. Pavement Design Guidelines for Low Volume Sealed Roads, 2017;
    e. Construction materials and current materials specifications and testing standards; and,
    f. Application software for pavement design for new roads and in particular, the French ALIZE, South African RUBICON and American AASHTO pavement design software.

Items (1), 1a.,1b., 1d., and f. have been reviewed in this report. During the Inception Phase, the Consultant was advised that items 1c. and 1e. should be done during drafting of the manual after the gaps to be addressed have been clearly identified and hence the appropriate reports and data gathered. These will therefore be reviewed at the time of drafting and used as inputs into the draft.

4.8 Proposed updated manual idealised table of contents and gap analysis

During the consultations conducted during the Inception Phase of this project, several stakeholders praised the existing RDM III. Moreover, the contents list of many design manuals are very similar. They will address the subgrade, traffic, environment, materials (natural gravels, crushed rock, unbound, cement-bound, and bituminous), pavement catalogue, cross-section, shoulders and drainage. It is on this basis that the Consultant proposes that only minor re-ordering of the existing table of contents is required in order to achieve and idealised Table of Contents (ToC) for Kenya. The proposed, re-ordered ToC is as shown in **Table 4-6**.

4.9 References

1. Austroads. (2009). *Guide to Pavement Technology. Part 2. Pavement Structural Design.* Austroads Ltd, Sydney, Australia.

2. Austroads. (2020a). *Sustainable Roads Through Fit-for-purpose Use of Available Materials: Evaluation Tool and User Guide.* Austroads Ltd, Sydney, Australia.

3. Austroads. (2022). *AP-R666-22: Laboratory Fatigue Characterisation of Foamed Bitumen Stabilised Materials.* Austroads Ltd, Sydney, Australia.

4. Austroads. (2020). *AP-R640-20: Development of Design Procedures for Lightly Bound Cemented Materials in Flexible Pavements.* Austroads Ltd, Sydney, Australia.

5. Austroads. (2018). *AP-T336-18. Design and Performance of Foamed Bitumen Stabilised Pavements.* Austroads Ltd, Sydney, Australia.

6. Axle Load Limits (kta.co.ke)

7. Courteille, G., & Serfass, J. P. (n.d.*). Survey of Subgrade Conditions in Kenya and their Influence on Pavement Performance. Report 345.* Nairobi: Ministry of Works Materials Branch.

8. Kenya National Highways Authority(KeNHA) Weight Limits – Venas News

9. Ministry of Transport Housing and Urban Development Kenya (MoTIHUD). (2017). *Pavement Design Guideline for Low Volume Sealed Roads.* Nairobi, Kenya.

10. Ministry of Works. (1999). *Pavement and Materials Design Manual.* Dar- Es-Salaam. The United Republic of Tanzania.

11. Moloisane, R. J. and van Wyngaard, W. A. (2004). *Performance of Water-bound Macadam Pavements Constructed Labour Intensively: Case Study.* Proceedings of the 8th Conference on Asphalt Pavements for Southern Africa (CAPSA'04) 12 – 16 September 2004 ISBN Number: 1-920-01718-6 Sun City, South Africa.

12. Rolt, J., Gourley, C. S., and Hayes, J.P. (2002). *Rational Drainage of Road Pavements.* TRL Report PR/INT/244/2002. Transport Research Laboratory, Crowthorne, Berkshire, UK.

13. Rolt, J., Otto, A., Mukura, K., Reeves, S., Hine, J., Musenero, L. TRL Limited (2020*). Rural Road Note 01: A Guide on the Application of Pavement Design Methods for Low Volume Rural Roads*, First Edition. London: ReCAP for UK Aid.

14. SABITA. (2019). *Manual 33: Design procedure for High Modulus Asphalt (EME).* ISBN 987-1-874968-68-9. SABITA, Howard Place, South Africa.

15. Smith, H.R. & Edwards, A.C. (1996*). PR/OSC/567/96. A Study of Bitumen and Bituminous Mixes for Road Pavements in Kenya.* Transport Research Laboratory, Crowthorne, Berkshire, United Kingdom.

16. Smith, H.R., O'Connell, M. J. & Jones, C.R. (1996). *PR/ORC/115/96. Aspects of road design in Kenya.* Transport Research Laboratory, Crowthorne, Berkshire, United Kingdom.

17. The Indian Road Congress (IRC). (2005). IRC-019:2005. *Standard Specifications and Code of Practice For Water Bound Macadam*. Puram, New Delhi, India.

18. Transport Research Laboratory (1993). *Overseas Road Note 31. A guide to the structural design of bitumen-surfaced roads in tropical and sub-tropical climates.* Overseas Centre, TRL, Crowthorne, Berkshire, UK. (4th edition).

19. Van Zyl, N.J.W and Freeme, C.R. (1984) *Determination of relative damage done to roads by heavy vehicles.* Proc. Annual Transportation Convention, 4th, CSIR, Pretoria, 6 – 9 August 1984: Vol C-1.

Table 4-9: Adequacy of existing or draft manuals for incorporation into new manual: Flexible Pavements

Status Key: (green) = Fully Developed, (yellow) = Partial, (red) = Not Developed, (grey) = Not Applicable

New Manual Chapter	Topic	Sub-Chapter	Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Approved/Existing Manual Ref.	Additions/Modifications to Chapter or sub-Chapter
1	General	1.1	Introduction	(yellow)	Contains list of existing parts of the RDM. This will require update to the new structure and coding	Chapter 1.1	Requires revision to include new list of documents
		1.2	*Purpose and Scope of the Manual*	(red)	*New*	*New*	*Require clear delineation of scope and its intended use.*
		1.3	*Structure of the Manual*	(red)	*New*	*New*	*Provide the structure of this particular manual*
		1.4	Units of Measurement	(yellow)	This contains the SI units of common measures. This is largely irrelevant in the present day.	Chapter 1.2	This section could then be dedicated to a new sub-chapter for example 'Effects of Climate Change' or 'Economic Considerations'
		1.5	Definitions and Abbreviations	(green)	Generally adequate	Chapter 1.3	In Figure 1.3.1 requires clear demarcation of the Foundation. Requires definitions of new items/materials/parameters that will be introduced in the revised manual.

New Manual Chapter	Topic	Sub-Chapter	Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Approved/Existing Manual Ref.	Additions/Modifications to Chapter or sub-Chapter
2	Traffic *Assessment and Estimation*	2.1	General			Chapter 2 Traffic	Name of chapter proposed to be changed
		2.2	*Vehicle Classification*		Vehicle classification has since changed.	Chapter 1.3.4	This section needs to be brought from 1.3.4 to the Traffic Chapter.
		2.3	Axle Load Distribution		Legal axle load limits have been superseded. Reference to specific roads in Kenya may not be relevant.	Chapter 2.2 Axle Load Distribution	Update required to include new legal axle load limits
		2.4	Equivalence Factors		The damaging exponent n has been provided as 4.5 only. The options for consideration of VEF depending on legal limit and on actual measured axles is very good and must be retained.	Chapter 2.3 Equivalence Factors.	Literature and practice in other jurisdictions provide various values of n depending on the pavement type/structure. This update is required.
		2.5	Evaluation of Traffic for Design Purposes		Lacks guidance on estimating Diverted Traffic and Generated Traffic.	Chapter 2.4	
		2.6	Traffic Classification		Traffic classification does not reach the LLP range (80 MESA)	Chapter 2.5 Traffic Classification	A new traffic class from 60 to 80 MESA is required. LLP is achieved at 80 MESA, so in cases of MESA > 80, a statement is required.

New Manual Chapter	Topic	Sub-Chapter	Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Approved/Existing Manual Ref.	Additions/Modifications to Chapter or sub-Chapter
3	Earthworks	3.1	Cuttings			Chapter 4.1 Cuttings	This topic will require minor updates, such as emphasis on how materials from cuttings can be re-used as capping or subgrade replacement in other parts of the alignment or even for other adjacent projects.
		3.2	Embankments			Chapter 4.2 Embankments	Under the stability of slopes, reference should be made to other documents (which could be external to Kenya) and software that deal with slope stability analysis in detail.
4	Subgrade *Assessment*					Chapter 6 Subgrade	Rename Chapter
		4.1	Natural Materials and Soils		A quantitative definition of the soils zones in terms of BSCS may be required.	Chapter 3.2 Natural Materials and Soils	Adding estimated BSCS for the soils.

New Manual Chapter	Topic	Sub-Chapter	Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Approved/Existing Manual Ref.	Additions/Modifications to Chapter or sub-Chapter
		4.2	Classification of Kenyan Soils		Areas in Kenya where problem subgrades are likely to be encountered is missing.		Should include list of areas in Kenya where problem subgrades can be encountered. List of common soils should be accompanied by USCS or BSCS classification codes.
		4.4	Problems Associated with Expansive Clays		One of the best chapters of the manual	Chapter 11.1 Problems Associated with Expansive Clays	It is proposed that this chapter should be merged with the Chapter 6 Subgrade, and expansive clays and other problem subgrades (dispersive, collapsible, etc)
		4.3	*Treatment of Problem Subgrades*		*New*	*New*	*This should include treatment of expansive soils, dispersive soils, and collapsible soils. The content for treatment of expansive soils already exists.*
		4.5	Recommended Design and Construction Procedures		One of the best chapters of the manual	Chapter 11.2 Recommended Design and Construction Procedures	That is, the classification of the level of expansivity of the clays. The Tanzania manual offers a good criterion for the method of treatment depending on the level of expansivity of the soil.

New Manual Chapter	Topic	Sub-Chapter	Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Approved/Existing Manual Ref.	Additions/Modifications to Chapter or sub-Chapter
		4.6	Determining the Subgrade Strength		Compaction energy for subgrade classification at 2.5 kg rammer is not appropriate for current levels of compaction machinery.		The use of the 4.5 kg rammer (heavy compaction) is proposed for classification of the subgrade.
		4.7	Subgrade Requirements for Pavement Design		Improved subgrades are discussed without mention of foundation classes.		More options for achieving foundation classes should be provided. These can be taken from the LVSR (2017).
5	Pavement Materials	5.1	General			Chapter 7.1 General	Requires a commentary on how to select materials or enhance design for climate resilience of pavements.
		5.2	Sub-base Materials		The use of recycled materials has not been included.	Chapter 7.2 Sub-base Materials	Include the use of recycled materials.
		5.3	Base Materials		Macadam, Telford, HRBS, Foamed Bitumen, and Recycled Materials have not been included.	Chapter 7.3 Base Materials	There is a need to include Macadam bases, Telford bases, materials such as HRBs (cement with additions, GGBFS), Foamed Bitumen materials. Recycled Materials.

New Manual Chapter	Topic	Sub-Chapter	Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Approved/Existing Manual Ref.	Additions/Modifications to Chapter or sub-Chapter
		5.4	Surfacings		Does not have specifications for materials new to the RDM e.g. EME and SMA. PRD Design has not been included in accordance with recommendations of (PR/OSC/567/96). Guidance on selection of polymer modified binders is required. The procedure of the Bailey method of selection of suitable aggregate grading should be included in detail. The use of recycled materials has not been included.	Chapter 7.4 Surfacings	Emphasis on the use of Prime emulsions and emulsion tack coats is required. Specifications based on the Hubbard Stabilometer are no longer tenable. Stone Mastic Asphalt, EME. Mix design methods (Modified Marshall, Superpave). Bailey Blends. Prime coat, Tack coat, Sand Seal, Primer Seals, Surface dressing (inverted, racked-in), Slurry seal, Cape Seal, Otta Seal.
		5.5	*Materials for Pavement Shoulders*		*New*	*New*	*Other materials such as cinder (scoria) gravel, that may not be suitable for base course materials of high volume roads are suitable for their shoulders. Scoria, in particular, possesses very good drainage characteristics.* *For urban roads these may include Block pavers, Cobble stones, recycled materials, etc.*

New Manual Chapter	Topic	Sub-Chapter	Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Approved/Existing Manual Ref.	Additions/Modifications to Chapter or sub-Chapter
6	The *Kenyan* Environment					Chapter 3 The Natural Environment	Rename to 'The Kenyan Environment'
		6.1	Rainfall		A quantitative definition of the climatic zones in terms of rainfall and temperature distribution is required.	Chapter 3.1 Climate	Ideally, a map of Kenya showing the maximum and minimum road temperatures would be required, but this requires a major study to be undertaken to measure the road temperatures or to calibrate a suitable model.
		6.2	Temperature		A quantitative definition of the climatic zones in terms of rainfall and temperature distribution is required.	Chapter 3.1 Climate	Ideally, a map of Kenya showing the maximum and minimum road temperatures would be required, but this requires a major study to be undertaken to measure the road temperatures or to calibrate a suitable model.
		6.3	*Effects of Climate Change*		*New*	*New*	*Dicuss the impacts of climate change on pavement performance and principles of mitigation.*

New Manual Chapter	Topic	Sub-Chapter	Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Approved/Existing Manual Ref.	Additions/Modifications to Chapter or sub-Chapter
7	Pavement Drainage and Erosion Control					Chapter 5 Drainage and Erosion Control	Rename Chapter
		7.1	Pavement Cross-sections			Chapter 10.3 Pavement Cross-sections	Should be linked to the cross-sections in the geometric design manual.
		7.2	Shoulders			Chapter 10.1 Shoulders	Several sketches should be added to illustrate the shoulder and drainage systems. The existing sketches should be enhanced. Recycled pavement materials are also suitable for use in shoulders. Other materials such as cinder (scoria) gravel, that may not be suitable for base course materials of high volume roads are suitable for their shoulders. Scoria, in particular, possesses very good drainage characteristics.

New Manual Chapter	Topic	Sub-Chapter	Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Approved/Existing Manual Ref.	Additions/Modifications to Chapter or sub-Chapter
		7.3	Drainage of Surface Water			Chapter 5.1 Drainage of Surface Water.	It is recommended that this chapter should focus primarily on sub-surface drainage. The Surface Water and Erosion Control should be taken to the Drainage Manual. The list of situations where ground water could be encountered and that warrant investigation should be enhanced. Under the drainage of surface water, reference has been made to Part I of the Road Design Manual. This is agreeable and should now be referred to appropriate volume (hydrology and drainage design) of the Road Design Manual.
		7.4	Drainage of Ground Water			Chapter 5. 2 Drainage of Ground Water	Rename to 'Sub-surface Drainage'. Chapter 5 should be integrated into this chapter and adequately cross-referenced to the Hydrology and Drainage Manual.

New Manual Chapter	Topic	Sub-Chapter	Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Approved/Existing Manual Ref.	Additions/Modifications to Chapter or sub-Chapter
		7.5	Erosion Control			Chapter 5. 3 Erosion Contrrol	The Surface Water and Erosion Control should be taken to the Drainage Manual.
8	The Structural Design Method	8.1	Design Principles			Chapter 8.1 Design Principles	The discussion on design period, stage construction, safety factors, and minimizing surfacing thickness is very useful.
		8.2	Practical and Experimental Considerations		A reminder on the use of recycled materials should be included. Foundation classes are missing. The units of the moduli of materials should be expressed in MPa which is now common practice.	Chapter 8.2 Practical and Experimental Considerations	Especially important section to remind design engineers of practical considerations of their design. The foundation classes need to be defined here and the options for achieving the classes on various subgrades should be included. These can be taken from the work that was used for the development of the Pavement Design Guideline for Low Volume Sealed Roads 2017. The moduli of any materials new to the RDM III, such as EME and SMA should added in.

New Manual Chapter	Topic	Sub-Chapter	Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Approved/Existing Manual Ref.	Additions/Modifications to Chapter or sub-Chapter
		8.3	Calculation of Stress, Strain, Deflection and Layer Thickness		Guidance on the use of mechanistic-empirical design is not included. Equations for Figures 8.2.1, 8.2.2, and 8.2.3 have not been included.	Chapter 8.3 Calculation of Stress, Strain, Deflection and Layer Thickness	The graphs of the permissible strains should be converted to equations to facilitate use in mechanistic-empirical design software. Criteria for use of empirical or mechanistic-empirical methods to be provided. Caution on weaknesses of the mechanistic-empirical method as spelt out in PR/ORC/115/96.
		8.4	Construction Principles		Minimum layer thicknesses should be increased to 125 mm for sub-base, and 150 mm for base to promote use of coarser materials.	Chapter 8.4 Construction Principles	The minimum thickness should be related to at least 2NMAS or 150 mm whichever is greater.
9	Standard Pavement Structures	9.1	The standard Pavement Structures			Chapter 9.1 The standard Pavement Structures	
		9.2	Method of Use			Chapter 9.2 Method of Use	Steps of using the standard structures are well-presented.

New Manual Chapter	Topic	Sub-Chapter	Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Approved/Existing Manual Ref.	Additions/Modifications to Chapter or sub-Chapter
		9.3	Examples of Pavement Design		Not based on Foundation Classes	Chapter 9.3 Examples of Pavement Design	Should be based on Foundation Classes and moved to Appendix.
		9.4	The Standard Catalogues		Does not cover traffic range to LLP. Not based on Foundation Classes	Chapter 9.4 The Standard Catalogues	Requires overhaul to be based on foundation classes and to cover LLP traffic range. Also to cover materials new to the RDM. Criteria for selection of pavement structures, Catalogues of structures. Pavement structures for shoulders, NMT Lanes, and pedestrian sidewalks.
10	*Low-Volume Sealed Roads*					Chapter 12 Low Standard Bitumen Surfaced Roads	Rename to Low-Volume Sealed Roads.
		10.1	General		Limit of 0.5 MESA no longer applicable. Crossfall limit of 4% reduced to 3.25%; minimum of 3% not 2.5%.	Chapter 12.1 General	The PDG LVSR 2017 now uses 1 MESA

New Manual Chapter	Topic	Sub-Chapter	Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Approved/Existing Manual Ref.	Additions/Modifications to Chapter or sub-Chapter
		10.2	*Low-volume Roads*		Cold-mix asphalt and Cape Seal are not included. Should be revised in accordance with PDG LVSR 2017.	Chapter 12.2 Low-standard Roads	The use of the words 'Low-standard Roads' is inappropriate and gives a sense that low quality is acceptable. 'Tertiary Roads' or 'Low-volume Roads' more appropriate.
		10.3	*Base Materials for Low-Volume Roads*		Should be revised in accordance with PDG LVSR 2017. Include use of recycled materials.	Chapter 12.3 Low-standard Bases	The use of the words 'Low-standard Roads' is inappropriate and gives a sense that low quality is acceptable. Rename to Base Materials.
		10.4	*Sub-base Materials for Low-Volume Roads*		Should be revised in accordance with PDG LVSR 2017. Include use of recycled materials.	Chapter 12.4 Low-standard Sub-bases	The use of the words 'Low-standard Roads' is inappropriate and gives a sense that low quality is acceptable. Rename to Sub-base Materials
		10.5	*Surfacings for Low-Volume Roads*		*New*	*New*	*Discuss Primer Seals, Otta Seal, Sand Seal, Cape Seal*
		10.6	Dry Compaction			Chapter 12.5 Dry Compaction	Should be revised with limits of application, and roller type requirements as detailed in PR/OSC/115/96

New Manual Chapter	Topic	Sub-Chapter	Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Approved/Existing Manual Ref.	Additions/Modifications to Chapter or sub-Chapter
11	*Design of Unpaved Roads*					Chapter 13 Gravel Roads	Rename to ,Design of Unpaved Roads'
		11.1	Materials for Gravel Wearing Course			Chapter 13.1 Materials for Gravel Wearing Course	The traffic limitations need to be revised to reflect recent experience in Kenya. The wearing course specifications could be revised to include the recent research that utilises Grading Modulus and Plasticity Product. Control of gravel loss, control of roughness. Consideration should be made to adopting the Australian risk-based approach of materials selection in this regard.
		11.2	Design of Gravel Roads			Chapter 13.2 Design of Gravel Roads	The materials and thickness requirements need to be revised to reflect recent scarcity of gravel, and to reflect maintenance strategies.
Appendix A	Materials Sampling	*A.1*	General			Chapter 14.1 General	There is a need to add aspects of the British Soil Classification System into the chapter.

New Manual Chapter	Topic	Sub-Chapter	Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Approved/Existing Manual Ref.	Additions/Modifications to Chapter or sub-Chapter
	and Testing Programme	*A.2*	Minimum Mass of Samples Required			Chapter 14.2 Minimum Mass of Samples Required	It requires additions to the sections on sampling frequency (intervals along alignments, and by quantity for borrow materials).
		A.3	Preliminary Design			Chapter 14.3 Preliminary Design	There is also a need to describe the methods of sampling in deep cuts (along the alignment).
		A.4	Final Design			Chapter 14.4 Final Design	There is also a need to describe the methods of sampling in deep cuts (along the alignment).
Appendix B	Standard Methods of Testing	*B.1*	Soils and Gravels		The have since been updates to the test methods listed.	Chapter 15.1 Soils and Gravels	This should be retained, but the list of test method should be updated to include recent modifications and numbers. A decision has to be made as to whether to retain BS test methods or move to the equivalent BS EN test methods or KEBS.
		B.2	Stone, Aggregates, Sands, and Filters			Chapter 15.2 Stone, Aggregates, Sands, and Filters	
		B.3	Cement and Lime			Chapter 15.3 Cement and Lime	

New Manual Chapter	Topic	Sub-Chapter	Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Approved/Existing Manual Ref.	Additions/Modifications to Chapter or sub-Chapter
		B.4	Cement or Lime-treated Materials			Chapter 15.4 Cement or Lime-treated Materials	
		B.5	Bituminous Binders			Chapter 15.5 Bituminous Binders	
		B.6	Bituminous Mixes			Chapter 15.6 Bituminous Mixes	
Appendix C	References and Bibliography	*C.1*	References and Bibliography		No list of references and bibliography		Should include Key references and bibliography, but not over the top
		C.2	Materials Branch Reports		Recent reports missing	Appendix A List of Materials Branch Reports	Should be moved to References and Bibliography

New Manual Chapter	Topic	Sub-Chapter	Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Approved/Existing Manual Ref.	Additions/Modifications to Chapter or sub-Chapter
Appendix D	Axles, Climate, and Geology	*D.1*	Typical Axle Load Distributions and Equivalence Factors		Not relevant, and promotes laxity. Designers should carry out their own studies	Appendix B Typical Axle Load Distributions and Equivalence Factors	
		D.2	Mean Annual Rainfall		The legend of the map is not easily legible. Unfortunately, in the map, the six climatic zones are not labelled.	Appendix C1 Mean Annual Rainfall	Needs to be redrawn to make it clear and legible.
		D.3	Air Temperature Charts		Figures of showing the air temperatures in selected parts/towns of Kenya	Appendix C2 Air Temperature Charts	These are perhaps better represented in tabular format.
		D.4	Geological		A geological map is included in an appendix, but a soils map is not included	Appendix C3 Geological	Requires update to redraw the Geological map and to include Soils Map .

5 Review of Materials and Pavement Design Manuals for New Roads – Rigid Pavements

5.1 Review of 2016 EGIS Part 3 – Chapter 13: Concrete Pavements

5.1.1 Background

The existing manual (Design manual for roads and bridges, Part III: Materials and Pavement Design for New Roads (1987)] does not provide information required for design of rigid pavements. It only covers a few minor aspects on cement bound materials (i.e. cement and lime improved materials; cement stabilized materials) and lean concrete that may be applicable for both flexible and rigid pavement design. There is also a brief mention of the failure criterion considered in relation to subgrades when dealing with rigid and semi-rigid pavements.

The 2016 EGIS DRAFT Part III included a new Chapter 13: Concrete Pavements (Apr 2016). This was rejected by the Kenyan road authorities as not being suitable for purpose. The contents page of the EGIS (2016 DRAFT) is shown in Figure 5.1. Some sections of the draft manual contained no information e.g. 13-4 Roller Cement Concrete.

Figure 5-1: EGIS 2016 RDM Part III – Rigid Pavement Design Chapter Contents

5.1.2 Approach to review

The 2016 EGIS DRAFT Chapter 13: Concrete Pavements (Apr 2016) was reviewed and errors and omissions were noted, together with notes of gaps with information required to fill these gaps.

A detailed review of recent trends in structural pavement design of rigid pavements and associated materials utilisation in South Africa, Ethiopia, Uganda, USA, Australia, the UK and India has been undertaken.

Some of the manuals and specifications selected for review have been recently revised and therefore incorporate the current state of knowledge and innovations in the area of structural design of rigid pavements. In the UK, Highways England revised its Design Manual for Roads and Bridges (DMRB) in 2020 with different parts being rewritten to make them compliant with the new Highways England drafting rules. In 2018, Austroads (Australia) also revised its Guide to Pavement Technology Part 2: Pavement Structural Design [3].

These were examined in several key areas:

1. Pavement Types.
2. Pavement Joints.
3. Design Procedure.
4. Rehabilitation of Rigid Pavements.

5.1.3 Expectation from the process

The review of the 2016 EGIS DRAFT Chapter 13: Concrete Pavements (Apr 2016) aimed to identify errors, gaps and omissions in the chapter. All of this information would be crucial to rewriting the concrete pavement manual to be more user friendly and expanded to contain all of the information necessary for the designer to use, with particular emphasis on the engineer who may be unfamiliar with concrete road specifics and design.

Examination of relevant international manuals gave a lot of useful information, which varied from different methods of pavement design for various types of concrete pavements, a range in the types of new concrete pavement allowed, comparison of concrete definitions, different presentation styles and information about the latest rehabilitation methods. All of which was useful information that would be useful in revision of Kenya RDM, Pavement Design Manual for concrete pavements.

5.1.4 Findings – existing manual/compared to idealised

The findings of the Review of the EGIS DRAFT Chapter 13: Concrete Pavements (Apr 2016) are given in **Table 5-1** overleaf.

Detailed review of Chapter 13 of this draft manual covering concrete pavements has identified that major revision and rewriting is required to bring it up to international standards.

Table 5-1: Summary of review of EGIS Draft Chapter 13 on rigid pavements

Comment no.	Gap in Existing Manual	How Gap to be Filled
Pavement Design		
1	Different sections and parts obtained from different design manuals have been combined to produce this chapter, leading to a lack of coherence. Some aspects provided in different parts of the manual contradict each other. The different design manuals mentioned include: • the French mechanistic-rational method; • the Guide to Structural Design of Roads Pavements - Austroads 2004 (Australia); • the Guide for Mechanistic-Empirical Design of Roads Pavements – Transportation Research Board (USA); • the Guide for Thickness Design for Concrete Highways and Street Pavements – Portland Cement Association (USA); • The Guidelines for Design of Plain Jointed Rigid Pavements for Highways – IRC (Indian Road Congress).	The text mentions several design manuals but does not explain where each is used. Whichever pavement design method is used in the revised manual, there needs to be absolute clarity for the designer.
2	One of the main issues is that in 'Section 13.5 Structural Design Method', design structural catalogues have been developed based on the French software 'ALIZE'. The information provided under this section is specifically tailored on how to use the ALIZE software. It is expected that in a rigid pavement design manual and/or specifications, what should be provided is a pavement design approach that would give guidance on the thickness design of rigid pavements. If analytical methods are provided under the pavement design procedures, they should provide information on how to model the stresses/strains and assumed material properties to determine design thicknesses rather than being tailored to a specific software. However, what is provided under this Section is more like a user manual, which gives brief instruction on how to use the software to undertake a design.	It is understood that the client does not want reliance on one specific software package i.e. ALIZE. Therefore, the design method will need to be replaced. We are proposing either the Australian or the UK thickness designs for JUCP and CRCP With possibly the South African design for UTRC. A comparison of thickness designs could be undertaken using these two methods with various traffic/soil combinations to see if there are any significant differences in concrete thickness.
3	Different coefficients were applied to the average experimental strain or stress to deduce the allowable level of strain or stress. It is stated that the formulas were adapted to suit Kenyan conditions and that fine-tuning of the design method used, compared to the behaviour observed on real and/or experimental roadways (coefficient kc for each material), was done and presented in section 13.5.1. However, it is not clear how these formulas were 'fine-tuned' and adapted to Kenyan conditions.	There was no clarity or explanation of the coefficients used in the modelling. We will replace the ALIZE design software with standard pavement design methods from Australia or UK (to be agreed).
4	Sections '13.10: Std Pavement Structures for New Roads' and '13.11.4: Std Concrete Overlays' have been provided. It is not clear how these have been developed and what design method was used.	We will revise basic pavement structures based on the new agreed design methods.

Comment no.	Gap in Existing Manual	How Gap to be Filled
General comments		
5	Ease of use. There is no Contents Section at the start of the Manual (Part III: Materials and Pavement Design for New Roads). Instead, each Chapter has the contents at the start. This makes it difficult to find information as you need to know which section to go to, in order to find out where the information is.	All contents should be at the start of the manual (Part) and possibly the contents of each chapter should be repeated at the start of each chapter.
6	Some sections of 'Chapter 13 Concrete Pavement' require enhancing to include more information. Examples of this include: more information on joints (particularly expansion joints), curing, surface texture, transitioning to other pavements (which is too brief and hidden in '13.9.1 Joints'), testing of concrete, when the road can be trafficked, etc.	More information will be provided in the revision. Either because it is not in the original draft (e.g. RCC) or because there was not enough information e.g. transitions between concrete pavements and other roads/bridges.
7	Some sections of the chapter contain aspects common to both rigid and flexible pavements that are already covered in earlier chapters.	Hence, these sections need to be synthesised and dealt with in the other chapters e.g. traffic and pavement materials.
8	In the Chapter, there is a distinct lack of figure captions, figure numbers, table captions, table numbers and equation numbers. Some section numbers are wrong e.g. '13.2 Traffic' (p13-14) is followed by the next paragraph '13.1 General', etc. there is also another heading '13.2 Pavement Materials' (p13-17).	The revised version will be corrected and adequately checked.
9	Several typos, spellings, numbering and formatting issues exist in this chapter. In addition, incorrect reference to other chapters of the manual has been noted.	The revised version will be corrected and adequately checked.
10	Some tables, figures and equations in this chapter appear to be snapshots and are not clear.	These will be corrected.
11	Information seems to have been cut and pasted from elsewhere. There appears to be no information that is specific to Kenya, e.g. Kenyan cement classifications and standards.	Copyright issues will be checked to see if we can use any of the draft diagrams, etc. We will also include references to current Kenyan standards & specifications.
12	No guidance is given on which type of pavement should be used in what circumstances traffic/climate/etc or the pros/cons of each type of pavement.	This will be included in the revised version.
13	It is not known if the photos and figures given in the Egis draft have copyright and whether they can be used in the new pavement Design manual.	Copyright clarification needs to be sought as it would be useful to use some of these pictures in the revised version. If they technically belong to Kenya then it would make sense to use them.
14	Cost comparison of designing a new asphalt road vs a new concrete road. In Section 2.4.3.2, the design period is given as 15-20 years for an asphalt road and 40 years for a concrete road. It is not clear that when comparing costs for both types of pavement, the same (40-year) period should be used for both.	This will be clarified as it could make the difference between choosing a concrete road and not choosing a concrete pavement.

Comment no.	Gap in Existing Manual	How Gap to be Filled
Specific Comments (in section order)		
15	'Section 13.1.1 Sub-base'. The manual recommends a bound or lean mix subbase. However, on page 13-6 there is the statement that the subbase can be omitted if the CBR of the subgrade is greater than 15%.	The option of not using a bound sub-base should be removed. Water will inevitably enter the pavement and traffic action can wash away a granular sub-base, leading to voids, stepping, pumping and cracking. The South African Pavement Engineering manual (Chp 10: Pavement Design, page 6) states "The design of the subbase is essential to mitigate erodibility. This is generally achieved by selecting good material and by stabilising the subbase".
16	'Section 13.1.2 (Concrete) Pavement Types' lists 4 main types of concrete pavement and gives standard designs for these: • undowelled skewed jointed plain (unreinforced) concrete pavements; • dowelled square jointed plain (unreinforced) concrete pavements; • continuously reinforced pavements, • rolled cement concrete pavements. " It is unclear why undowelled jointed concrete pavements are listed as a different type of concrete pavement to dowelled jointed concrete pavements since design thickness would be the same.	It is proposed that undowelled jointed concrete should be removed as a separate pavement type. Instead, some text will be inserted into the Jointed unreinforced concrete pavements to the effect that 'dowels could be omitted in certain cases where traffic is light with no significant HGV trafficking'.
17	There is no mention (or limited detail given) for concrete block paving, Roller compacted concrete, jointed reinforced concrete pavement, continuously reinforced concrete roadbase (CRCR), prestressed concrete pavements or Ultra-thin reinforced concrete pavements (UTRCP) (although this is mentioned elsewhere).	Concrete Block Paving, RCC and UTRCP and JRC will be included.
18	Section 13.1.3 (page 13-6) Separator (separation membrane). It is not clearly defined or stated when this should (or shouldn't) be included.	Information that is more detailed will be added in the revised version.
19	Section 13.1.3 (page 13-11) Surface Texture. There is a lack of information here. For example, the section does not explain what a burlap drag is. There is mention of 'exposed aggregate' as an option for surface texture. This should be removed as it is a complicated procedure that requires great skill to execute correctly. To achieve adequate skid resistance, a second (thinner) layer of concrete containing only special high friction durable aggregate is paved onto the first concrete layer before it hardens. A chemical inhibitor spray is applied to retard setting, that is removed later by brushing with timing being critical. The photo of an exposed aggregate surface (p13-12) shows rounded	The surface texture section will be revised and clarified to give more detail. All of the main types of surface texture will be included. It is also proposed that the main recommended texturing method should be brushing or tines in the transverse direction (to aid water drainage) and not longitudinally.

Comment no.	Gap in Existing Manual	How Gap to be Filled
	river gravel aggregate which would be unsuitable for a main road due to low skid resistance.	
20	Section 13.2 Traffic	It is understood that this will be moved to a different Volume / Part of the Design Manual.
21	Section 13.1.3 (should be 13.2.3) (page 13-15) Traffic class nomenclature. This applies to more than rigid pavement design. It seems illogical that traffic classes run from T5 (low traffic) to T0 (High traffic: 60-100mMESA). With increased traffic, when new categories have to be added such as TX. It would make more sense to rename traffic classes as T0=low traffic to T10 High traffic. This would enable new classes to be added as and when required in a logical sequence. In order to avoid confusion the naming would need to be different e.g. TN0 to TN10. It is appreciated that this could lead to confusion, but it would be more logical.	This will need a wider discussion as it relates to Kenyan National Standards.
22	Section 13.2.1 Drainage Layer. The manual seems to be obsessed with including a drainage layer. This is shown in the cross-section diagrams (p13-3 and 13-4), is the first thing mentioned in '13.2 pavement materials' and is included in 5 of the 9 pavement structures shown (CC1-CC8 and RCC).	It is not clear why a drainage layer is given such a high priority. It is unlikely that the client specified it as a requirement. It is proposed that this is mentioned as an option in areas where drainage is an issue, but it should not be forced into the standard designs.
23	Section 13.3. A list of standards is provided which should not be included here but rather should be part of references.	This will be updated.
24	Section '13.4 Rolled Cement Concrete' contains no information and says "to be added".	This information will be added in the revised version
25	Section '13.5 Structural Design Method'. As mentioned before, this is based on ALIZE software. It is understood that the client does not want to be reliant on one software package with unknown factors. Also, there is no section 13.6	We will replace the ALIZE software with a different design method for JUCP and CRCP (TBA) and probably the South African design for UTRC.
26	Section 13.10 Standards Pavement Structures for New Roads (pages 13-33 to 13-54). Nine standard designs of concrete pavement are given i.e. CC1-CC8 + RCC. The choice of pavement type and the order they are given (which seems to be in order of sub-base type) seems inappropriate. They should be in terms of weakest to strongest pavement. Five of the nine designs have a drainage layer, which seems unnecessary. In addition, one third of the designs are for undowelled, skew-jointed, plain concrete pavements (this seems a particularly strange choice). In CC1 (p13-36), this type of pavement with a lean concrete subbase is only allowed for higher Traffic classes T3-TX (i.e. 3-400 MESA) so it seems strange as this type of pavement (no dowels) would be more suitable to low traffic situations and definitely NOT high traffic situations. We suggest that this option	The choice of standard pavement designs is curious and in some cases misleading. Standard pavement designs will still be provided (probably in the Appendices). It is proposed that this will be revised to include: • BP (block paving) • UTRCP • JUP • JRCP • RCC • CRCP

Comment no.	Gap in Existing Manual	How Gap to be Filled
	(skew joints no dowels) is either removed or restricted to low traffic situations such as urban minor roads or rural access roads. This type of pavement (undowelled joints) is cheaper to construct but will frequently lead to significant cracking and joint issues, i.e. significant maintenance issues/costs in the future. A lot of the standard designs CC1-3, 6-8 and RCC have options listed as being 'technically unsuitable' for lower traffic levels. This is incorrect – what it means is that a minimum thickness is required for interlock, etc. so it would be better to show these values?	All jointed concrete pavements to include a cement bound sub-base but without a drainage layer.
27	Section 13.10. Page 13-34. CC1 Design. See below. There is no specification given for the lean concrete subbase. **Subbase** Lean Concrete according to Chapter XX, Chart XX of Flexible Pavements Manual. Minimum Thickness: 200 mm on Subgrade S2 to S4; 180 mm on Subgrade S5 & S6.	All jointed concrete pavements (except block paving) to include a cement bound sub-base.
28	Section 13.10. Pages 13-33 to 13-54. Standard concrete pavement designs CC7 and CC8 seem to be a thicker concrete slab at the expense of a lean concrete or DBM subbase, which goes against earlier text where the importance of a non-erodible subbase is stressed. It is unclear why these designs are included.	All jointed pavements to include a cement bound sub-base.
29	Section '13.11: Overlays'. A very brief (less than 1 page) section on overlays is given, with little detail and only includes concrete overlays, with 3 designs presented. This overlay thickness is based on deflection but are they maximum/average values? Deflections are given in mm/100 not microns (i.e. mm/1000), so the deflection range is 0.3 to 2.5mm which is huge and must be wrong! The choice of pavement type is also incorrect. To say that an undowelled jointed plain concrete overlay is suitable for the highest traffic levels is just wrong.	It is understood that concrete overlays will stay in this section, but 'Maintenance and Rehabilitation of concrete pavements' will be in a different section. This will be completely rewritten.
30	References. There are no references. Just a list of BS EN numbers on p13-18 to 19.	References and sources of useful information will be given in the revised version. There will also be a list of relevant Kenyan Specifications.

5.2 Detailed review of other regional and international manuals

5.2.1 General

A detailed review of recent trends in structural pavement design of rigid pavements and associated materials utilisation in South Africa, Ethiopia, Uganda, USA, Australia, the UK, The Philippines and India has been undertaken. Some of the manuals and specifications selected for review have been recently revised and therefore incorporate the current state of knowledge and innovations in the area of structural design of rigid pavements. In the UK, Highways England revised its Design Manual for Roads and Bridges (DMRB) in 2020 with different parts being rewritten to make them compliant with the new Highways England drafting rules.

In 2018, Austroads (Australia) also revised its Guide to Pavement Technology Part 2: Pavement Structural Design [3].

Findings from the detailed review of manuals and specifications are presented below.

5.2.2 Pavement types

According to Federal Highway Administration [4], rigid pavement types for new constructed roads can be classified within three general categories of Unreinforced (Jointed Plain), Jointed Reinforced and Continuously Reinforced Concrete Pavements. However, design manuals and standards in different countries provide categories that may sometimes slightly differ from the above general categories. Different categories of rigid pavement types found in manuals and specifications from various countries are presented hereunder.

United Kingdom

The following categories of rigid pavement types are specified by Highways England's Design Manual for Roads and Bridges (DMRB) [5]

1. Unreinforced jointed concrete (URC)(with dowel bars).
2. Jointed reinforced concrete (JRC)(with dowel bars).
3. Continuously reinforced concrete pavement (CRCP).
4. Continuously reinforced concrete base (CRCB).
5. Roller compacted concrete (RCC).

It should be noted that in the UK, unreinforced jointed concrete (URC) and jointed reinforced concrete (JRC) rigid pavements are only allowed for maintaining or widening existing jointed rigid pavements. The last three pavement types can be used for construction of new carriageways.

United States of America

The following categories of rigid pavement types are specified by The Florida Department of Transportation [6] and The Texas Department of Transportation [7].

1. Continuously Reinforced Concrete Pavement (CRCP).
2. Concrete Pavement Contraction Design (CPCD) or sometimes referred to as jointed concrete pavement (JCP)(dowels usually included).
3. Jointed Reinforced Concrete Pavement (JRCP).

4. Post-tensioned Concrete Pavement.
5. Composite Pavement.

Continuously reinforced concrete pavement (CRCP) and concrete pavement contraction design (CPCD) are the two types of concrete pavements commonly used in Texas.

South Africa

The following categories of rigid pavement types are specified as the most common concrete road pavements in South Africa by South African Pavement Engineering Manual [8].

1. Jointed unreinforced (plain) concrete that can be doweled or un-doweled.
2. Jointed reinforced concrete pavement with light reinforcement to increase joint spacing.
3. Continuously reinforced concrete pavement (CRCP).
4. Ultra-thin concrete pavement (UTCP).
5. Prestressed Concrete Pavement.
6. Steel Fibre Reinforced Jointed Concrete Pavement.

Australia

The following categories of rigid pavement types are specified by Austroads Guide to Pavement Technology [3].

1. Jointed plain concrete (unreinforced) (PCP).
2. Jointed reinforced concrete (JRCP).
3. Continuously reinforced concrete (CRCP).
4. Jointed steel fibre reinforced concrete pavements (SFCP).

Uganda

The following categories of rigid pavement types are specified by Uganda's Ministry of Works, Housing and Communications Road Design Manual [9] and Ethiopian Roads Authority (ERA) Pavement Design Manual [10].

1. Jointed Unreinforced Concrete Pavements (JUCP).
2. Jointed Reinforced Concrete Pavements (JRCP).
3. Continuously Reinforced Concrete Pavements (CRCP).

India

Different guidelines are provided by Indian Roads Congress (IRC) for the design and construction of different categories of rigid pavement types such as:

1. Jointed Plain Concrete Pavement.
2. Jointed Reinforced Concrete Pavement.
3. Continuously Reinforced Concrete Pavement.
4. Fibre Reinforced Concrete for Pavements.
5. Roller Compacted Concrete Pavements.

5.2.3 Pavement joints and sealing

Joints are generally provided to permit expansion, contraction and warping of the slab, and therefore relieving stresses due to environmental changes (temperature and moisture) and to facilitate construction. Generally, the joints identified in the different manuals and specifications reviewed fall within the four categories presented below:

1. **Transverse (contraction) joints:** Transverse joints are perpendicular to the centreline of the roadway. Their purpose is to prevent uncontrolled cracking and reduce curling induced stresses.
2. **Longitudinal joints:** The purpose of longitudinal joints is to prevent uncontrolled cracking of slabs. Longitudinal joints are often tied with rebar to maintain the aggregate interlock between slabs.
3. **Expansion joints:** The purpose of an expansion joint is to provide for the expansion of concrete pavement due to volume changes resulting from temperature and moisture variations.
4. **Construction joints:** The purpose of a construction joint is to provide a clean transition from one concrete pouring operation to the next. An example would be fresh concrete against old concrete from one day to the next. These could be both longitudinal and transverse joints.

Joint sealing is applied is applied to reduce infiltration of moisture and incompressible materials into the joints for improved pavement performance. Moisture in the pavement foundation can allow loss of slab support from base and subgrade erosion and pumping, which causes concrete pavement distress. Sealing also can prevent incompressible materials from entering joints. Incompressible materials lock joints and create excessive stresses that may cause spalling, blow-ups, or shattering.

5.2.4 Design procedure

5.2.4.1 General

Design procedures for the different types of pavements, slab reinforcement, joint details and joint layout have been reviewed. The design procedures incorporate various aspects such as: Design Life; Design Traffic Loading; Thickness Design (i.e. Capping, Sub-base and Concrete Slab Thickness/Reinforcement); Design for Movement (i.e. Transverse and Longitudinal Joint Spacing); and Design Detailing. Any procedure for designing a rigid pavement must be carefully selected since it can have profound effect on the economy, performance, maintenance, durability and sustainability of the pavement. Design procedures of rigid pavements found in manuals and specifications from various countries are presented below:

5.2.4.2 United Kingdom

In 2022 Highways England, which manages the UK Motorway and Trunk Road network in the UK, renamed itself 'National Highways'. They also updated their Design Manual for Roads and Bridges (DMRB). The new publication CD 226: Design for new pavement construction [5] deals with the design for new pavement construction (both rigid and flexible) and replaces HD 26/06 that was withdrawn in 2020. It also sets out the requirements, which must be followed for the design of a new pavement (both rigid and flexible) using alternative design procedures. Alternative pavement designs provided for utilise analytical methods to model the stresses and strains and assumed material properties to determine design thicknesses. It clearly points out that all alternative designs require a 'departure from standard' approval by an Overseeing Organisation. Principles for alternative rigid pavement designs are set out in TRL RR87 [11] for jointed concrete pavements or TRL630 [12] for continuously reinforced concrete pavements. It is further stated that when designing an alternative CRCP or CRCB pavement, the design shall be based on the principles set out in TRL630 [12]. The analysis method used to model the pavement response and to calculate critical stresses and strains must use elastic multi-layer analysis based on Burmister's equations described in Burmister [13] with all layers modelled linearly including an infinite depth foundation. Note that proprietary materials cannot be specified in a design when using DMRB's CD 226 [5].

5.2.4.3 United States of America

The rigid pavement design procedures used in USA are based on the American Association of State Highway and Transportation Officials (AASHTO) Mechanistic-Empirical Pavement Design Guide plus numerous National Cooperative Highway Research Program (NCHRP), Transportation Research Board (TRB), and Federal Highway Administration (FHWA) publications.

A number of coefficients and variables are specified in the manuals, however, it is emphasized that there may be instances where variance from the values specified would be appropriate. In these instances, the Pavement Design Engineer is instructed to: (i) stay within the bounds established by the basic AASHTO Design Guide, (ii) justify the variance and (iii) document the actions [4].

(1) The Florida Department of Transportation [6].

This has been created using the AASHTO mechanistic-empirical pavement design process as a basis for rigid pavement design since 2009. The mechanistic-empirical design process was first adopted by AASHTO with the 2008 Interim Mechanistic-Empirical Pavement Design Guide (MEPDG) [14]. The current edition of the Florida Rigid Pavement Design Manual is based on the 2015 edition of the AASHTO MEPDG [15]. The mechanistic-empirical design and analysis process calculates pavement responses (stress, strain and deflections) and uses the calculated responses to compute incremental damage over time. The process then empirically relates the cumulative damage to observed distresses. The AASHTOWare Pavement ME Design software is used to perform the calculations and predict the smoothness, faulting and slab transverse cracking performance indicators for rigid pavements.

(2) The Texas Department of Transportation [7].

This provides analytical methods for designing pavements which include:

(a) TxCRCP-ME for continuously reinforced rigid pavements (CRCP): This design method was developed under TxDOT research projects which are detailed in Report 0-4714-1 [16] and Report 0-5832 [17]. The program performs an analysis of the pavement system for given inputs in estimating the frequency of punchouts, which is the primary structural distress of CRCP.

(b) For Concrete Pavement Contraction Design (CPCD), sometimes referred to as jointed concrete pavement (JCP): The 1993/1998 AASHTO Guide for Design of Pavement Structures [18] is the only approved design method. The AASHTO Guide also contains design procedures for rehabilitation of rigid pavements, including asphalt concrete overlays and Portland cement concrete (PCC) overlays of existing rigid pavements.

5.2.4.4 South Africa

Concrete pavement design in South Africa is generally done using the Mechanistic-Empirical Design Method, as implemented in software package concPAVE [19]. This method is based on the principle that the joint or a transverse crack is the weakest point in the pavement and load transfer, as defined in terms of relative vertical movement under a passing wheel load or under the FWD, is therefore the basis for predicting structural performance. Suitable design models have been developed from finite element and multilayer evaluations in South Africa. These models are used to determine aspects such as shrinkage which affects crack width as well as curling of the slab; effective subbase support by combining all support layers into one layer; erosion characteristics of the subbase; load transfer across joints from crack width, aggregate size and dowels defined in terms of relative vertical movement at joints/cracks under moving loads; development of voids under the slabs; and Structural capacity.

5.2.4.5 Australia

Guidance on the thickness design of rigid pavements is provided in Austroads Guide to Pavement Technology [3]. The guidance utilises the base thickness design method which is based on the USA Portland Cement Association (PCA) method [20] with revisions to suit Australian conditions [21]. The method assumes that the base and subbase layers are not bonded. The design thickness of the base is a function of the traffic loading, material properties, thermal effects and the cumulative stiffness of the subbase and subgrade. It was noted that many concrete pavement failures have been attributed to uneven support conditions that may occur over large underground services, culverts or at the transition of the cut and fill zones. Hence, the Austroads Guide to Pavement Technology [3] states that the concrete base layer should be longitudinally and laterally uniformly supported by the subbase and subgrade layers. More detailed advice on materials for concrete pavements is provided in Part 4C: Materials for Concrete Pavements of the Guide [22]. It is further emphasized that where the use of non-standard materials is proposed, the design shall clearly address how the material properties assumed in the design are to be achieved in situ.

5.2.4.6 India

Indian Roads Congress (IRC) Method of Rigid Pavement Design is based on mechanistic-empirical principles and the use of software IITRIGID for the computation of flexural stresses due to single and tandem axle loads [23]. The design of a rigid pavement basically consists of determination of the thickness of pavements; the design of joints; and the design of load-transfer devices such as dowel bars and tie bars. The guidelines provided also include procedure for design of pavements with widened outer lane, tied concrete shoulder, pavements bonded to stabilized subbase as well as design of longitudinal, expansion and contraction joints. Design of reinforcements for Pavement Slab is provided for continuously reinforced concrete pavements.

5.2.4.7 Ethiopia

The rigid pavement design procedures used in Ethiopia are based primarily on earlier versions of manuals by the UK's Highways Agency [24] and the 1993 AASHTO Guide for Design of Pavement Structures [18]. The AASHTO Guide also contains design procedures for rehabilitation of rigid pavements, including asphalt concrete overlays or Portland cement concrete (PCC) overlays of existing rigid pavements.

5.2.4.8 Uganda

The rigid pavement design procedures used in Uganda for the different types of pavements, slab reinforcement, joint details and joint layout are also based primarily on earlier version of manuals by the UK's Highways Agency [24]. The thickness design method (i.e. Capping and Sub-base; Concrete Slab Thickness and Reinforcement) is based mainly on empirical results and full-scale experiments.

5.2.5 Rehabilitation of rigid pavements

5.2.5.1 General

Several options that can be employed by pavement designers as rehabilitation options have been identified in the different manuals examined and specifications reviewed. However, an assessment of an existing concrete pavement must be done before rehabilitation can be undertaken. The different assessment methods include: Visual assessment; FWD measurements, and other measurements such as Roughness (e.g. MERLIN), Rut depth (after overlay only), Skid resistance (Skid Resistance Pendulum) etc. Furthermore, it is strongly emphasized that a careful analysis of life cycle costs of the different rehabilitation options must also be undertaken to determine the most cost effective one.

5.2.5.2 United Kingdom

Rigid pavement defects and deterioration mechanisms are provided in DMRB's CD 227 [25] which deals with design for pavement maintenance. Also, rigid pavement maintenance and rehabilitation techniques for retexturing of concrete surfacings and their range of expected service life are provided. These include Transverse grooving, Flailing, Bush hammering, Shot-blasting, Grinding with longitudinal grooving (following surface profile), Water jetting, etc. Furthermore, provision is made for design of surface only maintenance and deeper maintenance treatments (i.e. Strengthening and Non-strengthening treatments). Strengthening techniques include Full depth reconstruction; Fractured slab techniques such as Crack, seat and overlay (for jointed unreinforced concrete) and saw-cut, crack, seat and overlay (for jointed reinforced concrete); Bonded and Unbonded concrete overlays; and Asphalt overlays. Non-strengthening techniques include Bay replacement; Localised full depth repair; Slab lifting and pressure or vacuum grouting; Pressure and vacuum grouting. Further details can be found in Series 700 of the MCHW [26].

5.2.5.3 United States of America

(1) The Florida Department of Transportation [6].

This provides several rehabilitation options in its Rigid Pavement Design Manual. The first option is Concrete Pavement Rehabilitation (CPR) alternative which includes slab replacement, diamond grinding, installation of edge drains, cleaning and resealing joints, and routing and sealing random cracks. Another alternative provided in the manual is the Crack, Reseat and Overlay (CRO) alternative which involves cracking and reseating the existing concrete pavement and overlaying it with different options such as an Asphalt Membrane Interlayer (AMI), Structural Asphalt and Asphalt Friction Course. Furthermore, Rubblization and Overlay is another alternative recommended using specialized equipment which reduces the nominal size of PCC pieces and essentially reduces the slab to a high-strength granular base course and then overlay it with Structural Asphalt or Asphalt Friction Course. Other alternatives can involve removing or recycling the entire existing pavement and replacing it with a new pavement which could be concrete, or asphalt as determined by the pavement type selection process. Lastly, a fiber-reinforced polymer patching material is presented for use on isolated or random small spalls and/or corner cracks and can be used in conjunction with slab replacements or full depth repair. Additionally, using this patching could result in time and construction cost savings.

In addition, it is pointed out that a rigid pavement overlay of an existing flexible pavement structure is designed the same as a new rigid pavement, treating the existing flexible pavement structure as an asphalt base course over granular base.

(2) The Texas Department of Transportation [7].

This provides for bonded and unbonded concrete overlays. Bonded concrete overlay (BCO) consists of a thick concrete layer placed on top of the existing concrete pavement with operations conducted to ensure full bond between new and old concrete layers. A BCO has been found to be one of the most cost-effective ways of enhancing structural capacity of under-designed pavements by reducing deflections and extending service life. A thin BCO can also typically be used to restore pavement surface characteristics, such as ride and friction. Conversely, Unbonded concrete overlay consists of a concrete layer on top of an existing concrete with a HMA interlayer to separate new overlay and existing concrete. An unbonded overlay is a feasible rehabilitation alternative for PCC pavement for practically all conditions.

Furthermore, applying a concrete overlay on an HMA-surfaced pavement has been found to be a viable rehabilitation strategy under certain circumstances. Where existing distress in an HMA-surfaced structure is confined to the HMA itself (i.e. mix rutting, shoving, washboarding, cracking), but otherwise the existing substructure is sound, a concrete overlay can offer a durable replacement surface.

Another overlay option is through the reusing of Rigid Pavements as Base. This involves Break and Seat, Crack and Seat, Rubblizing and Multi-head Breaker (MHB) techniques.

5.2.5.4 Australia

The Austroads' Guide to Pavement Technology [3] provides for the design of concrete overlays using the same procedures for the design of new concrete pavements. In the design of concrete overlays, the existing pavement materials below any existing sound bound materials (e.g. asphalt) are considered part of the subgrade. The equivalent subgrade design CBR of any existing cracked asphalt, unbound granular materials, selected subgrade layers and the in-situ subgrade materials, is calculated using the procedure provided in the guide.

Provision for use of unbonded concrete overlay on rigid pavements is made for concrete pavements in poor condition, including severe cracking or material-related distress provided the pavement is stable and gives uniform support to the overlay. Unstable areas need to be repaired prior to overlay. An unbonded concrete overlay on rigid pavement is designed in the same way as a new rigid pavement, using the existing concrete base as a subbase. If the existing concrete base is stable, it is assumed to provide equivalent support to the concrete overlay as would a new lean-mix concrete subbase of the same thickness.

Furthermore, Asphalt Overlays may be provided on rigid pavements with critical consideration being given to the development of reflection cracks in the asphalt directly above cracks and joints in the underlying rigid pavement as the predominant distress mode for asphalt overlays on rigid pavements.

5.2.5.5 India

Indian Roads Congress (IRC) provides Guidelines for Maintenance, Repair and Rehabilitation of Cement Concrete Pavements [27]. It provides the different types of concrete pavement distresses and approaches of how to assess the existing pavement condition and to identify the pavement distresses to assessing their maintenance needs. Concrete pavement repair and restoration techniques which can be preventive and/or corrective include crack and joint resealing with flexible sealant; crack sealing with epoxy resin; crack cross stitching; Partial depth repairs; full depth repairs; diamond grinding; diamond grooving; slab stabilisation; slab lifting or jacking; Slab milling; retrofitting of dowel bars/edge drains and retexturing; concrete overlays (un-bonded, partially bonded, and fully bonded).

5.3 Proposed updated manual idealised table of contents and gap analysis

The proposed Table of Contents for the new manual and associated gap-analysis is as shown in **Table 5-2**.

5.4 References

(Note: Listed in order mentioned in text)

1. Road Design Manual for Roads and Bridges Part III: Materials and Pavement Design for New Roads (1987), Kenya Ministry of Transport and Communication, Kenya.
2. Draft Road Design Manual for Roads and Bridges Part III: Materials and Pavement Design for New Roads (2016), Kenya Ministry of Transport and Infrastructure, Kenya.

3. Guide to Pavement Technology Part 2: Pavement Structural Design (2018), Edition 4.2, Austroads, Australia.
4. Continuously Reinforced Concrete Pavement Manual: Guidelines for Design, Construction, Maintenance and Rehabilitation (2016), FHWA-HIF-16-026, Federal Highway Administration, USA.
5. CD 226 Design for New Pavement Construction (formerly HD26/06) (2021), Highways England, UK.
6. Pavement Manual (2022), Florida Department of Transportation, USA.
7. Pavement Manual (2019), Texas Department of Transportation, USA.
8. South African Pavement Engineering Manual, Chapter 9: Materials Utilisation and Design (2nd Edition 2014), South African National Roads Agency SOC Ltd, South Africa.
9. Road Design Manual, Vol. 3, Part II (Pavement Design: Rigid Pavements) (2010), Ministry of Works, Housing and Communications, Uganda.
10. Pavement Design Manual, Volume II, Rigid Pavements (2013), Ethiopian Roads Authority, Ethiopia.
11. Mayhew, H C and H M Harding (1987). Thickness design of concrete roads. Research Report 87. TRRL, Crowthorne, UK.
12. Hassan, K E, Chandler, J W E, Harding, H M and Dudgeon, R P (2005). “New Continuously Reinforced Concrete Pavement Designs”. Research Report 630. TRL, Crowthorne, UK.
13. Burmister, D. M (1945). “The General Theory of Stresses and Displacements in Layered Soil Systems III.” American Institute of Physics, Journal of Applied Physics 23:126-128, USA.
14. The Mechanistic-Empirical Pavement Design Guide (MEPDG) (2008), American Association of State Highway and Transportation Officials, USA.
15. The Mechanistic-Empirical Pavement Design Guide (MEPDG) (2015), American Association of State Highway and Transportation Officials, USA.
16. Freeman T, Uzan J, Zollinger D, and Park E (2006). “Sensitivity Analysis of and Strategic Plan Development for the Implementation of the M-E Design Guide in TxDOT Operations”, Report 0-4714-1 (http://tti.tamu.edu/documents/0-4714-1.pdf), USA.
17. Won M, Cho B, Ha S, Yeon J, Jung Y, Wimsatt A J, Zollinger D N (2010). “Develop Mechanistic/Empirical Design for CRCP”, Report 0-5832 (https://library.ctr.utexas.edu/hostedpdfs/txdot/psr/5832.pdf), USA.
18. AASHTO Guide for Design of Pavement Structures (1993) and Part II Rigid Pavement Design & Rigid Pavement Joint Design (1998), American Association of State Highway and Transportation Officials, USA.
19. South African Pavement Engineering Manual, Chapter 10: Pavement Design (2nd Edition, 2014), South African National Roads Agency SOC Ltd, South Africa.
20. Packard, RG (1984). “Thickness Design for Concrete Highway and Street Pavements”, Portland Cement Association, Skokie, IL, USA.
21. Jameson, G (2013). “Technical Basis of Austroads Guide to Pavement Technology: Part 2: Pavement Structural Design”, Research Report ARR384, ARRB Group, Vermont South, Victoria, Australia.
22. Guide to Pavement Technology Part 4C: Materials for Concrete Road Pavements (2017), AGPT04C-17, 2nd Edn, Austroads, Sydney, NSW, Australia.
23. IRC:58 Guidelines for the Design of Plain Jointed Rigid Pavements for Highways (2015), Indian Roads Congress, India.
24. Design Manual for Roads and Bridges (1997), The Department of Transport, London, UK.

25. CD 227, Design for Pavement Maintenance (2020), Highways England, UK.
26. MCHW, Manual of Contract Documents for Highway Works, Series 700: Road Pavements – General (2016), Highways England, UK.
27. IRC: SP:83 Guidelines for Maintenance, Repair and Rehabilitation of Cement Concrete Pavements (2008), Indian Roads Congress, India.

Table 5-2: Adequacy of existing or draft manuals for incorporation into new manual: Rigid Pavements

Key: Green = Fully Developed, Yellow = Partially Developed, Red = Not Developed, Grey = Not Applicable

New Manual Chapter	New Topic	New Sub-topic		Status	Gap: Proposed Content cw EGIS Draft or Approved Manual	EGIS Draft Manual Ref.	Remarks/Additional Comments
Contents		Contents Table		Red	There is no Contents Section at the start of the Manual. Instead, each Chapter has the contents at the start. This makes it difficult to find information.	n/a	It should be easy to find information - it is not in the current draft e.g.. to see if block paving is in the manual, you have to go to every chapter & look at the contents page – not easy.
Glossary		Definitions & Abbreviations		Red	New		New
1	Introduction	1.1	Introduction	Red	New		New
		1.2	Scope of Manual	Red	New		New
2	About Rigid Pavements	2.1	General Characteristics	Yellow	Text too brief.	13.1.1 Introduction (p13-2)	Some copied, some new.
		2.2	Pavement Structure and Layers	Yellow	Cross-sections but with errors.	Section 13.1.3 (p13-3 to 13-4)	Some copied, some new.
		2.3	Joints (Construction, Contraction and Expansion)	Yellow	Text too brief and some errors.	Section 13.1.3 Introduction (p13-6 to 13-8) + 13.9.1 Joints (p13-28,29)	Some copied, some new.
		2.4	Load Transfer Devices (Dowels and Tie Bars)	Yellow	Text too brief.	Section 13.1.3 (p13-8 & 13-10) and Section 13.9.2 Design of Steel Reinf. Bars (p13-30)	Some copied, some new.
		2.5	Reinforcement and Ground Anchors	Yellow	Disjointed information. Some hidden away in 13.9.1: Special Features of Concrete Pavements.	Section 13.1.3 (p13-10) and 13.9.1 Joint Design (p13-29)	Some copied, some new.
3	Types of Rigid Pavements	3.1	Block Paving (BP)	Yellow	No useful information in EGIS Chpt13 draft. However, some useful info in Chp 6.	Section 6.4.15 (p6-60)	Some copied, some new. The sub-committee has said this topic WILL be included here.
		3.3	Jointed Unreinforced Concrete Pavement (JUCP)	Red	EGIS draft lists 4 main types of concrete pavement and gives std designs for these: • undowelled skewed jointed plain (unreinforced) concrete pavements. • dowelled square jointed plain (unreinforced) concrete pavements.	Section 13.1.2: Pavement Types (p13-3)	It has been agreed that all jointed concrete pavements should have a CBM sub-base and dowels at joints. Undowelled jointed concrete should be removed as a separate pavement type. Instead some text will be

New Manual Chapter	New Topic	New Sub-topic		Status	Gap: Proposed Content cw EGIS Draft or Approved Manual	EGIS Draft Manual Ref.	Remarks/Additional Comments
					• continuously reinforced pavements, • rolled cement concrete pavements. It is unclear why un-dowelled JCP are listed as a different type of pavement to dowelled JCP since design thickness would be the same.		inserted into the Jointed concrete pavements saying something like 'a CBM sub-base and /or dowels could be omitted in certain cases where traffic is light with no significant HGV trafficking.
		3.4	Roller Compacted Concrete (RCC)		Very brief introductory text (4 paragraphs, no photos). Std Pavement structure for RCC includes drainage layer – not sure why.	Section 13.1.3: Terminology (p13-12,13) & Section 13.10 Std Pave. Structures (p13-33). RCC Std Pavement Structure (p13-34, p13-53, 54).	More info to be added. Using various country manuals. Std design examples will not have a drainage layer.
		3.~~5~~	Jointed Reinforced Concrete Pavement (JRCP)		No information in EGIS draft.		This will be included.
		~~3.5~~	Ultra-Thin Reinf. Concrete Pavement (UTRCP)		No information in EGIS draft.		Useful information freely available particularly South Africa.
		~~3.6~~	~~Continuously Reinforced Concrete Roadbase (CRCR)~~		No information in EGIS draft.		This will be included but may just link to CRCP design.
		3.7	Continuously Reinforced Concrete Pavement (CRCP)		Very brief intro to CRCP but this is hidden in "Longitudinal continuous reinforcement" sub-section.	Section 13.1.4 (p13-10)	This will be included.
4	Selection of Pavement Type	4.1	Traffic Level - Suitability of Each Pavement Type		No guidance is given on which type of pavement should be used in what circumstances traffic/climate/etc or the pros/cons of each type of pavement.	No info in Egis draft.	This will be included in the revised version.
		4.2	Pros and Cons of Each Pavement Type				
5		5.1	General Information		Unclear and based on ALIZE software.		Some copied, some new.

New Manual Chapter	New Topic	New Sub-topic		Status	Gap: Proposed Content cw EGIS Draft or Approved Manual	EGIS Draft Manual Ref.	Remarks/Additional Comments
	Design of Rigid Pavements	5.2	Stresses in Concrete Pavements		Design method is based which is to be replaced.	Section 13.5 Structural Design Method (p13-20)	This will depend upon which thickness design method is chosen.
		5.3	Design Life		Cost comparison for a new road (asphalt vs concrete). In Section 2.4.3.2, the design period is given as 15-20 yrs for asphalt rds & 40 yrs for concrete rds. When comparing design costs, the same (40 year) period should be used for both.	Outside Rigid Pavements chp: Section 2.4.3.2 (p2-18)	Design life for comparison of alternate pavement designs. This will be clarified as it could make the difference between choosing a concrete or an asphalt road.
		5.4	Design Traffic Loads		Traffic class nomenclature. This applies to more than rigid pavement design. It seems illogical that traffic classes run from T5 (low traffic) to T0 (High traffic: 60-100mMESA). With increased traffic, new categories have to be added e.g. TX. It would make more sense to rename traffic classes as T0=low traffic to T10 High traffic. This would enable new classes to be added as/when required in a logical sequence. To avoid confusion, names would need to be changed e.g. TN0 to TN10. It is appreciated that this could lead to initial confusion, but it would be more logical for future.	13.2 Traffic and axle loads. (p13-14). Section 13.1.3 (should be 13.2.3) (p13-15) Traffic class nomenclature. Section 13.5 Structural Design Method (p13-20) Kenyan EF values on p2-12	**Kenyan Traffic class nomenclature. Does this need to be updated?** **This needs to be discussed at a high level.** **Now would appear to be an ideal time to update it.**
		5.5	Environment		No useful information in EGIS draft Chp 13. However, it is on p3-1.	3.1 Climate (Temp & Rainfall), 3.2 Geology (p3-1 to 3-5)	New
		5.6a	Subgrade, Capping and Sub-base		The manual recommends a bound or lean mix subbase. However, on page 13-6 there is the statement that the subbase can be omitted if the CBR of the subgrade is greater than 15%.	Section 13.1.3 Sub-base (p13-5). Table 13-1 Subgrade classes. (p13-4) Elsewhere in PDM: Section 4: Subgrade & Earthworks	The option of not using a bound sub-base should be removed. Erosion of a granular sub-base will lead to voids, stepping, pumping and cracking. E.g. the South African Pave. Eng. manual (Chp 10: Pave. Design, p6) states that "The design of the subbase is essential to mitigate erodibility. This is achieved by selecting good material & stabilising the subbase".

New Manual Chapter	New Topic	New Sub-topic		Status	Gap: Proposed Content cw EGIS Draft or Approved Manual	EGIS Draft Manual Ref.	Remarks/Additional Comments
					CC1 Design. No specification is given for the lean concrete subbase. Subbase Lean Concrete according to Chapter XX, Chart XX of Flexible Pavements Manual. Minimum Thickness: 200 mm on Subgrade S2 to S4; 180 mm on Subgrade S5 & S6.		
		5.6b	Drainage Layer		The manual seems obsessed with using a drainage layer. As shown in the cross-section diagrams (p13-3 & 13-4), is the first thing mentioned in ‘13.2 pavement materials’ and is included in 5/9 pavement structures shown (CC1-CC8 and RCC).	Section 13.1.3 (P13-5) & Section 13.2.1 Drainage Layer (p13-17).	It is not clear why a drainage layer is given such a high priority. It is proposed that this is mentioned as an option in areas where drainage is an issue, but it should not be forced into the standard designs.
		5.7	Concrete Mix and Admixtures		No useful information in EGIS draft.		New
		5.8	Concrete Shoulders		No useful information in EGIS draft.		New
		5.9	Dowel Bars and Tie Bars		Under Reinforcement Section, but they are not reinforcement.	13.9.2 Design of Steel Reinforcement Bars (p13-30)	Some copied, some new.
		5.10	Joint Design & Spacing		See 2.3	13.9.1 Joints (p13-28)	Some copied, some new.
		5.11	Reinforcement		Some useful info but not enough.	13.9.2 Design of Steel Reinforcement Bars (p13-30)	Some copied, some new.
		5.12a	Slab Thickness		Explain characteristic thickness		New
		5.12b	Pavement Thickness		One of the main issues in the draft manual is that pavement designs are based on the French software ‘ALIZE’. The information in this section is tailored to this software. If analytical methods are provided under the pavement design procedures, they should provide info. On how to model the stresses/strains and assumed material properties to determine design thicknesses rather than being tailored to a specific software. This Section is more like a user manual, which gives brief instruction on	Section 13.5 Structural Design Method (p13-20)	Thickness design method to be decided by the sub committee et al at a later date. We will replace the ALIZE software with either the UK/AASHTO/South African or Indian thickness designs for JUCP and CRCP and probably the South African design for UTRC (yet to be agreed). New design examples to be added in Appx B

New Manual Chapter	New Topic	New Sub-topic		Status	Gap: Proposed Content cw EGIS Draft or Approved Manual	EGIS Draft Manual Ref.	Remarks/Additional Comments
					how to use the software to undertake a design.		
		5.13	Slab Shape and Joint LayoutConcrete Overlay Design Thickness				Uganda concrete pavements manual has good information.In Nov2022 sub committee apparently said they want a section on concrete overlays here.
6	Construction Details	6.1	Paving Plant		No useful information in EGIS draft about which types can be paver laid/hand laid.		New info to be added.
		6.2	Capping & Sub-base		See 5.6		Some copied, some new.
		6.3	Separation Membrane		Separator (separation membrane). It is not clearly defined or stated when this should (or should not) be included.	Section 13.1.3 (p13-6)	New info to be added.
		6.4	Concrete Joints (Construction, Contr-action & Expansion)		See 2.3. Gives useful joint spacings and diagrams of contraction /expansion joints.	13.9.1 Joints (p13-28)	Some copied, some new.
		6.5	Load Transfer Devices (Dowels and Tie Bars)		See 2.4		Some copied, some new.
		6.6	Reinforcement and Ground Anchors		See 2.5		Some copied, some new.
		6.7	Formwork		No useful information in EGIS draft.		New info to be added.
		6.8			No useful information in EGIS draft.		
		6.9	Concrete Mix and Admixtures		No useful information in EGIS draft.		New info to be added.
		6.10	Quality Control of Mix and Slab Thickness		EGIS draft has details of sampling & testing but this is all subgrade/ subbase/ aggregate NOT concrete mix.	Section 14 Materials Sampling & Test programme (p14-2)	New info to be added.
		6.11	Compaction		No useful information in EGIS draft.		New info to be added.
		6.12	Surface Texture		Lack of information here, e.g. does not explain what a burlap drag is. 'Exposed aggregate' option should be removed as it is a complicated procedure that requires great skill to get right. To get good skid resistance, a 2nd (thin) concrete layer with only special high friction durable aggregate	Section 13.1.3 (p13-11 & 12)	Some copied, some new. The surface texture section will be revised and clarified to give more detail.

New Manual Chapter	New Topic	New Sub-topic		Status	Gap: Proposed Content cw EGIS Draft or Approved Manual	EGIS Draft Manual Ref.	Remarks/Additional Comments
					is paved onto the 1st concrete layer before it hardens. A retarder spray is applied, and then removed later by brushing. Timing is critical. Exposed aggregate photo (p13-12) shows round river gravel aggregate - unsuitable for a main road due to low skid resistance.		It is proposed that all of the main surface texture types will be included. It is also proposed that texturing (brushing or tines) should mainly be in the transverse direction (to aid water drainage) and not longitudinally.
		6.13	Transition from Conc. Pavement to Asphalt Pavement/Bridge		Very brief text and 2 diagram of terminal slab and transition. Lost in other info: "Special features of Concrete pavements".	13.9.1 Joints (p13-28)	Some copied, some new.
		6.14	Curing		No useful information in EGIS draft.		New info to be added.
		6.15	Joint Sealing		1 line.	Section 13.1.3 Conc Pave. Terminology (p13-8)	New info to be added.
		6.16	Opening to Traffic		No useful information in EGIS draft.		New info to be added.
7	Concrete Overlays	7.1	Introduction		No useful information in EGIS draft.		New info to be added.
		7.2	Preparation before overlay		No useful information in EGIS draft.		New info to be added.
		7.3	Types of Concrete Overlay		No useful information in EGIS draft.		New info to be added.
		7.4	Concrete Overlay Thickness Design		No useful information in EGIS draft.		New info to be added.
8	Pavement Structure Catalogue	8.1	Introduction to Pavement Structure Catalogues given in Appx A-E		Nine std designs of conc. pavement are given i.e. CC1-CC8 + RCC. The choice of pave. Type & the order they are given (sub-base type?) seems wrong - should be weakest to strongest pavement. 5 of 9 designs have a drainage layer, which seems unnecessary. Also 3 of 9 designs are for undowelled, skew-jointed, plain conc. pavements (a strange choice). In CC1 (p13-36), a lean conc. subbase is only allowed for higher Traffic classes T3-TX (3-400	Section 13.10 Standards Pavement Structures for New Roads (p13-33 to 13-54).	The choice of standard pavement designs is curious and in some cases misleading. It is suggested that the (skew joints no dowels) option is either removed or restricted to low traffic situations such as urban minor roads or rural access roads. This type of pavement (undowelled joints) is cheaper to construct but will frequently lead to significant cracking and joint issues,

New Manual Chapter	New Topic	New Sub-topic		Status	Gap: Proposed Content cw EGIS Draft or Approved Manual	EGIS Draft Manual Ref.	Remarks/Additional Comments
					MESA) which is strange as a no dowels pavement would only be suitable for low traffic and NOT high traffic situations. Many of the standard designs CC1-3, 6-8 & RCC have options listed as 'technically unsuitable' for lower traffic levels. This is incorrect – the design thickness is less than the minimum thickness required for interlock, etc. so why not just show these min thick values? Also std designs CC7 & CC8 have a thicker conc. slab instead of a lean conc. or DBM subbase. This contradicts earlier text when a non-erodible subbase is stressed. It is unclear why these designs are included.		i.e. significant maintenance issues/costs in the future. Standard pavement designs will still be provided (in Appendices). It is proposed that this will be revised to: • BP (bock paving) • UTRCP • JUP • JRCP • RCC • CRCP • CRCR All pavements to include a cement bound sub-base but without a drainage layer.
		8.2	Design Method Explained		**Design Method TBA**		**TBA**
9	References	9.1	References		New. There are no references. Just a list of BS EN numbers on p13-18 and 13-19.	Section 13.3 Concrete Slab (p13-18 to 19).	
		9.2	Other Useful Publications		New.		
10	Relevant Standards				A list of relevant UK standards (BS EN numbers) is provided in Section 13.3 of the draft. This should be moved here & should show Kenyan specifications.	Section 13.3 Concrete Slab (p13-18 to 19).	Egis draft includes UK standards (BS EN). This should be Kenyan standards. Note: subcommittee also mentioned to include South African specs COLO and COLTO.
Appx A:	Pavement Structure Catalogue:				New.		
		A1	Concrete Block Paving		New.		
		A2	JUCP		New.		
		A3	JRCP		New.		
		A4	RCC		New.		
		A5	UTRCP		New.		
		A6	CRCP		New.		

New Manual Chapter	New Topic	New Sub-topic		Status	Gap: Proposed Content cw EGIS Draft or Approved Manual	EGIS Draft Manual Ref.	Remarks/Additional Comments
		A7	CRCR		New.		May be combined with CRCP
Appx B:	Examples of Concrete Pavement Design:				New.		
		B1	Concrete Block Paving		New.		
		B2	UTRCP		New.		
		B3	JUCP		New.		
		B4	JRCP		New.		
		B5	RCC		New.		
		B6	CRCP		New.		
		B7	CRCR		New.		May be combined with CRCP

6 Review of the Pavement Rehabilitation and Overlay Design Manual

6.1 Approach to review

The following influenced the review approach taken:

1. The need to bring the manual up-to-date with international best practice. There was also the need to get a good understanding of the documentation available in Kenya. To achieve this the following was carried out:
    a. Review of manuals and guidelines being used by other countries including:
        i. DMRB (Design Manual for Road and Bridges, UK).
        ii. Pavement Design Manual for Queensland Department of Transport and Main Roads, Australia.
        iii. AASHTO Handbook for Pavement Design, Construction and Management.
        iv. South African Pavement Engineering Manual, SAPEM 2013 SANRA.
        v. Rehabilitation Design Manual for Mozambique, 2019.
    b. Review of the coverage of different aspects of rehabilitation including field and laboratory investigations, pavement evaluation, materials and design procedures.
2. Understanding of the information available in Kenya on rehabilitation design and maintenance particularly in the existing manuals. To achieve this the following documents were reviewed in addition to Part V (1988) and Part 4 (2009):
    a. The Road maintenance Manual, 2010.
    b. Pavement Design Guideline for Low Volume Sealed Roads, MTRD 2017.
    c. Minor Roads Programme Interim Technical Manual, April 1987.

6.2 Expectation from the review process

In addition to the coverage of aspects of rehabilitation design is the requirement of details and content necessary to support the correct application of the concepts and methodologies of pavement evaluation and analysis as well as rehabilitation design and maintenance. These include:

1. The level at which the technical information is pitched. How much is enough or too little or too much information? This is important and varies from country to country or one authority to another. Some manuals are too brief that application is subject to interpretation, which will most certainly lead to high variations in design outputs for the same conditions. This is undesirable. Too much information as in textbooks is also undesirable and difficult to follow. Manuals should be practical and concise on what to do and how to do it.
2. There are different preferences on design approaches and these vary from one manual to another. Understanding these differences in preferences is essential because they may be influenced by implementation challenges, high data demand, suitability issues, accuracy, compatibility with current or modern aids like software, etc.

6.3 Comparative analysis process

Adaption is a major element of rehabilitation design. While many options are available for the design, adaptation of the various methodologies is usually a problem. Some systems such as mechanistic design require calibration to local conditions and materials to be effective – short of this, results and indeed the designs cannot be trusted because the analysis could yield wrong or inaccurate results. Some methodologies require extensive experience in pavement performance including pavement responses to loading. In these cases, engineering judgement applied by different people could lead to very different design outputs.

Each method or approach has pros and cons and these must be clearly understood before embarking on any option. The most disturbing of these are the basic assumptions, e.g., assumptions that:

1. Pavement behaviour and response to loading is linearly elastic which is the basis of linear elastic theory that is well known to be incorrect as pavement are non-homogeneous, anisotropic and exhibit non-linear response or behaviour.
2. Conversion from one method to another is assumed to be of a linear relationship which is also not necessarily correct.
3. Most approaches are based on bottom-up cracking and tensile stress and strain at the bottom of the layer being the predominant factor, which is not necessarily correct. This has resulted in crushed stone base to be considered as 3 times weaker that asphalt, which is also not correct.
4. Terminal condition is contentious. Is it PSI or 20mm rut or 30 mm rut that defines the terminal condition of a pavement? Does a wide rut imply subgrade failure or shoving of the asphalt indicate failure of the base or subbase – not necessary. Simply filling up the rut with HMA and resealing could extend the life of the pavement by more than 10 years and there is very little evidence of deformation of the subgrade. Cases of subgrade deformation usually occur where there is inherent geotechnical instability of the road foundation or very weak subgrade (CBR<3%).

It is important to find out how the different authorities and manuals/guides deal with these pertinent technical issues.

6.4 General observations on the existing and approved manual (May 1988 version)

The existing and approved manual was produced in May 1988 and has been successfully used over the years as a draft. It is the current manual in use. The manual is comprehensive in coverage and provides details that were relevant at the time, most of which are still relevant to this day.

The manual is written in a very concise format, although some sections seem too brief and may need more content. In a significant number of sections, the manual is written in the form of a guide and some important details are missing.

The coverage of the content is good and should be taken on board in the new edition. However, there are some advancement and good practice internationally, which the new edition could benefit from, and this will be the major focus while updating the existing manual.

6.5 Existing and draft manuals detailed review

Details of the preliminary review are given in **Table 6-1** below.

Table 6-1: Details of preliminary review of PRODM 1988 and PRODM 2012

No.	Item	PRODM 1988	PRODM 2012 Draft	Comments/Gaps
1	Table of Contents	Available at the beginning of the manual	Each chapter has its own separate table of contents, which is inconvenient.	1988 format is preferred
2.	Chapter 1 Introduction	Provides general purpose of the manual and definitions and descriptions to distinguish rehabilitation from maintenance and reconstruction	It is a direct copy of the 1988 version, but poorly copied with many typing errors, omissions and some meaningless sentences	This section needs to state strong links of this manual to the Road Asset Management System and the Road Network Planning and Management Manual for investment decisions (if they exists).
3	Chapter 2 Planning Considerations	Provides general considerations on road standards, pavement condition surveys, traffic data and flow patterns, economics and costs as well as benefits of associated investments. There is mention of rigid and semi-rigid pavements, but very little detail is given.	It is a direct copy of the 1988 version but poorly copied too, with many typos and repeated text. The authors or the Client did not review this Draft Manual. It appears to have been the very first draft.	The 1988 version is better. There is no reference to any planning manual or road asset management system. The information on planning is too brief and should be in a separate manual. Road Network Planning and Management Manual is required if it does not already exist. Otherwise more detail should be included in this chapter
4	Chapter 3 Pavement Behaviour and Deterioration	Title: Pavement Behaviour and Deterioration	Title: Identification, Causes and Treatment of Visual Distress	1988 title is more appropriate and could be improved to: Pavement Performance and Evaluation of Defects
		Most of the defects are listed. Possible causes are also listed but without details	Most defects are listed and photos are included, which may be helpful. Possible causes are also listed but without details.	Much more work is required to improve this chapter because it is the first and critical step towards developing a rehabilitation solution. E.g., the impact of using low quality binders and impact

No.	Item	PRODM 1988	PRODM 2012 Draft	Comments/Gaps
				of climate change need to be included. There is not enough detail on the defects and causes including the complexity of combinations of defects and their causes. There is not enough detail regarding their measurement, quantification and significance to overall pavement performance
5.	Chapter 4: Pavement Evaluation	The chapter covers pavement surface and structural condition evaluation and analysis	This chapter is almost a replica of the 1988 version but with less detail on relationship between deflection and pavement condition/ properties	Generally, significant improvement is required
		Content: The use of deflection measurements is given in significant detail	Details are very similar to the 1988 version	Upgrading through inclusion of new technologies is required including more coverage of FWD deflection measurements and the procedures as well as methodologies is needed.
		Materials sampling and testing as well as surface condition measurements are covered in detail. The results are then used to calibrate deflections and a table is provided for this.	Details are very similar to the 1988 version	This procedure of using pavement properties to calibrate deflections needs significant review and improvement. The approach may need to be changed or reversed. Not enough detail is given on what to do and how to do it regarding both pavement condition evaluation and data processing as well as analysis. Also, other critical tests on materials required for performance evaluation need to be included
6.	Chapter 5 Criteria for	The manual covers criteria related to	This chapter is a replica of the 1988 version.	This is a key chapter in the manual regarding the

No.	Item	PRODM 1988	PRODM 2012 Draft	Comments/Gaps
	Maintenance and Rehabilitation	surface condition, roughness, present serviceability, deflection, product RD (radius of curvature and deflection). Rigid pavements are not included.	No improvements were made except changes in the formatting	decision process towards sustainable rehabilitation or maintenance solutions. Much more is required here to guide the engineers in developing solutions and to determine the technical designs required. A lot more work is required to update the engineering content of the manual to compare and contrast the requirements for maintenance and rehabilitation including the thresholds. Climate resilience should be factored into it. Rigid pavements should be included if not covered in the pavement design manual (Part III).
7.	Chapter 6: Techniques and Materials for Road Strengthening	This chapter is comprehensive on overlays and rightly includes drainage improvements as an essential component of pavement strengthening.	This chapter is a replica of the 1988 version	This chapter is very well written but significant improvement is required to include new techniques, climate resilience relating to higher temperatures and flooding as well as consideration of extreme weather events.
		Details of materials given in this chapter relate to the situation and conditions in 1988. The tables for reading out the required overlay thickness are useful	There was no update on the standards and what is in the draft still relates to the conditions and standards of 1988 Additionally, the tables for overlay thicknesses were not included.	More details are required to include other approaches and standards. In addition, there are newer materials, techniques and improved standards which should be included to update this chapter.
8.	Chapter 7: Structural Design of Overlay for Flexible Pavements	This chapter covers standards for minimum thicknesses, consideration of design periods, design traffic,	This chapter covers standards for minimum thicknesses, design traffic, design periods, pavement structural analysis and charts relating deflections and	There are significant differences in this chapter between the 1988 version and the draft version. Information for both versions should be used to update this chapter.

No.	Item	PRODM 1988	PRODM 2012 Draft	Comments/Gaps
		structural analysis based on the multi-layer elastic theory, determination of pavement equivalent moduli, etc. culminating in the determination of Overlay Thicknesses Required.	overlay thickness for various traffic loadings. In addition, included are details relating to the use of FWD deflections and back calculation to determine residual pavement strength and the structural number method to determine overlay thickness. There is little on bound materials strain criteria. There is also little on recycling	Methods of analysis for rehabilitation design may need to be enhanced
9.	Chapter 8: Structural Design of Overlay for Rigid and Semi-Rigid Pavement	This chapter covers design of overlays for intact and deteriorated rigid pavements but it is lacking in details	Not in Draft Manual	A decision should be made on whether rehabilitation of rigid pavements should be covered in PRODM or Pavement Design Manual, Part III.
10.	Chapter 9: Other Rehabilitation Techniques and Reconstruction	This chapter covers other techniques of rehabilitation such as crack sealing, edge repairs, widening, reconstruction	Not in Draft Manual	This content needs to be covered in the new manual
11.	Appendix 1:	Procedure for Determining Present Serviceability Ratings	Derivation of Structural Number of a New Pavement	Both are important and should be covered in separate Appendices in the new manual
12.	Appendix 2:	Benkelman Beam Deflections – Testing Procedures	Derivation of Effective Structural Number of Existing Pavement	Both are important but Benkelman Beam should be replaced with FWD
13.	Appendix 3:	Does not exist	-	-
14.	Appendix 4:	Principles of Moving Averages	-	To be discussed
15.	Specifications of materials	Covers specifications for stabilised materials, aggregate, dense bituminous macadam, dense emulsion	-	To be included or referenced if in other manuals.

No.	Item	PRODM 1988	PRODM 2012 Draft	Comments/Gaps
		macadam, lean concrete, bituminous binders		

6.6 Status of existing and draft manuals

6.6.1 Additional information status of the existing manual

The following are key observations on the status of the existing manual:

1. The manual was developed to suit a typical rehabilitation design cycle and this approach needs to be maintained.
2. Some of the technologies and technical information are outdated and need modernisation with new advancements.
3. The manual is generally good and covers the key areas required for rehabilitation design, albeit with information gaps discussed below.

6.6.2 Status of the 2012 draft

The draft prepared in 2012 has shortcomings that include the following:

1. The draft manual has too many typing errors and the formatting is not consistent.
2. The majority of the sections were copied directly from the existing manual but there were lot of errors made while copying.
3. Some sections have well written content, but it needs updating because it is directly copied from the 1988 edition.
4. The structural number method was an update to the 1988 manual and should be taken on board in the new manual.
5. The use of pictures to illustrate defects will need to be discussed to determine whether the approach should be adopted in the new manual. This was a significant departure from the 1988 manual.

It was concluded to use the 1988 Manual as the base document for updating as it is stipulated in the ToR.

6.7 Key requirements and good practice references

Good practice starts from the definition:
"Rehabilitation is an activity that improves the functional and structural condition of a pavement using some or all of its existing structure ***(Queensland Department of Transport and Main Roads, 2020)"***

6.7.1 Key requirements for pavement rehabilitation and maintenance

Key requirements for pavement rehabilitation and maintenance include but are not limited to the following:

1. Work to be carried out within Kenya policies, standards, and road network requirements.

2. Assessment and application risk management and budgetary constraints for the whole road system.
3. Consideration of local conditions and materials.
4. Optimisation of designs and in-service treatments based on budgets and life-cycle costs.
5. Factoring future maintenance with the aim of ensuring low maintenance demand that is affordable.

6.7.2 Key requirements of the process:

1. Collecting and correctly interpreting pavement condition data.
2. Applying adequate engineering input and judgment.
3. Applying past experience relating to performance.
4. Developing rehabilitation treatments as required and supported by engineering and economic considerations.

6.7.3 Key requirements for design of treatments:

1. Preparation of designs for treatment options (at least 3).
2. Calculation of life-cycle costs for each option.
3. Carrying out an economic analysis of the options.
4. Providing recommendations on the most optimal option(s) and their implementation.

6.8 Proposed technical scope:

6.8.1 Types of pavements to be covered:

1. Unsealed pavements
2. Granular pavements with thin bituminous surfacings
3. Full-depth or deep-strength AC pavements
4. Pavements with modified or stabilised layers
5. Concrete (rigid) Pavements
6. Pavements with discrete surfacings

6.8.2 Design applications:

1. Granular overlays – these are granular layers placed on top of the existing pavements to enhance the capacity of the pavement for future traffic loading.
2. Asphalt overlays –.are required for strengthening existing pavements and the required thickness is determined through the overlay design. The overlay design involves determining the residual strength and hence residual life of the existing pavement and determining the additional strength and hence capacity required for the pavement to adequately carry future traffic loading forecasted for the given design life.
3. Asphalt inlays – are required where defects would have developed to some depth determined during condition surveys. The defective layer or component of the layer

is milled off and replaced with recycled or new material, placed and compacted to the required standards

4. Treatments that include a cement modified or stabilised layer – additional capacity can be developed by stabilising existing layers to improve their strength and load carrying capacity.
5. Treatments that include a foamed bituminous (and lime) stabilised layer – to enhance the load carrying capacity.
6. Treatments that include a lime stabilised layer – to enhance the load carrying capacity the layer.
7. Segmental surfacing – these are discrete surfacings made of pavers, cobble stone, stone sets, etc. they can be used to enhance the load carrying capacity of the existing pavements.
8. Combinations of the above

6.8.3 General content of the manual – rehabilitation and maintenance design process

1. Information from Asset Management and Maintenance – to develop indicators for the need for pavement rehabilitation and maintenance.
2. Pavement rehabilitation system
    a. Condition assessment – reconnaissance, preliminary and detailed condition surveys.
    b. Structural capacity analysis – determination of residual life of the existing pavement
    c. Rehabilitation and maintenance design – design for interventions necessary to meet requirements for the stipulated design life.
    d. Economic analysis – economic evaluation for the different design options of interventions
3. Design purpose and scope
    a. Based on traffic forecast – current pavement may be in a fair condition but is inadequate for future traffic
    b. Due to pavement condition – state of deterioration requiring maintenance or rehabilitation interventions
    c. Increase in traffic or future developments – where traffic would have increased faster than predicted when it was last constructed or rehabilitated and the pavement capacity has become inadequate
4. Evaluation of existing pavement and subgrade
    a. Historical data – this should also include key phenomena that may have occurred and influenced performance such as previous extreme flooding.
    b. Routine condition assessments – these are essential for development of pavement performance trends in order to determine whether rates of deterioration are normal for each defect i.e. time to initiation and subsequent progression. This will bring information regarding any premature failures and general poor performance.
    c. Maintenance history – this is necessary when evaluating and interpreting visual and structural condition of the pavement, there may be no visible cracks due to a recent reseal which may have covered the cracks.

   d. Serviceability assessments
5. Develop alternative strategies
   a. Evaluate alternative strategies based on:
      i. Purpose
      ii. Pavement type
      iii. Configuration
      iv. Distress mechanisms
   b. Determine the most appropriate solutions (maintenance treatments or rehabilitation design)
6. Design treatments
   a. Selection of appropriate design methods – there are several design methods most of which are detailed below
   b. Design of treatments
7. Select option(s) and make recommendations
   a. Comparison for optimal solution(s)
   b. Decision guided by economic assessment(s)
8. Purpose of rehabilitation
   - Synergies and opportunities

6.8.4 Pavement evaluation (DMRB-CD227, 2022)

Working out origin of Defects and Identification of Maintenance

1. Construction types and layer thicknesses present
2. Nature, extent and severity of defects
3. Probable cause of defects
4. Whether the defects are confined to the surface or extend deeper into the pavement structure
5. Types of remedial treatment needed.

6.8.5 Pavement evaluation tailored for pavement type (DMRB-CD227, 2022)

1. Flexible unpaved
2. Flexible with thin seals
3. Flexible with an asphalt base
4. Flexible with an HBM base – cement, lime, pozzolanic, fly ash, etc. RECYCLED - Hydraulically Bound Materials (HBMs) are made using recycled material and cement to produce a (CBGM) Cement Bound Granular Material and are a great cost saving alternative to a traditional subbase or base coarse aggregate
5. Jointed rigid
6. Continuously reinforced rigid; or (CRCP and CRCB)
7. Evolved, not fitting any of these construction types.

6.8.6 Data collection and analysis (DMRB-CD227, UK)

1. VCS presented in the form of a strip plan.
2. The network-level data collected as described in CS 230 [Ref 11.N].
3. Deflectograph results for flexible pavements – both residual life and temperature corrected deflection

4. Profiles
5. Core information - layer type, thicknesses, condition and bond between layers
6. DCP results
7. GPR results (if available).
8. Summary values of the most important in situ and laboratory tests (if available)
9. FWD profiles for flexible pavements (if available).
10. Joint evaluation test results (FWD) for jointed rigid pavements (if available)
11. FWD/HWD profiles for continuously reinforced concrete pavements (if available).
12. Skid resistance
13. *Benkelman beam tests on flexible pavements (Queensland Department of Transport and Main Roads, 2020)*
14. *LWD (light weight deflectometer) – suitable for low volume roads but not commonly used in the UK*

Key corrections to deflection data area noted: temperature, moisture and rate of loading.

6.8.7 Selection of design methods (Queensland Department of Transport and Main Roads, 2020)

Key considerations:

1. Purpose of rehabilitation or maintenance
2. Existing pavement type
3. Desired pavement performance
4. Constraints, relevant design, construction considerations
5. Maintenance considerations
6. Condition of existing pavement and nature of defects
7. Generic vs proprietary products or specifications
8. Pavement types
9. Residual life of pavement
10. Effect on public
11. Road geometry
12. Drainage
13. Shoulder sealing
14. Pavement surfacing
15. Stage construction
16. Timing and funding
17. Whole life cycle costs – economics

6.8.8 Technical details of specific rehabilitation treatment

1. Rehabilitation process
2. Drainage – treatment to correct drainage problems
3. Surfacings:
    a. Stone mastic asphalt (SMA)
    b. French Enrobé à Module Élevé (EME) – greater resilience against rutting and the environment.
    c. Superpave – for rut resistance and environmentally optimised design (still under development in Kenya)

   d. Ultrathin surfacings
   e. Slurry seals and micro surfacing
   f. Hot-in-place asphalt recycling (HIPAR)
   g. Cold in place asphalt recycling
   h. Cold milling
   i. Asphalt overlays
   j. Asphalt inlays
   k. Granular overlays
4. Treatment of concrete pavements
   a. Undersealing (pumping grout to fill voids)
   b. Crack and seat with AC overlay
   c. Full-depth concrete patching (full and half)
   d. Joint repairs, crack sealing, diamond grinding
   e. Etc.
5. Construction considerations
6. Granular mechanical stabilisation
7. Stabilisation using cement and cementitious binders
8. Stabilisation using chemical stabilising agents
9. Use of polymer modified and multiple grade binders.
10. Segmental surfacing/block paving

6.8.9 Deign of pavement rehabilitation treatments – including pavement capacity calculation

1. HDM4 – economic analysis and prioritisation of roads and interventions. This feeds into the selection of options and prediction of pavement performance under various in-service conditions.
2. Deflection reduction method – based on maximum allowable deflection for future traffic *(Queensland Department of Transport and Main Roads, 2020)*
3. General Mechanistic Procedure *(Queensland Department of Transport and Main Roads, 2020)*
4. Empirical methods (*ASANRA, SAPEM, 2013, ORN 31/RN31*)
5. Mechanistic-empirical (ME) methods *(ASANRA, SAPEM, 2013*), *(AASHTO Handbook for Pavement Design, Construction and Management - Mechanistic-Empirical Pavement Design Guide – A Manual of Practice (MEPDG,),*
   a. Characterisation of pavement structure, materials, design loading
   b. Inputs: Young's modulus and Poisson's ratio
6. South African Mechanistic Empirical Design Method (SAMDM) based on following damage functions *(ASANRA, SAPEM, 2013*)
   a. HMA fatigue
   b. Unbound granular base and subbase – permanent deformation
   c. Stabilised base and subbase layers – crushing failure, fatigue, permanent deformation
   d. Subgrade -permanent deformation
7. Catalogues *(ASANRA, SAPEM, 2013, ORN 31/RN31, Pavement Design Manual-Mozambique*)

8. Pavement Number (PN) – based on the structural number concept *(ASANRA, SAPEM, 2013*)
9. Dynamic Cone Penetrometer (DCP) Method – based on DCP-CBR or DCP-DN design for LVRs *(ASANRA, SAPEM, 2013, ORN 31, Rural Road Note-RRN, Pavement Design Manual-Mozambique*)
10. AASHTO Structural Number (SN) Method (1993) *(ASANRA, SAPEM, 2013,*)
    a. Empirical method
    b. AASHTO equation
    c. SN calculated from layer strength coefficients and layer thicknesses
    d. Deflection ball parameter analysis
11. Falling weight deflectometer SN design method *(ASANRA, SAPEM, 2013*)
12. TRRL Surface deflection design method *(ASANRA, SAPEM, 2013*) – outdated
13. Asphalt Institute surface deflection method *(ASANRA, SAPEM, 2013*)

6.9 Pavement rehabilitation and overlay design software

Software that can be used for rehabilitation design is given below. More details on the software are given on **Table 4-8**. Most of this software is proprietary and commercial. It is therefore inappropriate and unprofessional to recommend any particular software.

AASHTOWare Pavement ME Design – is a computer-based programme that requires installation. It is built upon the National Cooperative Highway Research Program (NCHRP) mechanistic-empirical pavement design guide for the design of new and rehabilitated pavement structures.

6.9.1 ALIZE 2

ALIZE2 – is a pavement structural design software based on the French design method and compliant with the design standards for new pavement structures (NF P98-086 [1]).

RUBICON TOOLBOX – is cloud-based to ensure quicker and easier updates as well as inclusion of new features. The toolbox offers several design tools that include: the AASHTO 1986 tool, Pavement Number tool, Layered Elastic Theory (LET) stress-strain calculator tool, the LET standard axle tool and the LET axle spectrum analysis tool.

HDM4 – this software is used for economic analysis and prioritisation of road project and interventions. It can be used for all roads but it is more appropriate for medium to high trafficked roads.

ELMOD – this software used for analysis of FWD data and overlay design.

ROSY – this software that is used for analysis of PRIMAX FWD with 9-12 geophones.

HAWKEYE – this software is used for the analysis of the visual condition survey data collected by HAWEYE machines.

RADAN – this software processes data collected using ground penetration data. An experiences engineer is required to interpret the data and profile images

UKDCP – this software is used for analysis of penetration data obtained during DCP tests on pavements. It is used to determine layer thicknesses and their strengths as well as overall pavement strength. The DCP-CBR output is used for rehabilitation design.

WINDCP – this software is used to determine pavement layer thicknesses and strengths from DCP penetration tests data. The DCP-DN output is then used for rehabilitation design.

6.10 Proposed updated manual idealised table of contents and gap analysis

The proposed Table of Contents for the new Pavement Maintenance, Rehabilitation and Overlay Design Manual, and associated gap-analysis, is as shown in **Table 6-2.**

Table 6-2: Adequacy of existing or draft manuals for incorporation into new manual: Pavement Rehabilitation and Overlay Design

Key: [green] = Fully Developed, [yellow] = Partial, [red] = Not Developed, [grey] = Not Applicable

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content cw Draft or Approved Manual	Draft Manual Ref.	Recommendations/Proposals Remarks/Additional Comments
Contents		Contents Table		[yellow]	There is no Contents List. It should be included in the new draft for easy reference	n/a	Contents at the beginning of the manuals make it easier to find information relevant for the task Recommendation: Consultant to propose. General Table of Contents to be in initial pages and detailed Tables of Contents at start of each chapter. This can be applied to all manuals
Glossary		Definitions & Abbreviations		[yellow]	Not included. This is necessary to clarify terms and terminologies as well as use of standard abbreviations	Not in draft manual	Definition of Pavement rehabilitation, maintenance and reconstruction to be included. All necessary initial pages should be included as in the Pavement Design Guideline for Low Volume Roads
1	Introduction	1.1	Scope of the manual	[yellow]	Current scope does not include rehabilitation design of unpaved and urban roads. Also, design considerations for climate resilience and mitigation are not covered because the concept is relatively new. The rehabilitation design methods provided are also limited. See details in Chapter 7 below. The manual does not clearly distinguish approaches based of road classes. The manual does not make reference to Road Asset Management Systems (RAMS) or relevant documentation of economic appraisal software like HDM4	Text similar in draft manual badly copied	The new manual will include additional chapters on rehabilitation design considerations for unpaved roads and urban roads as well as climate resilience and mitigation. Additional design methods will be added with guidance on their application. The coverage of the manual and where it can be applied needs to be clear to the users including classes of roads and related different aspects of pavement evaluation and design. There is need to coordinate with Kenya Roads Board on the issue of management systems

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content cw Draft or Approved Manual	Draft Manual Ref.	Recommendations/Proposals Remarks/Additional Comments
							Additional information on scope to cover a. Investigation plan b. Condition surveys c. Optional surveys d. Purpose e. Testing
		1.2	Planning period		Planning periods of 2 years for periodic maintenance and 4 years for rehabilitation are covered but should be reduced where condition data are collected regularly (annually) and are disaggregate for different classes of road.	Text similar in draft manual badly copied	Enhancements required – Planning periods need to be further disaggregated different classes of roadsLVRs, medium trafficked roads and high volume roads (HVRs) as well as where regular condition and traffic surveys are collected e.g. 1 year and 2 years respectively.
		1.3	Key Requirements		These are covered but based on the review of manuals from other jurisdictions and TTF discussions. Improvements are required on: a. Key requirement for rehabilitation b. Key requirements for the process c. Key requirements design of treatments	Not covered in manual	Critical understanding required from the outset. The manual to include rehabilitation design requirements based on change in functionality, environment, or traffic forecasts. The process and treatments may be varied for different classes of roads and authorities.
		1.3	Priorities for consideration		These are covered in significant details but there is no reference to project appraisals and PMS where prioritisation of interventions is made.	Text similar in draft manual badly copied	Minor enhancements – need to itemise information and data areas that are relevant for rehabilitation and maintenance as well as make reference to Pavement Management Systems and tools such as HDM4 for prioritisation of interventions
		1.4	Maintenance and upgrading		Enhancements required – section needs to make distinction between network management and vital aspects necessary for rehabilitation and strengthening.The definitions fall short of classifying the different	Text similar in draft manual badly copied	General maintenance to be included in Road Asset Management Manual

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content cw Draft or Approved Manual	Draft Manual Ref.	Recommendations/Proposals Remarks/Additional Comments
					forms of maintenance in which case general maintenance should not be part of this volume		
		1.5	Rehabilitation, strengthening or reconstruction		Enhancements required – Definitions are too brief and need improvementRehabilitation refers to bringing the pavement back to its intended condition, whereas strengthening includes increasing capacity e.g., through overlays. Reconstruction refers to situations where realignment or reprofiling may be required. While the definitions look good different jurisdictions define them differently and they are sometimes intertwined.	Text similar in draft manual badly copied	. Definitions should include designing for future traffic and relate upgrading to the 3 areas stated.
2	Planning Considerations	2.1	General		The manual lacks referencing to RAMS, HDM4 or RED Models, etc. for performance and road economics. Planning is key to any pavement rehabilitation and maintenance, and coverage is too brief. Requires information from network management including maintenance history, performance data, etc. There is need to distinguish network planning and project planning.	Text similar in draft manual badly copied	The new manual will make reference to key economic appraisal tools such as HDM4, Red Model, Life Cycle Analysis, etc. as well as performance data from PMS and so on. Project appraisal and feasibility study will also be referenced.
		2.2	Total transport cost		There is mention of vehicle operating costs (VoCs) but not their determination or derivation from HDM4. This may be covered under Economic appraisal below.	Text similar in draft manual	Concise information and consideration for VoCs including the surveys necessary will be mentioned and reference made Economic Appraisals Section
		**	Traffic considerations and analysis		Traffic loading is mentioned and its use in the evaluation of pavement performance is covered. However, the determination of traffic growth rates, vehicle equivalent factors, cumulative traffic loading in MESAs, impact of overloading, etc are not covered. The value exponent to be used in developing VEFs needs review though currently 4.5 is used for all circumstances.	Not covered in draft	This is useful for pavement assessment, economic appraisal as well as rehabilitation and maintenance design Reference will be made to the RDM Vol 3 for traffic assessments and classifications. However, targeted axle load surveys and limited traffic counts and classification including origin

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content cw Draft or Approved Manual	Draft Manual Ref.	Recommendations/Proposals Remarks/Additional Comments
					Currently the manual mentions a. Required traffic data is influenced by road class and upgrading requirements. b. Traffic volumes, composition and loading related to defects and mode of deterioration		destination surveys will be covered in more detail for rehabilitation purposed. Analysis of historical data and development of appropriate exponent for damage factor will also be covered. Reference will be made to RDM Vol 3 for consistency. The power factor of 4.5 will be considered and may be refined further when the materials to be used are known.
		**	Environmental considerations		Environmental conditions influence: a. Nature and progression of defects b. Performance of pavements and selection of pavement materials for use in rehab and maintenance Impacts of climate change have changed the operating environments and extreme weather events need appropriate mitigation are lacking	Not covered in draft	Environmental considerations especially relating to climate change are a critical subject, which requires proper Kenyanisation of standards. The temperature maps and rainfall intensity data/maps will be referenced. Both temperature and rainfall intensity influence pavement performance and can be worked out through HDM4
		**	Economic Appraisal		This is mentioned but not properly covered. Details of the inputs required and the outputs anticipated are lacking. The manual lacks referencing to RAMS, HDM4 or RED Models, etc. for performance and road economics. Economic Appraisal for rehabilitation projects is an important part of planning for rehabilitation and prioritisation of interventions. HDM4 is currently in use in Kenya. This information is particularly important for policy makers	Partially covered in the draft manual	This is essential at both project level and network level. At project level, the economic rate of return influences the level of investment and hence the rehabilitation design options and maintenance. This information is vital for policy makers and economists and concise information will be provided Referencing to RAMS, HDM4 or RED Models, etc. for performance and road economics will be made.
		**	Rehabilitation purpose		This will guide the investigations and data required from the outset	Not in draft	Well detailed in several manuals including the Australian

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content cw Draft or Approved Manual	Draft Manual Ref.	Recommendations/Proposals Remarks/Additional Comments
		2.3	Further investment costs		The information provided is vital. However, it is too brief – there is need to cover different scenarios where further investments would be required to: a. Enhance value for money as well as anticipated future developments, b. Including climate change impacts, c. Include future geometric demands, etc.	Text similar in draft manual	Information will be enriched.
3	PAVEMENT BEHAVIOUR AND DETERIORATION	**	Origin of defects and identification of maintenance		This gives prior understanding of: a. Defects and how they develop b. How initiation of defects can be delayed and mitigated when progressive This is not covered in the current manual	Not covered	Ref: UK's CD227 provides good guidance on this and a similar approach in Kenya Manual would be useful. This will be included in Vol 5 Part 1 condition surveys and referenced in Part 2.
		3.1	Flexible and rigid pavements		This section covers differences in performance between rigid pavements and flexible pavements. Their applications are not fully covered and so are the causes of deterioration necessary to develop a complete distinction as well as similarities in their structures. The title ''Pavement Behaviour and Deterioration' provides wider coverage than visual destress. The performance of combinations of rigid and flexible pavements is lacking in detail.	Title in 2009 limits the manual to visual destress	Section will be enhanced.
		3.2	Modes of deterioration		The list of defects and causes is not exhaustive and needs enhancements. The causes are limited and should be expounded. No distinction is made for rigid pavements which appear not to be covered at all though some defects may apply to both. The manual lacks details and a catalogue of defects and photos would be useful. Interpretation of defects is not covered properly	The pictures are good, but the coverage is not adequate. Some defects are caused by a combination of causes and interpretation is important e.g.,	Most of the information in the current and draft manual will be included in both Part 1 and Part 2. Part 1 will have the list of defects, their photos, and some texts given in the Appendix. The Maintenance Manual will be used for this purpose because it has the defects in the form of a catalogue which are useful.

New Manual Chapter	Topic	Sub-topic		Stat us	Gap: Proposed Content cw Draft or Approved Manual	Draft Manual Ref.	Recommendations/Proposals Remarks/Additional Comments
						distinction should be made between causes of cracks in pavements related to pavement failure or geotechnical problems	Interpretation of defects and field and lab results will be covered in greater detail Details of test standards to be covered in RDM- Vol 5-Part 1 Pavement. Condition Surveys). See item 4.1 below.
		3.3	Most usual defect patterns-possible causes		Rigid pavements are not properly covered though some defects may apply to both rigid and flexible pavements. The list of causes is not exhaustive, and more details and explanations are required	Not covered	Defects caused by deficiencies in load transfer capacity for rigid pavements will be covered in more detail. In addition, key assumptions that are made in like bottom up instead of top-down cracking will be discussed.
		3.4	Impact of preventative maintenance on road deterioration		Not covered. This is essential for prolonging life of pavements and should be given priority in the manuals and through practice.	Not covered	Techniques of preventative maintenance to be covered in detail
4	PAVEMENT EVALUATION	4.1	Surface condition		Pavement evaluation: Existing manual provides PSR (subjective), PSI (rideability) KRB has adopted IRI and PSI. PSR is in RDM and PCI in ASTM. The measurement of surface defects is not covered properly. There are more modern methods of measurement such as ultrasonic & laser profilers, straight edge, Merlin, Roughometer, Road Lab App (WB), GPR, LB Tool Kit, Skit Resistance, etc., which need to be covered. The approach of intensity and severity is not covered. It is commonly used nowadays. The new approach involves 'Deterioration Index, DI. DI=RdI + DfI + PPI + CrI). Index = extent x severity	Similar information is provided	PSR and PSI will be retained Other options from recommended jurisdictions like UK, AASHTO, Australia, South Africa will be review and recommendations will be made. The details of how to carry out the measurement will be given in Vol 5 Part 2 Deterioration Index method will be included as an Appendix.

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content cw Draft or Approved Manual	Draft Manual Ref.	Recommendations/Proposals Remarks/Additional Comments
		4.2	Structural evaluation		Only the Benkelman beam is covered in detail. Other methods of pavement structural evaluation are not properly covered e.g., GPR, FWD, Profilers, LWD, etc are not included. Additional details are required regarding the testing e.g., loading rate sensitivity and pavement characteristics at the time of testing, etc and this impacts on results.	Only Benkelman Beam and FWD are covered in detail.	Benkelman beam, HWD, FWD, GPR, Core drilling, test pits and LWD will be included and their application clearly defined. For the Benkelman beam – D_{90}, product RD, radius of curvature, will be used for pavement structural evaluation. For FWD, radius of curvature, max deflection (D_0), pavement layer and subgrade stiffness (moduli), pavement residual life determination will be used
		**	Premature pavement failures		Not covered. This is not normal deterioration emanating from normal causes Investigation of the defects requires a different approach	Not covered in draft manual	Will be covered based on knowledge from best practice and experience in Kenya and the Region The extent of testing/investigations will depend on whether the evaluation includes need for expert opinion for arbitration/litigation or just for repair and rehabilitation. It may involve specialised testing like Liquid Gas Chromatography
		4.3	Summary of the procedure for pavement evaluation		Table 4.2 gives verification of consistency of deflection with deterioration which in some cases does not apply, e.g., cracked Cement Treated Bases may exhibit low deflections. Investigation procedures: Procedure given in existing manual indicates regular spacing of test points for all tests – Regular spacing should only apply to deflections Practical application or method of using maximum and minimum values of deflection and strong and weak points for determination of locations of subsequent tests using results of preceding tests should be included for more	Partially covered in manual but no new information	Additional information may be required on how to develop correlations amongst results from different tests will be included.

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content cw Draft or Approved Manual	Draft Manual Ref.	Recommendations/Proposals Remarks/Additional Comments
					accurate assessment of causes of deterioration and more robust rehabilitation design.		
5	CRITERIA FOR MAINTENANCE AND REHABILITION	5.1	Surface condition criteria		Table 5.1 should be based on severity and extent not m/m^2 . Related condition assessment criteria should be added. Intervention Thresholds for Cracking: local patching - $5m/m^2$. Overlay - 30-50% of wheel paths Crack sealing should be part of routine maintenance and is a very simple and cheap exercise It is not advisable to allow the road to deteriorate significantly before the interventions. Generally, the approach is when crack initiation starts it means that the binder at the top of the surfacing has deteriorated and cracks should be sealed and a reseal or thin overlay should be applied and not wait until there are numerous potholes. Intervention Thresholds for Rutting - reaches 15mm for 20% of the section Intervention Threshold for Major Overlay or Reconstruction: mean rut depth = 20-25mm It is not normally the case that when a rut reaches 20mm then the subgrade has failed. Subgrade failures are rare. There is need to investigate so that if it the rut is due to densification of upper layers then it can be filled with compacted AC and section is then resealed with surface dressing or thin overlay. If there is de-densification of the layer(s) then the affected layers should be reconstructed.	Partially covered in manual but no new information	The TRRL approach is outdated. The manual to specify crack sealing each year before the rainy season + reseal soon after crack initiation unless clearly localized (use Indices for the determination) Intervention levels to be set properly and be based on the classes of roads. Manual to specify: 15 mm at 90%tile of values, fill rut with medium grading AC, regularize then reseal or apply thin overlay. Use of percentiles is recommended. Thresholds of pavement terminal condition set differently for different classes of roads and defined on whether subgrade has failed or not and whether deformation has progressed through all pavement layers. The contrary meaning terminal condition is not reached. Terminal condition is triggered by failure not when design traffic is exceeded, while pavement is sound.
		5.2	Surface roughness criteria		Thresholds are not clearly defined. Intervention threshold for Surface roughness : Reseal IRI – 2.8-3.1. Overlay and	Partially covered in manual but no new information	Clearer guidance to be given in the manual on consideration of qualified IRI thresholds for different classes of

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content cw Draft or Approved Manual	Draft Manual Ref.	Recommendations/Proposals Remarks/Additional Comments
					Reconstruction – IRI 3.4-3.7. These criteria are not appropriate e.g., could be a result of backlog maintenance. Classification criteria for roughness not evaluated based on current standards and road classes.		roads. Qualifying IRI involves determination on whether high IRI is a result of pavement failure or a backlog of routine maintenance such as unpatched potholes while crossfall is intact.
		5.3	Present serviceability criteria		Interventions and cost comparison should be based on 20 yrs. for asphalt roads & 40 yrs. for concrete roads. When comparing design costs, the same (40 year) period should be used for both.Intervention levels are set at PSI 3.0-2.5 for LVRs to HVRs but they are also unqualified. PSI is derived from a combination of defects and not all of them trigger the same intervention if at all. PSI is only applicable for terminal condition when deformation or irregularities are due to structural failure. Constants (a) and (b) were not developed it is not clear how they can be determined accurately.	Partially covered in manual but no new information	PSI limits given in the manual of 3.0-2.5 to be maintained. Additional qualifying specs to be included in the manual. Development of accurate constants (a) and (b) to be explored. Key information to be obtained from the DMRB, CD227.
		**	Pavement condition index		This is an alternative to Present Serviceability Criteria, and it is calculated from the severity and extent of defects through analysis of the data.		To be explored for inclusion.
		5.4	Deflection criteria		Deflection criteria of Tolerable Deflection is a good approach, Chart in Figure 2. However, chart does not cater for >10MESA (Kenya Model). Standards for maximum allowable deflections to be determined and provided for different road classes and cumulative traffic.	Partially covered in manual but no new information	The Australian method for the deflection reduction method to be considered. Extension of the chart for >10MESA to be explored.

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content cw Draft or Approved Manual	Draft Manual Ref.	Recommendations/Proposals Remarks/Additional Comments
					The application in rehabilitation design based on the deflection reduction method for rehabilitation and overlays to be included		
		5.5	Product RD criteria		Included in the existing manual but the details are limited. Product rd Criteria – product rd depends on depth and moduli ration e1/e2 for 2-layer system. Threshold values are set for adequacy of pavement Consideration of the pavement as one layer and subgrade as the second layer is inaccurate hence scatter is very common	Partially covered in manual but no new information	Method to be retained but enhancement of the information is required.
			FWD deflection criteria		Not included in the current manual. The is now the more preferred method in rehabilitation design because it is less cumbersome than the Benkelman beam.	FWD is well covered in the draft manual. It covers max deflection, layer stiffnesses through back calculation and pavement residual strength can be determined. Results are also applied in mechanistic design.	The content on FWD will be transferred from the draft to the new manual with enhancements.
			LWD		LWD is mentioned but not developed at all. It provides direct measurements of surface stiffness or moduli for the pavement layer through deflection measurements on each later during excavation of test pits	Not covered	LWD to be included in the new manual particularly for the design of LVRs and medium trafficked roads. It provides data on E-modulus, deflection, and CBR of subsurface layers through direct measurement or back calculation when 3 additional geophones are attached. Applicable

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content cw Draft or Approved Manual	Draft Manual Ref.	Recommendations/Proposals Remarks/Additional Comments
							load is varied between 40kN (FWD) or 80kN full axle.
6	TECHNIQUES AND MATERIALS FOR ROAD STRENGTHENING	6.1	Restoration and improvement of the drainage system		This is covered reasonably well. Enhancement is required on how to carry out measurements and assessment of drainage deficiencies and the mitigation design. Use of drainage layers and design for subsurface drainage to be added with reference to the drainage design manual.	Partially covered in manual but no new information	
		6.2	Preparation of the existing pavement for overlay		This is well covered. There is need to add more details on rut filling, cold milling, etc. as part of the preparation for overlays		
		6.3	OVERLAYS		This section covers different types of Overlays well. Enhancements are required to include stone mastic asphalt (SMA), open graded asphalt (OGA), DBM, DEM, CTB, ETB, Lean concrete, CRCP, Superpave, refusal density methods or reference to the Part III. The manual lacks details on composite overlays and ultra-thin inlay + overlay. These are materials that are also covered in Vol 3. Extensions to limits of traffic loading (MESAs) and general application of different materials needs to be reviewed and extended because some are too low prohibiting wider use of materials effectively.	Information is similar to the existing manual	Materials for road strengthening will be covered under Vol 3 Pavement Design. Volume 5 Part 2 Rehabilitation and Overlay Design will reference Vol 3. **Proposal** to provide details on implications for the design + extension of flexible pavements for traffic beyond 10MESA **Proposal** to extend CTB from 10MESAto 80MESA if not more Proposal to extend to 80MESA or more, and it is a better option to gravel for strength **Proposal** to extend to 80MESA for 50mm thickness with low allowable deflection <150 microns **Proposal:** harder binders can be used where necessary with a seal on top Proposal to apply DBM for all traffic loading **Proposal** to apply DBM for all traffic loading

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content cw Draft or Approved Manual	Draft Manual Ref.	Recommendations/Proposals Remarks/Additional Comments
							Proposal to include in-situ mixing of cement stabilised bases considering use of disc harrows and esp. pulvemixers **Proposal** to include ETB design, based on strength and moisture sensitivity or reference Vol 3 Consideration to be made of the need for rapid curing materials for works in urban areas where traffic disruption needs to be minimised
		6.4	INLAYS		In-lays are not covered in detail and will be included in the new manual. Inlays can be wearing course or a combination of wearing course and binder course. It can also be granular or CTB, OGA to be underlaid by DGA. Influence of depth of defects and strengthening as well as design life to be covered.	Not covered in draft manual	Consideration to be made of the need for rapid curing materials for works in urban areas where disruption needs to be minimised
7	STRUCTURAL DESIGN OF OVERLAYS FOR FLEXIBLE PAVEMENTS	7.1	Design principles		The principles cover overlay thickness and characteristics, design period, and stage construction. The design methods provided in the manual are limited to 2-layer linear elastic method, deflection reduction method, D_{90}, radius of curvature and product RD mostly based on the Benkelman Beam deflections. The shortfalls are some of the missing design methods such as the South African Mechanistic Empirical Design Method, the Catalogues, The General Mechanistic Method used by the Australians. Deflection Reduction Method also used by the Australians, Pavement Number Method Used in South Africa, etc. Asphalt Institute Deflection Method, long-life pavements, new AC mix designs are also missing. The application of	Partially covered in draft manual	Enhancements will include long-life pavements, new materials, asphalt mix designs, and other design methods, etc., covered below.

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft Manual Ref.	Recommendations/Proposals Remarks/Additional Comments
					these methods differs in principles and assumptions as well as versatility.		
		7.2	Practical and experimental bases		The section covers flexible overlays (unbound, bound and bituminous mixes, etc)	Partially covered in draft manual	Materials for rehabilitation and overlays will be covered under Vol 3.
		7.3	The structural approach		The manual covers the 2-layer system for the linear elastic method where the pavement is one layer and the subgrade is the other layer. Moduli ration E1/E2 is considered with thresholds below which design is considered inadequate. This method is not accurate and lead to significant scatter. The deflection D and radius of curvature R and thickness h are used to determine E1 and E2. Key parameters of DE2, R/E2 and E1/E2 are provided in Figures and derived from Alize 3 software and the manual also provides equations for calculation of E1/E2 Characterisation is carried out based on maximum allowable deflections, schematisation and characterisation of layer systems, using moduli approach for a multi-layer system or equivalent modulus approach calculated using the elastic method. Stress and strain is then calculated using the load and poisons ratios i.e. vertical stress at the surface of unbound layers and bottom stress for bound layers and semi-rigid and rigid pavement. This is then compared with maximum allowable stress and strain to determine the overlay thickness for given design traffic. Product rd is also covered. This is the product of the radius of curvature and deflection. This approach is also limited by the traffic loading which can be designed for.		The the 2-layer and multilayer linear elastic method, D_{90} vs Traffic loading, product rd, radius of curvature given in the current manual will be retained. The overlay design catalogues given in the existing manual will also be retained.

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content cw Draft or Approved Manual	Draft Manual Ref.	Recommendations/Proposals Remarks/Additional Comments
		7.4	Overlay design charts		Design charts are provided. Enhancements will include use of key charts to be proposed in Part III covering traffic loading of up to ≥ 80 MESA	Partially covered in draft manual	Overlay charts to be improved. They are not clearly readable.
		7.5	Method of use		Determination of allowable stress and strain for given design traffic, and consideration of fatigue laws for different layers. Moduli E1/E2 and equivalent modulus, Eq, are determined. Moduli and thicknesses are obtained from charts or equations. 7 steps are provided for the overlay design.	Partially covered in draft manual	
		**	Structural number method (AASHTO)		This method can be used for both LVRs and HVRs. It is much easier The structural number method is not included in the manual	The AASHTO Structural Number Method is given in good detail in the draft Manual It is based on back calculation of the FWD deflections . The method also covered	The AASHTO Structural Number Method is used to determine pavement strength by aggregating products of layer strength coefficients and layer thicknesses. These can in turn be determined from stiffness determined from deflections. Standards coefficients can also be applied. a. Empirical method b. Uses AASHTO equation c. SN calculated from layer strength coefficients and layer thicknesses d. Deflection ball parameter analysis This method can be used with the pavement structure catalogues for different traffic classes.
		**	Mechanistic-Empirical Design Method		Not covered in the manual The South African Mechanistic-Empirical Design Method would be a good reference for this. There are also standards given in other mechanistic methods like the Australia approach which may be useful. However,	Not covered in draft manual	The South African Mechanistic Empirical Design Method considers the following: a. HMA fatigue

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					there are a lot of assumptions that come with this method which should be clearly understood This one may be linked with the structural approach detailed above.		b. Unbound granular base and subbase – permanent deformation c. Stabilised base and subbase layers – crushing failure, fatigue, permanent deformation d. Subgrade -permanent deformation Calibration is a key requirement as parameters and predictions are material and condition dependent. Caution needs to be taken in applying this method.
		**	Dynamic Cone Penetrometer (DCP) Method		This approach includes: DCP-CBR approach (TRL, UK-DCP) DCP-DN approach (ReCAP)	Not covered in draft manual	This method is most suitable for LVRs. The DCP method will be applied in the new manual only of pavement evaluation.
		**	Deflection reduction method		The manual also provides for the maximum allowable deflection D_{90} where D_{90} is plotted against traffic loading showing deflection beyond which the pavement becomes inadequate. This is a method where an overlay or inlay is design to ensure that the permissible deflection for future cumulative traffic is not exceeded. Values are obtained from charts and equations.	Not covered in draft manual	Key approach used in Australia which are disaggregated for different levels of traffic and environments will be explored.
		**	Pavement Number Method		It is similar to structural number method and it is used in South Africa. May be optional for Kenya	Not covered in draft manual	Details will be provided in the manual if inclusion of the method is agreed upon. The method was developed on the principles of the structural number method.

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8	STRUCTURAL DESIGN OF OVERLAY FOR RIGID AND SEMI- RIGID PAVEMENT	8.1	Preventive overlays for intact rigid pavements		The principle of design requires that the stress and strain at the bottom of the bond layer should not exceed the permissible values. A design software ALIZE 3 (French) is given in the existing manual. Enhancement will involve widening the options for design software without recommending any particular one because it is not professional. More details are required in terms of applicability and design considerations for such overlays	Partially covered in draft manual	Rehabilitation design of rigid pavements to be moved to Design of New Rigid Pavements The choice of standard pavement designs is paramount to the whole rehab design system. Design of load transfer at joints for concrete pavements is also important for rehabilitation. It is proposed that this will be revised to: • CBP (concrete blocks) • UTRCP • JUP • RCC • CRCP All pavements to include a cement bound sub-base but without a drainage layer.
		8.2	Strengthening of deteriorated rigid pavements		Manual covers strengthening of pavements that deteriorated due to loss of cohesion and fracture without loss of cohesion. Design is based on principle of strain reduction to allowable levels. The information provided is inadequate for design and significant improvement is required.	Partially covered in draft manual	Enhancements are required for overlay design involving cement concrete or AC or composites
9	MAINTENANCE AND OTHER REHABILITATION TECHNIQUES AND	9.1	Surface treatments		The section covers emulsion, fog seal or surface enrichment.	Partially covered in draft manual	Enhancement will include use of Cape seals, SSD, DSD, milling and replacement, etc.
		9.2	Crack sealing		Crack sealing. Applicability and distinction by pavement types is required.	Partially covered in draft manual	
		**	Pothole patching		Only mentioned but details not provided	Partially covered in draft manual	The standards for managing potholes are critical for performance and serviceability of pavements.

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content cw Draft or Approved Manual	Draft Manual Ref.	Recommendations/Proposals Remarks/Additional Comments
	RECONSTRUCTION				This is an important pavement maintenance intervention that can be carried out on its own or as preparation for reseal or overly. Standards for pothole management will be included.		
		**	Deep treatments		Not covered in manual These are applicable to both rigid and flexible pavements. For concrete pavements some surface defects may require deep treatments because of difficulties of effectiveness and constructability shallow treatments	Not covered in draft manual	Ref: CD227 of the DMRB.
		**	Recycling		Not covered adequately in the manual. Recycling is a major consideration in rehabilitation and strengthening of pavements particularly due to significant cost savings, requirements to reduce the carbon footprint and environmental impacts of road provision and scarcity of materials	Not covered in draft manual	Recycling is now the first port of call in the design for maintenance and rehabilitation, especially for urban roads .
		9.3	Edge and shoulder reinstatement and upgrading		Edge and shoulder reinstatement. Materials specification is required.		
		9.4	Widening		Widening. Not enough design detail for widening. Enhancements to include benching, settlement of embankments, etc.	Partially covered in draft manual	
		9.5	Pavement reconstruction		Pavement reconstruction, rehabilitation and reconstruction techniques. Others include new alignmentEnhancement will include recycling and design of long-life pavements where required.	Partially covered in draft manual	
10	PAVEMENT MAINTENANC	**	Consideration of road classes in rehabilitation and		This will cover design considerations a. Trunk roads passing through urban areas b. Main industrial roads	Not in covered in draft manual	c. in the business areas d. Residential roads

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft Manual Ref.	Recommendations/Proposals Remarks/Additional Comments
	E AND REHABILITATION DESIGN CONSIDERATIONS FOR URBAN ROADS		maintenance of urban roads		a. RoadsNot included in manual b.		Accessibility and congestion are key elements of consideration
		**	Consideration of pavement geometry		This will cover considerations for: a. Maintenance of elevations for access b. Ancillaries and road furniture c. Impact of drainage on pavement performance d. Services and service lines running along and across pavement structuresNot included in manual	Not in covered in draft manual	e. Diversity of functionality to be considered
		**	Consideration of traffic management		Consideration of disruption of traffic and design mitigations to minimise it including: a. Rapid curing materials b. Long-life pavements through rehab and strengthening design c. Low maintenance pavement options (e.g., coarse bases and discrete elements surfacings)Not included in manual	Not in covered in draft manual	Traffic volumes are generally high on urban roads and pick hour flow is difficult to manage. Mitigation can be made through design d.
		**	Selection of materials for use in road rehabilitation and maintenance		Consideration of: a. Rapid curing materials Construction considerations of design optionsNot included in manual	Not in covered in draft manual	Several options and techniques will be provided and reference made to Vol 3.
11	PAVEMENT MAINTENANCE AND	**	Performance of unpaved road pavements		This will cover: a. Rate of gravel loss b. Rate of roughness progressionNot included in manual	Not in covered in draft manual	

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content cw Draft or Approved Manual	Draft Manual Ref.	Recommendations/Proposals Remarks/Additional Comments
	REHABILITATION DESIGN CONSIDERATIONS FOR UNPAVED ROADS	**	Rehabilitation scheduling		Information regarding determination of performance under future traffic will be provided.Not included in manual	Not in covered in draft manual	This be based on the Life Cycle Costing Calculator (Model) for unpaved roads developed by TRL (Eng. Kenneth Mukura)
		**	Selection of materials for pavement maintenance and rehabilitation		This will cover: a. Traffic assessment – traffic volume as opposed to traffic loading b. Use of performance-based specifications for wearing course materials for future traffic volumes Not included in manual	Not in covered in draft manual	Performance based specifications developed by TRL (Eng. Kenneth Mukura)
12	SPECIAL DESIGNS FOR RESILIENT PAVEMENTS				Not provided in manual		Climate mitigation and resilience needs to be covered in detail. • Materials of low heat and moisture sensitivity for strengthening layers or inlays • Armouring and pitching of pavements • Drainage enhancements • Pavement profiles (hydrodynamic and prevention of vortices • Use of material and construction methods with low carbon footprint • Recycling • Greening of roads Materials to be handled under Vol 3 and drainage under Hydrology and Drainage Design. Make references.
10	SOFTWARE				While it is not possible to recommend any particular software which is tantamount to promoting proprietary products, key inputs and expected output will be provided.	Not in covered in draft manual	

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content cw Draft or Approved Manual	Draft Manual Ref.	Recommendations/Proposals Remarks/Additional Comments
APPENDICES TO BE DETERMINED BASED ON NEED					Below are the appendices given in the existing manual		
Appx 1:	PROCEDURE FOR DETERMINING PRESENT SERVICEABILITY RATINGS						
		A1	Concrete Block Paving				
		A2	UTRCP				
		A3	JUCP				
		A4	RCC				
		A5	CRCP				
Appx 2:	BENKELMAN BEAM DEFLECTION						
		B1	Concrete Block Paving				
		B2	UTRCP				
		B3	JUCP				
		B4	RCC				
		B5	CRCP				
Appx 3:	THE PRINCIPLE OF MOVING AVERAGES						
Chart B2	Cement and Lime – Improved materials for base						
Chart B3	Cement – Stabilised Materials for Base						
Chart B4	Grade Crushed Stone for Base						
Chart B6	Dense Bituminous Macadam for Base						
Chart B7	Lean Concrete for base						
Chart S 1b	Surface Dressing Design						

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Chart S 2c	Graded Asphalt and Sand Asphalt						
Chart S3	Emulsion slurry seal						

7 Review of the Road and Bridges Design Manual – Part 1A: Geometric Design (2009 EGIS)

7.1 Introduction and scope

Although the list of contents shows the reader the scope of the manual, it is important to remind the reader of the fundamental aspects of geometric design at an early stage and to outline the format and organisation of the manual. Thus, this Introduction and Scope introduces the fundamental principles and many of the most important considerations that have to be taken into account in the design process.

These are:

1. Safety considerations such as design speed. The design speed affects almost every aspect of the geometric standard of the road from the sight distances essential for safety, its cross-section and its horizontal and vertical alignments;
2. Human factors and driving skills;
3. Other road users including pedestrians and motor and pedal cyclists;
4. Traffic volume and characteristics;
5. Road function capacity and level of service;
6. Location and route selection;
7. Environment and social considerations;
8. Economic and financial considerations;

The geometric design standards and characteristics of a road depend on three principal defining factors namely:

1. The function of the road;
2. The traffic that it is designed to carry; (this could be classified as a component of its function but it is more convenient to keep it separate);
3. The location of the road and especially the topography of the alignment of the road, the surroundings of the road (urban or rural) and the climate.

Designing a new road or upgrading an existing road requires many skills and effective documents to provide advice, instructions, and guidance, not only at the design stage but also from conception, planning, through to maintenance, and eventual rehabilitation or upgrading. A road is designed to provide good service for many years and therefore good planning and good-long term management are required. These activities rely on data and information. Some data are required only at one stage of the process and for one purpose but some data are required at different times in the life cycle of the road.

The procedures for the geometric design of roads presented in this manual are applicable to roads carrying an AADT of more 10,000 motorised vehicles over the design life of the road. However, if the traffic is less than 300 vehicles per day or the design traffic is less than 1 MESA then the Design Standards for Low Volume Sealed Roads in Kenya (2012) should be used.

The EGIS *Road and Bridges Design Manual Part 1A – Geometric Design* covers three basic design situations, namely upgrading from a lower class of road to a higher class; designing a road to replace an existing track; and designing a completely new road where nothing existed before. The manual does not deal in detail with the design of major grade-separated interchanges between restricted-access freeways (motorways) although the topic is introduced sufficiently for some of the simpler designs to be carried out.

7.2 Organisation of the manual

The manual initially sets out the functional requirements for roads in Kenya and identifies the details of the functional classes for both rural and urban roads. The next step is to develop the engineering standards that will permit the functional requirements to be achieved. This necessarily requires the collection of data concerning the nature of the traffic and the nature of the terrain where the road is to be constructed or upgraded. Important parts of this data collection are the traffic survey required to measure the current traffic and predict the future traffic and the ground surveying required to determine the route and alignment of the road. These topics are the subjects of specialist manuals but summary versions are included in the Appendices of this manual.

The design of a road requires decisions concerning engineering factors, the most important of which is the traffic speed for which the road is to be defined. This is because the design speed affects almost every aspect of the geometric standard of the road ranging from its cross section through its horizontal alignment and its vertical alignment. The next part of the manual (Chapters 4, 5', 6, and 7) describes and explains the components of the design to provide the cross-section details, and the horizontal and vertical alignment details. Chapter 8 then brings all these details together to define the design standards of all the road classes covering the specified traffic range and functional requirements defined earlier in Chapter 2 and 4.

The final step in the process is to connect the road to the existing network in a safe and reliable way, hence the remaining chapters are concerned with junctions and intersections ranging from simple junctions where two roads meet through to roundabouts and major junction at grade (Chapter 10) roundabouts (Chapter 11, and grade separated junctions (Chapter 12). Overriding all this is the question of road safety which is always in need of improvement and some aspects not fully covered up to this point are brought together in Chapter13.

7.3 Fundamental principles and considerations

7.3.1 Safety considerations

Road collisions are now recognised as costing Kenya about 5.5% of GDP and the economic case for reducing this cost by engineering improvements to the highway system is irrefutable. However, recognising an improvement that will reduce collisions has not been without its difficulties. Sometimes, what seems to be a sensible improvement has not had the desired effect. There is no substitute for good research in this subject. Much of the existing information is best understood with visual examples. The publication 'Human Factors Guidelines for a Safer Man-road Interface' by The World Road Association (PIARC) (available on their website http://www.piarc.org) from which previous transcriptions were made providing details and examples of good practice.

Designing safety features into roads therefore has two principal objectives namely to:

1. Provide design features aimed at preventing accidents; and to
2. Reduce the seriousness of accidents if they occur.

Relevant safety features for each type of road must be included during the initial design phase. The following issues are of particular importance:

1. Provision of physical separation between motor vehicles and non-motorized traffic (pedestrians, cyclists, animals); and separate facilities for these two road user types.
2. Provision of a balanced design, i.e. compatibility between the various design elements.
3. Avoidance of surprise elements for the drivers; i.e. no abrupt changes in standard, adequate visibility conditions and proper phasing of horizontal and vertical alignment.
4. Avoidance of situations where drivers must make more than one decision at a time.
5. Provision of design features that reduce speed differentials between vehicles; e.g. flat grades and speed change lanes.
6. Proper location and design of junctions with particular emphasis on sufficient sight distances, a minimum of conflict points, and clearly defined and controlled traffic movements.
7. Proper design, application and location of traffic signs, road markings and other traffic control devices. (Refer to the Design Manual for Roads and Bridges - Part 5)
8. Provision of design elements compatible with traffic volumes and type of traffic (long-distance, through, local, etc.).
9. Provision of proper drainage of the road surface.

Some collisions will happen even on roads designed to high safety standards because of the human element involved. A basic consideration in road design is, therefore, to minimise injuries and damage when accidents do occur. Important issues are:

1. Roadside slopes should be made as flat as possible whenever feasible, desirably 1:4 or flatter, and the roadside area should be well rounded where slope planes intersect.
2. Road sign and lighting supports and other utility poles should be located far enough from the carriageway to make them unlikely to be struck by an out- of-control vehicle, or they should have breakaway capability and/or guardrail.
3. All drainage structures should be designed so that out-of-control vehicles either can pass safely over them or be safely deflected.
4. Barrier systems should be considered only when fill slopes of 1:4 or flatter are not feasible, and the damage caused by hitting a safety fence would be less serious than damage from leaving the carriageway.
5. Roadside barriers should be provided at dangerous obstacles which cannot be removed, and which would cause serious damage if hit by an out-of-control vehicle (e.g. bridge piers and abutments).

Road safety considerations and features are built into the principles, criteria and values for the various design elements given in this manual. However, this does not necessarily ensure that the completed road will be of a safe design unless the designer is fully aware of, and takes into account, road safety aspects throughout all phases of the design work.

Where upgrading is required for rural and urban roads, accident data should be obtained and evaluated for considerations with respect to the new design. Such data should include accident type, cause and severity. This will help in identifying the measures of accident prevention that must be considered in the road design.

To improve road safety, the geometric design should take into account the road environment, road characteristics and human factors that are explained under various chapters. This holistic approach is aimed at reducing the probability of 'failure' to the lowest possible level and should minimise the adverse consequences should failure occur.

To ensure road safety at various project stages, a road safety audit should be considered as detailed in Part 1 b) of the Design Manual for Roads and Bridges.

7.3.2 Design speed

Design speed is the fundamental parameter of geometric design. It is a selected speed used to design many of the various geometric features of the roadway; for example, the minimum radii of horizontal curvature for a section of road.

It is essentially an index which links the design parameters of sight distance and many aspects of road alignment and road curvature to traffic flow and terrain to ensure that a driver is presented with a reasonably consistent speed environment.

The current definition is simply that the design speed is the speed selected as the basis for establishing appropriate geometric elements for a section of road. These elements include horizontal and vertical alignment, super-elevation and sight distance. Other elements such as lane width, shoulder width and clearance from obstacles are also indirectly related to design speed.

The chosen design speed should be consistent with the road function as perceived by the driver and one that considers the type of road, the anticipated operating speed, and the terrain that the road traverses, as discussed in Chapter 4. Recommended design speeds for each functional class of road are shown in the summary Tables of characteristics for each road class in Chapter 8.

7.3.3 Sight distances

Drivers must be able to see objects in the road with sufficient time to either stop or to manoeuvre around them. There are several situations requiring different sight distances, these are:

1. Stopping sight distance.
2. Intersection sight distance.
3. Decision sight distance.
4. Passing sight distance.

Each depends on the initial speed of the vehicle and the factors listed in Chapter 4.

7.4 Human factors

7.4.1 General

Human factors in this context are defined as the 'contribution of the stable physiological and psychological limits of humans to the development of a technical dysfunction or failure in handling machines and vehicles'. This is not a new idea but was first introduced over 80 years ago. It excludes temporary mental or physical conditions. It is concerned with the general and stable reactions of common road users. The subject deals with identifying road characteristics that are not compatible with normal human threshold limit values and therefore, potentially, trigger accidents.

It is therefore important that human factors are considered in many aspects of design, as indicated in the details of design in this manual, but the subject is of such importance that the fundamental principles are summarised here.

Drivers learn through experience that some events are likely to happen, or not happen. To avoid surprises and such expectancies, and their possibly dangerous reactions, it is essential to provide drivers with a continuous flow of information on the state of the road ahead

A roadway should confirm what drivers expect based on previous experience and should present clear clues as to what is expected of them. If these expectations are violated, problems are likely to occur which, in the most severe cases, may lead to accidents.

To avoid surprises, and their possibly dangerous consequences, it is essential to provide drivers with a continuous flow of information on the state of the road ahead, including information on:

1. The road alignment,
2. Approaching decision points, and
3. Other traffic, vehicular or pedestrian activity that may affect, or be in conflict, with them.

This advice should be mostly visual and provided by means such as road layout, signposting, traffic signs, and pavement markings. The receipt and subsequent treatment of this information depends largely on each driver's visual ability, reaction time and decision-making skills.

Designers should apply the following criteria:

1. Unexpected, unusual and inconsistent design should be avoided or minimised so that complex decisions by the driver are not required.
2. Predictable behaviour is encouraged through familiarity. For example, similar junction designs should be used in similar situations and the range of possible designs should be minimised.
3. Consistency of design should also be maintained from element to element along the road. This corresponds to relating the design speed to actual driver behaviour as expressed by the 85th percentile speed of cars under free-flow conditions. The difference between the 85th percentile and the design speed on an element such as a horizontal curve should be less than 20km/h.
4. To avoid information overload, the information provided to the driver should be presented in sequence to avoid presenting several alternatives at the same time.
5. Clear sight lines and sight distances must be sufficient to allow time for good decision-making.
6. Where possible, margins are allowed for recovery in case of error.

7.4.2 The 6-second rule

A user friendly road will give a driver enough time to assess a situation and to modify driving behaviour accordingly. In contrast to emergency stopping situations where a driver's response is automatic and driver reaction times and stopping sight distances are important.

It is not enough to provide the driver with a section of road that allows only a reaction time of 2-3 seconds. The design should also provide an anticipation section with a minimum of 2-3 seconds more to identify an unexpected or unusual situation which may require more complex decision demands and to adjust driving accordingly. Sight distances for various situations are described in detail in Section 4.4 but are also so fundamental to geometric design that they are discussed throughout this manual.

In situations that are more complex or involve higher speeds, it is recommended that there should also be an advance warning section with proper signing and instructions.

Thus, it is necessary to arrange transition zones, remove visibility restrictions, and make junctions perceptible at least 6 seconds before any critical location (e.g. junctions, curves, railway crossings, bus stops, bicycle paths, entrances of villages and towns, end of newly upgraded road sections and changes in road hierarchy).

7.4.3 The field of view rule

The field of view can either stabilise or destabilise drivers, it can tire or stimulate them. It can also result in either increased or reduced speed. Speed, lane-keeping and reliability of direction are functions of the quality of the field of view.

A good-quality field of view safeguards the driver and keeps him from drifting to the edge of the lane or even leaving it. Misleading and eye-catching objects in the periphery of the field of view activate unconscious changes in direction.

A user friendly, self-explaining road will give drivers a well-designed field of view and will give good optical guidance. A self-explaining road will avoid optical illusions or misleading eye-catching objects that destabilise drivers and negatively impact their driving, especially in adverse visibility conditions´.

7.4.4 The logic rule: the road has to follow a driver's perception logic.

Drivers follow the road with an expectation logic based on their experience and recent perceptions. Unexpected abnormalities disturb a mostly automatic chain of actions and may cause a driver to 'stumble' (to use an apt analogy). Several critical seconds can pass before the disturbance can be processed. Designers should introduce inevitable changes as early and clearly as possible and avoid sudden changes that would confuse the driver.

7.5 Other road users

7.5.1 Pedestrians

In Kenya about 40% of all road fatalities are pedestrians (NTSA, 2020) therefore facilities that improve pedestrian safety should be included wherever possible. In general, pedestrian safety is enhanced by the provision of median refuge islands of sufficient width at road junctions, and separate pedestrian footpaths (sidewalks) where pedestrian traffic warrants it, for example, on approaches to villages. Indeed, the design of rural roads and highways through urban centres should encompasses a range of safety features including traffic calming and well-designed village centres permitting trading in relative safety, as described in Chapter 13. In metropolitan areas pedestrian facilities need to be incorporated as a traffic stream in all facilities.

Pedestrians' age is an important factor that may explain behaviour that leads to collisions. It is recommended that older pedestrians be accommodated by using simple designs that minimize crossing widths and assume lower walking speeds. Pedestrian safety is further enhanced by the provision of:

1. lighting at locations that demand multiple information gathering and processing;
2. safe crossing locations with provision of speed management measures;
3. pedestrian overpasses across fully access controlled roads;
4. well lit pedestrian underpasses.

7.5.2 Motor cycles and motor cycle-based multi-passenger vehicles.

Kenya is experiencing a very rapid growth in motor cycles and transport based on the motor cycle. A single motor cycle is highly manoeuvrable and capable of high speeds but the adapted version, either for delivery services or used as a taxi, carrying up to four persons, although also highly manoeuvrable, is relatively slow. Planning for the future growth of these kinds of transport is not an easy task but there are some guidelines emerging from countries where the process is already far advanced. Single motorcycles are not a major problem except on narrow LVRs where an increased width of paved shoulder can be used to separate the motorcycle from other vehicles. The main problem is the slow motorcycle-based passenger vehicles that are rapidly becoming an essential part of the transport system within many metropolitan areas. Research is required as to how to deal with this potential situation in Kenya. The effect of such vehicles at all traffic facilities needs to be considered.

7.5.3 Pedal Cyclists.

Bicycle use is increasing, although it can be fairly local at the moment but should be considered in the design process. Improvements in the following can enhance safety for bicycle riders:

1. Paved shoulders;
2. Bicycle-safe drainage grates;
3. Ensuring that manhole covers are precisely at grade;
4. Repairing any edge of carriageway potholes.

7.6 Traffic characteristics

Traffic information is also required for many aspects of highway engineering including the planning of highway investment, the management of maintenance and rehabilitation and the design of individual roads. Details of the traffic in terms of vehicle types, the number of vehicles and their loading must be collected using suitable survey techniques and stored in a suitable database for current and future use. The main traffic related issues are described in Chapter 7 and in Appendix A and a more comprehensive manual is available.

7.7 Road function, capacity and level of service,

The term capacity is used to express the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane or a carriageway during a given period under prevailing carriageway and traffic conditions.

Highway capacity information serves three general purposes:

1. It is used in transportation planning studies to assess the adequacy or sufficiency of the road network to service existing traffic and to estimate the time when traffic growth may overtake the capacity of the network or result in unacceptable congestion.
2. Highway capacity information is of vital importance in the design of roads and road networks. Knowledge of highway capacity is essential to the proper fitting of a planned road to the requirements of estimated traffic, both in the selection of the road type and the dimensions of lanes and weaving sections.
3. Capacity information is used in the analysis of traffic operations (either existing or planned) for many purposes, but particularly for the identification of bottlenecks and assessing the benefits to be accrued from spot improvements to the geometry of the road.

When the volume of traffic is high, the road space occupied by different types of vehicles is an important element in designing for capacity, namely the highest traffic flow per hour that the road can carry. As traffic increases, traffic interaction increases until eventually the traffic level exceeds the capacity of the road.

It should be noted that the functional classification is not in exact one-to-one correspondence with the various geometric design standards. Although the engineering design standard is higher if the road is of a higher functional class, the exact geometric design standard also depends on the traffic level and the terrain in which the road is built. This is because, for reasons of safety and cost, the design speed also depends on the terrain where the road is built and design speed has a very strong influence on the geometric design standard, indeed it is the principal factor controlling it. As a result, there are many more potential geometric standards than there are functional classes. There is therefore potentially more than one design standard appropriate for each functional class. Although a design standard usually corresponds to a major functional class, it can also serve for other functional classes. A functional class could include a range of traffic levels and be built in several terrains but a design class is rigidly associated with a single traffic range and other design parameters that depend upon the design speed.

In summary, the primary issue is not functional classes but geometric design standard. The point is that drivers should always know the geometric standard that they are on but any geometric standard could fulfil more than one function. This will not happen often because the term function can be quite wide but in the middle range of standards, several functions can be covered depending on how narrow the term is used

The rural roads in Kenya are divided into the six functional classes (including motorways) (S, A, B, C, D, and E) according to their major function in the road network. Each functional class can be constructed in one of four different terrains– (but the mountainous terrain can be too severe) and there are five basic traffic levels defined (T1 to T5). For urban roads, the functional classes are similar (only the location has changed). Thus, the number of possible combinations is also high. Fortunately, some combinations do not exist or are simply not practicable or sensible (e.g. S class geometry on a very low traffic local road). The standards are introduced in the following chapters and summarised in Chapter 8, with one functional design per page showing most of the characteristics of that design standard.

Roads have two basic traffic service functions which, from a design standpoint, are very different in many respects. These functions are:

1. To provide traffic mobility between centres and areas – rural context; and
2. To provide access to land and properties adjoining the roads – urban context.

For rural roads the major function is to provide mobility to cater for through and long-distance traffic where high and uniform speeds and uninterrupted traffic flows are desirable. For urban roads the major function is to provide land access mobility, hence high speeds are unnecessary and, for safety reasons also undesirable.

Thus, the function of a particular road in the national, regional and local road network has a significant impact on the design criteria to be chosen, and the design engineer has to consider this aspect in the early stages of the design process- The steps are:

1. Classification of the road in accordance with its major function;
2. Determination of the level of access control compatible with the function of the road and its location – essentially urban, metropolitan (or semi or peri -urban) and or rural, and the nature of the topography (flat, rolling, mountainous, and climate;
3. Determination of the traffic that the road must carry and for how many years;
4. Selection of geometric design standards compatible with function, traffic, level of access control, and terrain.

The classification establishes a hierarchy of roads according to the importance of each road in the road network, and the socio-economic function that they serve or intend to serve.

Roads grouped under a particular functional class are characterised by their 'level of service' (Section 2.7.4) which is a measure of the quality of the service that they provide. This depends on various indicators such as the existing and predicted future traffic on the road and to the transport characteristics of the trip length, as well as the design standards and the level of maintenance requirements. It is, therefore, an overall indicator of the national importance of an individual road. Thus when designing or planning to design a road, identifying its role in the National, Regional, or Urban road networks, that is its functional classification is the first step.

When the functional classification and level of access control are decided, design standards are applied that will encourage the use of the road as intended. Design features that can convey the level of functional classification to the driver include carriageway width, continuity of alignment, spacing of junctions, frequency of accesses, standards of alignment and grades, traffic controls and road reserve widths.

The conflicting transport requirements of mobility and accessibility are the key design features that are used to differentiate between the design standard categories. Details of the road categories for rural and urban roads, their location in the road network and their defining characteristics are presented in the following sections and are in accordance with the study conducted on reclassification of the roads network in Kenya by MoR. (MoR, 2008 or traffic act reference)

7.8 Terrain

7.8.1 Overview

Terrain is a major factor in determining the physical location, alignment, gradients, sight distances, cross-section and other design elements of a rural road. Flat terrain may have little influence on route location, but may cause difficulties in some design elements, e.g. drainage. Furthermore, it may encourage monotonous straight alignments with abrupt changes in direction which may cause problems for drivers because the terrain gives no indication of what to expect.

7.8.2 Flat terrain

The topographical condition where highway sight distances, as governed by both horizontal and vertical restrictions are generally long or could be made to be so without construction difficulty or expense. The natural ground cross slopes perpendicular to natural ground contours in a flat terrain are generally below 5 %.

7.8.3 Rolling terrain

The topographical condition where the natural slopes consistently rise above and fall below the road or street grade and where occasional steep slopes offer some restrictions to normal horizontal and vertical roadway alignment. The natural ground cross slopes perpendicular to contours in rolling terrain are generally between 5-20 %.

7.8.4 Mountainous terrain

In mountainous terrain, the route location and certain design features may be almost entirely governed by the terrain. The longitudinal and transverse changes in the elevation of the ground with respect to the road or street are abrupt and benching and side hill excavation are frequently required to obtain acceptable horizontal and vertical alignment. The natural ground cross slopes perpendicular to contours in mountainous terrain are generally above 20 %.

7.9 Route selection and site investigations

The first consideration in the design process is route location. An appropriate route must take into account the intended functional classification, public opinion, environment, cost and benefits. The objective of route selection should be to choose a route that has both the minimum effect on landform and requires the smallest quantity of large earthworks.

A fundamental consideration in route location and final design is to fit the road sympathetically into the landscape, with a broad awareness of the character and features of the area through which it passes. This is required not only to obtain an aesthetically pleasing alignment, but in general is also necessary to obtain the most economical solution and the best possible service to the traversed area with the least detrimental effects.

For selecting the route of the road site investigation techniques are required which are also important for identifying sources of road building materials and for bridge design, drainage design and for all geotechnical studies. Thus, site investigation in general is wide ranging and is the subject of a separate manual. (Reference) but the important aspects related to route location are presented in Appendix B for completeness and convenience.

Of particular importance is the prevention of soil erosion. Areas should be identified where there are possible occurrences of landslides, slips, earth flows, and rock falls. These areas are to be avoided if possible in identifying alignment alternatives. Similarly, cuts on steep slopes in volcanic rock should be avoided as these may result in collapse of the hillside. Areas of unstable soil and marked erosion should also be avoided, and in all cases where the foregoing are unavoidable, a detailed geotechnical study of slope stability should be undertaken.

7.10 Environmental and social considerations

The following factors, related to the environment, must be considered in the location and design of a road project:

1. The preservation of the natural beauty of the countryside.
2. The preservation of particular areas and land used for specific purpose, including:
   a) national parks and other recreational areas;
   b) wildlife and bird sanctuaries;
   c) forests and other important natural resources;
   d) land of high agricultural value or potential;
   e) other land of great economic value of importance in a local context;
   f) forests, wetlands and other important natural resources;
   g) historic, *archaeological and cultural sites, cemeteries* and other fabricated features of outstanding value.
3. The prevention of soil erosion and sedimentation;
4. The prevention of health hazards by ponding of water leading to the formation of swamps;
5. The avoidance or reduction of visual intrusion;
6. The prevention of undesirable roadside development.
7. Other considerations are mainly related to the operation of the road as a facility for moving traffic and include the following detrimental effects:
   a) Noise pollution;
   b) Air pollution;
   c) Vibration;
   d) Severance of areas (barrier effect).

These operational effects are mainly a problem of urban roads and traffic, but in some cases are also relevant to the design of roads in rural areas.

Some of the adverse environmental effects are easy to quantify (e.g. noise levels and air quality), whilst others are more difficult (e.g. visual impact). In many cases, it is necessary to employ the services of other professions to reach a proper evaluation of the problems and establish adequate remedial measures. These will apply mostly to new roads.

7.11 Economic and financial considerations

The standard of a road and associated level of service increases with the level of traffic. This is entirely consistent with economic principles in that the basic whole life costs and lost benefits from a poor road network subject to congestion, poor surface condition and so on can be calculated with a tolerable degree of precision. Vehicle operating costs, in particular, are very dependent on road condition and travel time is a major cost that is greatly reduced when traffic can travel speedily.

Although many of the costs and benefits of modifications and improvements in a geometric design can be calculated, there remain several issues that cannot be quantified in monetary terms. This includes many environmental issues (e.g. benefits of not damaging a wetlands area), preservation of cultural issues (e.g. not using a burial area as part of a new road), the long term costs of not re-instating quarries properly, the cost of road accidents and the reduction in accident costs when significant safety features are incorporated into the design; and many more. Thus, although economic analysis is vital for optimising some of the major costs, there will always be a need to include other issues that are difficult, if not impossible, to quantify and therefore consultation, compromise, and flexibility are essential and the services of an experienced Transport Economist should be obtained.

7.12 Flexibility in road design

It should also be recognised that every road project is unique. The characteristics of the area, the values of the surrounding community, the needs of the highway users and the physical challenges are unique factors that highway designers must consider. The corollary of this is that designers must exercise flexibility and, most importantly, to understand the safety and operational impacts of various design features and modifications. As part of a flexible approach, the views of the public should be canvassed at the very beginning of the process, even before the project has been defined.

There are a number of design controls that must be balanced against one another. These include:

1. The design speed;
2. The design year peak-hour traffic and level of service;
3. The physical and performance characteristics of the typical vehicle or the vehicle chosen as ‘the design vehicle’;
4. The capabilities of the typical driver on the facility e.g. local residents driving at low speed on neighbourhood streets compared with long distance drivers on inter-urban freeways;
5. The possible future traffic demands on the facility.

These considerations are captured in the characteristics of each functional class and are discussed in the appropriate chapters.

Nevertheless, flexibility is constrained because a roadway should conform to what drivers expect based on previous experience. In practical terms, this means that flexibility exists with the class of road selected but within that class the geometric design features should be as expected for that class of road.

7.13 The design domain concept

In keeping with the concept that flexibility in design is required, the design domain concept formalises this to some extent by recognising that there is a range of values which could be adopted for a particular design element within absolute upper and lower limits. Values adopted for a particular parameter within the range would achieve an acceptable though varying level of performance in average conditions in terms of safety, operation, economic and environmental consequences. The design domain concept essentially sets the limits for the values selected for each parameter (SANRAL, Geometric Design Guidelines Chapter 2).

7.14 Indirect effects

Indirect factors (also known as secondary or tertiary, factors) that are usually linked closely with the project and may have more long-term consequences on the environment than direct impacts. Indirect impacts are more difficult to measure, but can ultimately be more important. Over time, they can affect larger geographical areas of the environment than anticipated. Some of the indirect factors to consider include:

1. Degradation of surface water quality by the erosion of land cleared as a result of a new road;
2. Potential for spontaneous urban growth near a new road;
3. Increased deforestation of an area, stemming from easier (more profitable) transportation of timber or charcoal to market;
4. Potential influx of settlers into an undeveloped area;
5. Rapid depletion of animals due to poaching.

7.15 Results of the review of Road and Bridges Design Manual – Part 1A: Geometric Design (2009 EGIS)

Table 7-1 overleaf presents the findings of the review of the above-mentioned manual, in tabular format.

Table 7-1: Results of the review of Road and Bridges Design Manual – Part 1A: Geometric Design (2009 EGIS

New Manual Chapter	Pages	Sub-sections	Subject	Sub-topic	Review Findings	Status	Additional Comments
1	19	1.1	**General**	Introduction			Several inappropriate sections that belong elsewhere.
		1.2		Purpose	In general, the combination of topics in each chapter does not always make the most sensible mix. Topics usually required at the same time should, ideally, be together.		
		1.3		Scope			
		1.4		Organisation of manual			
		1.5		Units of measurement			
		1.6		Design techniques			
2	23	2.2	Road Classification Concept and Design Standards	Road classification concept	There are 7 main classes of rural and 7 of urban. Each class has a different standard that also depends on terrain (4 levels) making a total of more than 40 standards. This is too many (see accompanying note). Our proposal is 5 rural and 3 urban		For the whole document, normal general text editing always required for consistency of style and format and to clarify, remove repetition, abbreviate, expand, provide cross references, minor restructuring etc..
		2.3		Hierarchy essentials			
		2.4		Access control	Access difficult to quantify but probably acceptable.		
		2.5		Road reserve			
		2.6		Design type	The standards are described here but the actual values of all the variables for each class should also be here for easy reference or moved to follow the details of their calculation		

New Manual Chapter	Pages	Sub-sections	Subject	Sub-topic	Review Findings	Status	Additional Comments
3		3.2	**Design control and criteria**	Terrain, land use and physical features	The introductory format used for this chapter is repetitive and unnecessary.		
		3.3		Environment and social considerations	The chapter heading is misleading	-	
		3.4		Safety considerations	The chapter is a mixed bag and some sections are better located elsewhere		
		3.5		Road function and access control	The chapter should concentrate on initial planning aspects. It is not about design controls and criteria, which should be in a separate chapter.		
		3.6		Traffic characteristics	Traffic information, both volume of types of vehicle, motorcycles and trucks and axle loading plus forecasts for the future are required for several manuals therefore it must be decided whether one manual for all traffic data is the best alternative.		
		3.7		Road capacity and level of service	Level of service cannot be measured unlike most attributes. Maybe a measurable level of congestion is better.		

New Manual Chapter	Pages	Sub-sections	Subject	Sub-topic	Review Findings	Status	Additional Comments
	22	3.8		Speed and speed controls	Currently Tables of a characteristc show the variations of a parameter across the design standards. For the convenience of experienced users, looking up details of a particular design class it is more helpful to show Tables for each design class with ALL the characteristics for that class together on one page but, both methods of presentation are probably needed.		
		3.9		Design vehicles	More useful to also define and identify the classes of road that might cause problems and why. The principal road classes should be capable of accommodating all legal vehicles.		
		3.1		Human behaviour	Human behaviour is discussed in several places. Where it impacts on design should be consolidated in one chapter.		
		3.11		Other road users	Rather general. Specific references to other road users where their needs add to or affect design should be mentioned at the appropriate		

New Manual Chapter	Pages	Sub-sections	Subject	Sub-topic	Review Findings	Status	Additional Comments
					place where that design feature is discussed.		
		3.12		Sight distance	There are several sight distances required for different situations. It would be sensible if they were all described and tabulated in one chapter.		
		3.13		Road surface	A very short paragraph that is unnecessary here and should be part of the calculations for stopping sight distance.		
		3.14		Economic considerations	An aspect of planning, not detailed design at this stage		
4	20	4.2	**Route selection and survey**	Route corridor selection	Another planning item	-	
		4.3		Survey		-	
		4.4		Information gathering	Information about surveying techniques should be in another manual. The design engineer is not the surveyor	-	
		4.5		Surveying applications		-	
		4.6		Records and reports		-	
5	31	5.2	Design elements	Sight distance	Sight distances are fundamental to many aspects of geometric design and all should be introduced in this chapter. Emphasize consistency.		

New Manual Chapter	Pages	Sub-sections	Subject	Sub-topic	Review Findings	Status	Additional Comments
		5.3		Horizontal alignment	I recommend that horizontal and vertical alignment are adjacent chapters preceded by the chapter on cross-section		
		5.4		Superelevation			
		5.5		Vertical alignment	Good figures of combinations and phasing		
6	20	6.2	Cross section	Lane width			
		6.3		Shoulders	Similar in length and content to a previous manual that John R wrote so I expect many sections to be similar in content. Expect that minor improvements may be required but nothing major. It will also be good to have one page summaries for all classes for quick reference		
		6.4		Choice of cross section			
		6.5		Typical cross sections			
		6.6		Normal cross fall			
		6.7		Side slopes and back slopes			
		6.8		Drainage channels			
		6.9		Widening on curve and fill			
		6.10		Clear(safety zone)			
		6.11		Four lane and divided roads			
		6.12		Single lane roads and passing places			
		6.13		Median			
		6.14		Cross section over bridges and culverts			
		6.15		Headroom and clearances			
		6.16		Provision for pedestrians and cyclists			
		6.17		Service roads			

New Manual Chapter	Pages	Sub-sections	Subject	Sub-topic	Review Findings	Status	Additional Comments
		6.18		Design standards	Changes proposed but agreement required as early as possible. See previous note		
7	57	7.2	At-grade intersection design	Design principles	Human factors should be elsewhere not just here. Define types early in chapter		A long chapter (over 50 pages) Generalization is not possible but normal text editing is required
		7.3		Geometry of approaches at intersection	The capacity of a priority intersection also depends on approach speed and this is omitted. Sight distances and gap acceptance times at junctions are quite complex and different methods are available. An alternative to the method here is to be investigated. This section is poorly written and some figures not labelled properly.		
		7.4		Requirements for pedestrians equestrians and cyclists	A single page. Probably sufficient		
		7.5		Roundabouts	Only 13 pages compared with 21 in my previous manual		
		7.6		Design of signalised intersections	Very similar to my previous manual		
8	16	8.2	Grade -separated junctions	Siting			Potentially a much larger chapter but perhaps not required if the number of such
		8.3		Design procedure			
		8.4		Traffic flows			

New Manual Chapter	Pages	Sub-sections	Subject	Sub-topic	Review Findings	Status	Additional Comments
		8.5		Geometric design standards			junctions is not expected to increase much and if they are not to be located in very congested urban environments
9	14	9.2	Roadside Amenities	Rest area			
		9.3		Service centres			
		9.4		Stopping places	A curious chapter that is mostly common sense and could be shortened but not urgent		
		9.5		Inspection sites			
		9.6		Roadside vending places			
10	20	10.2	Safety systems	Signs, lighting supports			
		10.3		Roadside barriers	Possibly needs expanding		
		10.4		Median barriers	Seems to be OK but I am not an expert on this topic. Could perhaps be shortened		
		10.5		Kerbs			
		10.6		Bridge parapets			
		10.7		Pedestrian barriers			
		10.8		Lighting			
		10.9		Traffic calming			
Appendix A	13		Dictionary of engineering terms				
			References				
Appendix B	9		Cross section and drawings		Not expected to be a problem		Not checked thoroughly

New Manual Chapter	Pages	Sub-sections	Subject	Sub-topic	Review Findings	Status	Additional Comments
Appendix C	6		**Missing**		Missing from my version of the document		
Appendix D	15		Plan drawings		Not expected to be a problem		Not checked thoroughly
Appendix E	5		More diagrams (some cross section)		Not expected to be a problem		Not checked thoroughly
	290						TOTAL pages of main text = 331
Urban manual					The proposed new manual is fully compatible with urban issues. Several chapters are almost entirely about urban issues (e.g. design of at-grade intersections, design of roundabouts). There are over 150 locations where urban issues are mentioned and 200 where pedestrians are mentioned and a section is devoted to village geometric design		A separate manual is not required

8 Review of the Road and Bridges Design Manual – Part 2: Drainage Design (2009 EGIS)

8.1 General

The current existing Kenya bridge design manual was produced in 1991 and has been used as a draft since then. The manual is inclusive of flood calculation and waterway computations. The details are brief, partially clear and in use to date. Most of the details in the manual were solely used and handled by the bridge section. Over time, some sections are found to be brief and hence requiring more details. The road flood computation tended to utilise only one key single method which is limited. In order to complement the bridge design manual, other related documents have been utilised over time by the practitioners.

The following documents have been found useful and complementary to the design manuals in current use:

1. Transport Road Research Laboratory Report 706, TRRL – East African Flood Model Department of Environment, Fiddes et al 1976.
2. Transport Road Research Laboratory Report 623, The prediction of storm Rainfall in East Africa TRRL – East African Flood Model Department of Environment, Fiddes et al, 1976.

Due to the changing nature of the hydrology of catchments, and to accommodate regional and international practice, the old manual therefore should be revised in tandem with the current best practice. This detail will be provided in the manual updating exercise.

EGIS International drafted the highway and bridge design manuals. The following is the key document related to bridge design:

1. Design Manual for Roads & Bridges, Part-III: Drainage Design (Draft), 2009.

8.2 Approach to review

The purpose of review of the existing manuals for Bridge Design is to assess the different topics that has been covered and to identify the gaps that need to incorporate while updating the manuals. The review process shall be carried out considering the best practices in the current changing trends in the hydrology field and bride design. The reviews will consider the current trends in the region and in developed countries meeting the requirements of local Kenya conditions. Key checks will be made from the various hydrological models and aspects of the bridge design whether these are covered or not and their appropriateness to meet the required objectives in the new hydrology and drainage manual.

Some of the documentation aspects to be looked include and not limited to includes appropriateness of document chapters, sub chapters and their scope he subject, document structuring, consistency in numbering, formatting and styles, accuracy and adequacy of the technical contents to meet the current requirements. The current review process continues and will be able to identify and infill the gaps in the existing manual.

8.3 Expectation from the review process

The review process will cover the gap aspects that are required in hydrology and design of structures with details and content necessary to support the modern and changing trends in the field of hydrology. These include:

1. The level at which the technical information is optimised. It is worth to note that some manuals are too brief that application is subject to interpretation which may make certain outs become outliers under the same hydrological conditions.
2. Hydrological models are based on available data and preference from one catchment to another. Understanding the various methods of modelling makes easier for the practitioners in the field to easily customise data requirements, field surveys and the anticipated challenges in the design.

8.4 Comparative analysis process

Some of the key highlights of comparative approach are outlined below:

1. For every method that is adopted for the flow design estimated has its pros and cons and the practitioner must be clearly understood before embarking on any option. The basic assumptions should however cover the basic elements and content.
2. Changes in the catchment and land use is critical any anticipated or planned changes requires attention.
3. Use of hydro -meteorological data and is correctness should be well understood with unit's conversations.
4. Correctness of the data from the office requires to be validated with field observations.
5. Data sources should be from the accredited government agencies.

8.5 Existing manuals review

8.5.1 Preliminary review findings

Details of the preliminary review of the existing and draft drainage design manuals are given in **Table 8-1** below.

Table 8-1: Details of preliminary review of RDM 1991 and EGIS 2016

No.	Item	RDM 1991	EGIS 2016 Draft	Comments/Gaps
1	Table of Contents	Available at the beginning of the Section Water Way computations	Available at the beginning manual	The 1991 manual gives section on a single chapter
2.	Section Chapter 1 Introduction	Too brief and general purpose of the manual and	It is too brief with reference to the Part IV	This section needs to state strong links of this manual

No.	Item	RDM 1991	EGIS 2016 Draft	Comments/Gaps
		definitions and descriptions not spelt out	of the Road design manual draft version	and more localised and made a full chapter
3	Section / Chapter 2 Planning Considerations	Not provided and gives directly to method of TRRL model	Chapter 2 Planning Considerations	The 1991 version goes directly to a model of flow calculation. The general considerations will be a topic and localised. The TRRL method would be structured and arranged under a different Chapter all together. Clear description will be given as chapters for the gauged catchment and ungauged catchments. The 2016 version will be more improved.
4	Section/ Chapter 3 Design Standards	The provided information, is limited	The chapter is written though with some typos and inconsistent flow	To be reworded and flow content well written with localisation of the standards
5.	Section / Chapter 4: Design discharge	The section is shallow and does not cover in-depth analysis	Covered in various Chapters in the 2016 version	Generally, significant improvement is required for consistency, rearrangements of sub headers, with more regional and localised methods
6	Section 5 Selection of Sizes	The section is shallow and does not cover in-depth analysis is	Covered in various Chapters in the 2016 version	The Content is well covered and only requires rewording and flow content well written with localisation of the norm graphs

8.5.2 Additional information status of the existing manual (RDM 1991)

The following are key observations on the status of the existing manual:

1. The manual was developed to suit a design and hydrology and design all seems be captured as sections within Chapters in the manual.
2. Some of the methodology such as the Kenya Railways methods are old - technology and technical information need modernisation with new advancements on flow analysis.

3. The manual gives a good source of knowledge for practitioners.

8.5.3 Status of the EGIS 2016 draft manual

The draft prepared in 2016 is general and far improved than the 1991 manual, however, the following are observed:

1. The draft manual has numerous typing errors and the formatting is not consistent.
2. The majority of the sections were copied directly from the other regional existing manual but there were lot of errors made while copying.
3. There are some glaring gaps in the manual, for example, it does not capture all the methods that utilised in flow estimate.
4. Lots of the document content requires localisation to the Kenyan requirements.

In conclusion, the 1991 draft is not arranged as Chapters but as Sub section in the Chapter under drainage. The Egis Draft is far improved with chapters well arranged. However, more rearrangement of the information, correction and addition some pertinent with regional and localised content added. This hence requires updating as it is outlined in the ToR.

8.6 Good practice references

For the purpose of the reviews, an idealised framework in the forms of Table of Contents is prepared based on the best practices at regional and international level. In preparing this framework, the practices in Ethiopia, Uganda, USA and Australia are considered.

The following manuals were considered in this process:

1. Ethiopia: ERA Bridge Design Manual – 2013.
2. URA Bridge Design Manual - 2010.
3. Australia, Guide to Road Design Part 5; General and Hydrology Considerations 2021.
4. Australia, Guide to Road Design Part 5B; Open Channels and Culverts and Flood ways 2021.
5. USA: AASHTO LRFD Bridge Design Manual.

8.7 Idealised manual content

The idealised Table of Contents for the different parts of the new manual (Part 1 – Hydrological Surveys and Part 2 – Drainage Design) were prepared based on best practices. These are presented in **Table 8-2** and **Table 8-3** below.

Table 8-2: Idealised Table of Contents of Part 1 – Hydrological Surveys

Chapter	Topic	Section	Sub-topic
1	Introduction	1.1	General Information
		1.2	Objective of the manual
		1.3	Basic Design process
2	Hydrology and Planning	2.1	General Overview

Chapter	Topic	Section	Sub-topic
		2.2	Hydrological Basins In Kenya
		2.3	Planning & Location of Road Highways
		2.4	Location and alignment considerations
3	Hydrological Data Collection	3.1	Choice of drainage structures
		3.2	Specific Data requirements for drainage design
		3.3	Information and Data collection process
		3.4	Data Quality Checks and Controls
4	Design standards and Flow Return Periods	4.1	Concept of Return period and Design Frequency
		4.2	Applicable Design Flow return periods
5	Flood Estimation for gauged Catchments	5.1	General introductory Information
		5.2	Sources of Stream flow Data in Kenya
		5.3	Frequency / Statistical Analysis of stream flow data
		5.4	Flow Data procedure Analysis
		5.5	Regional Flood Frequency Curve
6	Flood Estimation for Un gauged Catchments	6.1	General introductory Information
		6.2	Key input parameters for Hydrological modelling
		6.3	Rational Method
		6.4	East Africa Flood Model – TRRL method
		6.5	Soil Consecration Service method
		6.6	Use of Mean Annual Flood - MAF
7	Climate Resilience & Adaptation	7.1	Introduction to climate changes
		7.2	Climate changes Factors
		7.3	Climate and Drainage Designs
		7.4	Climate Resilience Matrix and Infrastructure
		7.5	Anticipated Risks and adaptation measures on Road Infrastructure
8	Appendices		

Table 8-3: Idealised Table of Contents of Part 2 - Drainage Design

Chapter	Topic	Section	Sub – Topic
1	Introduction	1	General Information
2	Hydraulic Design of open Channels	2.1	Flow Types
		2.2	Channel Flow parameters using Manning Equation
		2.3	Hydraulic Analysis
		2.4	Design Consideration for open channels
		2.5	Channel design Techniques
3	Drifts and Low-level crossings	3.1	General introduction & Terminology
		3.2	Application Characteristics
		3.3	Design Consideration

Chapter	Topic	Section	Sub – Topic
4	Hydraulic Design of Culverts	4.1	Types of culverts
		4.2	Design criteria and considerations
		4.3	Hydraulic Design
		4.4	Design Limitations
5	Bridge Design	5.1	Hydraulic Performance of Bridges
		5.2	Design criteria and considerations
		5.3	Hydraulic Design
		5.4	Bridge scour and aggradation
6	River Channel Training & Erosion Protection Works	6.1	General introductory Information
		6.2	General river Training Designs
		6.3	Design of side drains
		6.4	Erosion Control & Drainage of Underground Water.
7	Urban Drainage	7.1	Urban Hydrology
		7.2	Types of Urban Drain
		7.3	Urban Drainage Networks
8	Appendices		

8.8 Proposed updated manual idealised table of contents and gap analysis

The proposed Table of Content for the new Hydrology and Drainage Design Manual parts, and associated gap-analysis, is as shown in **Table 8-4** and **Table 8-5**.

Table 8-4: Adequacy of existing or draft manuals for incorporation into new manual: Hydrological Surveys

Key: = Fully Developed, = Partial, = Not Developed, = Not Applicable

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content new Draft or Approved Manual	Draft Manual Ref.	Remarks/Additional Comments
Contents		Contents Table		Partial	The ToC is there but requires to be well organized		It should be easy to find information on a well arranged ToC
Glossary		Definitions & Abbreviations		Not Developed	New		To be included in the revised manual
1	Introduction	1.1	General Info	Not Developed	New		
		1.2	Objective of the manual	Not Developed	New		
		1.3	Basic Design process	Not Developed	New		
2	Hydrology and Planning	2.1	General Overview	Not Developed	New		
		2.2	Hydrological Basins ini Kenya	Not Developed	New		This gives reader the various hydrological basins in Kenya and improves sequence of information
		2.3	Planning & Location of Road Highways	Partial	Was a topic and now made a sub Topic in the new current working TRL manual. Some changes on texts done Text too	Section 2.0 (p 8-9)	This will improve the flow of information logically on the new manual
		2.4	Location and alignment considerations)	Partial	Text too brief require to merge some sections with others and remove some. Texts not so clear Correct typo errors	Section 2.3 (p10-14)	
3	Hydrological Data Collection	3.1	Choice of drainage structures	Partial	Some useful information in EGIS Chapter 2 draft. Requires improvement	Section 2.9 (p13)	
		3.2	Specific Data requirements for drainage design	Not Developed	New - No information in EGIS draft.		
		3.3	Information and Data collection process	Not Developed	New - No information in EGIS draft. Scant information on sources. Key informant Ministry and state departments like Water Resources, Department of Survey of Kenya where maps are available not mentioned. The National Custodian of Hydro met data the Kenya Met Department role not	Section 4.2 (p17)	Data sources and process of collection forms the foundation of hydrological analysis

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content new Draft or Approved Manual	Draft Manual Ref.	Remarks/Additional Comments
					coming out clear This will be included in the TRL reviews		
		3.4	Data Quality Checks and Controls		New		Critical for hydrological analysis
4	Design standards and Flow Return Periods	4.1	Concept of Return period and Design Frequency		Text is too brief, more information required, its presentation to be improved Design periods for Open channel, drains, pipe culverts, box culverts and bridges not well defined. They should also be checked for a higher return period before implementation.	Section 3.1 & 3.2 (p16)	Info on return period for open channels not included, PC return periods not clear This will be included in the revised version.
		4.2	Applicable Design Flow return periods				
5	Flood Estimation for gauged Catchments	5.1	General introductory Information		New		
		5.2	Sources of Stream flow Data in Kenya		All the key hydrological data sources need to be well illustrated	Section 4.2(p17)	
		5.3	Frequency / Statistical Analysis of stream flow data		The Manual information in EGIS draft need to be beefed up and improved. Some spelling and typo errors to be corrected	4.3 (p17-18)	
		5.4	Flow Data procedure Analysis		New		
		5.5	Regional Flood Frequency Curve		New No useful information in EGIS draft		
6	Flood Estimation for Un gauged Catchments	6.1	General introductory Information		Has useful information in EGIS draft. To be improved further	Section 5.1 (p 23)	
		6.2	Key input parameters for Hydrological modelling		New		
		6.3	Rational Method		Method is explained. Some additional texts and coefficient changes to be done	Section 5.3 (P24-28)	
		6.4	East Africa Flood Model – TRRL method		Method is well explained only with some minor changes and additional technical information to be assed	Sec 5.4 (29-33)	

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content new Draft or Approved Manual	Draft Manual Ref.	Remarks/Additional Comments
		6.5	Soil Consecration Service method		New. This method has been used in Kenya on a number of projects. Not included in the EGIS manual		Flow estimation method to be included in the TRL works
		6.6	Use of Mean Annual Flood – MAF		New. This method has been used in Kenya on a number of projects. Not included in the EGIS manual		Flow estimation method to be included in the TRL works
7	Climate Resilience & Adaptation	7.1	Introduction to climate changes		New. Not included in the EGIS manual		This Chapter is critical in the manual. Will guide on the emerging issues related to climate changes
		7.2	Climate changes Factors		New. Not included in the EGIS manual		
		7.3	Climate and Drainage Designs		New. Not included in the EGIS manual		
		7.4	Climate Resilience Matrix and Infrastructure		New. Not included in the EGIS manual		
		7.5	Anticipated Risks and adaptation measures on Road Infrastructure		New. Not included in the EGIS manual		
8	References	8.1	References		There are references in the document. To be enhanced		
Appx A:	Worked Example For the Flow estimations						
		A1	Gauged Data Worked Example		To be improved		
		A2	Rational Method Worked Example		New.		
		A3	EAFM worked Example		To be improved		
		A4	Soil Conservation Service method		New.		

Table 8-5: Adequacy of existing or draft manuals for incorporation into new manual: Drainage Design

Key: = Fully Developed, = Partial, = Not Developed, = Not Applicable

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content new Draft or Approved Manual	Draft Manual Ref.	Remarks/Additional Comments
1	Introduction	1	General Information		New		
2	Hydraulic Design of open Channels	2.1	Flow Types				
		2.2	Channel Flow parameters using Manning Equation		Channel hydraulics is mentioned briefly in connection with side drains. But not exhaustive	Section 9.2 (p 114)	Detailed hydraulic design of channels will be given in the new manual.
		2.3	Hydraulic Analysis		New		
		2.4	Design Consideration for open channels		New		
		2.5	Channel design Techniques		New		
3	Drifts and Low-level crossings	3.1	General introduction & Terminology		General information on the subject is given but too brief. More information required, it's presentation to be improved.	Section 7.1 & 7.2 (p76-78)	
		3.2	Application Characteristics		Presentation to be improved. Additional concepts to be included.	Section 7.3 (p79)	
		3.3	Design Consideration		Presentation to be improved. Additional concepts to be included.	Section 7.4 (p79-84)	
4	Hydraulic Design of Culverts	4.1	Types of culverts		New		
		4.2	Design criteria and considerations		Basic information is covered but very brief.	Sections 6.1 & 6.2 (P38-40)	To be enhanced and presented well.

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content new Draft or Approved Manual	Draft Manual Ref.	Remarks/Additional Comments
		4.3	Hydraulic Design		Only two application methods and examples are considered. No software application example. Other application processes including spreadsheet and software (HY-8) will be added and application examples included.	Section 6.3-6.5 (p40-57)	
		4.4	Design Limitations		Basic information available but not well arranged.	Section 6.3.3	To be enhanced and presented well.
5	Bridge Design	5.1	Hydraulic Performance of Bridges		Basic information is covered but very brief and disorganized.	Section 8.2.3 (p93-95)	To be well organized and enhanced.
		5.2	Design criteria and considerations		Basic information is covered but very brief and disorganized.	Section 8.2 (p91-95)	To be well organized and enhanced.
		5.3	Hydraulic Design		Only one application method and application example are considered. No software application example. Additional application examples including software will be added.	Section 8 (p86-96)	More application examples including software will be added.
		5.4	Bridge scour and aggradation		Has useful information in EGIS draft. To be improved further.	Section 8.3 (p97-113)	To be well organized and enhanced.
6	River Channel Training & Erosion Protection Works	6.1	General introductory Information		New		
		6.2	General river Training Designs		New. Some useful information is contained in the section on bridge score and aggradation; but not exhaustive.	Section 8.3 (p97-113)	This will be developed further.
		6.3	Design of side drains		Method is well explained. Only with some minor changes and additional technical information to be added.	Section 9.2 & 9.3 (P114-118)	This will be developed further.
		6.4	Erosion Control & Drainage of Underground Water.		Subject well covered. More information will be provided.	Section 9.4 & 9.5 (119-122)	This will be developed further.

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content new Draft or Approved Manual	Draft Manual Ref.	Remarks/Additional Comments
7	Urban Drainage	7.1	Urban Hydrology		Subject well covered. More information will be provided.	Section 10.2 (p123)	
		7.2	Types of Urban Drain		Subject well covered. More information will be provided.	Section 10.4 (p125)	
		7.3	Urban Drainage Networks		Subject well covered. More information will be provided. However, the application example given illustrates hydrologic flows only. Further example and detailed hydraulic procedure on design of sewer network will be included.	Section 10.6 (p128)	
8	References	8.1	References Bibliography		There are references in the document. To be enhanced		
Appx A:	Selected Examples				A number of application examples are given in the main text. These will re-organized and transferred to the Appendices section. They include:		Additional application examples will be given.
					1. Culvert design by Nomographs	Section 7.5 (p 59-74)	
					2. Design of low-level crossing.	Section 7.5 (p85-87)	
					3. Bridge Backwater Calculation (HDS 1)	Section 8.4 (p105-110)	
					4. Riprap at pier	Section 8.4 (p129-130)	
					5. Sewer Network	Section 10.6 (p126-130)	

9 Review of the Road and Bridges Design Manual – Part 6: Bridge Design (2009 EGIS)

9.1 General

The earlier Kenya bridge design manual and construction specifications were proposed and drafted in the 1980s and 90s. As a complement to the bridge design manual, other related documents are standard small span concrete bridges and standard concrete box culverts. Following is the listing of these documents:

1. Road Design Manual, Part-iv: Bridge Design (Draft), November – 1989.
2. Road Design Manual, Part-iv: Bridge Design revised August – 1993.
3. Standard Designs for Small Concrete Drainage Structures:

   Part I: Standard Small Span concrete bridges - 1987

   Part II: Standard concrete box culverts - 1987

EGIS International drafted the highway and bridge design manuals including the associated standard specifications in 2009. Following is the listing of these documents related to bridge design;

1. Design Manual for Roads & Bridges, Part-vi: Bridges and Culvert Design (Draft), 2009.
2. Catalogue of Drawings (draft)
   i) Standard Culverts and Drifts.
   ii) Standard Concrete Box Culverts – Schedules and Quantities (not available).
   iii) Standard Small Span Concrete Bridges.
   iv) Standard Structures (not available).

As a recent development, certain Eurocodes have been adopted as design standards in Kenya. The following Structural Design Eurocodes were adopted as Kenya Standards through the Kenya Gazette Notice No. 13048 of 14th September 2012:

1. KS EN 1990 – Eurocode 0: Basis of structural design.
2. KS EN 1991 – Eurocode 1: Actions on structures.
3. KS EN 1992 – Eurocode 2: Design of concrete structures.
4. KS EN 1993 – Eurocode 3: Design of steel structures.
5. KS EN 1994 – Eurocode 4: Design of composite steel and concrete structures.
6. KS EN 1995 – Eurocode 5: Design of timber structures.
7. KS EN 1996 – Eurocode 6: Design of masonry structures.
8. KS EN 1997 – Eurocode 7: Geotechnical design.
9. KS EN 1998 – Eurocode 8: Design of structures for earthquake resistance.
10. KS EN 1999 – Eurocode 9: Design of aluminium structures.

Kenya Bureau of Standards (KEBS) has also been running training courses on structural design of bridges to Eurocode standards.

9.2 Approach to review

The purpose of review of the existing manuals for Bridge Design is to assess the different topics that have been covered and to identify the gaps that need to incorporate while updating the manuals. The review process shall be carried out considering the best practices in the bridge sector, current trends in the region and in developed countries meeting the requirements of local climatic conditions. Assessment to be made for different aspects of the bridge design whether these are covered or not and their appropriateness to meet the required objectives. The various parameters to analyse includes appropriateness of titles, scope of the subject, document structuring, consistency in numbering, formatting and styles, accuracy and clarity in statements, adequacy of the technical contents to meet the current requirements, adequate drawings with necessary details, etc. The review process identifies gaps in the existing manual.

9.3 Good practice references

An idealised framework in the forms of Table of Contents is to be prepared based on the best practices at regional and international level. In preparing this framework, the practices in Ethiopia, UK, USA and India are considered.

The following manuals were considered in this process:

1. Ethiopia: ERA Bridge Design Manual – 2013
2. UK: Euro Codes EN 1990 - EN 1998
3. USA: AASHTO LRFD Bridge Design Manual
4. India: IRC-6 Bridge Loads, IRC-78 Design of Foundations, IRC-112 Concrete Bridges

With the adoption of Euro Codes as Kenya Standards through the Kenya Gazette Notice No. 13048 of 14th September 2012 and the trainings being imparted by KEBS, the bridge designers have more familiarity with these compared to other international standards. They provide the design principles of bridges in detail and gives the flexibility to adopt country specific values of certain variables such as adjustment factors for load models, wind velocities, temperature ranges, ground acceleration for seismic design. The technical contents of Euro Codes are much more relevant for Kenya. The various design factors/ variables can be revised to meet the Kenya specific design requirements and climatic conditions.

9.4 Idealised manual content

Reference will be made for the available literature and the practices at regional and international level while framing the new bridge design manual. All the relevant provisions will be made to analyse bridge structures for different loadings (dead loads, traffic loads, accidental loads, earth pressures, water loads, wind loads, thermal loads, seismic loads, etc.) and the combinations thereof. Consultant will study the existing design practices being used by the designers in Kenya. The vehicle live loads prevailing in the region such as BS 5400, Euro code, EAC loadings will also be studied while finalising the design live load standards for Kenya.

Design principles for concrete, steel and composite bridges for different elements of the bridges (foundation, substructure, superstructure) meeting the local climatic conditions will be incorporated. Use of prestress concrete is gaining prominence in the region for increased spans. Guidance will be provided on design principles of prestress concrete, cables, anchorage design, permissible stresses and losses, etc.

Guidance on classification of bridges, width of bridge deck elements, various design requirements such Geometric, hydraulic, geotechnical, constructability will also be covered in the new manual. The geometric requirements will cover the geometric parameter of the bridge in relation to the approach road geometry. Any guidelines in use regarding deck width, footpath withs, lateral and vertical clearances at underpass will also be referred. The geotechnical requirements will provide the guidance on geotechnical investigations required, number of exploratory boreholes and anticipated depth of drilling for the purpose of assessing suitability of different types of foundations and foundation designs.

Climatic conditions will affect the bridge designs. Available updated maps for design wind speeds, maximum and minimum temperatures, seismic zones will be used while finalising the design guidelines on these aspects. Guidance on new methods like response spectrum method will be provided for assessing seismic forces.

In order to reduce risk of failure due to impact of excess rainfall and subsequent increase in flood levels at bridge crossings, adequate margin for clearance to soffit of bridge deck over design flood levels will be provided. The foundations to have adequate depth for safety against erosion or the protective measures will be suggested. To take care of the impacts due to temperature variations which will cause expansion and contraction of the bridge superstructure and will lead to thermal stresses, joints in the bridge decks will be considered together with the design provisions for thermal forces in new design manual. Guidelines on different types of joints and general requirements considering the permissible movements will be provided. The bridge bearings will cover the detail description and design requirements for different types of bearings such as elastomeric bearings, POT bearings, sliding and restrained bearings, etc.

Retaining structures design will cover the guidance on working out lateral earth pressures for different conditions of back fill, active and passive earth pressures, horizontal and sloping back filles, effect of surcharge loads, stability checks, reinforced earth retaining structures.

The Bridges and Retaining Structures Design Manual will be developed as per the approved structure of the manual into following two parts.

Part 1: Bridges and Culvert Design Manual

Part 2: Retaining Structures Design Manual

The idealised Table of Contents for both the parts are prepared based on best practices and presented in **Table 9-1** and **Table 9-2** below.

Table 9-1: Idealised Table of Contents of Bridges and Culvert Design Manual

Glossary and Abbreviations		
Chapter 1:	Introduction	1. General 2. Scope
Chapter 2:	General Requirements	1. General 2. Design philosophy 3. Limit States 4. Planning considerations 5. Clearances
Chapter 3:	Loads and Load Factors	1. General 2. Dead Loads 3. Traffic Loads 4. Pedestrian Loads 5. Accidental Loads 6. Earth Pressures 7. Water Loads 8. Wind Loads 9. Thermal Loads 10. Seismic Loads 11. Construction Loads 12. Combination of Loads and Load Factors
Chapter 4:	Concrete Structures	1. General 2. Material Properties 3. Analysis 4. Design for Axial and Flexural Forces 5. Design for Shear and Torsion 6. Reinforced Concrete 7. Prestressed Concrete 8. Reinforcement 9. Seismic Design and Details
Chapter 5:	Steel Structures	1. General 2. Materials 3. General Dimension and Detail 4. Tension Members 5. Compression Members 6. Trusses 7. Beams and Plate Girders 8. Connections and Splices
Chapter 6:	Composite Structures	1. General 2. Materials 3. Composite Columns 4. Steel Beam and Concrete Deck 5. Shear Connectors
Chapter 7:	Masonry and Timber Structures	1. General 2. Masonry Structures 3. Timber Structures
Chapter 8:	Foundations	1. General 2. Spread Footing 3. Pile Foundations
Chapter 9:	Joints and Bearings	1. General

		2. Joints 3. Bearings
	Appendices	

Table 9-2: Idealised Table of Contents of Retaining Structures Design Manual

	Glossary and Abbreviations	
Chapter 1	Introduction	1.1 Scope 1.2 Structures
Chapter 2	Lateral Earth Pressures	2.1 General 2.2 Basic Earth Pressure 2.2.1 At Rest Earth Pressure 2.2.2 Active Earth Pressure 2.2.3 Passive Earth Pressure 2.3 Earth Pressure due to Compaction Stresses 2.4 Equivalent Fluid Method of Estimating Earth Pressure 2.5 Effects of Ground Water on Earth Pressures. 2.6 Effect of Earthquake on Earth Pressure 2.7 Apparent Earth Pressure for Anchored Walls 2.8 Earth Pressure for Mechanically stabilized Earth Walls 2.9 Earth Pressure due to Surcharge Loads 2.10 Earth Pressure for Culverts and Bridges
Chapter 3	Design of Bridges Retaining Structures	3.1 General Considerations 3.1.1 Loading 3.1.2 Abutments 3.1.3 Wing Walls 3.2 Expansion and contraction Joints 3.3 Movement and Stability at Service Limit State 3.3.1 Conventional Retaining Walls and Abutments 3.3.2 Overall Stability 3.4 Bearing Resistance and Stability at Strength Limit States 3.4.1 General Considerations 3.4.2 Bearing Resistance 3.4.3 Overturning 3.4.4 Scour 3.4.5 Passive Resistance 3.4.6 Sliding Resistance 3.5 Drainage 3.6 Pier Design - General Considerations 3.7 Design of Culverts and Other Buried Structures 3.7.1 Resistance Factors 3.7.2 Service Limit State design 3.7.3 Strength Limit State design
Chapter 4	Design of Reinforced Earth Retaining Structures	4.1 General 4.2 Structure Dimensions 4.2.1 Soil Reinforcement

		4.2.2 Front Face Embedment 4.2.3 Facing 4.3 Loading 4.4 Movement and Stability at Service Limit State 4.4.1 Settlements 4.4.2 Lateral Displacement 4.4.3 Overall Stability 4.5 Stability at Strength Limit State 4.5.1 General 4.5.2 Loading 4.5.3 Sliding 4.5.4 Bearing Resistance 4.5.5 Overturning 4.6 Safety Against Structural Failure 4.6.1 General 4.6.2 Loading 4.6.3 Reinforcement Pullout 4.6.4 Reinforcement Strength 4.7 Drainage
	Appendices	

9.5 Review Results

9.5.1 Road Design Manual, Part-iv: Bridge Design (Draft), November 1989 and Revised August 1993

The Bridge Design Manual (Draft), November-1989 broadly covers the design loads, combination of loads, materials, bridge deck cross-sections, site investigation & preliminary design, types of bridges, foundations, bearings, expansion joints, construction aspects, etc. This is not a complete copy and many pages are missing (2.2-1 to 2.2-14, 2.2-19 to 2.2-29, 2.2-37 to 2.2-42, 2.3-1 to 2.3-21,….). Chapter 3, 5, 6, 7 and 8 are totally missing. Many of the contents are extracts from different codes, papers and other references of that time. The details provided in manual are of preliminary level.

This manual was revised in August 1993, which contain 16 pages only. In this revised manual, BS 5400 is referred for live loads to be adopted in bridge design. The BS 5400 has also been referred for wind load, temperature load, Shrinkage, Creep, Settlement, etc. The design shall also be in accordance with the analysis and design as outlined in BS 5400. This has following sections:

SECTION 1 – GENERAL

SECTION 2 – BRIDGE STANDARDS

APPENDIX

In general, this is a very short document. BS 5400 has been referred for majority of provisions in Revised Manual-1993 except few deviations like applicability of HA & HB loadings to different class of roads (Class A to Class E), values of mean hourly wind speed, bridge cross sections, etc.

9.5.2 Design Manual for Roads & Bridges, Part-vi: Bridges and Culvert Design (Draft), 2009

9.5.2.1 General

The Bridges and Culvert Design Manual which is part of Design Manual for Roads & Bridges, drafted by EGIS in 2009. This is in Draft-3 stage with 16 chapters (word format). Glossary and Abbreviations are provided. Following is the listing of Chapters.

1. Introduction
2. General Requirements
3. Load Requirements
4. Planning Stage/Feasibility Study/Site Investigation
5. Preliminary Design/Layout of Bridges and Culverts
6. Substructure Design
7. Superstructure Design
8. Bridge Details
9. Reinforced Concrete
10. Structural Steel
11. Other Structural Materials
12. Detail Design of Bridges and Structures
13. Approximate Methods of Analysis
14. Strength Evaluation of Existing Steel, Concrete and Masonry Arch Bridges
15. The Quality System ISO 9000
16. Calculations, Drawings and Specifications

Title page is not there. Table of contents is available for one level sub-heads. The TOC shall cover the two sub-heads to make the searching of sub-topics easy.

This code is based on AASHTO LRFD Bridge Design Specifications 2nd edition 1998 as mentioned in Chapter-1 which is very old now and many provisions need to update with new developments. The latest publication of AASHTO is now 9th ed. 2020 (FPS units). A review of the different topics is provided below.

9.5.2.2 Minimum dimensions and bridge deck widths

In Chapter-2, section 2.4, minimum dimensions of different elements of bridge are provided. These shall be supported by diagrams so that user can have better understanding. The span of the bridge is to be correlated with width of river/ waterway. Opening width of underpass structure to be defined correlating with the underpass road width.

The free board of minimum 1.5m is provided for all bridges. Free board shall be varied and correlated with the design discharge or catchment area to economise for small bridges.

Bridges may be of various types depending upon the type of construction material, location, function, span and length of bridges. All these aspects could have been covered in Chapter 2 under subhead "Classification of bridges" which is missing in this manual. The bridge classification will be provided in new manual.

In section 2.4.6, the bridge crossfall of 2% provided and mentions that it need not be related to the carriageway crossfall. For the ease of speed and comfort, it is desirable to keep cross fall of road and bridge it and in curved bridges, it shall meet the geometric requirements unless there is any specific constraint.

9.5.2.3 Traffic loads

In Chapter-3, the design truck adopted in RDM 2009 draft contains of three axles with 300 kN each axle loading while in AASHTO Specifications, which was taken as base for RDM 2009 draft, it is 35 kN for front axle and 145 kN each for other two rear axles. Similarly, the design tandem consists of a pair of 300 kN axle in draft RDM 2009, while it is 110 kN in AASHTO specifications. The design lane load in draft RDM 2009 is 19.3 kN/m while it is 9.3 kN/m in AASHTO specifications. Comparing these load cases, the provisions for design vehicular live load in RDM Draft 2009 are on higher side and need to be revised. The traffic load models as per Euro Codes with the local adjustment factors will be considered in new manual.

Some details of traffic load, temperature loads and wind loads are provided in Chapter-2 and some details in Chapter-3. Duplicity should be avoided and thus to be removed from Chapter 2 and all details shall be provided in Chapter-3.

Special vehicle loading to account for heavy vehicles used in transportation of heavy industrial machinery, boilers, etc. with multi-axle trailer units is missing in the manual. This loading is important for international routes, trunk roads and the roads those lead to industrial areas and will be covered in new manual.

9.5.2.4 Temperature and wind loads

In Chapter-2, section 2.5.5.1, the extreme daily temperature range specified as between 20°C & 40°C while a value of 30°C is used in this manual for temperature loads. From the design aspects, a site-specific temperature value should have been recommended instead of using a uniform value throughout the country. For wind loads, a value of 40 m/s (145 km/h) is selected as the design value instead of site-specific wind velocity values.

In Chapter-3, the provisions for wind and temperature loads are based on a uniform value and need to update with country specific meteorological wind map and isothermal maps (temperature maps showing maximum and minimum values) for Kenya.

For wind loads on Open web girder type of structures, the shielding effect shall be taken into effect as well. It is not available in existing draft manual.

9.5.2.5 Seismic loads

In Chapter-3, the seismic map is provided which looks to be extracted from Code of Practice for the Design & Construction of Buildings & other Structures in relation to Earthquakes-1973. The acceleration coefficient Table 3-15 is missing in this Chapter, which is essential to work out the seismic forces. The provisions of seismic forces need to update taking into account the country specific seismic ground acceleration coefficients. In section 3.19.9, low seismic zones and high seismic zones mentioned. It is not clear which zones are low and which zones are high as per Kenya seismic map. While preparing new manual, latest seismic map of Kenya will be used.

9.5.2.6 Earth pressures

Earth Pressures under section 3.20 is too detailed and needs revision to make it concise by describing most common cases. In the lateral earth pressure formula, there are some typographical errors, which need to be corrected. Cross-referencing of the figures to be corrected such as Figure 3-15 and 3-16 are referred in section 3.20.5, but the actual reference to be made for Figure 3.17 and 3.18.

Section 3.20, Equation 3.21 $\Gamma = \left[1 + \sqrt{\frac{\sin(\varphi' + \delta)\sin(\varphi' - \beta)}{\sin(\theta - \delta)\sin(\theta + \beta)}}^{\,2} \right]$	This has typographical error. The corrected equation is $\Gamma = \left[1 + \sqrt{\frac{\sin(\varphi' + \delta)\sin(\varphi' - \beta)}{\sin(\theta - \delta)\sin(\theta + \beta)}} \right]^2$
Section 3.20.5, Earth pressure, para below Fig 3-16 reads as; *"For noncohesive soils, values of the coefficient of passive pressure shall be taken from Figure 3-15 for the case of a sloping or vertical wall with a horizontal backfill or from Figure 3-16 for the case of a vertical wall and sloping backfill"*	The Figure 3-15 and 3-16 are to referred as Figure 3.17 and 3.18

9.5.2.7 Geotechnical and foundations

Geotechnical investigations require more details under section 5.2.4 (preliminary design stage). There is only a brief mention in section 4.9.5 basically on feasibility stage investigations.

Foundations section 5.5.1 needs revision to be more specific to "selection of foundation type". The sections 5.5.2 to 5.5.5 need to revise fully to cover different soil types and foundation types (shallow and piled foundations etc).

Foundations in section 6.3 require complete revision with the main foundation types in separate sub heads, the headings and subheadings to be more appropriate, technical contents need improvement. This chapter is the main geotechnical specifications on bridge design and should be more exhaustive.

9.5.2.8 Superstructure design

Spacing requirements of Transverse reinforcement for beams, slabs, columns & shear reinforcement shall be included. Contents to be rearranged and updated.

9.5.2.9 Missing topics

Few topics are missing in the RDM 2009 and need to be included while updating the bridge design code. These are:

1. Prestress Concrete Bridges.
2. Concrete-Steel Composite Bridges.
3. Reinforced Earth Retaining Walls.

9.6 Proposed updated manual idealised table of contents and gap analysis

The proposed Table of Contents for the new Bridges and Culvert Design Manual and Retaining Structures Design Manual, and associated gap-analysis, is as shown in **Table 9-3** and **Table 9-4** respectively.

Table 9-3: Adequacy of existing or draft manuals for incorporation into new manual: Bridges and Culvert Design

Key: = Fully Developed, = Partial, = Not Developed, = Not Applicable

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft/Approved Manual Ref.	Remarks/Additional Comments
	Cover page, Glossary and Abbreviations, TOC				Cover page is missing RDM 2009 draft		Contents to update as per the revisions
1	Introduction	1.1	General		The reference used in preparation of RDM 2009 draft is old and needs overall updating	Chapter 1	The RDM 2009 draft is based on AASHTO LRFD Bridge Design Specifications 2nd edition 1998. This reference is very old now and many provisions need to update with new developments.
		1.2	Scope		Design of prestress bridges, composite bridges, certain steel bridges are missing in RDM 2009 draft, many other sections need complete revision and updating		Scope to revise and update with the inclusion of prestress bridges, inclusion and updating of design provisions of steel structures, composite structure, joints and bearing, etc.
2	General Requirements	2.1	General			Section 2.1	
		2.2	Design philosophy		Technical contents of the section to revise with the basis of design and requirements	Section 2.1	This will cover design basis, different type of actions and other requirements

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft/Approved Manual Ref.	Remarks/Additional Comments
		2.3	Limit States		Principles of limit state design to enhance and update	Section 2.8	This will cover different limit states, ultimate limit state, serviceability limit state of design
		2.4	Planning considerations		Various requirements such as geometric, hydraulic, geotechnical, collection of data, etc. to add. Minimum dimensions of bridge elements to update with diagrams, classification of bridges to add.	Section 4, 2.4	This section will cover the planning considerations and technical requirements.
		2.5	Clearances		Lateral clearances for underpass are missing	Section 2.4	This section will cover the horizontal and vertical clearances for bridges and underpasses
3	Loads and Load Factors	3.1	General			Section 3.1	
		3.2	Dead Loads		Description to update	Section 3.6	Dead load of different material commonly used in construction will be provided in this section
		3.3	Traffic Loads		Technical content and the Traffic load models need complete revision. Special vehicle loadings are missing.	Section 3.8	Different traffic load models, truck loads and uniform lane loads, dynamic impact factors, etc. will be covered in this section

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft/Approved Manual Ref.	Remarks/Additional Comments
		3.4	Pedestrian Loads		Description to update	Section 3.12	This section will cover the pedestrian loads on bridges
		3.5	Accidental Loads		Many of the vehicle collision loads are missing in RDM 2009 Draft	Section 3.16	Vehicle collision with bridge supports, decks, kerbs, railings, vehicle on walkways, etc. to add
		3.6	Earth Pressures		Earth Pressures under section 3.20 is detailed and needs revision to make it concise. Certain formula and cross referencing for lateral earth pressure have typographical errors in RDM 2009 draft	Section 3.20	Earth Pressures – generally adequate in terms of content. Review mainly to improve flow, cross referencing etc. The details of earth pressure will be provided in " Part-2: Retaining Structures Design" manual
		3.7	Water Loads		Technical contents for velocity of flow, pressure and drag coefficient needs improvement	Section 3.17	Technical content to update with drag coefficient for different pier shapes supporting diagrams. Velocity and pressure variations with depth of water to add
		3.8	Wind Loads		Basic design wind velocity maps are not available in RDM 2009 draft	Section 3.18	Local maps for wind velocities to incorporate in the proposed manual
		3.9	Thermal Loads		Thermal loads are to be revised considering local temperature ranges	Section 3.21	Local temperature ranges to consider in the proposed manual

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft/Approved Manual Ref.	Remarks/Additional Comments
		3.10	Seismic Loads		The acceleration coefficient Table 3-15 is missing RDM 2009 draft. The provisions of seismic forces need to update taking into account the country specific seismic ground acceleration coefficients.	Section 3.19	Seismic forces to revise completely taking into account the local seismic factors
		3.11	Construction Loads		No information in RDM 2009 EGIS draft manual		Construction loads for personnel & hand tools, storage of moveable item, equipment, etc. to add
		3.12	Combination of Loads and Load Factors		Technical content to revise	Section 3.3	The load combinations and load factors to update for different limit states of design
4	Concrete Structures	4.1	General				
		4.2	Material Properties		Properties of prestressing steel and anchorage devices are missing	Section 9.3	This section will cover the properties of concrete, reinforcing steel, prestressing steel, anchorage devices
		4.3	Analysis		Technical contents to be improved	Chapter 13	This section will cover linear and non-linear analysis
		4.4	Design for Axial and Flexural Forces		Information to update and to re-arrange properly	Chapter 7, 12	Design provisions for axial forces, flexural with or without axial forces, bi-axial bending, etc. to update

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft/Approved Manual Ref.	Remarks/Additional Comments
		4.5	Design for Shear and Torsion		Information to update and to re-arrange properly	Chapter 7, 12	Design provisions for shear and torsion to update. Shear between web and flange of T sections, Design procedure shall be added
		4.6	Reinforced Concrete		The contents to rearrange and update	Chapter 9	Design details for reinforced concrete to update
		4.7	Prestressed Concrete		Prestress concrete bridges design details missing in RDM 2009 Draft, only a small information is provided	Section 12.14.1	Various design requirements, losses in prestress for pre-tension & post-tensioned bridges, sheathing ducts, end blocks, etc. to add
		4.8	Reinforcement		Detailing provisions are not adequate	Section 9.4	Detailing provisions, reinforcement and spacing requirement will be elaborated
		4.9	Seismic Design and Details		Details missing	Section 12.3	Seismic provisions and detailing to add
5	Steel Structures	5.1	General			Section 10.1	Design provision for axial & flexural members, trusses, beams and girders to add
		5.2	Materials			Section 10.2	
		5.3	General Dimension and Detail		limited information is provided in RDM 2009 Draft	Section 10.3	
		5.4	Tension Members		missing in RDM 2009 Draft		
		5.5	Compression Members		missing in RDM 2009 Draft		

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft/Approved Manual Ref.	Remarks/Additional Comments
		5.6	Trusses		very small information in RDM 2009 Draft	Section 7.6, 12.14.2	
		5.7	Beams and Plate Girders		missing in RDM 2009 Draft		
		5.8	Connections and Splices		missing in RDM 2009 Draft		
6	Composite Structures	6.1	General		This chapter is missing in RDM 2009 Draft	Section 7.5.3, 12.12	All the design requirements, material properties, design requirements for steel beams and concrete deck, shear connectors, etc. to add
		6.2	Materials				
		6.3	Design Philosophy				
		6.4	Composite Columns				
		6.5	Steel Beam and Concrete Deck				
		6.6	Shear Connectors				
7	Masonry and Timber Structures	7.1	General		Contents to update	Section 7.7, 11	
		7.2	Masonry Structures		Technical contents to be improved	Section 11.4	Design details to add
		7.3	Timber Structures		Technical contents to be improved	Section 11.3, 12.13	Design details to add

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft/Approved Manual Ref.	Remarks/Additional Comments
8	Foundations	8.1	General		Selection of different type of foundation is missing	Section 6.1	Revise to cover selection of foundation type in different soil types. Contents flow, headings and subheadings, separate sub chapter on limit state and resistance factors to improve, the chapter to be more exhaustive
		8.2	Spread Footing		Design procedures (empirical and soil mechanics methods) and on different soil types are missing in RDM 2009 Manual	Section 5.5, 6.3.2	Major improvement needed with the main foundation types in separate sub headers, design procedures on different soil types to add, technical content to improve
		8.3	Pile Foundations		Load capacity and settlement for piles and pile groups in different soils are missing in RDM 2009 draft	Section 5.5, 6.3.3	Load capacity and settlement for piles and pile groups in different soils to add, technical content to improve
9	Joints and Bearings	9.1	General				
		9.2	Joints		Little information provided in RDM 2009 Draft	Section 8.4	Different types of joints and their design requirements, movements at joints to add

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft/Approved Manual Ref.	Remarks/Additional Comments
		9.3	Bearings		Little information provided in RDM 2009 Draft	Section 8.3, 12.15	Different types of bearings and their design requirements, movements and loads on bearings to add

Table 9-4: Adequacy of existing or draft manuals for incorporation into new manual: Retaining Structures Design

Key: = Fully Developed, = Partial, = Not Developed, = Not Applicable

Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft /Approved Manual Ref.	Remarks/ Additional Comments
Contents			**Table of Contents**		New	n/a	
Glossary			**Definitions and Abbreviations**				
1	**Introduction**	1.1	Scope		New	n/a	
		1.2	Structure				
2	**Lateral Earth Pressures**	2.1	General		Fairly Comprehensive requiring only minor rearrangement and content updating	Currently seats in RDM Part 6(a) - 2009 draft - Chapter 3.20	
		2.2	Basic Earth Pressures				
		2.2.1	At Rest Earth Pressure				
		2.2.3	Active Earth Pressure				
		2.2.4	Passive Earth Pressure				
		2.3	Earth Pressure due to Compaction Stresses				
		2.4	Equivalent Fluid Method of Estimating Earth Pressure				
		2.5	Effects of Ground Water on Earth Pressures.				
		2.6	Effect of Earthquake on Earth Pressure				
		2.7	Apparent Earth Pressure for Anchored Walls				
		2.8	Earth Pressure for Mechanically stabilized Earth Walls				
		2.9	Earth Pressure due to Surcharge Loads				
		2.1	Earth Pressure for Culverts and Bridges				
3	**Design of Bridges**	3.1	General Considerations		Some content in RDM Part 6(a). Very brief. Needs a complete rewrite	RDM Part 6(a) 2009 draft chapter 6.5	
		3.1.1	Loading				
		3.1.2	Abutments				

Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft /Approved Manual Ref.	Remarks/ Additional Comments
	Retaining Structures	3	Wingwalls		to include all aspects of geotechnical design as proposed in the list of contents here		
		3.2.1	Expansion and contraction Joints				
		3.3	Movement and Stability at Service Limit State				
		3.2.1	Conventional Retaining Walls and Abutments				
		3.2.2	Overall Stability.				
		3.4	Bearing Resistance and Stability at Strength Limit States				
		3.4.1	General Considerations.				
		3.4.2	Bearing Resistance				
		3.4.3	Overturning				
		3.4.4	Scour				
		3.4.5	Passive Resistance				
		3.4.6	Sliding Resistance.				
		3.5	Drainage				
		3.6	Pier Design - General Considerations				
		3.7	Design of Culverts and Other Buried Structures		Brief content in RDM Part 6(a). Too Brief - expand to be more instructive.	RDM Part 6(a) chapter 6.7	
		3.7.1	Resistance Factors				
		3.7.2	Service Limit State design				
		3.7.3	Strength Limit State design				
3	**Design of Reinforced Earth**	4.1	General		To include design aspects as in the proposed content listed here		
		4.2	Structure Dimensions				
		4.2.1	Soil Reinforcement				
		4.2.2	Front Face Embedment				

Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft /Approved Manual Ref.	Remarks/ Additional Comments
	Retaining Structures	4.2.3	Facing				
		4.3	Loading				
		4.4	Movement and Stability at Service Limit State				
		4.4.1	Settlements				
		4.4.2	Lateral Displacement				
		4.4.3	Overall Stability.				
		4.5	Stability at Strength Limit State				
		4.5.1	General				
		4.5.2	Loading				
		4.5.3	Sliding				
		4.5.4	Bearing Resistance				
		4.5.5	Overturning				
		4.6	Safety Against Structural Failure				
		4.6.1	General				
		4.6.2	Loading				
		4.6.3	Reinforcement Pullout				
		4.6.4	Reinforcement Strength				
		4.7	Drainage				

10 Review of the Road and Bridges Design Manual – Part 5: Traffic Control Devices (2009 EGIS)

10.1 General

Traffic control facilities are mainly road signs, road marking and traffic signals. The existing manuals that cover these aspects are:

1. Road Design Guidelines for Urban Roads (Geometric Design of Urban Roads), Draft, August 2001.
2. Street Design Manual for Urban Areas in Kenya, Draft, April 2019.
3. Road Marking Manual, Draft, 1972.
4. Traffic Signs Manual, 1974.
5. Design Manual for Roads and Bridges, Road Signs, Part 5a, Draft, 2009.
6. Design Manual for Roads and Bridges, Road Markings, Part 5b, Draft, 2009.
7. Design Manual for Roads and Bridges, Traffic Signals, Part 5c, Draft, 2009.

The manuals are dated and need to be revised. Table of contents have been prepared for the new manual containing signing, marking and signals. The areas that have gaps, need addition material have been identified. The reference manuals that can be used to update the manuals have also been identified.

Other traffic control devices, which are not covered in the present manuals, are changeable message signs, temporary traffic control, traffic calming measures and traffic incident management.

Another aspect of traffic control facility is street lighting. There is no existing manual for this. The Table of Contents for this manual has been prepared listing sections and sub-sections. The reference manuals have also been identified.

10.2 Approach to review

The existing manuals were studied at first for signs, marking and signals. Existing manuals on these subjects from USA, UK and Australia were studied. A table of contents was prepared from international manuals. The sections and sub-sections missing in the existing manuals in Kenya were highlighted. Any new area that has not been covered was also included in the table of contents.

For other traffic control devices and street lighting, a table of contents was prepared from the international manuals present, to suit the conditions in Kenya.

It is expected that by bringing in sections and sub-sections from various international manuals, the Kenyan manuals can be developed to cover all the recent and relevant topics.

For the manuals where the sub-topics exist but needs revision, it was assessed how much revision is required. The sub-topics that are very well developed were marked in green. The sub-topics that need significant revision were marked in yellow and the other sub-topics which currently do not exist in the manuals and need to be included, were marked in red.

For the topics where there is currently no manual, are to be developed in entirety. Table of contents for sub-topics was prepared and reference identified.

10.3 Good practice references

For each section of manuals to be revised or prepared anew, good practice reference materials were identified.

10.3.1 Reference for Traffic control devices:

1. Manual on Uniform Traffic Control Devices, 2011, FHWA, USDOT.
2. Changeable Message Sign Operation and Messaging Handbook, 2004, FHWA.
3. Portable Changeable Message Sign Handbook, FHWA.
4. IRC: SP: 55 – 2014, Guidelines for Traffic Management in Work Zones.
5. IRC: 99 – 2018, Guidelines for Traffic Calming Measures in Urban and Rural Areas.
6. Around the School, Safe Routes to School Online Guide.
7. Traffic Incident Management Handbook, 2000, FHWA.

10.3.2 Reference for street lighting manual

1. Lighting Handbook, 2012, FHWA, USDOT.
2. Lighting Handbook, 2012, FHWA, USDOT.
3. IS: 1944 (Part V) Code of Practice for Lighting of Public Thoroughfares, 1981, Bureau of Indian Standards.
4. TD 510 Road Lighting Design, 2020, DMRB, Highways England.
5. TCG 006 Guidelines to Street Light Design, 2016, VicRoads.

10.3.3 Reference for traffic signals

1. Impact of Traffic Signal Controller Settings on the Use of Advanced Detection Devices, Texas Transportation Institute, USA.

10.4 Idealised manual content

Table 10-1: Idealised tables of content for traffic control devices manual

Traffic Signs	
Chapter	Description
1	Introduction
2	General

3	Maintenance of Signs
4	Mandatory / Regulatory Signs
5	Cautionary / Warning Signs
6	Informatory Signs
7	Facility Information Signs
8	Signs for persons with disabilities
9	Route Marker Signs
10	Guidelines for Signs on Expressways / Motorways/ Super ways
11	Guidelines for Signs on Urban and City Roads
12	Sign Plan Examples for Typical Situations
Traffic Signals	
Chapter	Description
1	Introduction
2	Design Data for Signal Sites
3	Geometric Design at Signal Sites
4	Traffic Signal Control Equipment
5	Signal face layout and display sequences
6	Signal Phasing
7	Installations and Layout of Traffic Signal Equipment
8	Traffic Defection
9	Traffic Signal Controllers
10	Electrical Design
11	Installation Checks and Maintenance
12	Traffic Control and Strategies and Tools
13	Signal Timings
Street Lighting	
Chapter	Description
1	Introduction
2	Terms and Concepts
3	Warrants for lighting
4	Impacts of lighting
5	Lighting System
6	Lighting application

7	Lighting design
8	Related roadway system
9	Maintenance considerations
Other Traffic Control Devices	
Chapter	Description
1	Introduction
2	Changeable Message Sign
3	Temporary traffic control
4	Traffic calming
5	School zone traffic management
6	Traffic incident management

10.5 Proposed updated manual idealised table of contents and gap analysis

The proposed Table of Contents for the new Traffic Control Devices Manual – Road Marking and Traffic Signs, and associated gap-analysis, is as shown in **Table 10-2** and **Table 10-3** respectively.

Table 10-2: Adequacy of existing or draft manuals for incorporation into new manual: Road Markings

Key: = Fully Developed, Partial, Not Developed, Not Applicable

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content wrt Draft or Approved Manual	Draft Manual Ref.	Remarks/Additional Comments
					Content table is given in draft manual 2009 at the very first page after cover page. However, after cover page, preface / glossary - definitions & abbreviations are needed.	n/a	
Glossary		Definitions & Abbreviations			Glossary is given in draft manual 2009 but that is after table of contents. It may be replaced before table of contents.	Refer page 5 to 9 after table of contents.	Glossary will be placed at suitable location.
1	Introduction	1.1	General		Given in draft manuals – No comments	Refer page 10 sub section 1.1.	
		1.2	Scope		New contents		Paragraph related to scope and objective of this manual may be provided mentioning applicability and to establishing uniformity in Kenya.
		1.3	Definition		New contents may be given. Definition of road marking mentioned in general.	Para 3 under sub section 1.1, General page 10 and repeated in para 2 page 11.	Brief definition, specifically for road marking as a part of traffic control devices may be provided.
		1.4	Authority		Given in para called 'Legal'	Sub section 1.3-chapter 1 page 10.	Details in short para about authority such as Road authorities in consultation with Police.
2		2.1	General		New		

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content wrt Draft or Approved Manual	Draft Manual Ref.	Remarks/Additional Comments
	Road marking materials and general features	2.2	Thermoplastic Markings		New	Sub section-1.4 referring separate Appendix A.	Guideline regarding materials present partially in appendix, combined with road signs, only in 2 pages. Details about different type of materials not given as mentioned in proposed contents. Appendix in draft manual further refers to AASHTO M247, AASHTOM248, AASHTO M249 for Type A and Type B. *Details of road materials will be added.*
		2.3	Solvent borne and waterborne road marking paints		New		
		2.4	Cold applied plastics		New		
		2.5	Preformed Adhesives Tapes		New		
		2.6	Colour pattern for road markings		New		
		2.7	Visibility related to speeds		New		
		2.8	Retro reflectivity		New		
		2.9	External factors influencing marking performance		New		
3	Classification of Pavement marking	3.1	Longitudinal markings		Provided. Some definition and significance /purpose not given	Sub section 2.1 page 11-14.	Definition of each class and applications part required to be added.
		3.2	Transverse markings		Provided. Some definition and significance /purpose not given	Sub section 3 page 18.	Will be improved.
		3.3	Hazard markings		As per proposed content, hazard marking is to be considered for facilitation of merging / diverging, crossover and to deflect traffic at hazardous locations. This is generally done with chevron marks on road. In the draft manual, this	Sub section 6.6 page 44, sub section 11 page 73-74.	Will be improved.

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content wrt Draft or Approved Manual	Draft Manual Ref.	Remarks/Additional Comments
					requirement has not been specifically mentioned. However, at various places the marking details have been given. Where and why hazard marking is to be provided is not given clearly at one place.		
		3.4	Block markings		Provided in different name as triangular give way approach marking, pedestrian crossing markings, zebra crossing markings and stripes. However, speed breaker marking also comes under block marking.	Sub section 3.5 page22, pedestrian crossing marking. Sub section 9.1, 9.2 9.3.	The proposed contents for block marking includes zebra crossing for pedestrians, triangular and checked marking for speed breakers and GIVE WAY symbol painted on carriageway.
		3.5	Arrow markings		Provided in draft manuals. However, information related to positioning of arrows on highway not given.	Sub section 8 page 52-54.	*Positioning* of arrows may be more understandable for designer if those are presented in a tabular form.
		3.6	Directional markings		New, all type of directional marking may be written at one place.	Sub section 3.6 page 22 as NO ENTRY marking.	Will be improved.
		3.7	Facility markings		Provided under word messages – No comments.	Sub section 10 page 59-61.	
		3.7	Colour of pavement markings		New chapter. Detailed chapter for colour of pavement is not available. Draft manual provides for two colours - white and yellow.	Sub section 2.1 page 11.	*Details of coloured pavement will be added.*

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content wrt Draft or Approved Manual	Draft Manual Ref.	Remarks/Additional Comments
		3.8	Applications		New sub section		A paragraph on application of various categories of marking (longitudinal, transverse, etc.) for various purpose is to be given.
4	Marking for road links	4.1	Centre line		Information is scattered in various sections of the draft manual. However, details about types of marking is given in different sections of the draft manual. Rearrangement of details from various sub section is needed.	Sub section 2.1b page 11 - 30.	This chapter is to cover line markings required for mid-block sections. At mid-block, cross section remains the same on grade separated or at-grade sections, to provide guidance to traffic for smooth movement. Re-arranging the available content is required. *Suitability of 150mm and 200mm wide lines will be seen and included if necessary.*
		4.2	Traffic lane lines				
		4.3	No overtaking lines				
		4.4	Warning lines				
		4.5	Boarder of edge lines				
		4.5	Longitudinal markings for undivided roads				
		4.6	Longitudinal markings for divided carriageway				
		4.7	Longitudinal markings for ramps/ slip roads/ one-way streets				
5	Road studs	5.1	General		New, for definition, purpose and importance.	Refer chapter 12, Page 78-86.	This para may contain purpose, importance of studs and

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content wrt Draft or Approved Manual	Draft Manual Ref.	Remarks/Additional Comments
							relevant clauses of specifications.
		5.2	Type of road studs		Different types of road studs not defined.		Para to include type of road studs, normal and solar road studs, uni-directional and bi-directional etc.
		5.3	Lateral Placement of road studs		Given, it can be presented in a tabular form.		Para regarding lateral stud placement for different road category and different locations may be given in a tabular form.
		5.4	Colour of road studs		Separate para for colour road studs not given with their application. However, partial description of white, yellow and red studs are given in draft manual		A para regarding colour of road studs, their use and locations where to be used may be given separately.
		5.5	Spacing of road studs		Given, it can be modified in tabular form		Will be improved.
		5.6	Solar road studs		New, not given in draft manual.		
6	STOP and GIVE WAY Markings	6.1	STOP lines		Details for STOP and GIVE WAY lines should be given separately. STOP line shall also be used at other locations such as near pedestrian zebra crossings. No details given for single and double STOP lines.	Chapter 7 page 50-51 for STOP lines under Road Junction making signal control junctions, chapter 3.3.	Will be improved.
		6.2	GIVE WAY lines		Given	Chapter 3.4. 3.5 page21 to 22	To add importance and uses of give way marking.
		6.3	Guidance for Installation of		New		To add in order to differentiate between application of GIVE

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content wrt Draft or Approved Manual	Draft Manual Ref.	Remarks/Additional Comments
			STOP and Way Markings				WAY and STOP markings and signs.
7	Markings for transition and lane changes	7.1	General		New		Why it is needed as transition and lane change marking
		7.2	Diagonal and Chevron markings		Given	**Chapter 11 page 73-75.**	
		7.3	Continuity Lines		Given	Chapter 4 para 4.3.2 page 29.	
		7.4	Lane changes and merging/ diverging markings		**New**		**Specific subsection for lane change, merging diverging marking may be given.**
		7.5	Hatch markings		Given	Chapter 11 page 73-75.	
		7.6	Raised profiles Edge lines		New		
		7.7	Lane reduction/ Narrowing situations and transitions		New	Given in road junction marking chapter in sub section 6.8 page48.	Specific details of lane reduction, narrowing situation and transition may be elaborated.
8	Arrow and word messages	8.1	Directional arrows		Given	Chapter 8page 52-55.	
		8.2	Deflection arrows		Given		
		8.3	Bifurcations arrows		Given		
		8.4	Arrows on side road approach		Given		

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content wrt Draft or Approved Manual	Draft Manual Ref.	Remarks/Additional Comments
		8.5	Arrows on main road approaches		Given		
		8.6	Word messages		Given	Chapter 10 page-59 -73.	
9	Markings for At grade Intersections	9.1	General		New, to describe specific requirements of marking, type of marking for at-grade junctions		Draft manual describing two chapter as priority Junctions and Signalised junction.
		9.2	Simple Junctions		New	Chapter 6 page 40 -47.	The related chapter in draft manual namely, Road junction marking shows priority Junctions in the form of type of line. However as chapter is named Marking for at grade junctions, it may be modified based on the road marking required as per the type of junction.
			Skew or Y junctions		New		
			Ghost island Junctions		New		
			Right turn Protected T junctions		New		
			Staggered Junctions		New		
			Dual carriageway junctions		New		
			Signalised Intersection		New		
			Round about		Given,	Chapter 5, PAGE 37-39	
			Signal controlled roundabout		New		
			Double roundabout		New		

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content wrt Draft or Approved Manual	Draft Manual Ref.	Remarks/Additional Comments
			Mini roundabout		Given	Chapter 5 sub section 5.3 page 37.	
	Grade separated Junctions	10.1	General		New		No details given for Grade separated junctions.
10		10.2	Merging/ diverging without lane gain or lane drop		New		
		10.3	Merging/ diverging with lane gains/ Lane drop		New		
	Markings for speed reduction measures, pedestrian crossing and cyclist	11.1	Marking on speed breakers		New		A separate chapter for VRU (pedestrians & cyclists) is required for enhancing the safety of all road users. However, details regarding various type of marking required for speed reduction measures are given in various sub section of the draft manuals.
		11.2	Thermoplastic bar markings		New		*Details of Thermoplastic Bar Marking (TBM) will be added.*
		11.3	Pedestrian crossings		Given	Chapter 9 page 55- 59.	
		11.4	Marking for vulnerable road sections		New		
11		11.5	Bicycle lane marking		New		*Details of bicycle lane marking will be added.*
		11.6	Railway level crossing		Given	Chapter 6 sub section 6.9, page 49.	

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content wrt Draft or Approved Manual	Draft Manual Ref.	Remarks/Additional Comments
12	Marking for buses, Trucks lay bye and toll plazas	12.1	Bus lanes		Given	Chapter 10, sub section 10.18 page 68.	
		12.2	Bus stop		Given		
		12.3	Bus bay marking		Given	Chapter 4 sub section 4.7.3, page 36.	
		12.4	Truck lay bye marking		New		Current practice will be reviewed and included if appropriate.
		12.5	Toll plaza markings		New		
13	Parking's and restrictions	13.1	Parking spaces		Given	Chapter 10 sub section 10.8, 10.9. 10.10.	
		13.2	Restrictions		Given		
		14.1	Object markings		New		Objects on or adjacent to the carriageway are physical obstructions and are serious hazards. Such objects should be visible at night. A separate chapter may be included for object marking. *Details of object marking will be added.*
14	Object Paintings	14.2	Markings for objects within the carriageway		New		
		14.3	Markings for objects adjacent to Carriageway		New		
		15.1	General		New		The section is to contain the level of performance required to govern the quality of road marking, reflectivity, day and night time visibility, wet reflectivity, wear, durability etc. Assessment of these performance parameters is essential to reap the benefits of
		15.2	Wear durability		New		
15	Performance assessment and monitoring	15.3	Day time Visibility		New		
		15.4	Night time visibility		New		

New Manual Chapter	Topic	Sub-topic		Status	Gap: Proposed Content wrt Draft or Approved Manual	Draft Manual Ref.	Remarks/Additional Comments
		15.5	Performance Criteria		New		road marking for safety of road users.
		15.6	Skid resistance		New		
		16.1	Warranty		New		The material and laying process determines the time period for relaying and warranty of material laid. It also determines the reflectivity and luminescent coefficient. A chapter on warranty, testing methods, marking evaluation process and type of defect is to be added. *Details of performance measurement will be added.*
	Warranty and test methods	16.2	Testing methods		New		
16		16.3	Assessment of wear		New		
		16.4	Assessment of Luminance coefficient		New		
		16.5	Road marking evaluation process		New		
		16.6	Category of defects and maintenance records		New		

Table 10-3: Adequacy of existing or draft manuals for incorporation into new manual: Traffic Signs

Key: (green) = Fully Developed, (yellow) = Partial, (red) = Not Developed, (grey) = Not Applicable

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content wrt Draft or Approved Manual	Draft/ Approved Manual Ref.	Remarks/Additional Comments
	Glossary and Abbreviations				• Not Available.	NA	
1	Introduction			Partial	• The introduction section in the manual does not cover the history of guidelines on road signs, any law regarding road signs in Kenya. • Protocol adopted worldwide regarding signs and how the revision of road sign manual proceeded is not present,	Section 1.1	Will be improved.
				Partial			
2	General	2.1	Classification of Road Signs	Partial	• Existing draft manuals does not cover purpose for signs in the sub section. • Legal framework does not describe road traffic acts in Kenya. It only has two lines. • Principles of road sign as 6C not given. • Classification of road signs given but color pictures of signs not given. • Para regarding color and size of signs not given. • Basic information about size of signs with road classification not available. • Details about siting of signs are less. Ready reference in tabular form about height and clearance requirement not available. Material for signs not available.	Section 1	Will be improved.
		2.2	Siting of Signs with respect to the Carriageway	Partial			
		2.3	Orientation of Signs	Partial			
		2.4	Material for Signs	Partial			
		2.5	Posts and Mountings for Signs	Partial			
		2.6	Color for Signs	Partial			
		2.7	Size of Signs	Partial			
		2.8	Visibility of Signs	Partial			
		2.9	Size of Letters	Partial			
		2.10	Maintenance of Signs	Partial			

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content wrt Draft or Approved Manual	Draft/ Approved Manual Ref.	Remarks/Additional Comments
		2.11	Testing for retro-reflectivity				*New section to be added.*
	Maintenance of Signs		Maintenance of Signs		• Details given for maintenance of signs is not sufficient. • More details about responsibility of maintenance, time span for maintenance, replacement after losing reflectivity not given.		
3		3.1				Section 1.8	Will be improved.
	Mandatory/ Regulatory Signs						
4		4.1	Classification of Regulatory Signs		• Section for classification of regulatory sign not given. • Every type of mandatory/ regulatory sign should be elaborated in sub sections covering information regarding purpose, size, shape, color, location for installation, any warrant for installation etc. This is absent in draft manual. Flow of content for every type of sign is not proper. • No information given about visibility funnel requirement for sign installation.	Chapter 5	Will be improved.

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content wrt Draft or Approved Manual	Draft/ Approved Manual Ref.	Remarks/Additional Comments
5		5.1	Size, Shape and Color		• Different sizes of cautionary signs are given in one symbolic sign. Categorization	Chapter 6 of draft manual and chapter 8 of draft manual	*Will be improved.*
		5.2	Location and Siting				*6 second rule for positioning of signs will be explained.*
		5.3	Signs for road work		Separate section on signs during road work not present.		*Separate section is to be added.*
6		6.1					
		6.2	Directional and Place identification signs		has been done based on importance. • Specific category of road and which size of sign to be adopted is not given. • Traffic management and work zone safety Signs are given in chapter 8 as signs for road works.• Given.		
		6.2.1	Shape, colour, and language of Inscription		• Given.	Chapter 2 table 2.1	
7		7.1				Chapter 4.4	
		7.5	Toilet Block		• Not Given.		Will be added.
		7.6	Filling Station (Fuel Pump)		• Not Given.		Will be added.
		7.8	Public Telephone		• Not Given.		Will be added.

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content wrt Draft or Approved Manual	Draft/ Approved Manual Ref.	Remarks/Additional Comments
		7.9	U turn Ahead		• Not Given.		Will be added.
		7.10	Pedestrian Subway		• Not Given.		Will be added.
		7.11	Foot over Bridge		• Not Given.		Will be added.
		7.12	Chairlift		• Not Given.		Will be added.
		7.13	Police Station		• Not Given.		Will be added.
		7.15	Repair Facilities		• Not Given.		Will be added.
		7.16	Railway Station/ Metro Station/ Monorail station		• Not Given.		Will be added.
		7.19	Taxi stand				Will be added.
		7.23	Parking Restriction Signs for Traffic Management				Will be added.
		7.24	Flood Gauge Sign		• Not Given.		Will be added.
							Will be added.
8		8.1					Will be added.
		8.2					Will be added.
		8.3	Parking Information Reserved for Disabled Person		• Given.	Sub section 4.4.8	
		8.4	Ramped Entrance to Subway/ Over way Bridge				Will be added.
		8.5					Will be added.
		8.6					Will be added.
		8.7					Will be added.

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content wrt Draft or Approved Manual	Draft/ Approved Manual Ref.	Remarks/Additional Comments
9	Route Marker Signs						Route marking sign for different types of roads will be explained in the manual.
10		10.1	General			Chapter 3	Will be improved.
		10.2	Color of Signs		• Given as Color Coding.	Sub section 3.2.1	
		10.3			• Given under Alphabets.	Sub section 3.2.3 and 3.3.3	
		10.4	Sign Installation		• No specific guiding principle mentioned for siting and sign installation.		
		10.5	Sizes of the Signs		• For sizes of signs, detailed description not given in specific para.		
		10.6	Placement of Signs with Respect to carriageway		• Not given. Some information about direction sign given under direction sign para, figure 3.21.	Sub section 3.3.5	
		10.7	Size of Letters		• Briefly given under Alphabet para.	Sub section3.2.3	
		10.8	Guidelines for Informatory Sign Installation		• Not given specifically.		
11	Guidelines for Signs on Urban and City Roads	11.1	General		• No specific chapter in draft manuals for Urban and city road. • However colour scheme for urban road given.	Table 2.1 para 2.2.1 Urban roads.	Will be improved.

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content wrt Draft or Approved Manual	Draft/ Approved Manual Ref.	Remarks/Additional Comments
		11.2	Color of Signs		• Given for urban roads.	Table 2.1 para 2.2.1 Urban roads.	
		11.3			• Specifics about all subtopic not given in draft manual.		Will be improved.
		11.4	Warrant for Sign Installation				
		11.5	Sizes of the Signs				
		11.6	Siting of the Signs with Respect to Carriageway				
		11.7	Size of Letters				
		11.8	Guidelines for Informatory Sign Installation				
		11.8.1	Gantry Mounted Signs				
12	Sign Plan Examples for Typical Situations				• Sign plans for road works section for different traffic management solution are given.	Fig 8.15 to Fig A37.	
	Figures				• Given.		
	Annexures						

11 Review of the Road and Bridges Design Manual – Part 1B: Road Safety Auditing (2009 EGIS)

11.1 General

Road Safety Audit (RSA) is a formal safety performance examination of an existing or future road or intersection by an independent, multidisciplinary team. It qualitatively estimates and reports on potential road safety issues and identifies opportunities for improvements in safety for all road users.

Traffic Impact Assessment (TIA) is a methodology to assess the impact of the traffic generated from a land development on the existing road network.

11.2 Existing manual details

2009 EGIS DRAFT RDM, Draft Part 1(b): Road safety audits is an existing manual for Road Safety Audit.

Currently there is no manual on TIA.

The sections that need to be included in RSA manual were identified and listed. These sections are:

1. History of RSA.
2. Road safety situation in Kenya.
3. Objectives and necessities of RSA.
4. What projects can be audited.
5. Benefits of audit.
6. Audit of urban roads.
7. Managing RSA.
8. Practice of RSA.
9. Audit case studies.

The sections for developing a TIA manual were listed. These include:

1. Introduction to TIA.
2. TIA application.
3. Circulation plan for small developments.
4. Methodology report.
5. Study of impact.
6. Masterplan.

11.3 Approach to review

The existing RSA manual was studied in detail. It was compared to the reference RSA manuals of UK, USA, India and Australia. The sections that were missing were listed and the sections where revisions need to be done were also listed.

TIA and Transportation Impact Study guidelines and manuals were studied from various countries. An idealised table of contents for TIA manual is presented. It was agreed that TIA manual will not be a part of the proposed manual.

After incorporating the changes it is expected that the RSA manual will be comprehensive, time relevant and user friendly.

The existing sections in the current RSA manual that are quite comprehensive were marked in green. The sections that needed revisions were marked in yellow. The sections that were not present or needed extensive revision were marked in red for reference during drafting.

11.4 Good practice references

The reference documents for RSA are:

1. Road Safety Audit Guidelines, FHWA, USDOT
2. Road Safety Audit, GG 119, UK
3. Road Safety Audit Manual, Republic of Uganda
4. Guide to Road Safety, Part 6: Road Safety Audit, ARRB
5. Road Safety Audit Manual, IRC- SP 88 – 2019, India

The reference documents for TIA are:

1. Transportation Impact Study Guidelines, Abu Dhabi, UAE
2. Guide for Preparation of Traffic Impact Studies, California Department of Transportation
3. South African Traffic Impact and Site Traffic Assessment Manual
4. Traffic Impact Assessment Guidelines, Alberta, Canada

11.5 Idealised manual content

Table 11-1: Idealised Table of Contents for road safety manual

Chapter	Description
1	Introduction
2	RSA overview
3	Conducting RSA
4	Managing RSA
5	Practices for Safer Roads
6	Case Studies

7	Checklists

Table 11-2: Idealised Table of Contents for traffic impact assessment

Chapter	Description
1	Introduction to TIA
2	TIA application
3	Circulation plan for developments
4	Methodology report
5	Study of impact
6	Masterplan
7	Application of TIA

11.6 Proposed updated manual idealised table of contents and gap analysis

The proposed Table of Contents for the new manual parts, and associated gap-analysis, is as shown in **Table 11-3** for road safety audits.

Table 11-3: Adequacy of existing or draft manuals for incorporation into new manual: Road Safety Audits

Key: = Fully Developed, = Partial, = Not Developed, = Not Applicable

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft/ Approved Manual Ref.	Remarks/Additional Comments
0	**Glossary and Abbreviations**			Not Developed	New -Not available in Draft Part 1(b) Road Safety Audits 2009.	RDM for Road and Bridges Part 1(b) Road Safety Audits.	To understand the technical terms glossary and full forms of short form required in this chapter.
1	**Introduction**		**Introduction to the Manual**				
		1.1	A Brief History of Road Safety Audit	Not Developed	Not available- New.	Refer Section 1 page-1 of above part.	Brief history mentioning start of RSA and how it proceeds may be added.
		1.2	Purpose of Road Safety Audit	Partial	Modification is required. In the draft manual, need of road safety audit is given. It needs to be written in simple manner instead of long text.	Sub section 1.3 page 3.	A brief para mentioning who this manual is aimed for, the purpose of RSA, application of safety principle needs to be written. Provision of RSA is to be included for all improvement and maintenance of roads, irrespective of road category.
		1.3	How to use this Manual	Not Developed	New.		A brief procedure needs to be included on how to use the manuals and reporting system.
2			**Road Safety Audit : An Overview**	Not Developed			

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft/ Approved Manual Ref.	Remarks/Additional Comments
	Road Safety Audit – An Overview	2.1	The Road Safety Situation in Kenya		New.		Include a short section describing the number of crashes that occur in Kenya with number of fatalities and injury crashes to convey the importance of road safety.
		2.2	How can Engineers Reduce Road Trauma?		New.		The role of engineers as one of E under road safety interventions may be described.
		2.3	Prevention is Better than Cure		New.		To summarise RSA statement, a para may be added.
		2.4	What is Road Safety Audit?		New, only three line definition is given in the draft manual. It needs to be elaborated.	Para 1.1.	To define RSA, elaboration of various aspects of RSA is required to be added in separate subsections.
		2.5	Objectives of Road Safety Audit		New.		A para to mention objective of RSA is required.
		2.6	A Brief Outline of the Key Steps in a Road Safety Audit		Partial bullets points given for audit process required to be elaborated.	Sub section 1.6 and sub section 2 page 6-8.	Need to be more concise.
		2.7	Why is Road Safety Audit Necessary?		New.		A para need to be added to show practical solutions, considering the constraints.

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft/ Approved Manual Ref.	Remarks/Additional Comments
		2.8	The Five Stages of Auditing a Road Project		The draft manual provides six stages, separating feasibility stage and preliminary design stage. The basic difference in auditing for different stages have not been explained.	Sub section 1.2 page 2.	The number of stages can be modified to five instead of six stages.
		2.9	What Projects are to be Road Safety Audited?		New.		Section on types of projects to be taken up for road safety audits may be added. These could be new roads or existing roads to be upgraded, rural roads and urban roads.
		2.10	Key Groups Involved in a Road Safety Audit: their Roles and Responsibilities		Audit team is given but roles and responsibility of different groups not given.	Sub section 1.4 page 4-5.	Draft manual subsection 1.4 mentions audit team as client, designers, and auditors. The functions, roles and responsibilities may be elaborated. The contents are very lengthy. Paragraph may be revised.
		2.11	The Benefits of Audits		New.		A section may be added to appraise all manual users about the basic principles of RSA and how it benefits the road users.

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft/ Approved Manual Ref.	Remarks/Additional Comments
		2.12	Rural Roads		New.		Causes of crashes are different, depending upon the category of the road. The geometric design standards differ from urban to rural roads. A section explaining the audit process for various category of roads may be added.
		2.13	Urban Roads		New.		
3	**Conducting a Road Safety Audit - the Key Steps**		**Conducting A Road Safety Audit- the Key Steps**				
		3.1	Road Safety Audit Process		Draft manual contains audit process in lengthy paragraph; it should be in concise, in tabular form, showing steps for action. Content in the draft manual is not appropriate	Section 2 page 7 to 9.	Audit process can be shown in steps for action. The steps can be shortened if road is of low category. A tabular form of steps is required to be added.
		3.2	Deciding that an Audit is Necessary		New.		Considering the road hierarchy, the road authority may decide prioritisation of audit to be done based on road safety audit policy of road authority.

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft/ Approved Manual Ref.	Remarks/Additional Comments
		3.3	Selecting the Road Safety Audit Team		Lengthy text may be re-arranged.	Section 2.2 page 7.	
		3.4	Providing all the Background Information		Nil.	Section 2.4 page-9.	Adequate.
		3.5	Holding a Commencement Meeting		Nil.	Section 2.3.	Adequate.
		3.6	Checking the Drawings, Design Reports and Documents		Nil.	Section 2.5.	Adequate.
		3.7	Inspecting the Site		New.		Paragraph and procedure for site inspection may be added.
		3.8	Writing the Road Safety Audit Report		Nil.	Section 4 page 38.	Adequate.
		3.9	Holding a Completion Meeting		Nil.	Section 4.2 page 41.	Adequate.
		3.10	Providing Response to the Audit Report		New.		Paragraph may be added on how to proceed for response.
		3.11	Following up and Implementing Agreed Recommendations and Changes		Nil.	Section 4.4 page 42.	Adequate.
4	**Managing Road Safety Audit**		**Managing road safety audit**		New.		This chapter deals with how the authority can manage road safety audit work. It should contain:

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft/ Approved Manual Ref.	Remarks/Additional Comments
							• how to prepare term of reference for inviting tender to carry out road safety audit work • how to prepare road safety audit policy • empanelment requirement for road safety auditor • qualification, experience of auditors • risk assessment of safety concerns • prioritisation of suggested recommendations etc.
		4.1	Putting Road Safety Audit to Work in the Road Authority		New.		
		4.2	Options for having a Road Safety Audit undertaken		New.		
		4.3	A Suggested Road Safety Audit Policy		New.		
		4.4	Draft Terms of Reference for Commissioning a Road Safety Audit		New.		

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft/ Approved Manual Ref.	Remarks/Additional Comments
		4.5	Empanelment of Road Safety Audit Consultant		New.		
		4.6	Risk Assessment of Safety Concerns and Prioritization of Suggested Recommendations		New.		
5	**Practices for Safer Roads**		**Tips for safer roads**				
		5.1	Starting your Audit		New.		This chapter deals with basic technical tips for road safety auditor as a ready reference. Tips for engineering interventions for proving safer roads may be added.
		5.2	Technical Tips for Audit Teams: Warn, Inform, Guide, Control and Forgive		New.		
		5.3	Technical Tips for Audit Teams : Safety Elements in Junction Layouts		New.		
		5.4	Technical Tips for Audit Teams : Roadside Hazards		New.		This section will make the auditor aware of the road side hazards and about forgiving road design.
		5.5	Technical Tips for Auditors: Road Signs & Pavement Marking		New.		

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft/ Approved Manual Ref.	Remarks/Additional Comments
		5.6	Technical Tips for Auditors: Pedestrians		New.		
		5.7	Principles for Safer Design		New.		
6	**Safety Audit Case Studies and Reporting**		**Safety Audit Case Studies and Reporting**		New.		This chapter shall deal with the case studies of different stages of audit. Layout and format of report to summarise the audit findings is to be included. This shall be useful to auditors to have uniformity of reports and to arrange the issues in the same order as in the checklist.
		6.1	Case Study 1: Design Stage Audit		New.		
		6.2	Case Study 2: Construction Stage Audit		New.		
		6.3	Case Study 3: Pre-opening Stage Audit		New.		
		6.4	Case Study 4: Existing Road Audit		New.		
7	**Road Safety Audit Checklists**		**Road safety audit check lists**				
		7.1	The Purpose of Checklists		Nil.		Adequate.
		7.2	When and how to use the Checklists		Nil.		Adequate.

New Manual Chapter	Topic		Sub-topic	Status	Gap: Proposed Content cw Draft or Approved Manual	Draft/ Approved Manual Ref.	Remarks/Additional Comments
		7.3	The Road Safety Audit Checklists		Nil.		Adequate.

12 Review of the Existing and Approved SRBC, 1986

12.1 Summary of review of the approved Standard Specifications for Road and Bridge Construction, 1986 (SRBC)

12.1.1 General

The current and approved Standard Specifications for Road and Bridge Construction, 1986 (SRBC) contains 22 sections. The SRBC is written in a format that is different from that adopted recently in a number of countries in the region, which consist of about 7 or 8 series covering most aspects of the new road and bridge construction works.

The review indicates that most of the technical content of the Road and Bridge Construction, 1986 (SRBC) is still valid. However, values of some parameters need to be changed in light of recent research whilst new parameters and their values need to be included; obsolete parameters need to be excluded; and finally the document needs to be restructured.

12.1.2 Section 1 - General

Generally, the section has very brief sub-sections, which have required writing up of particular specifications in most contract documents. Definition of contractual terms are not given. The link to contract documents is referred to in terms that are too general. It is also not clear which GCC are being referred to in the advent of use of various such conditions in many contracts.

The section does not bring out clearly the following issues, amongst others:

- Handing over of site to Contractor.
- Contractor designed works.
- Drawings format.
- Treatment of HSE issues.
- Community Liaison.

The new SRBC will require addition of more definitions, and would require clauses to ensure that the works are compatible with recent social/labour laws and environmental compliance.

12.1.3 Section 2 - Materials and Testing of Materials

The section will require addition of new tests and test methods, and removal of obsolete tests and test methods such as the Hubbard-Field Stability. Addition of tests such as gyratory compaction and new bitumen tests such as performance grading tests are required.

12.1.4 Section 3 - Setting Out and Tolerances

There is a need for consultation with stakeholders regarding tolerance limits given that the advent of new technology and test methods is now available.

12.1.5 Section 4 - Site Clearance and Topsoil Stripping

The section does not give a clear distinction between topsoil, other soil, soft rock and hard rock. As the new specification is drafted this will be taken as very important to avoid over-payment that can arise form misclassification of excavation.

12.1.6 Section 5 - Earthworks

The section defines hard material by reference to equipment power and weight and this then means that changes in technology could lead to different classifications. It is preferable that a strength test such as 10% FACT, ACV or CBR be used for this purpose.

This section should also include specifications for fill materials.

12.1.7 Section 6 - Quarries, Borrow pits, Stockpiles and Spoil Areas

The contents of this section are quire comprehensive and adequate for the purpose. These will be carried to the SRBC update exercise.

12.1.8 Section 7 - Excavation and Filling for Structures

The technical contents of excavation of foundation for structures need improvement. Any excess excavation done beyond limits of excavation shall be made good by Contractor at his own cost. Relevant clause for setting out of limits of excavation, stripping and storing of topsoil for re-use in covering embankments, tools & equipment, etc. to be referred from Section 4. Specifications for blasting and storage of explosives and operations to be added. Certain provisions can be updated / added such as-

> *Cofferdams can be included to keep the excavation dry. Where it is not possible to keep dry, concreting shall be done by tremie pipe only as specified in concreting under water. Water flow or pumping to be stopped while concreting. Care shall be taken to discharge the drained water into suitable outlets as not to cause damage to the works, crops or any other property.*
>
> *When rock or other hard strata is encountered, it shall be free of all soft and loose material, cleaned and cut to a firm surface either level or stepped as directed by the Engineer. All seams shall be cleaned out and filled with cement mortar or grout to the satisfaction of the Engineer.*
>
> *The surplus useful material shall be stacked as per directions of Engineer.*
>
> *In case of excavation in rock, the annular space around footing shall be filled with concrete class 15/20 up to the top of rock level.*

Safety for the public, workers can also be added. All excavations shall be securely fenced, provided with proper caution signs and marked with red lights at night to avoid accidents.

12.1.9 Section 8 - Culvert and Drainage Works

Section 8 adequately covers most of the activities that pertain to construction of culverts. However, the sequencing of the contents does not follow the correct order of undertaking such works. As the content is carried over to the new specification, the content will be rearranged accordingly.

Section 9 - Passage of Traffic

The section does not cover management of traffic in work zones.

12.1.10 Section 10 - Gravel Wearing Course

Material specifications may need to be revised in line with recent research. The plasticity characteristics and grading matrix has to be specified and special specifications should also be retained given the current scarcity of gravels.

12.1.11 Section 11 - Shoulders to Pavement

Since this section is made up of only cross-references to other parts of the specifications, it is better to exclude it as a stand-alone section and instead provide the specifications in appropriate places. This will be instituted in the update process.

12.1.12 Section 12 - Natural Material Subbase and Base

This needs to be updated to include more modified materials and materials sheets currently included in the pavement design manual should be reproduced in this section.

12.1.13 Section 13 - Graded Crushed Stone Subbase and Base

This section will require to be updated and incorporated into the new specification in the same manner as Section 12.

12.1.14 Section 14 - Cement and Lime Treated Materials

The section should include materials treated with GGFBS.

12.1.15 Section 14A - Lean Concrete

Only minor edits required for this section. The content for lean concrete aspects is comprehensive.

12.1.16 Section 15 - Bituminous Surface Treatments and Surface Dressings

Content of Section 15 need to be updated to include recent emulsions used in Kenya. RC cutbacks to be removed from this section. Prime coat and tack coat materials to include emulsions. Grit Seal to be included. Gravel seals can now be made using emulsions.

12.1.17 Section 16 - Bituminous Mix Bases, Binder Courses and Wearing Courses

The section will be updated to include stone mastic asphalt, hot-rolled asphalt and performance-graded mixes. There is a need to modify and incorporate the draft specifications contained in Appendix G of the 1996 report on the performance of bituminous mixes in Kenya (PR/OSC/567/96).

12.1.18 Section 17 - Concrete Works

The clause 1701 describing scope is in brief. Scope shall be broadened to cover supply and storage of material, protection and testing of concrete, cast in place and precast, plain, reinforced and prestressed concrete, etc.

Clause 1702 covers definitions for structural and non-structural concrete, formed and un-formed surfaces. It shall be enhanced to cover some more definitions such as Characteristic strength of concrete, self-compacting concrete, false work, formwork.

Clause 1703 provides specifications of materials for concrete. Few more details shall be added such as identification of sources of materials, testing and approval by Engineer before procurement, cost of testing to borne by Contractor, basic requirements of chemical admixtures, restriction of use of seawater or brackish water for mixing or curing of concrete, use of curing compound.

The technical contents under this section must be updated to include the properties of materials (cement, fine aggregate, coarse aggregate, water, steel reinforcement) in tabular form. Grading and other properties to include for coarse and fine aggregate in tabular form for various classes of concrete.

Certain topics are given in brief and need to be elaborated. In clause 1704, high performance concrete (class above 40) is not there in existing specifications and shall be included. Minimum class of concrete for different exposure conditions, maximum cement content in concrete also to be defined. Requirements of Plum concrete shall be added. In clause 1705, details for batching, transportation, placing to be enhanced. Transportation of concrete by pumping in clause 1707 to be added. In clause 1708, concreting under adverse climate conditions (hot or cold) are provided in brief, need to provide more details. In clause 1708, reference of internal vibrators, external vibratos, surface vibrators shall be mentioned. Suitability of self-compacting concrete shall be introduced where compaction is not feasible.

In clause 1722, Construction of Formwork and False work, materials for formwork and other requirements shall be provided. Specialised formwork such as slip form, travelling form, void formers shall be included. Contractor to submit design and drawings of false work & formwork and got approval of Engineer.

Clause 1729 Bending Reinforcement shall be updated to include statements such as:

> *"Bar bending schedule shall be furnished by the contractor and got approved by the Engineer before start of work. Reinforcement laps/ joints/ splices shall be staggered or located at points along the span where stresses are low."*

Clause 1730 Fixing Reinforcement, provisions shall be updated to include strength and specification for concrete cover blocks not less than that of the member. Necessary stays, blocks, metal chairs, spacers, metal hangers, supporting wires etc. or other subsidiary reinforcement shall be provided to fix the reinforcement firmly in its correct position.

Clause 1738 Handling and Storage of Precast Units can be updated to include safety considerations during storage and staking, temporary supports during storage and transportation, placing and erection, etc.

Tests and standards of acceptance of concrete and other materials, sampling, frequency of testing, etc. to be mentioned in more detail under separate clause

12.1.19 Section 18 - Prestressed Concrete Works

Specifications for prestressed concreting works to enhance and update under certain clauses. In Clause 1802 General, Definition of various terms of prestressing such as pre-tensioned concrete, post-tensioned concrete, anchorage, etc. shall be added. The details and requirements for prestressed concrete to elaborate, higher grades of concrete to include. The material properties in tabular form gives better understanding to users and shall be provided in new specifications. In clause 1803, some more details shall be added for ducting type (spiral corrugated either in mild steel or HDPE) for internal tendons. External tendons shall be housed in either High Density poly-Ethylene (HDPE) sheaths or metallic steel sheaths (plain or with protective coatings), which have smooth internal surfaces

In clause 1808 tensioning operations; requirements for tensioning operations, post-tensioning, pre-tensioning, calculated and actual elongations, gauge pressures/forces, etc. to describe in more detail. A complete record of pre-stressing operations along with elongation and jack pressure data shall be maintained and be compared with those provided in drawings for acceptance.

In Clause 1817, the quantity of prestressing steel for in-situ concrete is measured in no. of each type of tendons for each length. Other countries have different modes of measurement. Indian standards provide measurement of prestressing tendons by weight (length multiplied by unit weight). COTO and Mozambique specifications provides in mega newton-metre (MN-m) which are recently prepared. ERA Standards provide in linear meter for each type of tendons. For the proposed specifications, though, measurement by weight is a simple way, it is recommended to use mega newton-metre (MN-m) which takes account of both parameters (length and prestressing force).

12.1.20 Section 19 - Structural Steelwork

Scope of this clause is provided in brief and shall be enhanced to include furnishing, fabricating, transporting, erecting and painting of structural steel

In clause 1903, British Standard referred for material properties. Some basic properties of materials shall be provided in tabular form as ready reference. Properties of steel tubes, bolts, nuts & washers, rivets, etc. shall also be added. In clause 1905 fabrication, erection, workmanship and safety requirements to elaborate. The requirements to use of steel plates and rolled sections to be in more detail. Clause 1907 and 1908 provide details for welding and bolting. Riveting in missing and shall be added. Provision of handling and erection under clause 1909 to elaborate. Requirements of grouting to fix base plates shall be added.

Clause 1911, which is partly available, provide detail for painting. Protective coating, galvanising of structural steel work to include, painting work to elaborate for prime coat, number of coats, thickness of coating, repairing of damaged coating during transportation and erection, etc.. The clause 1912, 1913 and 1914 are missing in the available copy of the document which pertains to paint systems, damaged surfaces, measurement and payment and thus cannot be commented.

12.1.21 Section 20 - Road Furniture

The section adequately provides for road furniture and content therein will be carried to the new specification with some modifications to reflect new technologies and architecture.

12.1.22 Section 21 - Miscellaneous Bridgeworks

This section pertains to miscellaneous aspects of bridges such as water proofing, bearings and joints, railings, wearing coat over decks, weep holes. The details are in brief and the detail requirements of various items shall be added. Requirements of different types of bearing such as elastomeric bearings, POT-PTFE bearings to be add. Provisions for concrete barriers and parapets, steel railings, concrete railings, service ducts to be made in new document.

Specifications for approach slab at bridge abutments, safety barriers over bridge decks are missing and to be added in new document. Indian specifications provide detail requirements for bituminous and cement concrete wearing coats. These details are missing in existing specifications and will be incorporated while updating.

12.2 Detailed review of the approved Standard Specifications for Road and Bridge Construction, 1986 (SRBC)

Table 12-1 to **Table 12-6** provide a detailed review of selected sections and clauses of the SRBC, 1986 edition.

Table 12-1: Detailed review of existing/approved SRBC – Section 1: General

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
Section 1 - General		Generally, the section has very brief sub-sections which have required writing up of specials in most contract documents. Definition of contractual terms not given. Link to contract documents is referred to in terms that are too general. Not clear which GCC are being referred to in the advent of use of various such conditions. Section does not bring out clearly the following issues: 1. Handing over of site to Contractor 2. Contractor designed works 3. Drawings format 4. Treatment of HSE issues 5. Community Liaison	Mozambique - General section derived from the SATCC model, which in turn was based on the South African COLTO Specification. Section is brief and to the point, includes definition of technical terms only. COTO - Equivalent section now more detailed than the previous COLTO version. Point to the general structure of the entire specification, clarifies relationship between technical specification documentation and conditions of contract, and includes key definitions. Content closes likely contractual loopholes that may lead to claims.	The sub-sections would need to be updated to include as much generic information as possible and reduce on the specials. List of common definitions necessary; each series must also contain specific definitions.
101	Location and Extent of Site	Handing over of site to Contractor not catered for.	COTO give good guidance on handing over of site to take into account availability of the land, sequencing of works, traffic management, etc.	Update EGIS draft to reflect all salient aspects of handing over the site to the Contractor; must take into account provisions in the applicable GCC.

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
104	Programme	Requirements stated in very general terms.	Requirements in the region generally stated in very generalised terms mainly aimed at placing responsibility on the Contractor. However, the new specification in South Africa under COTO is different and provides for more guidance to the Contractor through specifying two schemes - one for simple low value works where the Contractor presents an overall full programme, and a second scheme for complex and high value works, in which case a preliminary programme for first three months is submitted first and then updated thereafter.	More guiding detail required for Kenya, to emphasize demonstration of critical path and significant milestones. Setting of baseline programme to be seen as key to mitigating problems that can arise from claims.
107	Certificate of Completion	Allows issuance of certificate of completion when certain "miscellaneous" works are not completed, list needs review. Sub-section refers to Maintenance Period, not Defects Liability or Notification.	Commonly referred to as Taking Over Certificate to emphasize the shift for responsibility to the Employer, with the Contractor being notified of defects that may arise during a specific Defects Notification Period.	Recommend Kenya to adopt FIDIC approach where the Employer takes over completed works in a well-defined way that allows functionality of the completed product.

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
108	Method of Construction	Specification includes the requirements that the Contractor shall submit a method statement.	COTO, Mozambique - silent on submission of method statement by Contractor at commencement, contain text emphasizing the total responsibility of the Contractor for sound workmanship. EGIS 2009 Draft adopted what is in the existing and in-use specification and requires the Contractor to submit a method statement, aspect repeated in two clauses - 1206 and 1238.	Updated specification must call for submission of method statements, in a concise and clear manner, for all major activities on/off site. To correct the duplication of issue in Clauses 1206 and 1238.
109	Notice of Operations	Clause to brief, does not cater for the need for specific notices that enable Engineer to monitor the Contractor's works.	SATCC/COTO/EGIS - all documents have details that set specific notice periods required from the Contractor.	Update draft and clarify requirements from the Contractor.
110	Units of Measurement, Abbreviations and Terminology	On the whole adequate.		Expand, modernise as necessary.
111	National Specifications	List of national specifications not exhaustive, has called for modification through special specifications.	Aspect of listing national standards in specification not found in regional peer countries.	Improve list, categorise by works type, include versions and date of publication for each, make a comprehensive and up to date list.
115	Construction Generally	Clause contains important information which cover a variety of	Such subjects are usually given the prominence they deserve in	Unbundle and expand where necessary.

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
		subjects such as protection of the environment.	stand-alone clauses or sections of specifications.	
116	Protection from Water	Comprehensive treatise given.		Carry contents to updating the 2009 draft.
117	Health, Safety and Accidents	Clause give a quick overview of an otherwise critical subject on all projects. Too brief.	Practice is now to give OHS issues prominence.	To introduce comprehensive text un update; to include requirement that Contractor submits HSE management plans for approval by the Engineer.
120	Protection of Existing Works and Services	Contractor allotted full responsibility; not practical and can lead to increased tender amounts as there may be a lot of guesswork as to the location and extent of such services.	Common practice is for the Employer to pre-identify or locate all services and arrange for relocation or removal of the same.	Assign relocation of services as an Employer activities. At planning and design stage all services requiring relocation must be identified and the relevant authorities called upon to remove/relocate them.
121	Diversion of Services	As in Clause 120 above.	As in Clause 120 above.	As in Clause 120 above.
123	Liaison with Government and Police Officials	Requirements given in very open terms, can lead to unusual demands by authorities		Review requirements and provide guiding lists in specification.

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
124	Provision of Land	This and Clause 603, and modifications in special specifications seem to contain contradictory information on the responsibilities of the Employer and the Contractor vis a vis acquiring land.	COTO allows for land provided by the Employer and that acquired by the Contractor.	Land acquisition is always a contentious issue on most projects and if not completed before commencement of works can lead to late or non-handover of the site to the Contractor. Delays and claims can result. In updating the Kenya SRBC these sensitivities will be explored in great detail.
125	Water Supply	Potable water to satisfy Medical Officer in area? Not ideal.	Reference is usually made to a National Quality Standard or WHO stipulations.	Refer to a National Standard, of WHO standard.
127	Information from Exploratory Boring and Test Pits	Clause to brief. Does not treat the sharing of risks associated with boring and test pitting adequately. Refers to a Materials report, this may not necessarily be available at all times.		Expand and clearly describe responsibility.
130	Progress Photographs	Reference is made to obsolete format of photographs. Concept of when and how to take the photographs is acceptable.		Update, modernise.
131	Signboards	Reference to Period on Maintenance maybe outdated, needs reconsideration.		Refer to Defects Notification or Liability Period.

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
132	Housing Accommodation for the Engineer and his Staff, Offices and Laboratories for the Engineer with Laboratory and survey and Furniture Equipment	Clause to general, brief and lacks required detail.	Part of a stand-alone series in most cases, has much more generic detail to guide Contractor's in what is required by the Employer.	Make part of stand-alone series, include a much more generic specification of the requirements.
133	Time for Erection of the Engineer's Staff Houses, Offices and Laboratories	Clause to general, brief and lacks required detail.	Part of a stand-alone series in most cases, has much more generic detail to guide Contractor's in what is required by the Employer.	Make part of stand-alone series; include a much more generic specification of the requirements.
134	Insurance and Ownership of the Engineer's-Staff Houses, Offices, Laboratories, Furniture and Equipment	Clause to general, brief and lacks required detail.	Part of a stand-alone series in most cases, has much more generic detail to guide Contractor's in what is required by the Employer.	Make part of stand-alone series; include a much more generic specification of the requirements.
135	Maintenance of the Engineer's Staff Houses, Offices, Laboratories, Furniture and Equipment	Clause to general, brief and lacks required detail.	Part of a stand-alone series in most cases, has much more generic detail to guide Contractor's in what is required by the Employer.	Make part of stand-alone series; include a much more generic specification of the requirements.
136	Removal of Camps	Clause to general, brief and lacks required detail.	Part of a stand-alone series in most cases, has much more generic detail to guide Contractor's in what is required by the Employer.	Make part of stand-alone series; include a much more generic specification of the requirements.

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
137	Attendance upon the Resident Engineer and his Staff	Clause to general, brief and lacks required detail.	Part of a stand-alone series in most cases, has much more generic detail to guide Contractor's in what is required by the Employer.	Make part of stand-alone series; include a much more generic specification of the requirements.
138	Provision of Vehicles	Clause to general, brief and lacks required detail.	Part of a stand-alone series in most cases, has much more generic detail to guide Contractor's in what is required by the Employer.	Make part of stand-alone series; include a much more generic specification of the requirements.
139	Miscellaneous Accounts	Clause covers items that will be ordered by the Engineer, again is very briefly given.	Normal to indicate as comprehensively broken down Prime Sum specification.	Adopt practice in the SADC and EAC, provide for Prime Sums, introduce detailed breakdown of requirements and how the sums will be expended.
140	Payment of Overtime for Engineer's Junior Staff	Content is too brief, no specifics given.	More detail is given.	Expand series to provide clarity.
141	Measurement and Payment	Measurement and payment too lumped up.	More breakdown is given of all items, and their specification. Such detail aides Contractors as they bid and tender submissions become standardised to a large extent.	Adopt approach in COTO, SATCC, EGIS Draft, Uganda. Approaches are standard and have adequate detail that Kenya will benefit from.

Table 12-2: Detailed review of existing/approved SRBC – Section 7: Excavation and Filling of Structures

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
Section 7 – Excavation and Filling of Structures		Pile foundations are missing	Indian Standards, COTO provides adequate details for pile foundations.	Required specifications for pile foundations, types of piles, materials, concreting, testing of piles, etc. will be added..
701	Scope of Section	Pile foundations and Reinforced earth walls are not covered in the specifications.	COTO and other standards cover Pile foundations and Reinforced earth walls.	Specifications shall cover Pile foundations and Reinforced earth walls.
702	Classification of Excavation	Two types of classification are given for excavated material.	COTO and MZ specifications also classify into hard and soft for excavated material for the purpose of payment.	The existing classification be retained. The classification of excavation to be decided by the Engineer.
703	Excavation of Foundations for Structures	Some details to update.	International standards provide more details.	Any excess excavation done beyond limits of excavation shall be made good by Contractor at his cost. Relevant clause for setting out of limits of excavation, stripping and storing of topsoil for re-use in covering embankments, tools & equipment, etc. to be referred. Specifications for blasting and storage of explosives and operations to be added.

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
704	Excavations to be Kept Dry	Certain details are missing.	International standards provide more details to keep excavation dry.	Certain provisions be added: Cofferdams can be included to keep the excavation dry. Where it is not possible to keep dry, concreting shall be done by tremie pipe only as specified in concreting under water. Water flow or pumping to be stopped while concreting. Care shall be taken to discharge the drained water into suitable outlets as not to cause damage to the works, crops or any other property.
705	Foundations and Abutments Cast against In-situ Material.	Generally adequate, minor additions required		Few details to add: When rock or other hard strata is encountered, it shall be free of all soft and loose material, cleaned and cut to a firm surface either level or stepped as directed by the Engineer. All seams shall be cleaned out and filled with cement mortar or grout to the satisfaction of the Engineer
706	Surplus Excavated and Backfilling Materials	Generally adequate, minor additions required		The surplus useful material shall be stacked as per directions of Engineer

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
707	Backfilling of Excavations and Filling for Structures			In case of excavation in rock, the annular space around footing shall be filled with concrete class 15/20 up to the top of rock level
708	Protection of Structures	Safety aspects are missing.	Safety aspects are important and must be provided in detail.	Safety for the public, workers shall be added. All excavations shall be securely fenced, provided with proper caution signs and marked with red lights at night to avoid accidents.
710	Stone Pitching	Min size of stone 0.01 m^3 specified	It is 0.015 m^3 in Indian Specifications, filter media to be provided below stone pitching	To improve the relevant clause covering requirements of pitching stone size and filter media below pitching.

Table 12-3: Detailed review of existing/approved SRBC – Section 17: Concrete Works

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
Section 17 - Concrete Works		Certain topics are given in brief	COTO covers method statements and more items	Need to update and elaborate, method statement for concreting works can be added
1701	Scope of Section	The scope is given in brief	COTO and other specifications also cover supply and storage of material, protection and testing of concrete, cast in place and precast, plain, reinforced and prestressed concrete, etc.	Description of scope shall be broadened to cover these items
1702	Definitions	It covers structural and non-structural concrete, formed and un-formed surfaces	COTO specifications cover other definitions	Some more definitions shall be added such as Characteristic strength of concrete, self-compacting concrete, falsework, formwork.
1703	Materials for Concrete	Properties of material are provided in brief	More information is provided in COTO and other specification Chemical admixtures are proprietary items and some basic requirements are provided in these specifications	Few details shall be added such as-identification of sources of materials, testing and approval by Engineer before procurement, cost of testing to borne by Contractor. Properties of materials (cement, fine aggregate, coarse aggregate, water, steel reinforcement), grading of coarse aggregate & fine aggregates shall be provided in tabular form, basic requirements of chemical

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
				admixtures to add, restriction of use of seawater or brackish water for mixing or curing of concrete, use of Curing compound.
1704	The Design of Concrete Mixes	Concrete class up to 40 are defined in the existing specifications Other details also need revision and update.	COTO provides concrete up to class 115. Indian specification provides concrete class up to 90. High performance concrete requirements also provided.	High performance concrete (class above 40) to include and elaborate. Minimum class of concrete for different exposure conditions to include. Maximum cement content in concrete also to be defined Requirements of Plum concrete shall be added.
1705	Mixing Concrete	Batching, mixing, transportation, placing needs further elaboration	The specifications for Batching, mixing, transportation, placing of concrete can be improved referring international specifications.	Batching, mixing, transportation, placing needs further elaboration.
1707	Transport of Concrete	Transportation of concrete by pumping not provided	COTO and other codes specifies Transportation of concrete by pumping also.	Transportation of concrete by pumping to include.
1708	Placing of Concrete	Concreting under adverse climate conditions (hot or cold) are provided in brief	More details are provided for placing and compaction of concrete in COTO & other standards.	The specifications shall be improved to add more details on these aspects.

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
1709	Compaction of Concrete	Generally adequate, some details can be improved.	Reference of internal vibrators, external vibrators, surface vibrators is available in other standards.	Details shall be improved, suitability of self-compacting concrete to be introduced where compaction is not feasible. External vibration/ surface vibration also be used for compaction.
1710	Curing of Concrete	Lacks in defining the curing period.	Curing of concrete by water, curing compound, retaining formwork in place, etc. are mentioned in other standards. COTO also specifies the minimum time of curing.	Details to be enhanced to cover more details, curing period shall be added.
1711	Protection of Fresh Concrete	Generally adequate		Minor updates can be done
1712	Concreting in Hot Weather			
1713	Finishes on Unformed Surfaces			
1714	Mortar			
1715	Concrete for Secondary Purposes			
1716	Records of Concrete Placing			
1717	Construction Joints			
1718	Expansion and Contraction Joints			
1719	Waterstops			

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
1720	Grouting of Pockets and Holes and Underpinning of Baseplates			
1721	Formwork for Concrete			
1722	Construction of Formwork and Falsework	Certain clauses need updating and the new type of formworks to add	COTO and other specifications provide more details and requirements of formwork and false work	Materials for formwork and other requirements shall be provided. Specialised formwork such as slip form, travelling form, void formers shall be included. Contractor to submit design and drawings of falsework & formwork and got approval of Engineer.
1723	Preparation of Formwork	Generally adequate.		
1724	Removal of Formwork	Generally adequate.		
1725	Surface Finishes	Generally adequate, minor improvements to be made.	COTO and other specifications provide more details.	Details shall be updated to include more information on surface finish.
1726	Tolerances	This clause provides limited details.	COTO provides tolerances for different components in more detail.	Tolerances in formwork for different components such as footings, columns, walls, piers, beams, superstructure, etc. shall be added.
1727	Remedial Work to Defective Surfaces	Generally adequate, few details to be added.	Other standards provide the remedial measures in more detail.	Remedial treatment to defective surfaces shall be provided in more detail.

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
1728	Reinforcement for Concrete	Proper description of protection of reinforcement, coating over reinforcement shall be added.	Indian specification provides coating over reinforcement for protection of reinforcement.	Protection of reinforcement, coating over reinforcement shall be added.
1729	Bending Reinforcement	This clause needs some improvement.	Indian standards, COTO provide more details.	Shall be updated to include: Bar bending schedule shall be furnished by the contractor and approved by the Engineer before start of work. Reinforcement laps/ joints/ splices shall be staggered or located at points along the span where stresses are low.
1730	Fixing Reinforcement	This clause needs some improvement	COTO, Indian standards provide few more details.	Certain provisions can be updated such as: Cover blocks made of concrete shall not have the less strength and specification as those of the member. Necessary stays, blocks, metal chairs, spacers, metal hangers, supporting wires etc. or other subsidiary reinforcement shall be provided to fix the reinforcement firmly in its correct position.

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
1731	Precast Concrete	The details are in brief.		Precast concrete specifications to update with more details.
1732	Formwork for Precast Units	Generally adequate.		
1733	Reinforcement for Precast Units			
1734	Casting of Units			
1735	Curing precast unit			
1736	Dimensional tolerances of Precast Units			
1737	Surface Finish of Precast Units			
1738	Handling and Storage of Precast Units	Brief description is provided.	COTO and other specifications cover storage and staking, provision of temporary supports, etc.	Clause shall be updated to include safety considerations during storage and staking, temporary supports during storage and transportation, placing and erection, etc.
1740	Measurement and Payment	Measurement and payment specifications are provided.	COTO and other specifications provide detail for acceptance of concrete work.	Tests and standards of acceptance of concrete and other materials, sampling, frequency of testing, etc. to be mentioned in more detail under separate clause

Table 12-4: Detailed review of existing/approved SRBC – Section 18: Prestressed Concrete Works

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
1801	Scope of Section	Generally adequate		
1802	General	Brief description is provided	Other standards provide more details	Definition of various terms of prestressing such as pre-tensioned, post-tensioned concrete, anchorage, etc. shall be added. The details and requirements for prestressed concrete to elaborate, higher grades of concrete to include, material properties in tabular form will be included.
1803	Ducting	Material for ducting and properties can be defined.	COTO and Indian standards provide more details.	Some more details shall be added such as: Ducting shall be spiral corrugated type either in mild steel or HDPE for internal tendons. External tendons shall be housed in either High Density poly-Ethylene (HDPE) sheaths or metallic steel sheaths (plain or with protective coatings), which have smooth internal surfaces.
1804	Anchorages			Specifications to elaborate.
1805	Prestressing Tendons	Brief information is available in existing clause.	More details are provided in Indian and COTO standards for prestressing requirements.	Requirements of prestressing wires and strands to elaborate.

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
1806	Installation of Prestressing Tendons			The specifications to include the requirements of prestressing in drawings which shall contain information such as tendon alignment, tendon system, stages of tensions, tensioning force, elongations, etc.
1807	Jacks for Prestressing			Specifications for prestressing equipment and concreting works to elaborate
1808	Tensioning Operations	Limited details are provided in the existing clauses.	More details are provided in other International Standards for prestressing requirements.	The requirements for tensioning operations, post-tensioning, pre-tensioning, calculated and actual elongations, gauge pressures/ forces, etc. to describe in more detail. A complete record of prestressing operations along with elongation and jack pressure data shall be maintained.
1809	Post-Tensioning			
1810	Pre-tensioning			
1811	Bonding and Grouting		More details are provided in other standards	Requirements of grouting material and grouting operations to be elaborated
1812	Camber of Prestressed Precast Beams			Information provided in these clauses to be enhanced and improved.
1813	Rejection of Prestressed Work			

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
1817	Measurement and Payment	Prestressing tendons for in-situ concrete are measured in no. of each type for each length.	Indian standards provide measurement of prestressing tendons (high tensile steel) by weight (length multiplied by unit weight). COTO provides in mega newton-metre (MN-m). Mozambique standards provide in meganewton-metre (MN-m). ERA Standards provide in linear meter for each type of tendons.	The prestressing steel shall be measured in mega newton-metre (MN-m) for quantity actually used in finished work. No separate payment for anchorage, sheaths, ducts, tensioning, grouting, etc. and deemed to be included in prestressing steel rates.

Table 12-5: Detailed review of existing/approved SRBC – Section 19: Structural Steelwork

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
1901	General	Scope is in brief.	COTO and Indian Standards provide more details.	The scope shall be defined to include furnishing, fabricating, transporting, erecting and painting structural steel.
1903	Materials	Structural steel to comply BS 4360.	COTO & Indian standards provide more details.	Some basic properties of structural steel to be provided. Properties of steel tubes, bolts, nuts & washers, rivets, etc. shall also be added.
1905	Fabrication	Provisions are in brief.	More details are provided in COTO and other standards.	Fabrication, erection, workmanship and safety requirements to elaborate, requirements to use of steel plates and rolled sections to provide in more detail. Riveting also be added.
1907	Welding	Welding and bolting provisions are provided.	More details are provided in other standards.	Riveting shall also be added, some more provisions to be updated, welding material and operations to be detailed.
1908	Bolting			
1909	Transportation Handling and Erection			Provisions of handling and erection to elaborate, Requirements of grouting to fix base plates shall be added.
1910	Surface Preparation of Steelwork			The requirements of surface preparation to elaborate.

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
1911	Painting	Relevant pages partly available in the document	Different type of painting and protective coatings are given in other standards	Protective coating, galvanising of structural steel work to include, painting work to elaborate for prime coat, number of coats, thickness of coatings, damage repairs of coating during transportation and erection, etc. shall be added
1912	Paint Systems	Relevant pages are missing in the available copy of the document.		Appropriate detail specifications will be added.

Table 12-6: Detailed review of existing/approved SRBC – Section 21: Miscellaneous Bridgeworks

Clause	Topic	Review Remarks	Regional/International Experience	Update Action
Section 21 - Miscellaneous Bridge Works		Approach slab, safety barriers are missing		Specifications for approach slab at bridge abutments and safety barrier over bridge decks to be added
2102	Bridge Bearings	Inadequate details for bearings	Other standards provide requirements of different types of bearings	Requirements of different types of bearing such as elastomeric bearings, POT-PTFE bearings to add
2103	Movement Joints and Sealants	Inadequate details for joints	Other standards provide requirements of different types of joints	Requirements of different types of joints and materials to add
2104	Pipe Handrail to Bridges	Minor details are provided	Detail requirements and provisions are made in other standards for these items	Provisions for concrete barriers and parapets, steel railings, concrete railings, service ducts to be made
2105	Guardrails to Bridges			
2106	Surfacing to Bridges	No details are provided	Indian specifications provide detail requirements for bituminous and cement concrete wearing coats	Detail provisions for wearing coats over bridge decks shall be added

13 Next Steps

On approval of this Draft Review Report, the Consultant will use the existing content in the current manuals as well as new and well-researched content to prepare the first drafts of the manuals that are covered under the scope for this project. The Consultant will draw on their own recent experience and international best practice to formulate up-to-date manuals for Kenya.

The Consultant will seek to conduct working meetings with practitioners to enhance the drafting process and reflect local content. In addition, in order to take the TTF's invaluable guidance on board, the Consultant will seek to meet with designated TTF members informally within four weeks of commencement of the drafting process. The meetings will focus on the Consultant's proposals of the technical contents for each manual, or part of a manual, as well as the SRBC.

At the end of the above outlined tasks, the Consultant will prepare the first drafts of the manual volumes following the approved manual structure and coding. The first drafts of the manuals will be accompanied by the proposed improvements to the SRBC as well as a concise administrative report on the drafting process, as per the ToR. The TTF and TAs will submit the draft to the NSC for review and approval.

Appendix A Lists of Existing Manuals and 2009 Drafts

ANNEX 1A: ROAD DESIGN MANUAL

Part	Manual	Status	Publication Date	Received	KeNHA comments 17/01/22
i.	Geometric Design of Rural Roads	Approved	Jan 1979	Y	
ii.	Geometric Design of Urban Roads	Proposed	-	-	
iii.	Materials and Pavement Design for New Roads	Approved	Aug 1987	Y	
iv.	Bridge Design:		Original required	Y	Availed an update draft published in November 1989
	• Bridge Design	Draft	Jan 1982	Y	
	• Hydraulic Design of Drainage Structures	Draft	1983	Y	
v.	Pavement Rehabilitation and Overlay Design	Draft	May 1988	Y	

ANNEX 1B: DOCUMENTS COMPLEMENTING THE ROAD DESIGN MANUAL

No.	Manual	Status	Publication Date	Received
	Standard Designs for Small Concrete Drainage Structures: Part I: Standard Small Span	Approved	1987	Y
	Concrete Bridges Part II: Standard concrete box culverts			Y
	Road Design Guidelines for Urban Roads (Geometric Design of Urban Roads)	Draft	Aug 2001	Y
PDG 1	Pavement Design Guidelines for Low Volume Sealed Roads	Approved	April 2017	Y
	Street Design Manual for Urban Areas in Kenya	Draft	April 2019	Y

ANNEX 1C: OTHER DOCUMENTS/MANUALS

1. Manual on Traffic Control Devices

Part	Manual Description	Status	Publication Date	Received	KeNHA comments 17/01/2022
i.	Road Marking	Draft	1972	**Y – hard copy required**	Availed a clearer copy
ii.	Traffic Signs in Kenya	Draft	1975	**Y**	
iii.	Traffic Signals	Proposed			
iv.	Other Traffic Control and Road Safety Devices	Proposed			

2. Road Maintenance Manuals

Part	Manual Description	Status	Publication Date	Received	KeNHA comments 17/01/22
	Road Maintenance Manual	Approved	20104	**Y**	
	Minor Roads Programme Technical and Maintenance Manual	Approved	1989	**Y**	Availed drafts of the technical manual of 1987 and maintenance manual of 1988 The manuals were incorporated into the Roads 2000 manual published 2008
	Roads 2000 Operations Manual	Approved	2008	**Y**	

4. Manual on Roadside Development and Control

Proposed but not drafted.

5. Highway Capacity

Proposed but not drafted.

6. Manual on the Form and Layout of Road Design Plans and Reports

Proposed but not drafted.

ANNEX 1D. STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION

		Received
B. STANDARD SPECIFICATION FOR ROAD AND BRIDGE CONSTRUCTION The current Standard specification for Road and Bridge Construction was published in 1986. It is divided into sections, parts and clauses	1986	Y

ANNEX 2:

LIST OF DRAFT ROAD MANUALS AND STANDARD SPECIFICATIONS FROM RDM REVIEW OF 2009

A. Road Design Manual

Part	Manual Description	Received	KeNHA comment
1	a) Geometric Design	Y	
	b) Road Safety Audits	Y	
	c) Traffic Surveys	Y	
2	Drainage Design	Y	
3	Materials and Pavement Design – New Gravel, Bituminous and Concrete Roads	Y	
4	Materials and Pavement Design – Overlay and Asphalt Pavement Rehabilitation	Y	
5	Traffic Controls Devices		
	a) Traffic Signs	Y	
	b) Road Marking	Y	
	c) Traffic Signals	Y	
	d) Street Lighting	N	Proposed but not yet drafted
6	a) Bridge and Culvert Design	Y	
	b) Catalogue of Drawings i. Standard Culverts and Drifts	Y	
	ii. Standard Concrete Box Culverts – Schedules and Quantities	N	Not available
	iii. Standard Small Span Concrete Bridges	Y	
	iv. Standard Structures	N	Not available

B. **Standard Specifications**

The Draft proposed Standard Specification divided in seven SERIES as follows:

SERIES 1000: General

SERIES 2000: Drainage

SERIES 3000: Earthworks and Pavement Layers of Gravel or Crushed Stone

SERIES 4000: Bituminous Layers and Seals

SERIES 5000: Ancillary Roadworks

SERIES 6000: Structures

SERIES 7000: Tolerances, Testing and Quality Control

ANNEX 3:

LIST OF SUPPLEMENTARY DRAFT ROAD MANUALS, STANDARDS, STATUTES AND OTHER DOCYUMENT RECEIVED FROM MoTIHUD – MAY 2022

#	Description	Received	Remark
1	Bridge Repair Manual Presentation	Y	
2	EIA Regulations	Y	
3	GoK- MoTIHUD – Contract Management Guideline Edition 1 - 2016	Y	
4	GoK- MoTIHUD – Feasibility Study Scope Document – Edition 1 - 2016	Y	
5	GoK- MoTIHUD – Project Appraisal Guidelines for Road Transport Projects – Edition 1 - 2016	Y	
6	GoK- MoTIHUD – Project Management – Road Sector Process Map – Edition 1 - 2016	Y	
7	GoK- MoTIHUD – Risk Management Handbook for Traditional Road Projects – Edition 1 - 2016	Y	
8	Kenya Government Gazette, 2012-09-14; No 13048	Y	
9	Kenya Roads Act Nr 2 of 2007 (2012 Edition)	Y	
10	Minutes of the First Bridge Repair Sub-Working Group Meeting, 26-05-2022	Y	
11	Public Procurement and Disposal Act No. 33 of 2015	Y	
12	Technical Data Manual for Design of Bridges, Volume 2 0 Climatological data	Y	
13	Traffic Management Toolkit, EDF Manual Edition 1	Y	

Appendix B Minutes of TTF Meeting No. 5 – Review of Draft Review Report

TTF SUB-COMMITTEE SESSION: GEOMETRICS AND TRAFFIC

RECORD OF COMMENTS/DISCUSSIONS/RESOLUTIONS

Consultancy Services for Review and Updating of Road Design Manual and Standard Specification for Kenya Ref. No. KENHA/PCS/342/2021

TECHNICAL TASK FORCE GEOMETRICS SUB-COMMITTEE MEETING No. 1
Review of the Draft Review Report

11th November 2022

TTF Comments and Consultant's Responses

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
0	Documents under Review	EGIS drafted Highway and Structural Design Manuals (Road Design Manuals) - 2009 1) Part 1(a): Geometric Design. 2) Part 1(b): Road Safety Audits. 3) Part 1(c): Traffic Surveys. 4) Part 5: Traffic Control Devices.		
General				
1.1	Layout of the Manuals: Consultant to ensure the documents are not too voluminous "like a text-book". The layout to be succinct and additional information to be appended as Annexes.	Technical guidance will be in the main chapters. Theoretical sections will be put in appendices with cross referencing. Sub-committee chair to cascade the comment to the main TTF committee for uniformity of all Manuals.		
1.2	Approach to the review process: Consultant to come up with a structure of providing sections of the Proposed Manual for review by the sub-committee. About 3-5 chapters in one go.	Consultant Experts for Geometric, Traffic Control and Road Safety Audit Manuals to develop a plan of review and share with Sub-Committee.		

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
1.3	Communication: Consultant to create a WhatsApp group for the Client and Consultant team. Frequency of meetings to be discussed.	Email ids will be shared and a WhatsApp group will be set up.		
1.4	Review of the Table of Contents: Not necessary to include all signs in the ToC as it makes it lengthy. Consultant to revise.	Noted. Only types of signs and actions to be taken will be written in the comparison table.		
Traffic Control Devices				
2.1	Colour coding for signs: Consultant to confirm this has this been addressed in the review.	Yes, this has been addressed and included in the Proposed Manual. Refer to page 177 of the DRR – Proposed Manual Chapter 2.		
2.2	Street lighting: Consultant to ensure the Proposed Manual covers relevant aspects of street lighting including source of lighting, lighting class, extent of lighting, lumens etc. Consultant to consider lighting guidelines for rural intersections.	This will be included in the manual.		
2.3	Facilities for PWDs: Consultant has indicated that this was missing in the Draft Manual reviewed. Consultant to ensure additional to the signs, other audio-visual and mobility facilities such as tactile pavements, ramps etc are also included	This will be included as a separate section for PWD.		
2.4	Truck laybys: although this was not captured in the Draft Manual under review, by practice Kenyan agencies have	Consultant to follow up to obtain the standards currently used for truck layby design in Kenya and include in the review.		

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
	been using best practice standards. Consultant to refer to these standards as part of review.			
2.5	Pavement/lane markings: current Kenyan practice is provision of 100mm wide lane markings. Consultant to review this from the aspect of safety (especially night visibility) and sustainability (longevity) and recommend best practice. Also, consideration of materials used in markings.	Consultant to review and suggest if wider lane markings are needed.		
2.6	Road markings: Where the Consultant has indicated "deficiency in markings", it would be good to indicate what some of these deficiencies are.	Noted. The deficiencies will be mentioned.		
2.7	Sizes and retroreflectivity of signs: Consultant to confirm if this has been covered under the Proposed Manual	Confirmed, this is covered. Further, the Consultant has proposed to include guidelines for testing for retroreflectivity currently not present in the Draft Manual under review.		
2.8	Temporary signs: Consultant to ensure inclusion of temporary signs for roadworks.	Noted, temporary signs for construction period will be included.		
Road Safety Audit Manual				
3.1	Traffic Impact Assessments: Consultant refers to "small developments". Refer to Page 187 of the DRR. Revise this to encompass all developments requiring TIA.	Noted. Consultant to revise. TIA will be for all size of developments.		

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
3.2	Road safety situation in Kenya: Consultant to consider the relevance of this section bearing in mind the changing road safety landscape and statistics in the country.	The section is intended to provide situational information to road safety auditors who may not be familiar with the Kenyan landscape. Consultant to review to ensure relevance.		
3.3	Roadside safety: Consultant to review the provision for roadside safety in the Manual. What kind of roadside safety design is the Manual proposing?	Consultant to review. The Manual will however not provide detailed design for roadside facilities, but rather guidelines on best practice.		
Geometric Design Manual				
4.1	Rural and Urban Design Manuals: Proposed single Manual covering both aspects, with specific chapters delving into urban and rural aspects and cross referencing.	This will be adopted as discussed.		
4.2	Pedestrian issues: In urban cross sections, space for non-motorised traffic and pedestrians should be included. Consultant to consider latest research on human reaction time. Propose better methods to manage human behaviour – both for drivers and pedestrians. Must we have foot overbridges? Propose alternatives. Pedestrian behaviour crossing guardrails. Propose effective management in design.	Consultant will address the risk of pedestrian and consider the various aspects of tension between vehicular mobility and safety of pedestrians. This is to be incorporated both in urban road design and high mobility rural roads with pedestrian activities.		
4.3	Traffic surveys:			

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
	Road Design Manual Vol 1 Part 3 is Traffic Surveys. Clarification if this should be a separate standalone manual. Chapter 3 on Proposed Manual has data collection and analysis. Consultant to clarify what type of data	This will be a standalone document constituent of the Geometric Design Volume 1. Part 2: Traffic Surveys NOTE: Pavement design also has a chapter on Traffic Assessment and Estimation The traffic aspects will be cross referenced in other chapters. Traffic data for estimating future traffic.		
4.4	Urban road design: Speed should be different for urban and rural roads, trunk roads. One-way circulation should not be in isolation. It should be a part of larger scheme like BRT in urban areas. Traffic calming – international trunk routes pass through developments and urban centers. Speed humps used as traffic calming. Proposed Manual to suggest alternative effective traffic calming on such corridors.	The Draft manual did not consider the varying urban and rural speeds. Consultant shall also address selection of design speed in line with speed limits in urban areas. Design speeds out of phase with speed limit exacerbate risk of crashes. This aspect is not unique to Kenya but also in other countries not limited to LMICs. Consultant to incorporate international best practice of addressing ribbon development.		
4.5	Cross- section: Consultant to note that urban cross sections should be different from rural cross	This is noted and Consultant will address this in the Manual.		

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
	sections e.g., covered drains vis side drains. Proposed Manual to address these differences adequately. Consultant to address in the Proposed Manual effective width of a 7m carriageway with marking. If the width of the marking is included in the 7m width. Consultant to address the challenges of widening roads from 2-lane to 4-lane.			
4.6	Design speed and level of service: Level of service is difficult to estimate. Consultant to include in the Proposed Manual the most useful way to estimate LOS. Consultant to present charts in the Proposed Manual to make design easy for practicing engineers. Posted speed and design speed should be linked to class of road and cross section.	Consultant to address and provide charts/tables for easy determination of LOS and design speed. This to note that this might include further regulatory review on how speed limits are set, and the responsible jurisdiction.		
4.7	Intersection sight distance: Consultant to adequately address site triangle at intersections	Consultant will address		
4.8	Road classification: Proposed Manual to propose road hierarchy based on the latest road classification of Kenya.	The Consultant has received various documentation on road classification in Kenya-		

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
	Current classification systems to be reviewed emanate from: 1. RDM Part I – Geometric Design for Rural Roads, 1979 2. EGIS drafted Highway and Structural Design Manuals (Road Design Manuals) - 2009 Part 1 3. Roads Act 4. Legal Notice of 2016 5. System currently used on GoogleMaps	some are conflicting. Consultant to get back to the sub- Committee to provide guidance on the most recent and gazetted classification. The systems as given in the listed documents and platforms shall be subjected to review and findings included in the next version of the DRR.		
4.9	Access control: Consultant to suggest how to achieve full access control for high-speed facilities, then less access control for lower level of roads.	Consultant will address		
4.10	Economic considerations: Balance geometric design with economic considerations. Sometimes it becomes too expensive to construct high embankments.	Consultant will address and proposes optimal considerations. Additionally, safety considerations also critical.		
4.11	Headroom: There is inconsistency in headroom provided for bridges.	Consultant to address in the proposed manual and make considerations of overlay thickness during maintenance.		
4.12	Road signs and markings: This is indicated as a chapter in the Proposed Geometric Manual. Consultant to clarify if this is so.	Already provided for in the Proposed Manual - Traffic Control Devices. This section can therefore be cross referenced.		

TTF SUB-COMMITTEE SESSION: BRIDGES

RECORD OF COMMENTS/DISCUSSIONS/RESOLUTIONS

Consultancy Services for Review and Updating of Road Design Manual and Standard Specification for Kenya Ref. No. KENHA/PCS/342/2021

TECHNICAL TASK FORCE BRIDGES SUB-COMMITTEE MEETING No. 1
Review of the Draft Review Report

14th November 2022

TTF Sub-committee Comments and Consultant's Responses

Bridges and Retaining Structures

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
0	*Documents under review*	*RDM Vol 4, Part 1: Bridge and Culvert Design* *RDM Vol 4, Part 2: Retaining Structures Design*		
1	The current manuals and reference material currently in use do not clearly define use of bearings, especially elastomeric bearings.	Consultant briefed that bridge bearings will cover the detail description and design requirements for different types of bearings		
2	What will be covered under geometric requirement of bridges.	It will cover the guidance on alignment, vertical profile and related geometric parameters (width of carriageway, walkways, deck with, cross camber, etc.) in relation to the approach road geometry.		
3	What details will be provided under geotechnical requirements.	It will provide the guidance on geotechnical investigations required, number of exploratory boreholes and anticipated depth of drilling for the purpose of foundation design.		
4	The manual should cover the guidelines on different types of foundations	Noted The manual will cover suitability of different types of foundations depending upon the type of structure and the sub-soil strata.		
5	Consultant should study the existing design practices being used by the designers in Kenya. The vehicle live	Noted The consultant will study the design loadings in practice in Kenya. Consultant also pointed		

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
	loads given in BS 5400 and Eurocodes shall be referred.	out that Structural Design Eurocodes were adopted as Kenya Standards through the Kenya Gazette Notice No. 13048 of 14th Sept 2012.		
6	KeNHA have already issued some guidelines on lateral clearances at underpass. Consultant should refer these.	Noted		
7	The existing seismic design code in Kenya (1973) uses old methods of analysis. Consultant should consider the new methods like spectrum	Noted Consultant will consider the new methods, response spectrum method for analysis of the seismic forces Consultant requested Sub-Committee to assist in getting the updated seismic map, wind map and minimum & maximum temperatures maps of Kenya so that the manual can be updated with the latest parameters on these aspects.		
8	Joints & bearings requirements to elaborate in manual	Noted Consultant will include the different types of joints and bearings, their design requirements considering the permissible movements and rotations.		
9	What details will be covered under Reinforced Earth Walls	This chapter will cover different types of RE walls, facing and reinforcement materials, loadings and design requirements, stability, etc.		
10	Use of prestress concrete is gaining prominence in the region. Is it possible to give more details on Prestress Concrete like details of cables, tendons, anchorage design, maximum stress, etc.	Consultant briefed that prestress concrete design will cover all these details and the design requirements. Consultant also mentioned that Concrete Structures chapter will cover the both reinforced and		

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
	and consider the subject under separate volume/chapter of the manual.	prestressed concrete design. If the chapter becomes lengthy, then prestressed concrete can be provided under separate chapter. This will be reviewed at the time of preparation of the first draft.		
11	While proposing the bridge live loads, Consultant should consider Class of road and the appropriate loading for different class of roads. Consultant should also refer the EAC loadings. The EAC loadings shown by consultant during presentation (EAC Vehicle Load Control Act 2016) is old and should refer the latest.	Noted		
12	Consultant should also propose construction sequence	Consultant briefed that the construction sequence and the methodology of construction depends upon the Contractor and these are provided by the contractor before commencement of the works		
13	The bridge manual should also cover bridge maintenance	Consultant pointed out that as per the earlier discussions and finalised in TTF meeting dated 8th Nov 2022, the "Part 4: Bridge Maintenance Design" is out of scope of the proposed bridge design manual		

TTF SUB-COMMITTEE SESSION: PAVEMENTS

RECORD OF COMMENTS/DISCUSSIONS/RESOLUTIONS

FLEXIBLE PAVEMENTS - NEW

Consultancy Services for Review and Updating of Road Design Manual and Standard Specification for Kenya: Ref. No. KENHA/PCS/342/2021

TECHNICAL TASK FORCE - PAVEMENTS SUB-COMMITTEE MEETING No. 1
Review of the Draft Review Report
RDM Part III: Materials and Pavement Design for New Roads

Tuesday – 14th November 2022

Venue: Panari Hotels & Resorts (Mombasa Rd)

TTF Comments and Consultant's Responses

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
0	*Documents under review*	*RDM Part III: Materials and Pavement Design for New Roads*		
1	**<u>Traffic:</u>** Axle load damage exponent in RDM III is 4.5. Can the consultant provide justification as to why they have proposed that a range of values be adopted. Estimation of traffic is done prior to selecting materials. *Not difficult, a spreadsheet can be used to establish various traffic values for different n values. For rehabilitation not difficult since type of materials already known.*	Research in recent decades has shown that the different exponents apply to different pavement configurations.		A single value of 4.5 should be stated for preliminary estimation of design traffic. A recommendation for the designer to undertake preliminary analysis using n = 4.5, and then undertake a sensitivity analysis using different exponents for different pavement configurations should be included in the manual. Consultant to provide a detailed analysis and discussion on the effect of adopting different exponents. Consultant to revisit the UK wear factors and the Australian approach.
2	**<u>Traffic:</u>** Axle load damage exponent. Can the consultant describe the effect of using different exponents for different materials combinations.	Using one value means that sometimes we are under-designing on occasion and other times we are over-designing.		A description will be included in the DRR.
3	**<u>Traffic:</u>** How has the effect of temperature been considered in the damage exponents proposed?	Temperature effect is considered by designing the appropriate asphalt mix, not by the damage exponent.		The Consultant requires temperature data and bitumen grades currently used in Kenya. Currently for surface dressing it is

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				80/100 pen and 60/70 used in Mombasa and Lodwar and other such hot areas. Trials conducted using 30/40 and 50/70. Trial evaluation reports to be provided to the Consultant and the Project Coordinator's office to be consulted to obtain temperature data from meteorology department.
4	**Traffic:** How is the effect of stiffer tyre walls considered in the damage exponent?	The stiffer tyre walls means that the different values of standard axles have to be used for different tyre and axle configurations.		Generally, for simplicity in axle load surveys, each axle shall be weighed independently instead of weighing by axle groups and tyre types. For critical roads, a designer is expected to undertake performance design and will be required to assess the various effects. This will be emphasised in the manual.
5	**Traffic:** The formula for calculating the axle load equivalency factor is limited to 13 tonnes. What exponent does the Consultant propose should be used use for loads greater than 13 tonnes? **Addition from plenary:** The proposal to limit the maximum axle load in design to 13 tonnes is welcome but the Consultant should remember to add that if the excess axle load above 13 tonnes should be converted	To be further investigated. However, it is cheaper to enforce axle load control than to design for overloaded axles. The EAC Vehicle Load Control Act limits axles to not more than 10 tonnes with a tolerance of 5% (up to 10.5 tonnes), designing for over 13 tonnes would surely be too expensive. NOTED		Consultant to search for literature on this. The EAC Vehicle Load Control Act 2016 has made changes to permissible axle loads. The tandem load permissible is now 18 tonnes as opposed to 16 tonnes in the RDM III. The maximum permissible axle load to be designed for to be 13 tonnes? A policy decision to be made. Statement to be included in the manual.

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
	to generated traffic, because if axle load control is enforced then the excess load will generate traffic.			
6	**Traffic:** Local materials should be taken into consideration in choice of pavement structure, it should not be done the other way around, that is, by selecting an exponent for a pavement configuration and then looking for materials for that configuration.	Noted		A statement to that effect will be included in the manual.
7	**Traffic:** What should be done with the VEFs in the RDM III?	Suggest that it be based on road classes (not names of specific roads) and using recent axle load data.		The summary of VEFs on Kenya Roads should be included/moved to the appendices and categorised by road classes. MTRD to avail recent axle load data.
8	**Traffic:** The practice is to compute CESA for each vehicle class before summation. More emphasis is required in the RDM III.	Noted.		More emphasis is to be added in the RDM III.
9	**The Natural Environment:** There is a need for updated rainfall and temperature maps in RDM III. The zones may not change substantially. The consultant should check with meteorology department.	Noted.		The Consultant to liaise with the Project Coordinator's office to obtain this from the meteorology department.
10	**The Natural Environment:** The matrix of temperatures, and rainfall in the RDM III should be updated using recent data, and a matrix on evaporation should be included.	Noted.		The Consultant to liaise with the Project Coordinator's office to obtain this from the meteorology department.
11	**The Natural Environment:** The RDM III discusses 6 climatic zones. The cut-off is	The Consultant recommends three zones to enable use of more		Even in zones with rainfall less than 250 mm, sometimes there is flooding

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	rainfall value for wet/dry areas is 500 mm. The TRL study of 1996 recommended another zone at 250 mm. What does the Consultant recommend? **<u>Addition from plenary:</u>** The Consultant should liaise with Kenya Roads Board for the HDM-4 Workspace that includes calibrated climatic factors for the six zones of Kenya.	plastic materials in zones where the rainfall is less than 250 mm.		lasting for several days and weeks. Keep only two rainfall zones. All subgrades will be classified on the basis of 4 days' soaked strength. Materials classification will be dealt with separately as has already been initiated in LVSR 2017. Noted. Consultant to contact KRB.
12	**<u>Drainage and Erosion Control:</u>** Regarding erosion control. Propose to retain in the RDM III, but also cross-reference to hydrology and drainage manual.	Noted.		Retain erosion control in the RDM III, but also cross-reference to hydrology and drainage manual. Emphasis on sub-surface drainage and use of geo-textiles to enhance drainage, and also to minimise migration of fines.
13	**<u>Subgrade:</u>** For subgrades, why should the RDM III move to classifying at 90-93% MDD modified proctor? It is known that modified proctor may be best for granular soils while standard proctor is useful for soft soils. Over-compaction could lead to generation of fines. *use of geomembranes used as separators can minimise migration of fines.* **<u>Addition from plenary:</u>**	The Consultant proposes a move to 90-93% MDD modified proctor due to availability of powerful compaction equipment. **<u>Addition from plenary:</u>**		For subgrades, the classification 100 % MDD standard proctor shall be retained. This is due to the comprehensive empirical study undertaken. The Consultant may propose a study for conversion/ correlation to modified proctor. In special cases, a designer will be free to use the modified proctor. This will be emphasised in the manual.

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	With modern construction equipment, it is possible to achieve higher compaction. *The classification of the subgrade, for example S2 should not be based on strength alone, particle size distribution should be considered.* Still emphasise that a study must be undertaken before such a move. *Other countries including Kenya's neighbours have already moved. Kenya should think of moving to heavy compaction, especially for granular materials where the classification using heavy compaction is more meaningful. Light compaction is useful for fine-grained materials.*	There should be a reconsideration to move from the standard proctor to the modified proctor. This is because use of the modified proctor will lead to thinner pavements and save on construction costs.		The resolution made in the sub-committee still stands.
14	**<u>Subgrade:</u>** What the manual should provide are general provisions. In special cases heavy compaction may be recommended and other aspects such as the use of geofabrics and separators to prevent pumping of fines that could be generated by heavy compaction. Cut-to-spoil is very common these days and materials are wasted unnecessarily. Geotextiles may help improve material performance. *RDM III provides for a wide range of materials even*	Noted.		The manual will allow for special cases where these can be used.

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	expansive soils may be used to form embankment.			
15	**<u>Pavement Materials:</u>** In Chapter 7 on materials, should include guidance on blending of materials.	Noted.		Guidance on blending of materials to be incorporated in the materials chapter.
16	**<u>Pavement Materials:</u>** Classification of materials: Currently the RDM III sometimes refers to materials as "base quality" but applied to the sub-base. This includes Cement Improved Gravel and GCS. For ease of use a revision to this system should be made and materials codes should be used.	For consistency, propose the use of codes as in LVSR Guide, but revised and expanded should be used.		The materials codes adapted (to reflect the strength) from TRH 4 and used in the LVSR Guide 2017 will be amended, expanded, and used in the RDM III. e.g. G80 vs G4., HIG160, HBG2, HMS3. Brief materials description/specification is presented in a table and linked to traffic class and applicable layers.
17	**<u>Pavement Materials:</u>** For asphalt mix design, what does the consultant recommend? Currently the DRR only states that mix design approaches will be included in the update. What does the Consultant recommend based on the 1996 TRL study that recommended enhancing Marshall design by using refusal density design, and Superpave grading? The MTRD has had to increase the number of gyrations from 205 to 300 in order to make Superpave gyration compaction match the vibratory compaction for refusal density method.	The DRR was drafted and focussed at identifying the gaps. It was felt that once gaps are identified then solutions can be provided. In the revision, the Consultant will make recommendations on what to adopt. The use of refusal density to enhance Marshall is highly effective.		For low volume roads, Marshall mix design will be recommended, for medium and high volume roads = modified Marshall with vibratory hammer + Superpave grading + surface treatment. If stone crushing during vibratory compaction then change stone spec. For special cases or critical roads, performance design incorporating Superpave (carefully).

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	Currently outstanding in Kenya is the performance grading of binders. Marshall mixes have not resulted in high modulus asphalt but have improved reliability of results. Marshalls in Kenya, it is common to get stability of 12-15 kN. Many Superpave projects in Kenya have not implemented it to the full specification. Refusal density design has worked well on roads such as Mai Mahiu - Larnet, Malaba Rds. **Addition from plenary:** For asphalt mixes, the Consultant should look at what is not available in the RDM III, such as modified binders due to their importance in highly trafficked roads.	What is the experience in using Superpave in Kenya? Noted.		The Consultant has included this in their in the DRR; the point is noted.
18	**Pavement Materials:** The use of reprocessed material should be included.	This has been included as recycling.		There should be a distinction between recycling and reprocessing and guidance should be given for both. For asphalt there is usually a reduction in quality if recycled as asphalt. Recycled materials generally very good for sub-bases or bases in some cases.
19	**The Structural Design Method:** Which asphalt fatigue laws will be adopted?	The Kenyan fatigue models as presented in Figure 8.2.2 but no equations are available.		The Consultant should refer to the Egis draft where these equations have been defined.
20	**The Standard Pavement Structures:** Between a combination of catalogues, charts and	The issue raised by the Chief Engineer Materials was that the catalogue structures are based on		Catalogues should be presented for all traffic classes up to 150 MESA. However, above 60 MESA,

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	mechanistic analysis, what does the Consultant recommend? It should be noted that the catalogues in RDM III were determined mechanistically. Those in LVSR 2017 were determined using an empirical basis but checked mechanistically. **<u>Addition from plenary:</u>** The ranges of the traffic design classes should be reviewed. For example the range from T1 from 25 to 60 MESA appears large. It is recommended to select the median and then do a sensitivity analysis to test the range if say traffic varied by 2% on either side.	the highest traffic in the range. This means that at the lowest range there would be an overdesign. To resolve this issue, it would mean that charts should be used.		the catalogues should be used as guide for design. The design above 60 MESA should be performance designs with foundations checked, and in addition mechanistic analysis used to check the design. The Consultant will review the traffic class ranges objectively. The default start position is to retain what is contained in the RDM III.
21	**<u>The Standard Pavement Structures:</u>** The key question should be what method will be used to determine the thicknesses beyond 60 MESA, before deciding how they will be presented? This is because of effects such as temperature, assumptions, several	The Kenya subgrade criterion for LVSRs, the Shell 50% criterion for medium and high volume roads, and the Kenya asphalt fatigue equations. The pavement evaluation reports by MTRD will be useful in checking proposed catalogue thicknesses. The depth of influence of vehicle stresses does not depend on the MESA and hence LLP principles apply and in most cases subgrade deformation is rare, so very thick pavements could be unnecessary. Why do designs vary from country		For low volume roads, the Kenya subgrade fatigue criterion will be used. For medium and high volume roads, the Shell 50% subgrade criterion will be used. For the asphalt fatigue, the Kenya equations obtained from figure 8.2.2 in RDM III will be used. Pavement evaluations in Kenya shows that these are representative even for Superpave designed mixes. The materials failure criteria for cement treated materials will also be used to check designs containing cemented materials.

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
	variables. This is why we need stringent specifications.	to country yet a tonne is a tonne everywhere?		
22	**Gravel Roads:** The gravel roads thicknesses shown in RDM III are not being used for design of gravel roads because they are regarded as too thick. Agencies are using only 150 mm. Is there a problem with those thicknesses? What do other jurisdictions specify? **Addition from plenary:** The RDM III provides a model for estimation of gravel loss but determination of some of the model coefficients is not easy. Additionally, it is better in designing gravel roads to always consider the formation, a foundation/capping layer, and a gravel wearing course. The capping will be beneficial during upgrading of the gravel road to a sealed standard. It is also important to know what road can be gravelled. The foundation/subgrade should not be less than S2 Class. S4 may not require gravel since the subgrade may already be sufficient.	for normal soils, any rutting or roughness can be corrected during grading cycles, and therefore 150 mm would suffice. However, in areas of problem soils, the methods proposed for addressing problem soils should be used prior to applying gravel.		The thicknesses will be reviewed with foundation approach to equivalent to at least S2 subgrade. Emphasis shall be made on the formation and forming of side drains. Then the wearing course of gravel applied. For problem soils, the methods of treatment of these soils will be applied prior to any gravel thickness design. Other methods of wearing course specifications shall be reviewed by the Consultant. Same resolution as above.
23	**Gravel Roads:** The risk assessment -based approach used in Australia and recommended by the Consultant would not be acceptable to the road users.	This approach requires timely maintenance interventions.		The risk assessment-based approach will not be adopted.

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
	It is recommended that for gravel roads we should be as simple as possible.			
24	**Gravel Roads:** Which is recommended for determining design traffic for gravel roads, MESA or CV/d?	Recommend that CV/d be used to its simplicity and the short design periods of unpaved roads.		CV/d will be used for determining design traffic for gravel roads.
25	**Gravel Roads:** Kenya's road network is currently about 230,000 km of which 180,000 km are under county governments. The Consultant should see if the RDM system can be simplified. Perhaps emphasis should be made on the formation of the road, improvement of the roads unpaved and gravel, also check what is contained in the labour-based manual if some of the principles can be adopted.	Noted.		The RDM thicknesses will be reviewed to simplify it to be useable at county government level and application of labour-based methods.
26	**Addition from plenary:** Did the sub-committee consider the use of the Do Nou technology for use in "last mile" roads? This could be used as base, then gravel applied to it. It could then later be sealed. Do Nou technology can be considered as geosynthetics. Geogrids on expansive soils contain the migration of cracks. A section on the use of geogrids could be included in the manual.			There is a separate guideline for Do Nou technology which is nearing completion. Goegrids are proprietary products and their incorporation in the revised manual requires performance evaluation of some trials, then a separate guideline for their use will be developed. For now they can be referred to in the revised manual as "having potential". They are known to enhance

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
				strength, but use for thickness reduction has not yet been confirmed.
27	**<u>Addition from plenary:</u>** The use of geogrids			

RIGID PAVEMENTS

Consultancy Services for Review and Updating of Road Design Manual and Standard Specification for Kenya Ref. No. KENHA/PCS/342/2021

TECHNICAL TASK FORCE PAVEMENTS –SUB-COMMITTEE MEETING
Review of the Draft Review Report

14th and 15th November 2022

TTF Comments and Consultant's Responses

Rigid Pavements

No.	Discussion item	TTF Comment	Consultant's Response	Ref in Revised Manual	Resolution
0	*Documents under review*	*RDM Part III - Materials and Pavement Design for New Roads; Part 5: Rigid Pavements*			
1	Copyright of images/diagrams from previous Egis draft (2016).	The committee repeated what was said last week, that they thought that the Egis consultant had handed over copyright to Kenya for all photos/diagrams in the draft manual but they would check with their legal department. Some of the diagrams appear to have come from other manuals. Action: Committee to check copyright status (with their legal department) of photos and diagrams in Egis draft.	Agreed		
2a	Which types of concrete pavement to include in the manual? 2a. Block Paving - should this be in Rigid Pavements section or in another e.g. Materials?	After discussions, the committee decided that Block Paving should be included in this chapter.	Agreed		
2b	2b. UTRCP – should this be in the concrete pavements or the rehabilitation section?	After discussions, the committee decided that UTRCP should be included in this chapter and also mentioned in the rehabilitation section.	Agreed		

No.	Discussion item	TTF Comment	Consultant's Response	Ref in Revised Manual	Resolution
3	Which Design Methods to Use for concrete pavements.	Committee said they did not have enough information to make a decision.	Action: Consultant to put together more information to help guide the committee on choosing which concrete pavement design method to use for each pavement type. The committee requested information on UK, South Africa, USA (AASHTO) and India (Not Australia). This information was requested before the Stakeholder workshop on 13th December 2022.		
4	Which concrete surface texture types should be included in the manual?	The committee would like all concrete surfacing types to be included in the manual to give designers a choice.	The consultant agreed that all of the main surface texture types would be included in the manual, including exposed aggregate surfacing, even though it may never be used.		
5	Cement Bound Material (CBM) sub-base. The consultant proposed to specify a CBM sub-base under all jointed concrete pavements, with the exception of very low trafficked roads.	The committee agreed that the sub-base should be bound, but could also be asphalt on less volume roads as long as it was erosion-resistant. A granular sub-base would still be allowed under a jointed concrete pavement for very low volume roads.			
6	Other - Should the RDM Chapter be called 'Rigid' or 'Concrete' Pavements?	After discussions, the committee agreed that the term 'Rigid Pavements' would be used, and that this could easily be changed later, if required.	Agreed		
7	Other – Use of fibres (e.g. glass, steel) in concrete .	It was asked by the committee if use of fibres (e.g. glass, steel) in concrete could be included in the Manual?	The consultant agreed that guidance would be included in the manual.		
8	Other –Transitions between concrete	It was asked by the committee if information about transitions between concrete and asphalt	The consultant agreed that this information		

No.	Discussion item	TTF Comment	Consultant's Response	Ref in Revised Manual	Resolution
	and asphalt pavements.	pavements could be included in the Manual?	would be included in the manual.		
9	Other - More construction information.	It was asked by the committee if more construction information could be included in the Manual?	The consultant agreed that construction information would be included in the manual and showed the proposed contents of the new manual that included a large construction section.		
10	Other – The consultant asked for copies of Kenya concrete reports and Kenya Concrete/ cement specifications, including concrete mix design.	The committee suggested that South African COTU and COLTO specifications should also be included in the references as they are planning to adopt these. Action: Committee to provide consultants with Kenya concrete reports and Kenya Concrete/cement specifications including concrete mix design and also South African COTO/COLTO specs if these are not freely available online.			

PAVEMENT REHABILITATION

Consultancy Services for Review and Updating of Road Design Manual and Standard Specification for Kenya Ref. No. KENHA/PCS/342/2021

TECHNICAL TASK FORCE - PAVEMENTS SUB-COMMITTEE MEETING No. 1
Pavement Maintenance, Rehabilitation and Reconstruction Design – RDM Vol 5
Review of the Draft Review Report

15th November 2022

Comments and Consultant's Responses on the Draft Review Report

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
0	*Documents under review*	*RDM Vol 5: Pavement Rehabilitation and Overlay Design*		
	Short falls in Initial Pages			
1	Both the 1988 and 2009 lack initial pages such as: Preamble and Preface which are key ministerial and authority declarations Table of Figures and Tables, acknowledgements, abbreviations, glossary of items. In 2009 version ToC is provided with each chapter instead of a full ToC in the initial pages – this makes navigation difficult for users *Proposal: To include all necessary initial pages and full ToC at the beginning* TTF Comments: In modern document esp. from SA have ToC separated into individual chapters but precedence is set in the LVR Design Guideline	ToC at the beginning make navigation easier for the users		Consultant to propose a layout which will apply to all parts of the RDM
	Short falls in Chapter 1 – Introduction (2009 draft is a copy of 1988 edition)			

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
2	Manual refers to sealed roads only *Proposal: to include design considerations for unpaved and urban roads* TTF Comments: Agreed to consider urban and unpaved roads			Statement should be changed to included sealed roads, urban roads and unpaved roads
3	Purpose of manual – Term 'rational management of sealed roads' is misleading and is appropriate for Road Network Management Manual. Specs for procedures for assessment for rehab. are different. *Proposal: to provide guidance for Pav. Maintenance, Rehab and Reconstruction Design and make reference to RAMS + documentation* TTF Comment: Network Planning and Management Manual will be produced separately. Highway Maintenance and Management System is being put in pace. Brief write up is required including general referencing. Management systems need to be simple and currently HDM4 is being used but training is required.	Consultant agreed to included write up.		Information to be brought in to define the purpose of manual focussed on pavement maintenance, rehabilitation and reconstruction and make reference to network level management. There is need for the consultant to visit or make a call to Kenya Roads Board on the issue of management systems
4	Periods of 2yrs for periodic maintenance and 4yrs for rehab are not appropriate	Consultant agreed with the approach and to keep the statement as in the manual		Periods of 2yrs for periodic maintenance and 4yrs for rehab planning will remain but 2yrs

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
	Proposal: 5-7yrs for periodic and 15-20yrs for rehabilitation. TTF Comments: These periods refer the planning processes from decision to the implementation of works, not design life or scheduling of periodic maintenance			for period maintenance could be changed to 1yr if condition surveys are carried out annually
5	Key Definitions: Section 1.4 refers to Maintenance and Upgrading and Section 1.5 refers to Rehabilitation, Strengthening or Reconstruction. *Proposal discussions required on these definitions* TTF Comments: Maintenance should be taken to a separate maintenance manual and condition surveys should be a chapter in Vol 5	The maintenance referred to will be part of the interventions following the condition surveys for rehab. and not general maintenance.		Manual structure to be retained as agreed by the TTF General maintenance to be included in Road Asset Management Manual
	Short falls in Chapter 2 – Planning Considerations (2009 draft is a copy of 1988 edition) – well written and covers general network management, road transport economics and impacts of investments.			
1	It lacks referencing to RAMS, HDM4 or RED Models, etc. for performance and road economics. *Proposal: reference to be made to performance and economic tools.*	Consultant agreed to provide the information		Proposal accepted. It was agreed to provide the additional information also targeting policy makers

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
	TTF Comments: HDM4 is currently in use. This information is particularly important for policy makers			
2	The information provided is inadequate for application. Proposal: to reference other documents relevant to planning for more details. TTF Comments: Agreed and consultant should enrich this section.	Agreed		Proposal accepted. Concise information to be provided with appropriate referencing
	Chapter 3 – Shortfalls: Both manuals provide a list of defects, possible causes, pavement behaviour and deterioration.			
1	Title in 2009 limits the manual to visual destress *Proposal: to use title in existing manual 'Pavement Behaviour and Deterioration'* TTF Comments: Agreed	'Pavement Behaviour and Deterioration' provides wider coverage than visual destress		Agreed to use 'Pavement Behaviour and Deterioration'
2	Coverage in existing manual is too brief *Proposal: to include interpretation of defects and field and lab results and add photos in Appendix. Details of test standards to be covered in RDM- Vo l4-Part 1 Pavement. Condition Surveys)* TTF Comments: The current Maintenance Manual provides a catalogue of defect and possible remedies and should be	The pictures are good, but the coverage is not adequate. Some defects are caused by a combination of causes and interpretation is important e.g., distinction should be made between causes of cracks in pavements related to pavement failure or geotechnical problems		Information that adds value should be added as necessary

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
	appended to the PCS Vol 5 Part 1			
	Shortfalls in Chapter 4 –: Pavement Surface and Structural Condition Evaluation and Analysis			
1	Pavement evaluation: Existing manual provides PSR (subjective), PSI (rideability) *Proposal: to retain PSR and PSI and add a new approach 'Deterioration index, DI. DI=RdI + DfI + PPI + CrI). Index = extent x severity* TTF Comments: Which jurisdictions is this system being use e.g., UK, AASHTO, Australia, South Africa? It is preferred that concepts to be included in the manual are adopted in these during jurisdictions as per the ToR. KRB has adopted IRI and PSI. PSR is in RDM and PCI in ASTM. New knowledge is welcome so it should be in the appendix.	The Deterioration Index was a result of research carried out by TRL in several countries in Sub-Saharan Africa and is now included in manuals in Mozambique and the Rural Road Note also by TRL		Consultant to look at UK, AASHTO, Australia, South Africa and propose It was agreed to include Deterioration Index as an appendix.
2	Structural Evaluation: Existing Manual - Field testing – Benkelman Beam (D90) for uniform section structural strength + DCP, plate bearing and test pits. 2009 draft also includes FWD. Other common and modern tests are missing. *Proposal: to retain above tests and add ultrasonic & laser profilers, LWD, straight*	Some of the tests are not common but useful e.g., the Light weight deflectometer, which can measure deflection, CBR, surface modulus of pavement and underlying layers including the subgrade which are required for design. The FWD cannot be used to test surface modulus of underlying layers directly. Other tests are suitable for LVRs. GPR is useful for urban roads esp. for		It was agreed that the consultant should develop this further and recommend.

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	edge, Merlin, Roughometer, Road Lab App (WB), deflectograph?, GPR, LB Tool Kit, Skit Resistance, coring, etc. TTF Comments: Consultant has proposed many methods some of which some are not useful. Benkelman Beam is included in RDM. The design methods should be presented.	mapping out utilities under the pavements. The labour-based tool kit is useful for investigation on unpaved roads, etc.		
3	Investigation procedures: Procedure given in existing manual indicates regular spacing of test points – only appropriate for deflections *Proposal: to improve procedure to be systematic and based on results for more accurate evaluation* TTF Comments: Agreed. Any improvements to the procedures should be included. There is need to distinguish between network and project specific procedures including test intervals esp. for problematic soils.	The intention is to establish more robust procedures that can be used for investigations where FWD can be at regular intervals and subsequent tests positions and frequency are determined on the basis of results of previous tests e.g., locate further tests on the weakest and strongest points as indicated by results of previous tests.		It was agreed that the consultant would propose procedures that could improve the investigations procedures.
	Shortfalls in Chapter 5 –: Criteria for Maintenance and Rehabilitation: Very well written and still valid to date.			
1	Intervention Thresholds for **Cracking**: local patching - 5m/m^2. **Overlay** - 30-50% of wheel paths *Proposal: to do crack sealing each year before the rainy*	The proposed approached involves road pavement preservation. It is not advisable to allow the road to deteriorate significantly before the interventions. Generally, the		The proposed approach was agreed. Consultant to review and check

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
	season + reseal soon after crack initiation unless clearly localized + use Indices TTF Comments: Crack sealing should be part of routine maintenance and is a very simple and cheap exercise	approach is when crack initiation starts it means that the binder at the top of the surfacing has deteriorated and cracks should be sealed and a reseal or thin overlay should be applied and not wait until there are numerous potholes.		intervention intervals. Thresholds for intervention should be set properly and based on the class of road.
2	Intervention Thresholds for Rutting - reaches 15mm for 20% of the section *Proposal: 15 mm at 90%tile of values, fill rut with medium grading AC, regularize then reseal or apply thin overlay.* TTF Comments: Agreed to use percentiles. Percentiles are a good statistical approach.	By the time the affected section reaches the extent of 20% part of the section that reached 15mm first could be over 20mm so percentiles of measurements is a better evaluation method.		It was agreed that to use the percentile approach.
3	Intervention Threshold for Major Overlay or Reconstruction: mean rut depth = 20-25mm *Proposal: Need to discuss terminal condition of a pavement? Also need to definite the type of rutting, pavement layers affected, or whether de-densification has occurred.* TTF Comments: This is a serviceability limit.	It is not normally the case that when a rut reaches 20mm then the subgrade has failed. Subgrade failures are rare. There is need to investigate so that if it the rut is due to densification of upper layers then it can be filled with compacted AC and section is then resealed with surface dressing or thin overlay. If there is de-densification of the layer(s) then the affected layers should be reconstructed.		Consultant to review thresholds and recommend. Thresholds should be set differently for different classes of roads
4	Intervention threshold for Surface roughness : Reseal IRI – 2.8-3.1. Overlay and Reconstruction – IRI 3.4-3.7. These criteria are not appropriate e.g., could be backlog maintenance.	This roughness could be a that potholes are not patched in time and not necessarily pavement failure.		Consultant to review limits and recommend. Consultant to give guidance on IRI thresholds for

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
	Proposal: applicable when deformation or irregularities are due to structural deformation. PSI of 3.0-2.5 to be maintained TTF Comments: This is serviceability limit. It is not clear which			different classes of roads.
5	Deflection criteria of Tolerable Deflection is a good approach, Chart in Figure 2 *Proposal: Chart may require review to extend traffic loading to 80MESA from 10MESA in deflection/traffic loading (Kenya Model). Australian Model is a good platform (provides charts for different scenarios*) TTF Comments: This also involves pavement design and should be looked at by both experts	Low deflection has resulted in good performance of surfacings and the pavements in general		Extension of limits in MESAs to be discussed between Rehab and Pavement Design Experts.
6	Product rd Criteria – product rd depends on depth and moduli ration e1/e2 for 2-layer system. Scatter is common. Threshold values are set for adequacy of pavement *Proposal: to discuss applicability experience in Kenya*. TTF Comments: The RDM use the Benkelman beam deflections, product rd, radius of curvature, etc.	Agreed to retain method		The consultant should further expound on this and other methods.

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
	Shortfalls in Chapter 6 –: Techniques and Materials for Road Strengthening TTF Comments: Materials are covered in existing Part 3 and will be covered Vol 3 Design of flexible Pavement, and the 2 experts should meet and discuss the proposed changes and extensions to limits given in the current Rehabilitation and Overlay Design Manual.	These are materials that are also covered in Part 3. Extensions to limits of traffic loading (MESAs) and general application of different materials needs to be reviewed and extended because some are too low prohibiting wider use of material effectively.		It was resolved that Vol 5 Part 2 should provide brief information and make reference to Vol 3 Design of Flexible Pavements. Reliability levels need to be checked for further discussion Report of pavement performance evaluation will help in the determination of thresholds for Kenya
1	Surface water – does not cover inundation in extreme flooding, sheet flooding, vortices and wingwall design and criteria for erosion protection + hydraulics *Proposal: to include hydraulics check for adequacy and erosion control and/or references* TTF Comments: Agreed. Some of this will be covered under hydrology and drainage.			Consultant to review, recommend cross-reference with hydrology and drainage design.
2	Types of Overlays – existing manual recommends use of flexible, semi rigid and rigid options in place or in combination with asphalt. *Proposal to provide details on implications for the*	Extension of limits is required for flexible pavements and the materials		Consultant to give guidance on how to characterise materials for overlay design in terms of E values and structural

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
	design + extension of flexible pavements for traffic beyond 10MESA TTF Comments: Characterisation of materials is important, and the same material can be classified as base or subbase or surfacing depending on the design requirements			coefficients. This should be coordinated with Pavement design.
3	Hydraulically bound materials – Manual limits these to 3MESA max *Proposal to extend CTB to 80MESA if not more*	Same as (2) above		Same as (2) above
4	Graded crushed stone – Manual limits to 10MESA max and considered where gravel is unavailable *Proposal to extend to 80MESA or more, and it is a better option to gravel for strength* Performance of GCS is dependent on the support of the underlying layer and can perform if supported by CTB	GCS works for all types of traffic and at least up to 80MESA and should not be limited to 10 MESA even without CTB		Extension of limits regarding MESAs to be discussed for Vol3.
	ETB – manual recommends 2% emulsion stabilization (Proposal to include ETB design, based on strength and moisture sensitivity or reference Vol 3)	See (2) above		See (2) above
	Rapid binder deterioration in Kenya – binder harder than 60/70 not recommended (Proposal: harder binders can be used where necessary with a seal on top)	See (2) above		See (2) above

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	Medium grading AC – limited to 10MESA (Proposal to extend to 80MESA for 50mm thickness with low allowable deflection <150 microns)	See (2) above		See (2) above
	DBM limited to T1 or less (Proposal to apply DBM for all traffic loading)	See (2) above		See (2) above
	DEM limited to T1 or less (Proposal to apply DBM for all traffic loading)	See (2) above		See (2) above
	Cement stabilized gravel – manual recommends plant mix (Proposal to include in-situ mixing considering use of disc harrows and esp. pulvemixers)	See (2) above		See (2) above
	Shortfalls in Chapter 7 –: Structural Design of Overlay for Flexible Pavements			
1	Design period – definition 'end of period where strengthening will be required' 7-15yrs *Proposal to define design period as 20yrs and reliability levels of 95% for HVRs and 90% for MTR and 80% for LVRs* TTF Comments: Reliability levels have to be checked and further discussed. Kenya uses 20yr design life for rehabilitation, but there are cases where the client may require an interim solution due to budget constraints	Agreed incorporate possibility of design for interim solutions		Proposal is agreed. Reliability levels need to be looked at and consultant to propose.
2	GCS – not recommended for deformable pavement	Agreed		As stated for materials under Chapter 6 above

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	Proposal: to remove TTF Comments: Already discussed and to be part of Vol. 3			
3	Design of overlays for flexible pavements: Current manual provides for Multilayer linear elastic method. 2009 draft also has AASHTO Structural Number Method (SN), *Proposal to include the above + consider catalogues method, deflection reduction method, South Africa ME Design method, DCP for LVRs.* TTF Comments. The RDM uses Benkelman beam i.e., radius of curvature, product rd, D90 vs MESA, etc. and need to be included. Also, FWD moduli for all layers is covered. Not comfortable with DCP method but as an investigation tool. Also are we going to consider composites e.g., AC over concrete?	Agreed with comments. Most design methods have their flaws, and these should be taken into account. Composite overlays will be considered.		Consultant to check design methods used in UK, USA, India South Africa and Australia and recommend The shortfalls in the designs need to come out clearly regarding the residual life and design for future traffic in the overlays
	Shortfalls in Chapter 8 –: Structural Design of Overlay for Rigid Pavements			
1	Design of Rigid Pavement *Proposal to include in the Pavement Design for Rigid Pavements Volume 3* TTF Comments: The Maintenance is minor, and the processes involved in			Agreed to include rigid pavements together with design of new pavements

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	design and rehabilitation are similar.			
	Shortfalls in Chapter 9 –: Other Rehabilitation Techniques and Reconstruction			
1	Missing other surface treatments including Otta seals, cape seals, penetration macadam, etc. *Proposal: to include other seals e.g., micro surfacing* TTF Comments: Cape seal is in RDM Part III but may not be used for HVRs. Could work on HVRs as a seal over AC, e.g., DBM +SD +slurry would work very well	The bad experience on Cape seals in Kenya could have been due to poor construction. It has worked for high volume roads e.g., in Zimbabwe.		Consider Cape seal for medium traffic and LVRs.
2	Inlays – deterioration is top down *Proposal to include inlays as a major intervention* TTF Comments: Agreed.			Inlays to be included, and will be most useful in rehabilitation of urban roads
3	Recycling (reference to RDM Vol 3)			Agreed
	Proposal for Additional Chapters			
	Chapter 10: Rehabilitation design considerations for Urban Roads. **The Need**: • Inlays • Rapid setting options and discrete elements • Need to maintain road surface levels • Incorporation of utilities • Design of pathway, cycle lanes, etc.			Agreed

Item	TTF Comment	Consultant's Response	Ref in Revised Document	Resolution
	TTF Comments: Agreed			
	Chapter 11: Rehabilitation design considerations for Unpaved Roads. **The Need:** • Periodic Maintenance • Rehabilitation • Design Labour-based application TTF Comments: Agreed.			To check model for gravel loss for various jurisdictions and compare
	Chapter 12: Special designs for Resilient Pavements: **The Need** • Pavement profiles (hydrodynamic and prevention of vortices • Materials of low heat and moisture sensitivity for strengthening layers or inlays • Armouring and pitching of pavements • Drainage enhancements TTF Comments: This is more of materials and drainage improvements The issue of climate mitigation is important especially materials carbon with low and construction methods with low carbon footprint	Agreed		Materials to be handled under Vol 3 and drainage under Hydrology and Drainage Design. Make references. Climate mitigation and resilience needs to be covered in detail.
	General shortfalls in design methods			To be presented to MTRD

Consultancy Services for Review and Updating of Road Design Manuals and Standard Specifications for Kenya Ref. No. KENHA/PCS/342/2021

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