AN APPRAISAL OF THE GHANA HIGHWAY AUTHORITY ROAD DESIGN GUIDE

By

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DECLARATION

I hereby declare that this submission is my own work towards the Master of Science and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in text.

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Head of Department Signature Date

DEDICATION

I dedicate this work to all highway design engineers in whose name and for whose benefit this study was undertaken.

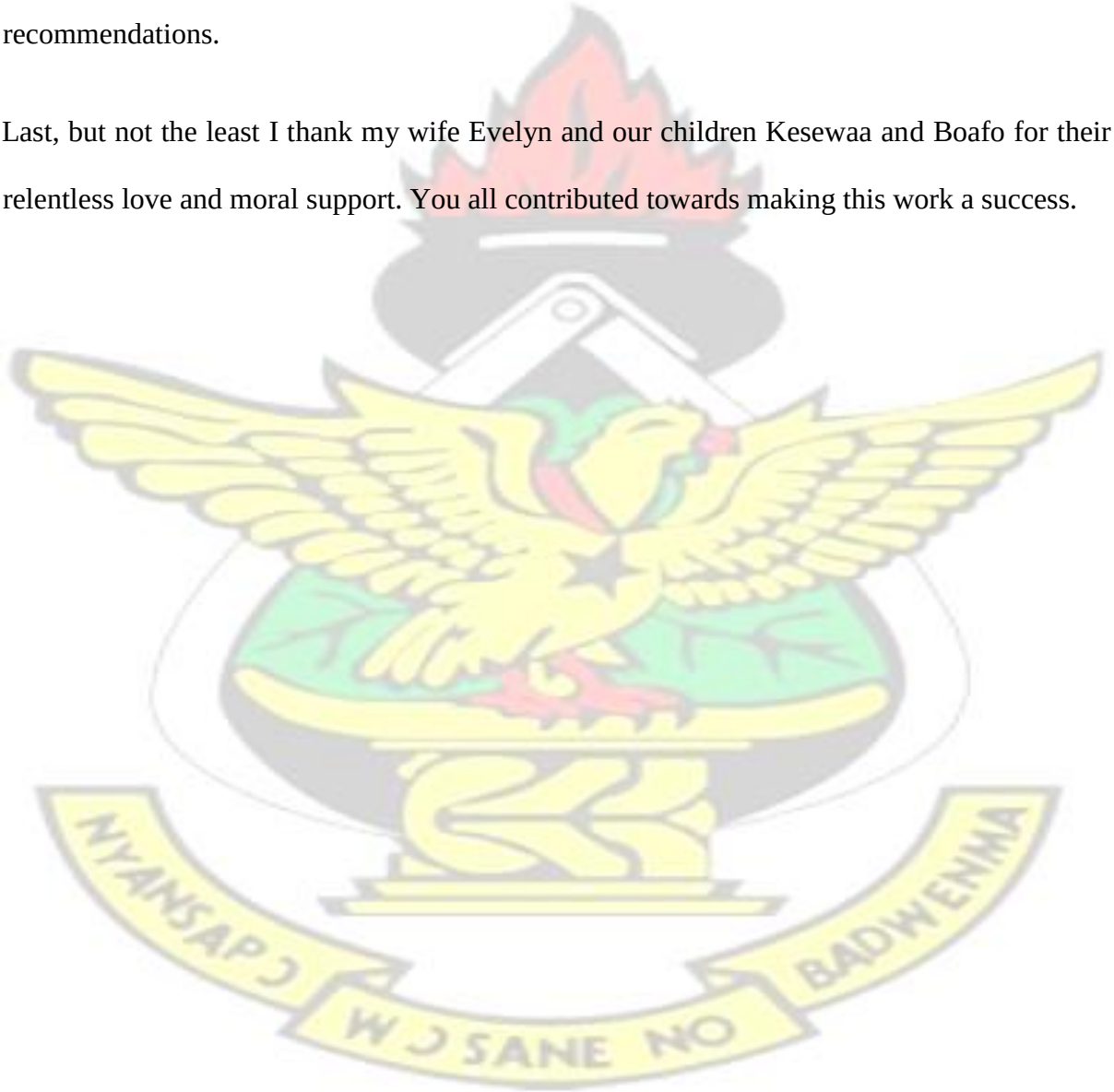
ACKNOWLEDGEMENT

I first thank God almighty for the gift of life and the strength to course through this Master of Science programme**.**

Secondly, I thank my supervisor Dr. Charles Anum Adams for guiding me through this study.

I also thank all respondents to the survey questionnaire and staff of the Ghana Highway Authority, whose immense contributions laid the foundation for analysis and recommendations.

Last, but not the least I thank my wife Evelyn and our children Kesewaa and Boafo for their relentless love and moral support. You all contributed towards making this work a success.



ABSTRACT

The Ghana Highway Authority Road Design Guide (GHA RDG) is over two decades old since it was published as a draft document in 1991. It was expected to be periodically updated and revised based on observations, comments, suggestions and criticisms from stakeholders as they utilised it. As of October 2015 however, no update or revision has been carried out. Increasingly, designers undertaking projects for the Ministry of Roads and Highways, in-house design engineers in the Ghana Highway Authority, consultants and other expatriate designers of projects in Ghana are resorting to the use of several other manuals as references for highway designs. As a result of this highway design in Ghana has become more laborious; it is difficult to ensure uniformity of design, consistency of designs across the trunk road network and also vetting of consultants' design presentations has become very laborious. The aim of this study was to make an appraisal with a view to modifying the Guide. The specific objectives of this study were first to critically assess the suitability of the GHA RDG and its contents regarding capacity, safety and economy for the geometric design of elements for modern trunk and urban roads. Secondly, the study was also to make an assessment of commonly used sources and standards for road element design in Ghana over the last ten years and thirdly to provide a theoretical basis for inclusion or otherwise in the GHA RDG. In order to achieve the objectives of the study views of experienced highway designers regarding the suitability of the GHA RDG for current highway design were sought through the administration of questionnaire. The GHA RDG was also compared with some current highway design manuals in Africa and the United States of America for suitability. The results indicate that the GHA RDG does not meet several of the requirements for current highway design in Ghana. Because of its deficiencies, highway designers in Ghana are resorting to other standards including the Green Book, AASHTO's A Policy on Geometric Design of Highways and Streets, and the Ugandan Geometric Design Manual, to mention a few, as references for geometric design. It is therefore necessary to revise several aspects of the Guide to ensure its suitability for modern highway designs in Ghana. Also, many areas would require revision and the inclusion of several topics which are not covered. A recommended table of contents for a revised GHA Road Design Guide has been proposed.

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CHAPTER 1: INTRODUCTION

1.1 Background

The use of highway design standards, often presented as highway design guides or manuals, is to fulfil a number of objectives, key amongst which are:

1. To ensure minimum levels of safety and comfort of road users
2. To arrive at an economic design
3. To maintain uniformity in alignments, drainage and other road facilities
4. To ensure sufficient capacity of road sections, intersections and other road related facilities in order to cater for design traffic demand

In 1991 the Ghana Highway Authority (GHA), drawing from unwritten Ghanaian standards and some standards or guidelines for design in use in countries like Japan, Britain, USA and Malawi amongst others, put together a draft Road Design Guide (RDG) to be primarily used by road designers in GHA and also some local and foreign consultants. This was a period when most designs were carried out in-house. It was intended to also serve the needs of the Department of Feeder Roads and the Department of Urban Roads. The Road Design Guide was a draft document expected to be periodically updated and revised based on practice, observations, comments, suggestions and criticisms from all stakeholders (GHA, 1991). As at October 2015 however no update or revision had been carried out. Over two decades after its publication vehicle standards have improved, concepts for safe design roadways have seen tremendous improvement. Also, the use of computers has dramatically changed how designs are carried out and also the level of accuracy that can be achieved.

1.2 Problem Statement

In Ghana an urban area is defined as any settlement inhabited by 5,000 or more persons. Between the years 1948 and 2000 the number of urban areas has increased from 41 to 364 (UNEP et al., 2012). The vehicle population in 2005 was 767,067 and this increased to 1,127,986

in 2009 resulting in an annual average growth rate of 8.3% during that period (MRH et al., 2011). In recent times, elevated highways, grade-separated intersections, multi-modal intersection designs, forgiving road environment and smoother alignments are being employed more for better traffic management and safety. This has resulted in the implementation of infrastructure projects such as the Tetteh Quarshie interchange (Accra), the George Walker Bush Highway (Accra), the Achimota – Ofankor multi-lane 'segregated' with varied access controls highway (Accra), the Sofoline Interchange (Kumasi), the Asokwa Interchange (Kumasi), the Nkawkaw by-pass, the Nsawam by-pass, and Suhum Interchange, to mention a few. There is therefore an increased need for designs to handle higher levels of traffic and traffic conflicts with a view to safety and economy. In other words there is the need to design roads which allow for greater mobility and speed without endangering the safety of pedestrians and other road users.

The GHA Road Design Guide provides some level of uniformity of design where designs fall within its scope. However, it is deficient in solutions such as roundabouts, grade-separated intersections and certain other aspects of geometric design like 'broken-back' alignment situations and number of curves per kilometre. These and others are reasons necessitating its revision.

Increasingly, in-house GHA highway geometric designers, and consultants undertaking designs for the Ministry of Roads and Highways are resorting to the use of several other manuals as references for highway designs in Ghana, and as a result:

i) Highway design in the Ghana has become more laborious for the designer ii) It is difficult to ensure uniformity of design across the trunk road network iii) Vetting of consultants' designs has become very laborious for road agency staff It is not even clear which manuals are most frequently utilised and for what purposes or elements of design. Should the GHA RDG be revised? What additional content might be necessary to be included and for what purposes

or design elements? This study sought to find answers to some of these searching questions by engaging stakeholders and undertaking a review of literature.

1.3 Study Justification

The results of the study would achieve the following:

i) Establish the strengths and deficiencies in the GHA Road Design Guide (1991).

ii) Improve upon the understanding of what manuals and guidelines are being used for designs in Ghana. iii) Recommend modifications to be considered in the revision of the GHA Road Design Guide (1991).

1.4 Study Objectives

The objectives of the study were:

i) Assess the suitability or otherwise of the GHA Road Design Guide (1991) for the geometric design of elements for modern trunk and urban roads.

ii) Make an assessment of commonly used sources and standards for road element design in the last ten years and provide a basis for inclusion or otherwise in the GHA RDG.

iii) Propose a detailed Table of Contents for a revised Manual, highlighting the main elements and requirements.

1.5 Scope of Study

The focus of the research was the geometric design of trunk and urban roads. The study therefore covered the following:

i) Theoretical assessment of geometric design criteria, controls and elements in the GHA Road Design Guide.

ii) Comparison between GHA Road Design Guide and other geometric design manuals.

iii) Recommendations for inclusion with future revision of GHA Road Design Guide.

1.6 Study Limitation

The study was conducted within a relatively short period of time. Consultations with stakeholders, based on which analysis was done, was therefore conducted within limited time. Views and comments of a broad spectrum of stakeholders could therefore not be solicited. Hence although the findings, conclusions and recommendations of this study are a result of thorough analysis they may not be exhaustive.

CHAPTER 2: LITERATURE REVIEW

2.1 Definitions

An Appraisal is:

The act of judging the value, condition, or importance of something: the act of appraising something (Merriam-Webster Dictionary, 2015).

The act of examining someone or something in order to judge their qualities, success, or needs (Cambridge Dictionaries Online, 2015).

A Road Design Guide is a document that fulfils the following objectives:

1. Provides design criteria, requirements, and guidance on highway design methods and policies which are as current as practicable, and assures uniformity in the application of design practices consistent with collective experience (New York State Highway Design Manual, 2015).
2. Ensures minimum levels of safety and comfort of road users, helps the designer arrive at an economic design, helps to maintain uniformity in alignments, drainage, and other road facilities (GHA, 1991).
3. Provides major benefits of the harmonization of professional practice and the ensuring of appropriate levels of safety, health and economy with due consideration of the objective conditions and need of the country (MWHC, 2005)

2.2 Road Network Development Stages

In reviewing geometric design standards for developing countries some researchers noted that there are three (3) distinct stages of development of a road network, namely:

Stage 1 – Need to provide a basic means of communication between centres of population. At this stage little attention is paid to geometric standards. Emphasis is on all year round "passability".

Stage 2 – Need to build network capacity. Geometric design standards required are only for road width and gradient. Emphasis is on whether a road is paved and whether it has structural capacity

Stage 3 – Need to provide operational efficiency on network. Geometric standards are very important at this stage (Boyce et al., 1988).

The researchers observed that developing countries are not usually at Stage 3 and yet employ standards generally developed for countries at Stage 3. The result is that economic and safe designs are achieved for high volume roads. They argued that the use of the same standards for low volume roads produces uneconomic and technically inappropriate designs.

GHA Road Design Guide was compiled drawing from empirical Ghanaian knowledge and standards based on practice. Some of its constituent standards were adapted from standards in countries such as Japan, Britain, USA and Malawi for their practicability in Ghana. Over two decades after its first publication there is the need however to assess the extent to which the GHA RDG satisfies the geometric needs of the entire network of trunk and urban roads at various stages of development.

2.3 Stages of Development of Ghana's Trunk and Urban Road Network

According to UNEP et al. (2012) an urban area in Ghana is defined as any settlement inhabited by 5,000 or more persons. The author found out that between the years 1948 and 2000 the number of urban areas in Ghana has increased from 41 to 364. The author explained that the rising trend of the urban areas has been occurring due to rural – urban migration, natural increase in towns and cities, reclassification as villages grow into towns upon attaining the minimum threshold, reduction in infant mortality rate, and increase in life expectancy.

According to the Ministry of Roads and Highways (MRH), Ministry of Transport (MoT) and Ghana Statistical Service (GSS) the vehicle population in Ghana increased from 511,755 in 2000 to 1, 1127,986 in 2009. Over this period, the average yearly growth of the vehicle population was about

8.2%. The vehicle population in 2005 was 767,067 and this increased to 1,127,986 in 2009 resulting in an annual average growth rate of 8.3% during that period (MRH et al., 2011).

From the foregoing it is realised that:

i) The number of settlements and traffic volume on the country's roads are increasing.

ii) There is an increased need for designs to handle higher levels of traffic and traffic conflicts with a view to safety and economy.

iii) Some roads in and around urban areas in Ghana fall within development stages 2 and 3 as described in Section 2.2.

It is also reported that as at the end of the year 2009 there were 605km of missing links within the trunk road network of Ghana (MRH, 2011). This implies that some roads in Ghana fall within development stage 1 as described in Section 2.2.

It can be inferred that the Ghanaian road network spans all three (3) stages of development described above.

2.4 Design Controls and Criteria

According to the New Hampshire Department of Transportation (NDOT) the objective of highway design is to provide a safe, efficient, economical and environmentally compatible highway system. When good judgment and application of design considerations and design criteria are adopted, the planned level of service is reached. Factors to be considered in designing a highway system are safety, environmental, cost, constructability, maintenance, and highway function. Safety is the principal design consideration (NDOT, 1999).

The criteria for geometric design of roads are the physical and psychological characteristics of roadway users, physical dimensions of vehicles, topography, safety, traffic stream characteristics, level of service, available funds, economy and maintenance feasibility and design speed (MassDOT, 1997).

2.4.1 Road Classification

According to AASHTO's A Policy on Geometric Design of Highways and Streets (2011) the classification of highways into different operational systems, functional classes, or geometric types is needed for communication among engineers, administrators, and the general public. Four (4) road classification types are identified, namely:

i. Classification of highways by design types based on the major geometric features (e.g., freeways, conventional streets, and highways) – the most helpful approach for highway location and design procedures. ii. Classification by route numbering (e.g., U.S., State, and County) – the most helpful approach for traffic operations.

iii. Administrative classification (e.g., National Highway System or Non-National Highway System) – used to denote the levels of government responsible for and the method of financing highway facilities.

iv. Functional classification (i.e. the grouping of highways by the character of service they provide) was developed for transportation planning purposes. Comprehensive transportation planning, which is an integral part of total economic and social development, uses functional classification as an important planning tool.

According to the Policy the functional concept is important to the designer and is consistent with a systematic approach to highway planning and design.

The first step in the design process is to define the function that the facility is to serve as well as the context of the project area. The level of service needed to fulfil this function for the anticipated volume and composition of traffic then provides a rational and cost-effective basis for the selection of design speed and geometric criteria within the ranges of values available to the designer. The use of functional classification as a design type should appropriately integrate the highway planning and design process.

According to the Ugandan Road Design Manual when the functional classification and level of access control has been selected, design standards can be applied which will encourage the

use of the road as intended. Design features like carriageway width, continuity of alignment, spacing of functions, frequency of access, standards of alignment and grades, traffic controls and road reserve widths can convey the level of functional classification to the driver (MWHC, 2005).

2.4.2 Safety

A safety engineering study at the General Motors proving ground by Stonex (1960) revealed that off-the-road accidents were the most prevalent type and concluded that this was the greatest potential hazard in the operation. The researcher observed that between 30 and 35 percent of highway fatalities occur in off-the-road accidents, year after year. According to the author, an objective look at many public highway roadsides shows that they offer few safeguards in the event of vehicle malfunction or human malfunction and in the eyes of the industrial safety engineer, much of the roadside is deficient in this respect. The objective of the study was to develop criteria for roadside design which would remove these deficiencies. The severity of operation through roadside and median ditches as a function of speed and crosssection detail is measured in terms of accelerations along the principal axes as a test car is driven through the ditch. Measured values are correlated with severity as gauged by the driver. Cross-section design criteria are developed such that the severity of accidents at legal road speeds can be kept within the tolerable range. Guardrails are recognized as a feature which must be resorted to on occasions and thus must be considered as a part of roadside design. Awatta et al. (2006-7) concluded that highway designers can theoretically improve roadway safety by evaluating design consistency. Their research identified four major areas in which the most promising consistency measures fall: operating speed, vehicle stability, alignment indices, and driver workload. The authors discussed a study to quantify relationships between individual and combined consistency measures to actual collision experience through regression analysis. A database of horizontal curves representing different classes of two-lane rural highways in Eastern Ontario provided a study model. Researchers developed several

statistically significant consistency measures to collision frequency relationship models which allowed examination of safety performance sensitivity for each model. These models may be used in safety-focused highway design because they represent a quantitative evaluation tool for design improvement safety benefits.

According to Ulfarsson and Shankar (2003) the number of horizontal curves per kilometre on a road has a negative effect on accident frequencies. In a related study Al-Masaeid (1997) also found out that, there is also a correlation between number of vertical curves and intersections per kilometre, and multiple-vehicle accidents. From the foregoing, it is inferred that the selection and coordination of elements during geometric design has an impact on how safe the design will be when implemented.

2.4.3 Free-flow Speed, Capacity, Cost, and Environmental Footprint

Chen et al. (2012) investigated differentiated design standards as a source of capacity additions that are more affordable and have smaller aesthetic and environmental impacts than modern expressways. The authors considered several tradeoffs, including narrow versus wide lanes and shoulders on an expressway of a given total width, and high-speed expressway versus lower speed arterial. The researchers quantified the situations in which off-peak traffic is sufficiently great to make it worthwhile to spend more on construction, or to give up some capacity, in order to provide very high off-peak speeds even if peak speeds are limited by congestion. The authors also considered the implications of differing accident rates. The results support expanding the range of highway designs that are considered when adding capacity to ameliorate urban road congestion.

2.4.4 Design Speed

According to Boyce et al. (1988) speed occupies a unique position in geometric design; it may be both the resultant and determinant of design standards. The authors also observed that road geometry, in terms of gradient and curvature would influence the speed adopted by drivers.

NCHRP Project 15-18 evaluated how speed is used within existing practices and developed recommended changes. The strongest statistical relationship between operating speed and roadway characteristics on suburban tangent sections was with posted speed limit. Other variables that showed potential influence on 85_{th} percentile free-flow operating speed included access density, median type, parking along the street, and pedestrian activity level. The findings from the field studies demonstrated than in urban areas, operating speed is insensitive to many geometric design decisions. Previous research showed that operating speed is sensitive to radius and grade on rural two-lane highways. When selecting the design speed value for a new roadway, the majority of the states use functional classification, with legal speed limit being used by almost one-half of the states responding to a mailout survey. A concern with the use of legal speed limit is that only between 23 and 64 percent of drivers operate at or below the posted speed limit, depending upon the roadway class. Data from 128 speed study zone surveys found that the speed limit at 10 percent of the sites was rounded upto the nearest 5-mph (8.1 km/h) increment.

2.5 Design Standards and Manuals

2.5.1 Design Controls and Criteria in the USA (AASHTO)

The Policy on Geometric Design of Highways and Streets (AASHTO, 2011) presents design controls and criteria as those characteristics of vehicles, pedestrians, and traffic that are criteria to optimize or improve design of the various highway and street functional classes. Controls and Criteria covered in the Policy are:

Design Vehicles – under this heading General Characteristics, Minimum Turning Paths of Design Vehicles, Vehicle Performance, Vehicular Pollution are discussed.

Driver Performance and Human Factors – this topic has to do with factors like Older Drivers and Older Pedestrians, The Driving Task, The Guidance Task (Lane Placement and Road Following, Car Following, Passing Maneuvers, Other Guidance Activities), The Information

System (Traffic Control Devices, The Roadway and Its Environment), Information Handling (Reaction Time, Primacy, Expectancy), Driver Error (Errors Due to Driver Deficiencies, Characteristics of the Older Driver, Crash Frequency, Countermeasures, Errors Due to Situation Demands), Speed and Design, and Design Assessment

Traffic Characteristics – this involves General Considerations, Volume (average daily traffic,peak-hour traffic), Directional Distribution, Composition of Traffic (passenger cars, trucks), Projection of Future Traffic Demands, Speed (operating speed, running speed, design speed), and Traffic Flow Relationships that have to do with traffic streams.

Highway Capacity – here, General Characteristics, Application (transportation planning studies, highway design, traffic operational analyses), Capacity as a Design Control (design service flow rate versus design volume, measures of congestion, relation between congestion and traffic flow rate, acceptable degrees of congestion), Factors other than Traffic Volume That Affect Operating Conditions (highway factors, alignment, weaving sections, ramp terminals, traffic factors, peak hour factor), Levels of Service, Design Service Flow Rates (weaving sections, multilane highways without access control, arterial streets and urban highways, intersections, pedestrians and bicycles) are presented.

Access Control and Access Management – this topic deals with the General Conditions, Basic Principles of Access Management (functional classification of road system, limiting of direct access, location of traffic signals, location of driveways and major entrances, management of access movements), Access Classifications, Methods of Controlling Access (control by the transportation agency, land-use ordinances, geometric design, driveway regulations)that determine highway capacity by reason of access provision, density and location.

The Pedestrian – issues like General Considerations, General Characteristics, Walking Speeds, of pedestrians together with Walkway Level of Service, Intersections, Reducing PedestrianVehicular Conflicts, Characteristics of Persons with Disabilities (Mobility Impairments, Visual Impairments, Developmental Impairments) are treated.

Bicycle Facilities – here, Bicycle Dimensions, Bicycle Operating Characteristics, and Bicycle Needs for use in geometric design are discussed.

Safety – the Key Factors Related to Traffic Crashes (Roadway Design, Roadside Design, Traffic Control Devices), Key Safety Resources, Safety Improvement Programs, Project Development Process, are treated under this heading.

Environment–here it is discussed how the highway can and should be located and designed to complement its environment and serve as a catalyst to environmental improvement. **Economic Analysis** –The costs associated with a proposed improvement and the benefits resulting from it are discussed.

2.5.2 Design Controls and Criteria in the Ugandan Road Design Manual

The Ugandan Road Design Manual (MWHC, 2005) adopts the following design controls and criteria for the geometric design of roads:

Design Vehicles – involves the discussion of design issues such as Design Vehicle type, Dimensions, Minimum design turning radius, Minimum inside radius, and Offtracking.

Terrain–Terrain type descriptions with threshold slopes for each terrain type are presented.

Driver Performance – driver-related factors like Continuation expectancy, Event expectancy, Temporal expectancy, Drivers Reaction, Design Response are treated here.

Other Road Users – Pedestrians (walking speeds, pedestrians' age, pedestrian actions, and pedestrian safety) and Cyclists (cycle paths, cyclist safety) are presented under this topic.

Traffic Characteristics – the crucial traffic stream parameter of Volume (Design Volume, Average Annual Daily Traffic (AADT), Average Daily Traffic (ADT), Peak-Hour Traffic and Design Hourly Volume, Composition of Traffic) is the focus of discussion.

Speed – types of speed are defined and explained such as Design Speed, Operating Speed, and Running Speed.

Capacity – highway capacity issues like Level of Service Characteristics by road type, Level of Service Criteria for two-lane rural roads, Level of Service Criteria for two-lane rural roads are presented here.

Determination of Service Volume (SV) – here the focus is on design volume factors such as Lane Width Factor, Truck Factor, Directional Factor.

Factors other than Traffic Volume that affect Operating Conditions – the Manual proceeds to discuss non-traffic volume factors such as Weaving Sections, Ramp Terminals, and Traffic Compositions.

Planning – Traffic mix, Directional split , No passing zone, as considerations for highway planning are presented.

Application – the Manual recommends that for design volumes close to the maximum capacity of the road, operational analysis should be performed for alternative designs to document the impact on traffic operations from horizontal and vertical alignment.

Safety Considerations – road safety issues like Injury Risks, Safety Responsibility, Safety Considerations in Design, Accident Prevention, Reducing the severity of accidents, Speed and Traffic Safety are discussed under this topic.

Environmental Considerations – effects of highway design related to the road as a Physical Feature, and effects related to the Traffic are discussed.

Economic Considerations– the economics ofRoute Selection (cost-benefit and objective analysis for all studied alternatives), and Detailed Design (cost-benefit analysis including construction and road user costs)are presented.

2.5.3 Design Controls and Criteria in the GHA Road Design Guide

The GHA Road Design Guide employs the following design controls and criteria for the geometric design of roads:

Design Vehicles– where it presents the Use of Vehicle Classification in design, GHA Classification of Vehicles

Classification of Roads – under this heading Terrain Type Classification, Functional Classification, and Maintenance Classification are indicated.

Design Speed – relationships between Design Speed and Terrain, and Design Speed and Road Classification are presented here.

Sectional Design –measures to be taken when a road design cannot be homogenous over its entire length, involving Minimum recommended lengths, Connection of Sectional Designs, Change Points of Sectional Designs are treated under this heading.

Control of Accesses – some options to be considered for access management such as Full Control of Accesses and Partial Control of Accesses are indicated.

It is clear that the GHA Road Design Guide covers only few of the important topics and omits controls and criteria like environmental considerations, economic considerations, safety considerations, other road users, capacity, and driver performance, as compared with the Ugandan Road Design Manual and the Policy on Geometric Design of Highways and Streets.

2.6 Highway Design Elements

Highway Design entails the selection of the physical or visual elements that make up the geometry or physical form of the finished road. The elements comprise horizontal curves, vertical curves, straights, grades, superelevation, cross fall, sight distance, through lanes, median strip, border strip, walkways, lighting and auxiliary lanes. These elements are often grouped into components like cross section, alignment, intersections, road surface drainage and accessories. According to AASHTO's A Policy on Geometric Design of Highways and Streets (2011) each alignment element should complement others to achieve a consistent, safe, and efficient design. The Ugandan Road Design Manual (2005) explains that the basic assumption for road alignment is that the driver at design speed should be able to perceive any possible road hazard on or close to the road to take action to avoid mishap.

A good highway design is hence one in which these design elements have been selected and combined for optimal performance, safety and economy.

2.6.1 Highway Design Elements and Features in the USA (AASHTO)

A Policy on Geometric Design of Highways and Streets (AASHTO, 2011) categorises highway design elements and features into Elements of Design, Cross-Section Elements, Intersections, and finally Grade Separations and Interchanges. In separate chapters it also applies these elements and features to various functional road classes such as Local Roads and Streets, Collector Roads and Streets, Rural and Urban Arterials, and Freeways.

Elements of Design cover the following:

- **Sight Distance** – various types of sight distance such as stopping sight distance, passing sight distance, intersection sight distance, and decision sight distance are presented.
- **Horizontal Alignment** – issues affecting design in the horizontal plane like superelevation, superelevation distribution, methods of attaining superelevaton, minimum radius, effects of grades on superelevation, compound curves, transition design controls, spiral curve transitions, compound curve transition, minimum transition grades, compound circular curves, offtracking, and sight distance on horizontal curves are treated under this heading.
- **Vertical Alignment** – vertical plane design issues such as terrain, grades, critical lengths of grade for design, climbing lanes, methods for increasing passing opportunities on two-lane roads, emergency escape ramps, and vertical curves are the focus under this heading.
- **Combinations of Horizontal and Vertical Alignment** – the Coordination of horizontal and vertical alignments in Design are presented here.
- **Other Features Affecting Geometric Design** – other road-related features such as erosion control and landscape development, rest areas, information centres, and scenic

overlooks, lighting, utilities, traffic control devices, and traffic management plans for construction are discussed here.

Cross-Section Elements cover the following areas:

- **Traveled Way** – cross-section factors like Surface Type, Cross Slope, Skid Resistance, and Hydroplaning are treated under this heading.
- **Lane Widths –** this part discusses how Cost, Driving Comfort, and Level of Service affect road lane widths.
- **Shoulders** – the General Characteristics, Width of Shoulders, Shoulder Cross-Sections, Shoulder Stability, Shoulder Contrast, and Turnouts are presented here.
- **Rumble Strips**– under this heading the Description and Uses of rumble strips are discussed.
- **Roadside Design**– Clear Zones and Lateral Offsets are the focus here.
- **Curbs**– General Considerations and designs for Curb Configurations and Curb Placement are presented.
- **Drainage Channels and Side Slopes**– General Considerations and designs for Drainage, Drainage Channels, and Side Slopes are treated.
- **Illustrative Outer Cross Sections**– normal crown sections and superelevated sections of roadways are presented under this topic.
- **Traffic Barriers**– general considerations and designs for longitudinal barriers (roadside barriers, median barriers), bridge railings, crash cushions are discussed.
- **Medians** – General Considerations and arrangements for median types are presented.
- **Frontage Roads** – General Considerations and Arrangements for employing frontage roads are discussed.
- **Outer Separations**– General Considerations for the use of outer separations are discussed.
- **Noise Control** – General Considerations, General Design Procedures, and Noise

Reduction Designs are the focus under this topic.

- **Roadside Control**– Roadside Control issues involving General Considerations, Driveways, Mailboxes, and Fencing are discussed.
- **Tunnels** – General Considerations for tunneling, Types of Tunnels, Tunnel Sections, and Examples of Tunnels are presented here.
- **Pedestrian Facilities**– provisions such as Sidewalks, Grade-Separated Pedestrian Crossings, and Curb Ramps are treated under this topic.
- **Bicycle Facilities –** General Considerations for the provision of bicycle lanes and crossings are presented.
- **Bus Turnouts** – bus turnouts onFreeways, Arterials, Park-and-Ride Facilities (Location, Design) are presented here.
- **On-Street Parking –** the provision of parking areas alongside carriageways are discussed under this topic.

The subject of **Intersections** covers at-grade intersections as follows:

- **General Design Considerations and Objectives**– Characteristics of Intersections (Focus of activity, Conflicting movements, Traffic control, Capacity),Intersection Functional Area, Design Objectives (Human Factors, Traffic Considerations, Physical Elements, Economic Factors), Design Considerations for Intersection User Groups (Motor vehicles other than trucks, Trucks, Transit, Pedestrians, Bicyclists), Intersection Capacity, and Intersection Design Elements are discussed.
- **Types and Examples of Intersections** – intersection types such as Three-Leg Intersections, Four-Leg Intersections, Multi-leg Intersections, Roundabouts (Miniroundabouts, Single-lane roundabouts, Multilane Roundabouts) are presented.
- **Alignment and Profile**– General Considerations and design for Alignments, Profiles at intersections are presented.

- **Intersection Sight Distance**– General Considerations for sight distance, Sight Triangles (Approach Sight Triangles, Departure Sight Triangles, Identification of Sight Obstructions within Sight Triangles), Intersection Control, and the Effect of Skew are discussed.
- **Turning Roadways and Channelization**– Types of Turning Roadways (General, Minimum Edge-of-Traveled-Way Designs, Design for Specific Conditions (RightAngle Turns), Passenger vehicles, Single unit trucks and city transit buses, Semitrailer combination trucks, Oblique-angle turns, Effect of Curb Radii on Turning Paths, Effect of Curb Radii on Pedestrians, Corner Radii into Local Urban Streets)are presented.

  Additionally, Channelization, Islands (General Characteristics, Channelizing Islands, Divisional, Islands, Refuge Islands, Island Size and Designation, Island Delineation and Approach Treatment), Free-Flow Turning Roadways at Intersections, Turning Roadways with Corner Islands (Right-Angle Turns with Corner Islands, Oblique-Angle Turns with Corner Islands)are treated. Superelevation for Turning Roadways at Intersections(General Design Guidelines, Superelevation Runoff, Development of Superelevation at Turning Roadway Terminals, General procedure, Turn-lane cross slope rollover, Superelevation transition and gradeline control),and Stopping Sight Distance at Intersections for Turning Roadways (General Considerations, Vertical Control, Horizontal Control)are also treated under this topic.

- **Auxiliary Lanes** – General Design Considerations and designs for Deceleration Lanes, Design Treatments for Left-Turn Maneuvers (Guidelines for Design of Left-Turn Lanes, Median Left-Turn Lanes, Median End Treatment, Offset Left-Turn Lanes, Simultaneous left turns, Double or Triple Left-Turn Lanes) are presented and discussed here.
- **Median Openings** – General Design Considerations and designs for medians such as

Control Radii for Minimum Turning Paths, Minimum Length of Median Opening, Median Openings Based on Control Radii for Design Vehicles (Passenger Vehicles, Single-Unit Trucks or Buses, Tractor-Semitrailer Combinations), Effect of Skew, Above-Minimum Designs for Direct Left Turns are discussed.

- **Indirect Left Turns and U-Turns –** General Design Considerations and designs for Intersections with Jug handle or Loop Roadways, Displaced Left-Turn Intersections, Wide Medians with U-Turn Crossover Roadways, Location and Design of U-turn Median Openings are treated.
- **Roundabout Design** – the Geometric Elements of Roundabouts, Fundamental Principles (Slow Speeds Using Deflection, Lane Balance and Lane Continuity, Appropriate Natural Path Alignment, Design Vehicle, Non-motorized Users, Sight Distance and Visibility are presented under this topic.
- **Other Intersection Design Considerations** – Design Considerations such as Intersection Design Elements with Frontage Roads, Traffic Control Devices, Bicycles, Pedestrians, Lighting, Driveways, and Midblock Left Turns on Streets with Flush Medians, are discussed.
- **Railroad-Highway Grade Crossings**–Horizontal Alignment, Vertical Alignment, Crossing Design, and Sight Distance for level crossings are presented here.

The topic of **Grade Separations and Interchanges** covers the following:

- **Introduction and General Types of Interchanges –** an overview of Interchange Configurations is given.
- **Warrants for Interchanges and Grade Separations–** warrants for resorting to interchanges such as Design designation, Reduction of bottlenecks or spot congestion, Reduction of crash frequency and severity Site topography, Road-user benefits, and Traffic volume warrant are discussed.

- **Adaptability of Highway Grade Separations and Interchanges** – adaptability factors such as Traffic and Operation, Site Conditions, Type of Highway and Intersecting Facility are discussed.

 Access Separations and Control on the Crossroad at Interchanges– Factors Influencing Length of Access Control along an Interchange Crossroad are presented.

- **Safety –** general considerations required to provide safe traffic operation of interchanges are discussed.
- **Stage Development –** stage development strategies for interchange design and construction are discussed.
- **Economic Factors**– Initial Costs, Maintenance Costs, Vehicular Operating Costs associated with grade separations are discussed.
- **Grade Separation Structures**– an Introduction to Grade Separation Structures, Types of Separation Structures, Overpass versus Underpass Roadways (General Design Considerations, Structure Widths), Underpass Roadways (Lateral Offset, Vertical Clearance), Overpass Roadways (Bridge Railings, Lateral Offset, Medians), Longitudinal Distance to Attain Grade Separation, Grade Separations without Ramps are presented.
- **Interchanges**– General Considerations and examples for Three-Leg Designs, Four-Leg Designs (Ramps in One Quadrant, Diamond Interchanges, Double Roundabout Interchange, Single-Point Diamond Interchanges, Cloverleaves, Partial Cloverleaf Ramp Arrangements, Directional Interchanges), and Other Interchange Configurations (Offset Interchanges, Combination Interchanges) are given. Additionally, General Design Considerations (Determination of Interchange Configuration, Approaches to the Structure, and designs for Interchange Spacing, Uniformity of Interchange Patterns, Route Continuity, Overlapping Routes, Signing and Marking, Basic Number of Lanes,

Coordination of Lane Balance and Basic Number of Lanes, Auxiliary Lanes, Lane Reductions, Weaving Sections, Collector-Distributor Roads, Two-Exit versus SingleExit Interchange Design, Wrong-Way Entry) are presented. Ramps (Types and Examples, General Ramp Design Considerations, Ramp Traveled-Way Widths, Ramp Terminals, Single-Lane Free-Flow Terminals (Entrances), Single-Lane Free-Flow Terminals (Exits), Other Interchange Design Features(Testing for Ease of Operation, Pedestrian and Bicycle Accommodation, Ramp Metering, Grading and Landscape Development, Models) are also presented under this topic.

2.6.2 Highway Design Elements and Features in the Ugandan Road Design Manual

For highway design the Ugandan Road Design Manual (2005) first discusses two pregeometric design topics, namely (i) Route Corridor Selection and (ii) Road Survey Procedures and Requirements. The Manual then proceeds to discuss highway design elements and features in the categories of Elements of Design, Cross-Section Elements, At-grade Intersections, Interchanges, Speed Management, Other Road Facilities and finally Road Furniture, Safety and Miscellaneous Design Items. There are no separate chapters devoted to the treatment of the various functional road classes such as International Trunk Roads, National Trunk Roads, Primary Roads, Secondary Roads, and Minor Roads.

Route Corridor Selection covers the following:

- The Project Cycle – is presented under sub-topics such as General, Identification, Feasibility and Preliminary Engineering Study, Detailed Design, Procurement/ Tendering, Construction Supervision and Management, Operation, Project Evaluation
- Desk Study for Identification and Feasibility of route corridors
- Preliminary Identification of Potential Corridors and Comparison
- Site Visit and Survey
- Recommendations– steps toward selecting a route corridor amongst competing

alternatives are given.

Road Survey Procedures and Requirements cover the following:

- General – an Introduction to road surveying, Units of Survey Measurement, Datum and Distance Measurement, Bench Marks, and Survey Data are presented
- Methods of Data Collection – Photogrammetry and Ground Survey are presented as methods of survey.
- Road Survey Procedures– a sequence and description of activities required to complete a road survey are presented.

Elements of Design cover the following:

- Alignment – a discussion of Alignment Choice and Terrain Adaptation is presented here.
- Horizontal Alignment – General Tangent Section, the Circular Curve, Widening on Curve, Sight Distance on Horizontal Curves are discussed.
- Vertical Alignment – this discusses Crest Vertical Curves and Sag Vertical Curves
- Phasing of Horizontal and Vertical Alignment – Alignment Defects due to Mis-phasing, Types of Mis-phasing and Corresponding Corrective Action (Vertical Curve Overlaps one end of the Horizontal Curve, Insufficient Separation between the Curves, Both ends of the Vertical Curve Lie on the Horizontal Curve, Vertical Curve Overlaps both ends of the Horizontal Curve, Other Mis-Phasing), The Economic Penalty due to Phasing are discussed
- Gradients – Maximum Gradients, Minimum Gradients, Gradients through Villages, Critical Length of Gradient are the topics presented here.
- Climbing and Overtaking Lanes– warrants and designs for climbing and overtaking lanes are presented here.
- Sight Distances – the various forms of sight distance such as Stopping Sight Distance, Passing Sight Distance, Decision Sight Distance, Meeting Sight Distance are treated.

Cross-Section Elements cover discussions and examples of the following:

- Headroom and Lateral Clearance
- Road and Lane Width
- Shoulders
- Normal Cross Fall
- Side Slope and Back Slopes
- Drainage Channels
- Clear Zone
- Side Roads and Culverts
- Right – of – way
- Four – Lane and Divided Roads
- Single Lane Roads
- Median
- Cross – section Over Bridges and Culverts
- Footways and Cycle ways – Footways and Cycle ways in Rural Areas, Footways and Cycleways in Built-Up Areas
- Service Roads

-

Typical Cross Sections

At-Grade Intersections cover the following:

- General considerations for at-grade intersections
- Intersection Types – Access, Junction/Intersection (Priority Intersections, Control Intersections), Junction Maneuvers, Junction Design Speed, and the Major Road as related to intersections are presented.
- Design Requirements – Safety and Operational Comfort, Capacity, Economy as related to intersections are presented.
- Selection of Intersection – General considerations, Selection of Intersection Category, Selection of Intersection Type are discussed.
- Junction Design Procedure – basic junction procedure involving Data Collection, Basic Junction Layout and Capacity are presented.
- Principles of Junction Design – principles related to Distance between Adjoining Junctions, Visibility Splays, Turning Lanes, Major Road Cross Section, Central Reserves, Traffic Islands and Minor Road Widening, Alignment and Widening of the Major Road are discussed. Additionally, a Checklist for Junction Design is provided.
- Design of Roundabouts – the General Requirements, Design Principle, Visibility and Sight Distances, Centre Island and Circulating Carriageway, Entries, Exits, Combination of Exit and Entry Curves, Alignment between Entry and Exit, Pedestrian and Cycle Crossings, and Capacity as related to Roundabouts, are presented.
- Design of Signalised Intersection – factors of signalized intersections like Control Strategy and Layout, Visibility, Lane Design, Swept Paths and Corner Curves, Signals, Spacing of Signalized Intersections, Pedestrian and Cyclist Facilities are presented.

The topic of **Interchanges** is treated under the following headings and sub headings:

- Introduction – General, Design Principles

- Interchange Warrants – Traffic Volumes, Freeways, Safety, Topography
- Waving
- Location and Spacing of Interchanges
- Basic Lanes and Lane Balance
- Auxiliary Lanes – The Need for an Auxiliary Lane, Auxiliary Lane Terminals, Driver Information
- Interchange Types – General, Systems Interchanges, Access and Service Interchanges, Interchanges on non-freeway Roads,
- Ramp Design – General, Design Speed, Sight Distance on Ramps, Horizontal Alignment, Vertical Alignment, Cross-Section, Terminals
- Collector – Distributor Roads
- Other Interchange Design Features – Ramp Metering, Express – Collector Systems

Speed Management is presented under the following headings and sub headings:

- Speed Management Principles
- Speed Control Measures – Gates, Speed Control Zone

Other Road Facilities are covered under the following:

- Pedestrian Facilities – Shoulders and Footways, Pedestrian Crossing Facilities, Footbridges and Subways
- Bus Lay-Bys
- Cycle Facilities

Road Furniture, Safety and Miscellaneous Design Items are covered under the following headings and sub headings:

- General
- Traffic Signs and Road Markings

  Safety Barriers – Principles, Performance, When to Use, Length of Need, Steel beam Strong Post Guardrail, Installation of Steel Beam Strong Post Guardrail, End Treatment

-

for Guardrail, Transition from Guardrail to Bridge Parapets and Concrete Barriers, Median Barriers, Concrete Barrier

- Kerbs – Function, Types of Kerb and Their Application (Barrier Kerb, Semi-Mountable Kerb, Mountable Kerb, Flush Kerb, Kerb with Integral Drain)
- Bridge Parapets
- Traffic Islands – Function, Design
- Pedestrian Barrier – Function, Design
- Lighting

2.6.3 Highway Design Elements and Features in the GHA Road Design Guide

The GHA Road Design Guide (1991) first presents Composition of Cross Section, Alignment, At-grade Intersection, Accessories to Road, and Presentation of Drawing. The GHA Road Design Guide does not cover Roundabouts, Grade Separation and Interchanges, and Speed Management. Similar to the approach in the Ugandan Manual there are no separate chapters devoted to the treatment of the various functional road classes such as Primary Roads and Secondary Roads.

Composition of Cross Sectioncovers the following:

- Basic Considerations of Cross-section Composition – segregation, Green Belts, Traffic Characteristics
- Carriageway and Lane–Functional Class, Terrain, Safety
- Median Strip and Borderline – Functions, Width
- Shoulder – Function, Width, Borderline
- Stopping Lane
- Bicycle Track and Sidewalk

-

  Planting Zone

- Clearances–Carriageway Clearances, Sidewalk and Bicycle Track Clearances, Vertical Clearances

Alignment covers the following:

- Basic Points of Alignment Design – Smooth Alignment, Compound Curves, Reverse Curves, Undulating Hill Terrain, High Embankment
- Horizontal Alignment – Horizontal Curve (curve radii, minimum curve lengths), Superelevation of Curve Section (maximum superelevation, non-superelevated curved sections, curve radius and value of superelevation), Transition Curves (transition length, minimum transition lengths), Widening of the Curve Section, Superelevation and Widening Runoff (superelevation runoff, widening runoff), Sight Distance (stopping sight distance, passing sight distance, sight distance on horizontal curves)
- Vertical Alignment –Gradient, Climbing Lanes, Vertical Curves (vertical curve lengths, minimum vertical curve lengths, omission of vertical curves)
- Cross Slope –Cross Slope of Carriageway, Cross Slope of Shoulder, Cross Slope of Sidewalk and Bicycle Track
- Phasing of Horizontal and Vertical Alignment – Alignment Defects due to Misphasing (overlaps, inadequate separation, other misphasing)

At-grade Intersection covers the following:

- Planning and Design
- Layout of At-grade Intersections – Types of Intersections, Intersection Legs and Angles (intersection legs, intersection angles), Deformed and Irregular Intersections (deformed intersections, irregular intersections)
- Spacing of Intersections – Restriction by Weaving Length, Restriction by Queue Length at Signal Control, Restriction by Length of Storage Lane

-

Visibility – Sight Distance (signal controlled intersection, intersection controlled by stop sign), Horizontal and Vertical Alignment

- Cross-section Composition – Width and Number of Lanes (lane width, lane number), Left-turn Lane (length of left-turn lane, lane shift run-off), Right-turn Lane (length of right-turn lane), Speed Change Lane
- Channel and Island – Channel (curve radius of channel, channel width, channel design method, wide channels), Island (island size, island shape, nose markings of islands)
- Stop Line and Pedestrian Crossings – Pedestrian Crossing, Stop Line, Layout of Pedestrian Crossing and Stop Lines **Accessories**

to Road covers the following:

- Bus Bay – Types of Bus Bays, Construction of Bus Bays
- Parking – Parking Lot, Methods of Parking, Dimensions of Parking Lot
- Road Marking
- Safety Fence – Roadside Safety Fence, Sidewalk Safety Fence, Median Strip Safety Fence

The chapter on **Presentation of Drawing** covers the following:

- Size of Drawing and Margin
- Cover Sheet
- Title Column
- Table of Contents
- Location Map
- Key Plan
- Typical Cross-sections
- Plan and Longitudinal Sections
- Cross-section
- Other Drawings

2.7 Summary

According to Quarshie (2015) Ghanaian consultants and regulators regularly consult foreign manuals and other publications in the pursuit of design excellence. It has become fairly common for American, European and British publications to be consulted in the design process where the Geometric Design Manual (GHA Road Design Guide) is found wanting. The AASHTO's A Policy on Geometric Design of Highways and Streets, popularly called The Green Book, and the Federal Highway Administration's Manual on Uniform Traffic Control Devices are two of such publications (Quarshie, 2015).

Table 2.1. Comparison of Highway Design Controls and Criteria

Control/Criteria	Road Design Manual(2005), Uganda	A Policy on Geometric Design of Highways and Streets (2011), USA	GHA Road Design Guide (1991),Ghana
Road Classification	√	√	√
Design Vehicles	√	√	√
Driver Performance and Human Factors	√	√	-
Traffic Characteristics	√	√	√
Highway Capacity	√	√	
Access Control and Access Management	√	√	√
The Pedestrian	√	√	√
Bicycle Facilities	√	√	√
Safety	√	√	-
Environment	√	√	-
Economic Analysis	√	√	-
Terrain	√	-	√
Speed	√	√	√
Determination of Service Volume (SV)	√	-	-
Weaving Sections, Ramp Terminals, and Traffic Compositions	√	√	-

Table 2.1 compares highway design controls and criteria in the GHA Road Design Guide with those in the Ugandan Road Design Manual and AASHTO's 'A Policy on Geometric Design of Highways and Streets' (Green Book). It can be seen that controls and criteria like Driver

Performance and Human Factors, Highway Capacity, Safety, Environment, Environment, Determination of Service Volume (SV), Weaving Sections, Ramp Terminals, and Traffic Compositions are not treated as main topics in the GHA Road Design Guide, although sublimely implied in the content of the Guide. Again, for all topics treated the other two manuals present more needed detail. For example under the topic Design Vehicle, the GHA Road Design Guide presents Use of Vehicle Classification in design and GHA Classification of Vehicles. The Ugandan Manual discusses Design Vehicle type, Dimensions, Minimum design turning radius, Minimum inside radius, and Offtracking under the same topic while the AASHTO policy discusses General Characteristics, Minimum Turning Paths of Design Vehicles, Vehicle Performance, and Vehicular Pollution.

Table 2.2. Comparison of Highway Design Elements/Features

Element/Feature	Road Design Manual(2005), Uganda	A Policy on Geometric Design of Highways and Streets (2011), USA	GHA Road Design Guide (1991),Ghana
(Route Corridor Selection)	√	-	-
The Project Cycle	√	-	-
Desk Study for Identification and Feasibility	√	-	-
Preliminary Identification of Potential Corridors and Comparison	√	-	-
Site Visit and Survey	√	-	-
(Road Survey Procedures and Requirements)	√	-	-
Methods of Data Collection	√	-	-
Road Survey Procedures	√	-	-
(Elements of Design)	√	√	√
Horizontal Alignment	√	√	√
Vertical Alignment	√	√	√
Gradients	√	√	√
Climbing and Overtaking Lanes	√	√	√
Sight Distances	√	√	√
Phasing of Horizontal and Vertical Curves	√	√	√

A similar comparison of highway design elements and features is given in Table 2.2. The comparison reveals that the GHA Road Design Guide covers all topics presented in the other manuals. An exception is Route Corridor Selection, and Road Survey Procedures and Requirements, presented in only the Ugandan Road Design Manual. Once again for all topics treated more details are given in the other manuals.

Table 2.3. Comparison of Cross-section Elements

Element/Feature	Road Design Manual(2005), Uganda	A Policy on Geometric Design of Highways and Streets (2011), USA	GHA Road Design Guide (1991),Ghana
(Cross-Section Elements)	√	√	√
Headroom and Lateral Clearance	√	-	√
Road and Lane Width	√	√	√
Shoulders	√	√	√
Cross Fall	√	√	√
Side Slope and Back Slopes	√	√	-
Drainage Channels	√	√	-
Clear Zone	√	√	-
Side Roads and Culverts	√	-	-
Right-of-way	√	-	-
Median	√	√	√
Traffic Barriers	-	√	√
Cross-section Over Bridges and Culverts	√	-	-
Footways and Cycle ways	√	√	√
Service Roads	√	√	√
Outer Separations	-	√	-
Curbs	√	√	-
Rumble Strips	-	√	-
Noise Control	-	√	-
Tunnels	-	√	√
On-street Parking	-	√	-
Roadside Control	-	√	-

Table 2.3 presents Cross-Section Elements featured in the three manuals. It is evident that the GHA Road Design Guide does not treat topics covered by the other manuals, such as tunnels, on-street parking, clear zone, curbs, outer separations, side and back slopes, and noise control.

The other two manuals present more needed detail for topics treated in the GHA Road Design Guide. For example under the topic Horizontal Alignment the GHA Road Design Guide treats

Horizontal Curve, Superelevation of Curve Section, Transition, Widening of the Curve Section, Superelevation and Widening Runoff, and Sight Distance. The AASHTO Policy discusses Superelevation, superelevation distribution, methods of attaining superelevaton, minimum radius, effects of grades on superelevation, compound curves, transition design controls, spiral curve transitions, compound curve transition, minimum transition grades, compound circular curves, offtracking, and sight distance on horizontal curves. **Table 2.4. Comparison of At-grade Intersections and Interchanges**

Element/Feature	Road Design Manual (2005), Uganda	A Policy on Geometric Design of Highways and Streets (2011), USA	GHA Road Design Guide (1991),Ghana
(At-Grade Intersections)	√	√	√
Intersection Types	√	√	√
Design Requirements	√	√	√
Selection of Intersection	√	-	-
Junction Design Procedure	√	-	√
Principles of Junction Design	√	√	√
Design of Roundabouts	√	√	-
Design of Signalised Intersection	√	-	-
Railroad-highway grade crossings	-	√	-
(Interchanges)	√	√	-
Interchange Warrants	√	√	-
Weaving	√	√	-
Location and Spacing of Interchanges	√	√	-
Basic Lanes and Lane Balance	√	√	-
Auxiliary Lanes	√	√	-
Interchange Types	√	√	-
Ramp Design	√	√	-
Collector–Distributor Roads	√	√	-
Other Interchange Design Features	-	√	-

Table 2.5 shows a comparison of At-grade Intersections and Interchanges. The GHA Road Design Guide does not cover the topics of Roundabouts, Signalised Intersections, Selection of Intersection Type and Railroad-highway Grade Crossings. Treated topics are presented in more

detail in the other manuals. The topic of Interchanges is not covered in the GHA Road Design Guide. The other two manuals however it is well treated in the other manuals.

Table 2.5. Comparison of Speed Management, Other Road Facilities, Road Furniture, Safety and Miscellaneous Items

Element/Feature	Road Design Manual(2005), Uganda	A Policy on Geometric Design of Highways and Streets (2011), USA	GHA Road Design Guide (1991),Ghana
(Speed Management)	√	-	-
Speed Management Principles	√	-	-
Speed Control Measures – Gates, Speed Control Zone	√	-	-
(Other Road Facilities)	√	√	√
Pedestrian Facilities	√	√	√
Bus Lay-Bys	√	√	√
Cycle Facilities	√	√	√
(Road Furniture, Safety and Miscellaneous Design Items) Traffic Signs and Road	√	√	√
Markings	√	-	√
Safety Barriers	√	√	√
Curbs	√	√	-
Bridge Parapets	√	√	-
Traffic Islands	√	√	√
Pedestrian Barrier	√	√	√
Ramp Design	√	√	-
Lighting	√	√	-
Erosion Control and Landscape Development	-	√	-
Rest Areas, Information Centers, and Scenic Overlooks	-	√	-
Utilities	-	√	-
Traffic Management Plans for Construction	-	√	-

Table 2.6 presents a comparison of Speed Management, Other Road Facilities, Road Furniture, Safety and Miscellaneous Items. The GHA Road Design Guide does not treat Speed Management. In fact the topic is only presented in the Ugandan Road Design Manual.The GHA

Road Design Guide coversOther Road Facilities well although they are treated in more detail in the other manuals. For Road Furniture, Safety and Miscellaneous Design Itemsthe GHA

Road Design Guide covers all but three items, namely, curbs bridge parapets, ramps, lighting,

Erosion Control and Landscape Development, Rest Areas, Information Centers, and Scenic Overlooks, Utilities, and Traffic Management Plans for Construction. In fact the latter four topics are treated only in the A Policy on Geometric Design of Highways and Streets.

From the foregoing it is evident that the GHA RDG is not meeting all the design needs of the Ghanaian road network. A thorough discussion of the adequacy of standards for various elements for their inclusion (or otherwise) in the revised Road Design Guide, based on reviewed literature and respondents' recommendations is presented in Chapter 4.

CHAPTER 3: METHODOLOGY

3.1 Study Procedure

In order to undertake the study the following procedure was adopted to systematically collect, collate and analyse information, and present findings conclusions and recommendations:

I. Consultation - Administration of carefully designed questionnaire to experienced designers (local and foreign) of road links and intersections in the last ten years for information on standards and guidelines applied apart from the GHA Road Design Guide and reasons for their choice.

II. Comparison of GHA Road Design Guide with other design manuals to identify omissions and to identify areas in the GHA Road Design Guide that may need to be brought abreast of international best practice.

III. Comparison of GHA Road Design Guide with other design manuals to identify improvements in standards that would promote road safety in designs.

IV. Review and theoretical analysis of all collated information on selected elements to establish the design requirements and standards to be adopted in a new GHA Road Design Manual.

V. Preparation of draft proposed detailed Table of Contents (TOC) for a revised GHA Road Design Manual.

The study procedure is summarised in Figure 3.1.

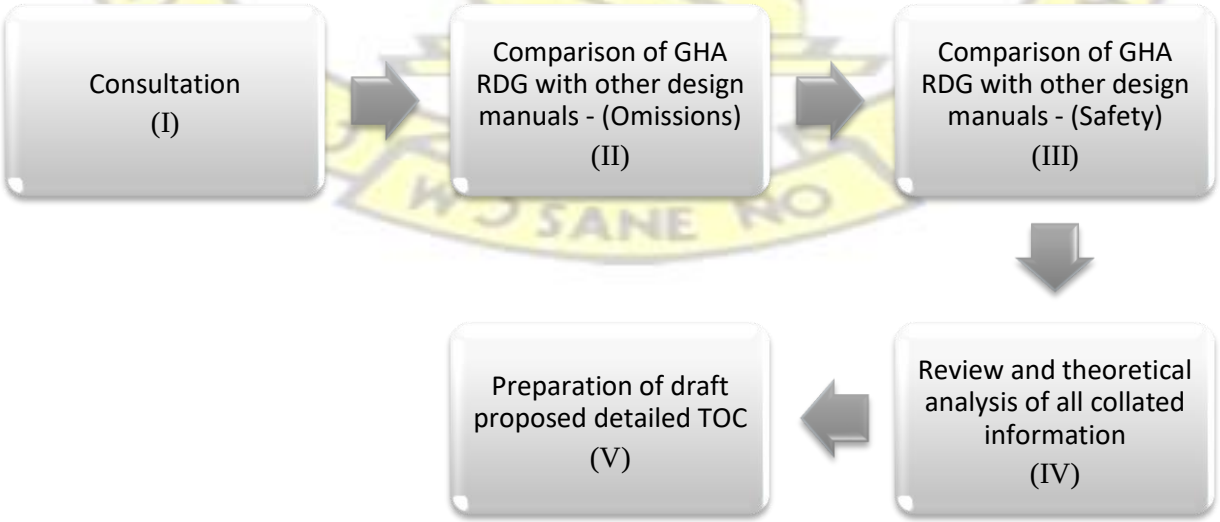

Figure 3.1: Flowchart for Methodology

3.2 Data Collection

Two sets of data were identified as being relevant to the effective conduct of this study, namely primary and secondary. The primary data, which refers to field data, were obtained with questionnaire developed from the objectives of the study. Secondary data was obtained from literature review, including the review of the GHA RDG and other highway design manuals.

The study aimed to collect qualitative data from administered questionnaire (participant observation) and reviewed literature in order make the analysis. For this reason, structured, mixed questionnaire was used during the data collection process.

A **Structured Questionnaire** was employed due to the following advantages:

a) Ability to ask definite and concrete questions.

b) Ability to supplement and check the data previously accumulated.

A **Mixed Questionnaire** was employed due to the following advantage:

a) Questions are both close and open ended.

b) Used in field of social research.

3.2.1 Characteristics of the Study Population

The population of the study consisted of clients/supervision agencies, highway consultants and road contractors associated with higway design projects executed by the Ghana Highway Authority and the Department of Urban Roads.

3.2.2 Sampling Design and Procedures

Having identified the target groups for the effective conduct of this study as described above, questionnaires were issued and the response rate was as follows: five clients/supervision

agencies engineers, and three highway consultants who had worked as designers or safety auditors on projects undertaken by the executed by the Ghana Highway Authority and the Department of Urban Roads.

3.2.3 Questionnaire Design

The questionnaire was divided into two different parts, which tried to cover all the necessary details for the report and analysis of the study. Each part had a certain number of questions from which the researcher collected qualitative data. These parts are explained below.

Part 1: Personal Data

Questions in this part were aimed at collecting qualitative information about the respondent's profession, experience in highway design, agency type and role played in road design projects. Information was also collected on the executing agency for projects in which the respondent participated. Data collected in this part was used to assess whether the respondent qualified to partake in the study.

Part 2: Information on design standards and manuals/guides used

Questions in this part were aimed at collecting qualitative information about the respondent's opinion regarding the following:

1. Whether respondents referred to the GHA Road Design Guide in their highway design practice.
2. What design controls and criteria respondents would select from the GHA Road Design Guide.
3. Whether respondents considered the GHA Road Design Guide sufficient for all highway designs.
4. What design elements/controls/criteria/features respondents were not able to use the GHA RoadDesign Guide for.
5. What specific changes/additions/omissions respondents would recommend in the revision of the GHA Road Design Guide.

6. . Whether made reference to other standars and manuals aside the GHA RDG.
7. Which other standards/manuals/guides respondents referred to, and reasons for referring to them.

Respondents were permitted to add more information as required.

3.2.4 Administration of the Data Collection Instrument

The questionnaires were delivered by hand and by email to the various target groups.

Responses were received by the same means.

3.3 Criteria for Interpreting Findings

3.3.1 Literature Review and Manual Comparison

The literature review and manual comparison were, respectively, used and undertaken as follows:

1. Information gathered from the review of research by other authors was used to understand and establish key highway design controls and criteria to be featured in any geometric design manual.
2. Against the background of established design controls and criteria, design elements and features in the GHA RDG were compared to those in the mostly used manuals. Deficiencies in the GHA RDG formed a basis for a proposing a table of contents for the revised GHA RDG.

3.3.2 Responses from Questionnaire

Findings from the questionnaires received were interpreted as follows:

1. Respondents' indication that they referred to other standards and manuals aside the GHA RDG implied that the GHA RDG was not meeting all needs for modern highway design.
2. Respondents' listing of design elements/controls/features for which they referred to other standards was an indication of defficiencies in the GHA RDG.
3. The manuals that Respondents referred to most were those to compare with the GHA RDG in order to make recommendations for revision.

4. Recommendations of respondents for modifications to the GHA RDG were issues to theoritically assess for inclusion with a revised GHA RDG.They formed a basis for a proposing a table of contents for the revised GHA RDG.

CHAPTER FOUR: RESULTS OF THE STUDY

4.1 Assessment of the GHA Road Design Guide (GHA RDG)

4.1.1 Organisation of the GHA RDG

The GHA RDG consists of eight chapters, namely Design Vehicles (Chapter 1), Classification of Roads and Design Speed (Chapter 2), Composition of Cross-section (Chapter 3), Alignment (Chapter 4), At-grade Intersection (Chapter 5), Road Drainage (Chapter 6), Accessories to Road (Chapter 7), and Presentation of Drawing (Chapter 8). There is a preface before Chapter 1 that states the reason for the Guide, the international standards and body of knowledge out of which the GHA RDG was composed, which users the Guide would serve and the need for periodic updates and revisions. There is however no chapter that introduces users to general issues like, units of measurement, limitations of the Guide's usage, general considerations that affect designs like legislation, speed, right-of-way, land use, and road user groups. The Policy on Geometric Design of Highways and Streets (the Policy) also has no introductory chapter. The Ugandan Geometric Design Manual and the Overseas Road Note 6 (TRRL, 1998) contain introductory chapters that discus design related issues as mentioned above, and also road function, approach to design and design process. A chapter including such discussions at the beginning of the Guide would serve as a useful orientation for designers. The Ugandan Geometric Design Manual after the introductory chapter presents a chapter in Route Corridor Selection and Road Survey Procedures and Requirements. The former chapter recommends methods for arriving at the optimum route corridor. The latter recommends appropriate methods for capturing topographical information purposely for road design. The GHA RDG does not include such chapters that if included would guide route selection and road-related land survey data collection.

Summary of Findings

- There is no chapter in the GHA RDG that introduces users to general issues like, units of measurement, road function, approach to design and design process, limitations of the Guide's usage, and general considerations that affect design like legislation, speed, right-of-way, land use, and road user groups.
- An introductory chapter after the preface at the beginning of the Guide would serve as a useful orientation for designers.
- The GHA RDG does not include a chapter on Route Corridor Selection.
- The GHA RDG does not include a chapter on Road Survey Procedures and Requirements.

4.1.2 Chapter 1: Design Vehicles

Vehicle Classes and Dimensions – Under this chapter, the GHA RDG presents the design vehicle as a basis for road alignment design. The nine identifiable vehicle classes used in GHA traffic mix are grouped into three design vehicle classes, namely, small vehicle, large vehicle, and trailer. Some overall dimensions of these design vehicle classes are given as shown in Figure 1 and Table 4.1. How design vehicles control various elements of design such as width, widening, intersection, vertical gradient, clearance and sight distance in the GHA RDG are presented in Table 4.2.

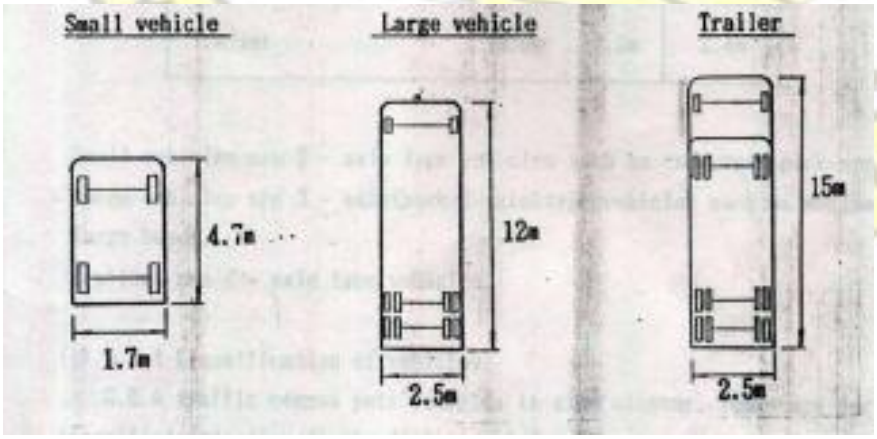

Figure 4.1. Different classes of design vehicles (Source: GHA RDG, 1991)

Table 4.1. Dimensions recommended for design (Source: GHA RDG, 1991)

Dimension / Design vehicle	Length	Width	Height
Small vehicle	4.7m	1.7m	1.5m
Large vehicle	12.0m	2.5m	4.0m
Trailer	15.0m	2.5m	3.4m

The Policy on Geometric Design of Highways and Streets uses four classes of design vehicles, namely passenger cars, buses, trucks and recreational vehicles. Dimensions for 20 design vehicles representing vehicles within these general classes are given. Three design vehicles fall within the passenger car class, six within the bus class, seven within the truck class and three within the recreational vehicle class. The GHA RDG generally covers all but the recreational vehicle class. Additionally, design vehicle dimensions are generally larger in the Policy. The Policy features overhang, minimum turning radius and wheelbase as key vehicle dimensions (Tables 4.3 and 4.4) whereas the GHA RDG does not.

Table 4.2. Design vehicles as controls in road design (Source: GHA RDG, 1991)

Design vehicles / Road characteristics	Small vehicle	Large vehicle	Trailer
Width composition	○	○	○
Widening of curved section	×	○	○
Design of intersection	×	○	○
Vertical gradient	×	○	○
Sight distance	○	×	×
Clearance	×	○	○

× ---- Not considered for design. ○ ----- Considered for design.

Table 4.3. Design vehicle dimensions (Source: AASHTO, 2011)

Design Vehicle Type	Symbol	Dimensions (m)											
		Overall			Overhang								
		Height	Width	Length	Front	Rear	WB_1	WB_2	S	T	WB_3	WB_4	Typical Kingpin to Center of Rear Tandem Axle
Passenger Car	P	1.30	2.13	5.79	0.91	1.52	3.35						
Single-Unit Truck	SU-9	3.35 4.11	2.44	9.14	1.22	1.83	6.10						
Single-Unit Truck (three-axle)	SU-12	3.35 4.11	2.44	12.04	1.22	3.20	7.62						
Buses													
Intercity Bus (Motor Coaches)	BUS-12	3.66	2.59	12.36	1.93	2.73[b]	7.70						
	BUS-14	3.66	2.59	13.86	1.89	2.73[b]	8.69						
City Transit Bus	CITY-BUS	3.20	2.59	12.19	2.13	2.44	7.62						
Conventional School Bus (65 pass.)	S-BUS 11	3.20	2.44	10.91	0.79	3.66	6.49						
Large School Bus (84 pass.)	S-BUS 12	3.20	2.44	12.19	2.13	3.96	6.10						
Articulated Bus	A-BUS	3.35	2.59	18.29	2.62	3.05	6.71	5.91	1.89[b]	4.02[b]			
Combination Trucks													
Intermediate Semitrailer	WB-12	4.11	2.44	13.87	0.91	1.37[b]	3.81	7.77					7.77
Interstate Semitrailer	WB-19[y]	4.11	2.59	21.03	1.22	1.37[b]	5.94	12.50					12.50
Interstate Semitrailer	WB-20[yy]	4.11	2.59	22.40	1.22	1.37[b]	5.94	13.87					13.87
"Double-Bottom" Semitrailer/Trailer	WB-20D	4.11	2.59	22.04	0.71	0.91	3.35	7.01	0.91[c]	2.13[c]	6.86		7.01
Rocky Mountain Double-Semitrailer/Trailer	WB-28D	4.11	2.59	29.67	0.71	0.91	5.33	12.19	1.37	2.13	6.86		12.34
Triple-Semitrailer/Trailers	WB-30T	4.11	2.59	31.94	0.71	0.91	3.35	6.86	0.91[d]	2.13[d]	6.86	6.86	7.01
Turnpike Double-Semitrailer/Trailer	WB-33D[y]	4.11	2.59	34.75	0.71	1.37[b]	3.72	12.19	1.37[e]	3.05[e]	12.19		12.34
Recreational Vehicles													
Motor Home	MH	3.66	2.44	9.14	1.22	1.83	6.10						
Car and Camper Trailer	P/T	3.05	2.44	14.84	0.91	3.66	3.35		1.52	5.39			
Car and Boat Trailer	P/B		2.44	12.80	0.91	2.44	3.35		1.52	4.57			
Motor Home and Boat Trailer	MH/B	3.66	2.44	16.15	1.22	2.44	6.10		1.83	4.57			

Table 4.4. Minimum Turning Radii of Design Vehicles (Source: AASHTO, 2011)

Design Vehicle Type	Passenger Car	Single-Unit Truck	Single-Unit Truck (Three Axle)	Intercity Bus (Motor Coach)		City Transit Bus	Conventional School Bus (65 pass.)	Large[a] School Bus (84 pass.)	Articulated Bus	Intermediate Semi-trailer
Symbol	P	SU 9	SU 12	BUS 12	BUS 14	CITY BUS	S BUS11	S BUS12	A BUS	WB 12
Minimum Design Turning Radius (m)	7.26	12.73	15.60	12.70	13.40	12.80	11.75	11.92	12.00	12.16
Center line[a] Turning Radius (CTR) (m)	6.40	11.58	14.46	11.53	12.25	11.52	10.64	10.79	10.82	10.97
Minimum Inside Radius (m)	4.39	8.64	11.09	7.41	7.54	7.45	7.25	7.71	6.49	5.88

The Ugandan manual features five design vehicles, namely, 4x4 passenger car, single unit bus, single unit truck, semi-trailer combination large, and interstate semitrailer. Vehicle dimensions given include height, width, length, overhang, wheelbase, minimum design turning radius and minimum inside radius.

Swept Path and Curve Widening – Both the Ugandan manual and the Policy give width widening required for each design vehicle turning at the minimum radius. The GHA RDG gives a formula for calculating the additional width required for any vehicle, given its dimensions and turning radius. This is however presented under a different chapter (Chapter 4: Alignment). Since off tracking and widening of curve sections is directly related to design vehicle it would be prudent to present the two topics in one chapter, as done in the other manuals.

Table 4.5 Dimensions of Design Vehicle (Source: Ugandan Geometric Design Manual, 2005)

Design Vehicle type	Symbol	Overall (m)			Overhang (m)		Wheel base (m)	Minimum design turning radius (m)	Minimum inside radius (m)
		Height	width	Length	Front	Rear			
4 x 4 passenger car	DV-1	1.3	2.1	5.8	0.9	1.5	3.4	7.3	4.2
Single unit truck	DV-2	4.1	2.6	9.1	1.2	1.8	6.1	12.8	8.5
Single unit bus	DV-3	4.1	2.6	12.1	2.1	2.4	7.6	12.8	7.4
Semitrailer combination large	DV-4	4.1	2.6	16.7	0.9	0.6	6.1 & 9.1	13.7	5.8
Interstate Semitrailer	DV-5	4.1	2.6	21.0	1.2	0.9	6.1 & 12.8	13.7	2.9

The Ugandan manual does not give any guide as to the choice of vehicle class for design. The Policy and the GHA RDG recommend specific design vehicles or vehicle class for design. Generally large vehicles control design of intersections, curve widening, gradient and clearance, whereas small vehicles control the design of sight distance. The tabular presentation of design vehicles and how they control design (Table 4.2) makes for easier design vehicle selection than the text-only presentation in the Policy.

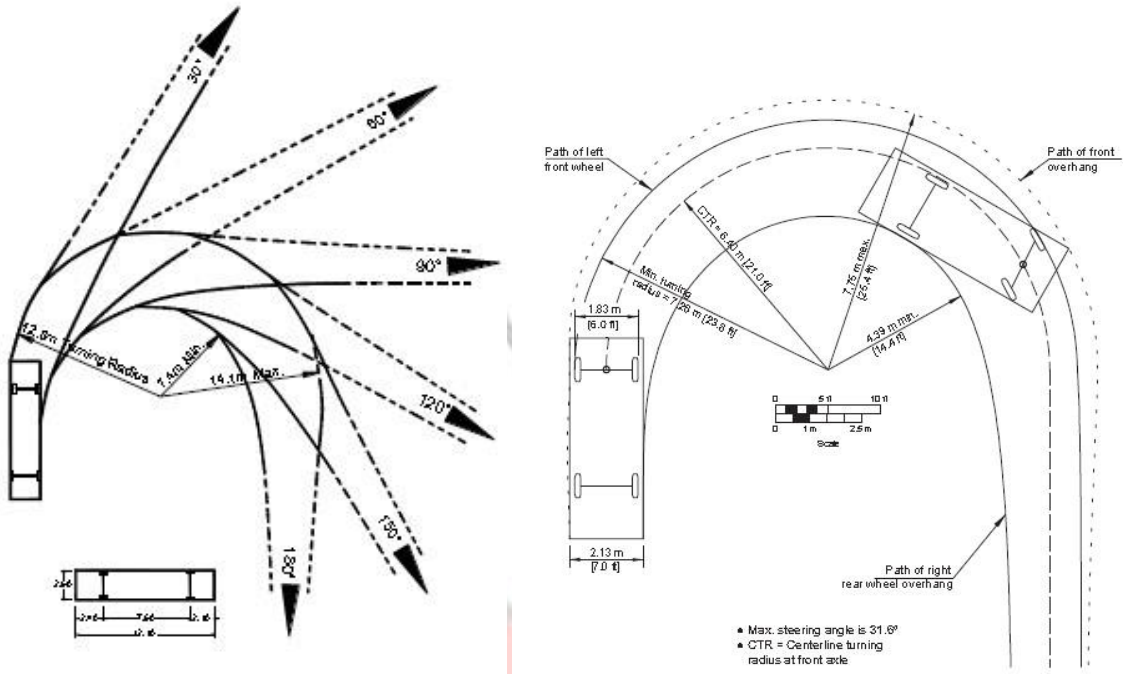

Figure 4.2. Turning path for design Vehicle no. 3 (DV-3) (Source: Ugandan Geometric Figure 4.3. Minimum Turning Path for Design Manual)
Passenger Car (P) Design Vehicle
(Source: AASHTO, 2011)

Knowledge of minimum turning radius of design vehicles is useful in determining channel radii and open space dimensions for intersections, but is lacking in the GHA RDG. The formula for computing the widening required in curve sections, and at intersections as presented in the GHA RDG, is necessary for achieving intersection capacity.

(1) Calculation of widening width.

(a) Trailer

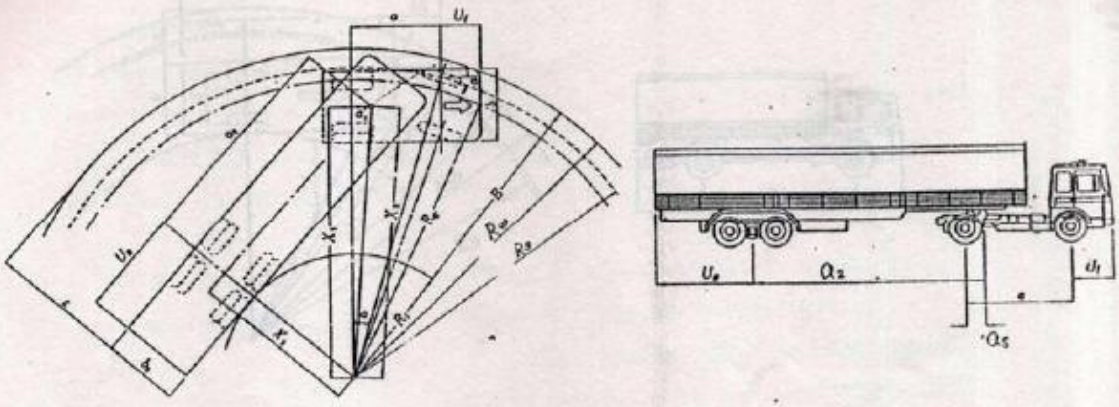

Fig.4.2.3 Trailer

B ; Running width of vehicles. Rc ; Radius of centre line.

L ; Length of vehicles. b ; Width of vehicles.

S ; Interval of wheels. a ; Wheel base.

Rw : Outer curve radius. Rs ; Radius of gyration of outer front wheel

Ri ; Inner curve radius. α ; Turning angle of outer front wheel.

U_B ; Back end overhang. U_f;Front end overhang.

ε ; Widening amount of one lane. a_s ; Off-set

<Formulae>

$$\varepsilon = B - b.$$

$$B = Rw + b_2/2 - \sqrt{Rc^2 - (a + U_f)^2 - a_2^2 + a_s^2}.$$

$$Rw = \sqrt{\left\{\sqrt{Rc^2 - (a + U_f)^2} + b/2\right\}^2 + (a + U_f)^2}$$

Figure 4.4. Calculation of Widening Width (Source: GHA RDG, 1991)

Summary of Findings

- The GHA RDG generally covers all but the recreational vehicle class. Additionally, design vehicle dimensions are generally larger in the Policy.
- The GHA RDG presents height, width, length, but does not feature overhang, minimum turning radius and wheelbase as key vehicle dimensions.
- Swept path (off tracking) and curve section widening are presented under a different chapter (Chapter 4: Alignment).

- The tabular presentation of design vehicles and how they control design makes for easier design vehicle selection than the text-only presentation.
- Since off tracking and widening of curve sections is directly related to design vehicle it would be prudent to present the two topics in one chapter, as done in the other manuals.
- The GHA RDG does not recommend values for minimum turning radius of design vehicles although it is useful in determining channel radii and open space dimensions for intersections.
- The formula for computing the widening required in curve sections, and at intersections as presented in the GHA RDG, is necessary for achieving intersection capacity.

4.1.3 Chapter 2: Classification of Roads and Design Speed

The existing GHA RDG classifies trunk roads into the functional categories, Primary, Major Secondary and Minor Secondary roads. These functional classes together with terrain determine design speed selection for any road. By a recent publication the Ministry of Roads and Transport (MRT) roads classification system has rechristened the trunk roads functional classes as National (formerly Primary) roads, Inter Regional (formerly Major Secondary) roads and Regional (formerly Minor Secondary) roads (GHA GTZ, 2003). Current terms of reference for road designs employ the current class names only and present designers with the task of mapping these new class names onto the previous ones, sometimes leading to error.

Again, roads in urban areas are referred to only as 'Town/Residential Roads' and 'Service Roads in Town' in the GHA RDG whereas the current system functionally classifies urban roads as Major Arterial, Minor Arterial, Collector/Distributor and Local Roads.

For geometric design roads in the GHA RDG are classified by their function and by terrain type. This is shown in Table 4.6.

Table 4.6. Road classification by function and terrain type (Source: GHA RDG)

Road type	Classification
Motorway	Flat
	Hilly
	Mountainous
Primary	Flat
	Hilly
	Mountainous
Secondary	Flat
	Hilly
	Mountainous

Road type	Classification
Feeder	Flat
	Hilly
	Mountainous
Town or Residential	Free way
	Dual carriageway
	Normal
Service road in town	

According to the Ugandan manual functional classification of a road is based on its proposed function and roads grouped under a particular class will be characterised by the level of service they provide (MWHC, 2005). The Ugandan manual also employs functional classification of roads for geometric design.

Classification and Access – The Ugandan manual controls access to a road depending on its class. The higher the class of road the more access to it is restricted (Table 4.7).

Table 4.7. Functional class and level of access control (Source: Ugandan Design Manual)

Functional Class	Level of Access Control	
	Desirable	Reduced
A	Full	Partial
B	Full or Partial	Partial
C	Partial or Unrestricted	Partial
D	Partial	Unrestricted
E	Partial or Unrestricted	Unrestricted

Although the GHA RDG discusses the benefits and risks associated with full, partial and unrestricted access control it does not recommend access control levels to be applied to the various road classes.

Classification and Level of Service – To ensure the achievement of required highway capacity the Ugandan manual and the Policy additionally recommend appropriate levels of service for each combination of functional road class and terrain type (Tables 4.8 and 4.9). A higher level of service goes with higher functional class and lower relief.

Table 4.8. Functional class and level of service (Source: AASHTO, 2011)

Functional Class	Appropriate Level of Service for Specified Combinations of Area and Terrain Type			
	Rural Level	Rural Rolling	Rural Mountainous	Urban and Suburban
Freeway	B	B	C	C or D
Arterial	B	B	C	C or D
Collector	C	C	D	D
Local	D	D	D	D

Table 4.9 Functional class and level of service (Source: Ugandan Design Manual)

Road Functional Class		Level of Service			
		Level terrain	Rolling terrain	Mountainous terrain	Road Design Class
A	International Trunk Roads	B	B	C	Ia Paved Ib, II and III Paved
B	National Trunk Roads	B	C	D	Ib, II and III Paved, A Gravel
C	Primary Roads	C	D	D	II and III Paved, A Gravel
D	Secondary Roads	D	D	E	A and B Gravel
E	Minor Roads	E	E	E	B and C Gravel

The GHA RDG does not indicate recommended levels of service for the various road classes. Such recommendation would have been useful in determining issues like access control levels and number of lanes for any class of road.

Classification and Design Speed – Based on function and terrain type applicable design speeds are given in the GHA RDG as shown in Table 4.10. It can be seen that high function and low relief go with high design speed.

Table 4.10. Design speed by function and terrain type (Source: GHA RDG)

Units ; km/h

Road type	Classification	Design speed	Absolute values
Motorway	Flat	120	100
	Hilly	100	80
	Mountainous	80	60
Primary	Flat	100	80
	Hilly	80	60
	Mountainous	60	40
Secondary	Flat	80	60
	Hilly	60	40
	Mountainous	50	30
Feeder	Flat	60	40
	Hilly	50	30
	Mountainous	40	20
Town or residential	Free way	80	60
	Dual carriageway	60	40
	Normal	50	30
Service road in town		40	20

The Policy also uses functional road classification and terrain type in road design. For example, for rural arterials other than freeways, design speeds of 100 to 120 km/h [60 to 75 mph] are normally used in level terrain; design speeds of 80 to 100 km/h [50 to 60 mph] are normally used in rolling terrain,; and design speeds of 60 to 80 km/h [40 to 50 mph] are used in mountainous terrain.

Design Speed and Sectional Design – the GHA RDG recognises that a route may have

different sections, which differ in terms of terrain, traffic volume and importance. It therefore recommends that the same design speed be adopted for homogenous sections (Table 4.11). To achieve a good connection between different design sections the GHA RDG recommends that the difference in design speeds must not exceed 20km/h (i.e. one design class step) as shown in Figure 4.5. Table 4.11 recommends applicable minimum sectional design lengths.

Table 4.11. Minimum lengths for sectional design (Source: GHA RDG)

Road type	Desirable	Unavoidable case
Motorway, Primary Secondary	20 - 30 km	5 km
Feeder	10 - 15 km	2 km
Town or Residential, Service road in town	From principal intersection to the next principal intersection	

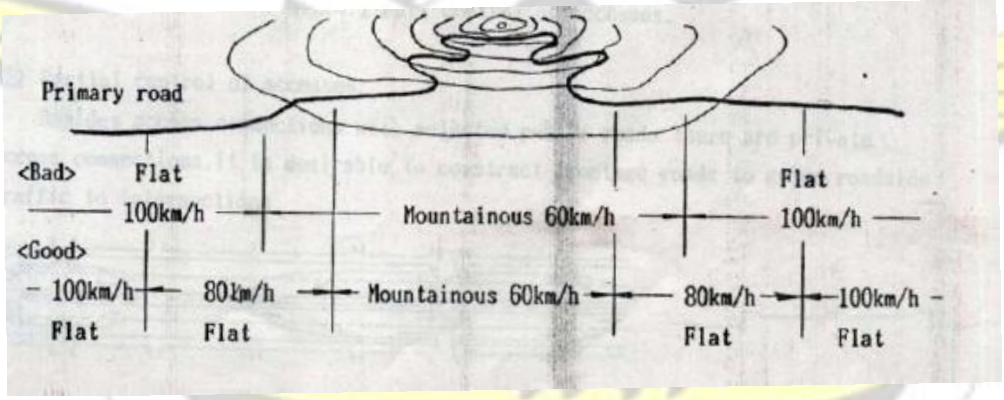

Figure 4.5. Connection of sectional design (Source: GHA RDG)

Acoording to the Overseas Road Note 6 geometric elements should not normally be designed to a design class more than a one design class step lower than the approach speed to that element. That notwithstanding, two design class steps may be achieved by successive reductions from a design speed of, for example, 85 km/h in rolling terrain to 70 km/h and then 60 km/h. Where this is not possible, consideration must then be given to redesign of the element or modifications to the geometry of the approach section to obtain this speed reduction. The

GHA RDG recommends sectional design, but does not indicate what designers should do when, for sectional design, stepwise design speed reduction cannot be achieved.

Summary

- Current terms of reference for road designs employ the current class names only and present designers with the task of mapping these new class names onto the previous ones, sometimes leading to error.
- Roads in urban areas are referred to only as 'Town/Residential Roads' and 'Service Roads in Town' in the GHA RDG whereas the current system functionally classifies urban roads as Major Arterial, Minor Arterial, Collector/Distributor and Local Roads.
- Although the GHA RDG discusses the benefits and risks associated with full, partial and unrestricted access control it does not recommend access control levels to be applied to the various road classes.
- The GHA RDG does not indicate recommended levels of service for the various road classes. Such recommendation would have been useful in determining issues like access control levels and number of lanes for any class of road.
- The GHA RDG recommends sectional design, but does not indicate what designers should do when, for sectional design, stepwise design speed reduction cannot be achieved.

4.1.4 Chapter 3: Composition of Cross-section

According to the Overseas Road Note 6 it is important that the designation of a road by functional type should not give rise to overdesign for the levels of traffic actually encountered. Uneconomic designs reduce the likelihood of roads being built and result in wastage of often scarce national resources (TRRL, 1998). The Overseas Road Note 6 recommends design standards as shown in Table 4.11 for carriageway and shoulder widths.

Table 4.12. Road design standards (Source: TRRL, 1998)

ROAD FUNCTION	DESIGN CLASS	TRAFFIC FLOW * (ADT)	SURFACE TYPE	WIDTH (m)		MAXIMUM GRADIENT (%)	TERRAIN/DESIGN SPEED (km/h)		
				CARRIAGE-WAY	SHOULDER		MOUNTAINOUS	ROLLING	LEVEL
Arterial	A	5,000–15,000	Paved	6.5	2.5	8	85	100	120
	B	1,000–5,000	Paved	6.5	1.0	8	70	85	100
Collector	C	400–1,000	Paved	5.5	1.0	10	60	70	85
	D	100–400	Paved/ Unpaved	5.0	1.0+	10	50	60	70
Access	E	20–100	Paved/ Unpaved	3.0	1.5+	15	40	50	60
	F	< 20	Paved/ Unpaved	2.5/3.0	Passing Places	15/20	N/A	N/A	N/A

* The two way traffic flow is recommended to be not more than one Design Class step in excess of first year ADT.
\+ For unpaved roads where the carriageway is gravelled, the shoulders would not normally be gravelled; however, for Design Class D roads, consideration should be given to gravelling the shoulders if shoulder damage occurs.

The Ugandan manual adopts the same principle of economy and recommends the standards shown in Tables 4.13and 4.14.

Table 4.13. Road design standards (Source: Ugandan Design Manual)

Design Class	Capacity [pcu x 1,000/day]	Road-way width[m]	Maximum Design speed Kph			Functional Classification				
			Level	Rolling	Mountainous	A	B	C	D	E
Ia Paved	12 - 20	20.80-24.60	120	100	80	√				
Ib Paved	6 – 10	11.0	110	100	80	√	√			
II Paved	4 – 8	10.0	90	70	60	√	√	√		
III Paved	2 – 6	8.6	80	70	50	√	√	√		
A Gravel	4 – 8	10.0	90	80	70		√	√	√	
B Gravel	2 – 6	8.6	80	60	50				√	√
C Gravel		6.4	60	50	40					√

Table 4.14. Road design standards Cont'd. (Source: Ugandan Design Manual)

Design class	Right of Way width [m]	Road way width [m]	Carriage way			Shoulder width [m]	Median width [m]
			Width [m]	Lane width [m]	No. of lane		
Ia Paved	60	20.80-24.60	14.6	3.65	4	2 x 2.5	1.2 – 5.0
Ib Paved	60	11.0	7.0	3.5	2	2 x 2.0	-
II Paved	50	10.0	6.0	3.0	2	2 x 2.0	-
III Paved	50	8.6	5.6	2.8	2	2 x 1.5	-
A Gravel	40	10.0	6.0	3.0	2	2 x 2.0	-
B Gravel	30	8.6	5.6	2.8	2	2 x 1.5	-
C Gravel	30	6.4	4.0	4.0	1	2 x 1.2	-

It is obvious from Tables 4.12, 4.13 and 4.14 that for economic reasons consideration must be given to traffic volume in determining widths of cross-section elements like right of way, lanes and shoulders. The general trend is that as traffic volume reduces design speed and crosssection widths decrease.

Table 4.15. Functional class, terrain and lane width (Source: GHA RDG)

Road type	Classification	Lane width	Road type	Classification	Lane width
Motorway * 3.50	Flat, Hilly	3.65		Flat	3.50
	Mountainous	3.50			3.25, 3.00
Primary * 3.65	Flat, Hilly	3.65 3.50 3.25	Feeder * 3.00	Hilly	3.25 3.00
	Mountainous	3.50 3.25		Mountainous	3.00 2.75
Secondary * 3.50	Flat	3.65 3.50 3.25	Town or resident-ial * 3.50	Freeway	3.65 3.50 3.25
	Hilly	3.50 3.25 3.00		Dual carriageway	3.50 3.25
	Mountainous	3.25 3.00		Normal	3.25 3.00
			Service road in town * 3.00		3.00 2.75

The GHA RDG gives a range of applicable lane widths for each road class and terrain type. It then recommends desirable widths for each class (Table 4.15). For example, a Secondary road in flat terrain could have widths ranging from 3.25m to 3.65m, and the recommended width is 3.50m for a Secondary road, irrespective of terrain. Table 4.16 also gives desirable lane widths based on design speed irrespective of road class or terrain. There is a conflict between the contents of Table 4.15 and that of Table 4.16 in the sense that whereas Table 4.16 recommends a width of 3.65m for design speeds greater than 80km/h in Table 4.15 a width of 3.50m has been recommended for a motorway in flat terrain whose design speed is 100km/h.

Table 4.16. Design speed and lane width (Source: GHA RDG)

Design speed (km/h)	Desirable lane width (m)
> 80	3.65
60	3.50
60,50 or 40	3.25
50,40 or 30	3.00

According to the Policy, Lane widths of 2.7 to 3.6 m are generally used, with a 3.6-m lane predominant on most high-speed, high-volume highways. The extra cost of providing a 3.6-m lane width, over the cost of providing a 3.0-m lane width is offset to some extent by a reduction in cost of shoulder maintenance and a reduction in surface maintenance due to lessened wheel concentrations at the pavement edges.

Table 4.17. Functional class and median width (Source: GHA RDG)

Road type		median	Borderline
Motorway	Rural	Minimun 10	———
	Urban	2 - 4	0.50 - 0.75
Other road		2 - 4	0.30 - 0.50

Table 4.17 gives median and borderline widths based on road class. The higher the road class the wider the borders or median. Table 4.18 also gives shoulder widths based solely on road class. Shoulder widths in the GHA RDG are based on road class alone. Here also the higher the road class the wider the shoulders.

Stopping Lanes - Table 4.19 presents widths for stopping lanes, also based on road class alone. Wider stopping lane widths are recommended for high road class and vice versa. **Table 4.18. Functional class and shoulder width (Source: GHA RDG)**

Road type	Width
Motorway	3.0
Primary	2.5
Secondary	2.5
Feeder	1.5

Road type		Width
Town or residential	Freeway	3.0
	Dual carriageway	2.5
	Normal	2.0
Service road in town		2.0

Table 4.19. Stopping lane widths (Source: GHA RDG)

Units ; m

Road type		median	Borderline
Motorway	Rural	Minimun 10	———
	Urban	2 - 4	0.50 - 0.75
Other road		2 - 4	0.30 - 0.50

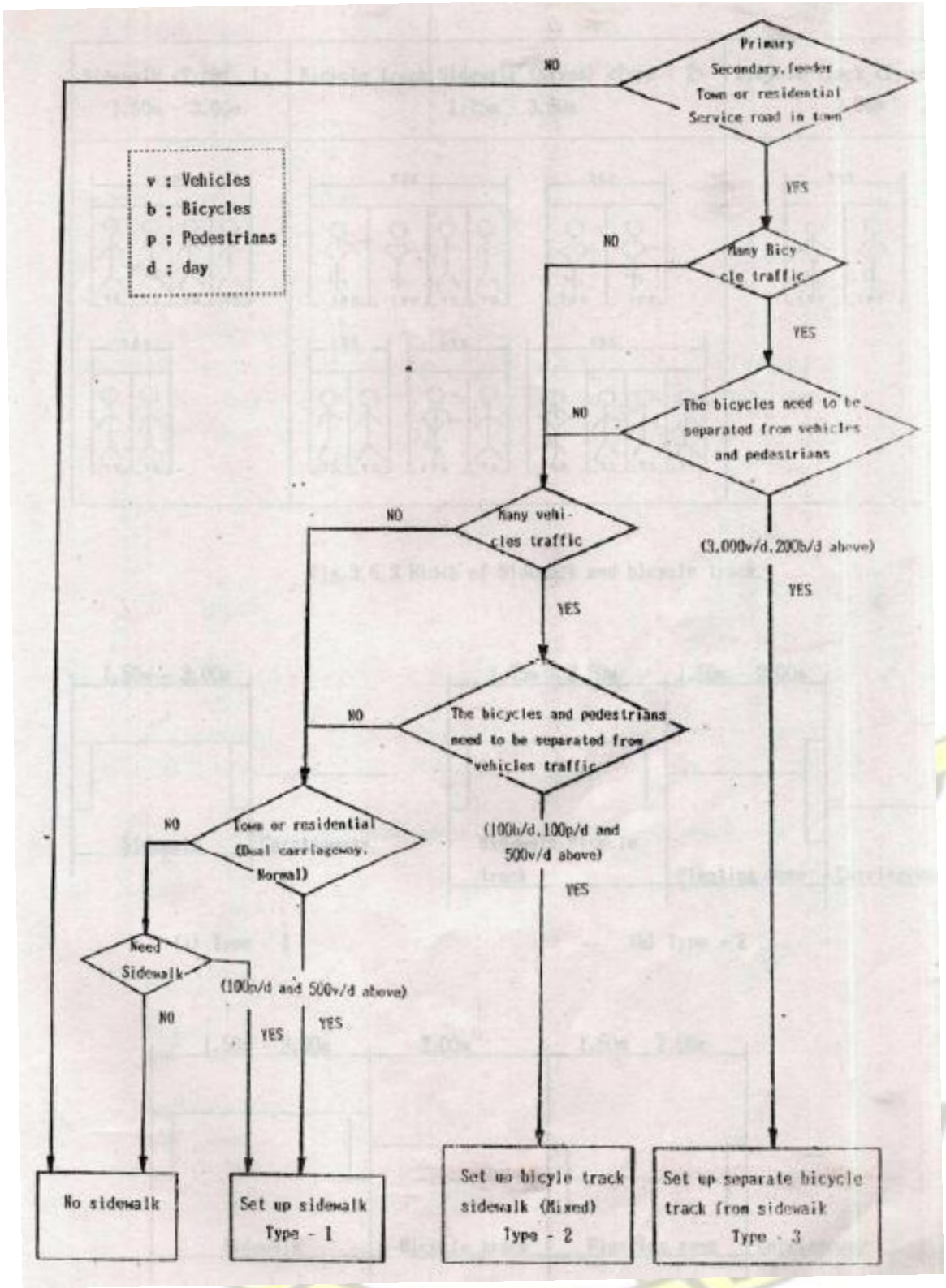

Figure 4.6 Flowchart for bicycle track and walkway determination (Source: GHA RDG)

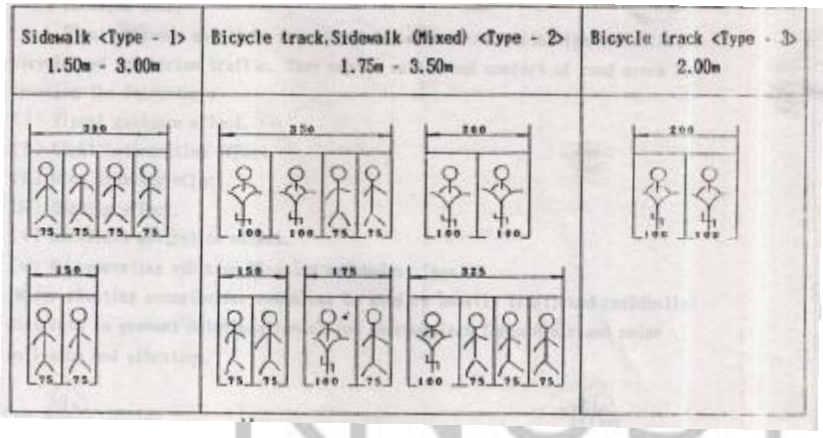

Figure 4.7. Side walk and bicycle track (Source: GHA RDG)

According to the Overseas Road Note 6 consideration needs to be given to the movement of pedestrians, cyclists and animal drawn vehicles either along or across the road. Measurements or estimates of such movements should be made, where possible, to give a firmer basis for making decisions on the design. There is no indication of how to determine number of lanes. According to AASHTO's Guide for the Development of Bicycle Facilities (AASHTO, 1999) bicycle counts can be used to identify locations of high use. It however adds that caution should be exercised when using bicycle counts as a measure of current demand. These numbers can considerably underestimate potential users. Minimum widths for bicycle/pedestrian tracks are recommended. There is again no indication of how to determine number of lanes. The GHA RDG recommends the use of certain threshold traffic volumes to decide on whether sidewalks and bicycle tracks would be needed, and whether they can be combined (Figure 4.6). It further recommends widths for segregated and combined cycle and pedestrian lanes. However like the other manuals discussed, there is no indication of how traffic volumes convert to design widths.

Planting Zones – The importance of planting zones and their typical widths are given in the GHA RDG, as also done in the Policy.

Clearances - The GHA RDG treats vertical and lateral clearance in detail. It gives minimum vertical clearances under highway structures for vehicles and pedestrians. It also gives lateral clearances under highway structures, and for road furniture adjacent to carriageways

Side Slopes – The GHA RDG shows side slopes in typical cross-sections, but does not recommend any dimensions for fore and back slopes of road pavements

Cross Slope – The GHA RDG presents cross slope and recommends cross slope values for different pavement surface types. The subject of cross slope is however presented in a different chapter (Chapter 4: Alignment).

Lay-bys – The GHA RDG on which road class lay-bys with and without separators may be employed. It proceeds to recommend dimensions of lay-by components based on design speed and road class. The subject of lay-bys is however treated in a different chapter (Chapter 7: Accessories to Road).

Traffic Barriers – The GHA RDG presents a cross-section of a median safety fence as a median type in this chapter. It however treats roadside safety fences, sidewalk safety fences and median strip safety fences in a separate chapter (Chapter 7: Accessories to Road).

Summary of Findings

- With the exception of the cases of sidewalks and bicycle tracks where an attempt is made to consider volumes, the GHA RDG does not employ traffic volume as a factor for determining travelled way cross-section widths. Widths are selected mainly based on road class and terrain type considerations.
- This approach will undoubtedly lead to overdesign, under usage and economic waste since a Primary (National) road with low traffic could end up being designed with carriageway and shoulder/stopping lane widths as wide as those for its counterpart in a high traffic zone.
- The GHA RDG does not recommend any dimensions for fore and back slopes of road pavements.
- The subject of cross slope is treated but presented in a different chapter (Chapter 4: Alignment)

- The subject of lay-bys is however treated in a different chapter (Chapter 7: Accessories to Road).
- It however treats roadside safety fences, sidewalk safety fences and median strip safety fences in a separate chapter (Chapter 7: Accessories to Road).
- Treating cross-section related topics like cross slope, lay-bys and traffic barriers in a chapter different from that on cross-sections appears to mislead designers, since their first impression would be that such topics are not covered at all by the GHA RDG.
- There is a conflict between the contents of Table regarding the recommended lane width to be used for design speeds greater than 80km/h.
- Important cross-section elements like Drainage Channels, Clear Zone, Side Roads and Culverts, Right-of-way, Cross-section over Bridges and Culverts, Outer Separations, Curbs, Rumble Strips, Noise Control.

4.1.5 Chapter 4: Alignment

Basic Points of Alignment Design – the GHA RDG gives a brief description of what to consider in order to achieve a good alignment by discussing smooth alignment, compound curves, reverse curves, undulating hill terrain and high embankments with illustrations. There is however no presentation on procedure for alignment design. The Ugandan manual gives a stepwise procedure for achieving a good alignment in harmony with its environment. The steps given are inventory, route planning (arc method and straight method), and detail design.

Horizontal alignment – the essential topics of horizontal alignment such as curve radii, superelevation, superelevation runoff, transition curves, curve section widening have been well treated in the RDG, however there are yet a few omissions and anomalies have been observed, and are discussed as follows:

Broken-back curves – the GHA RDG makes no mention of broken-back curves (curves in the same direction with relatively short straight in between them). A broken-back curve configuration (Figure 4.8) poses a safety threat since it does not meet driver expectations (MWHC, 2005; AASHTO, 2011).

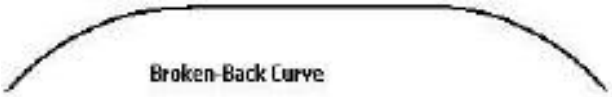

Figure 4.8. Broken-back curve (Source: Ugandan Geometric Design Manual)

Minimum curve radii – An anomaly is observed in the GHA RDG between the minimum desirable curve radius in Table 4.2.1 (420m) and that in the table in Appendix A, page 116 (458m) for a design speed of 80km/h and a superelevation rate of 5%.

Vertical Alignment – Some omissions and anomalies have been observed in the GHA RDG, and are discussed as follows:

Meeting sight distance – Meeting sight distance (distance required to enable the drivers of two vehicles travelling in opposite directions, on a two-lane rural road, with insufficient width for passing, to bring their vehicles to a safe stop after becoming visible to each other) is not discussed in the GHA RDG. According to the Ugandan manual it is the sum of the respective stopping sight distances for the two vehicles plus 10.0 m safety distance.

Control for Sag Curves – The GHA RDG recommends that sag curves are designed using driver comfort criteria since the headlight condition gives sight distances far in excess of the effective ranges of the headlamp beams. According to the Ugandan manual it is recommended to use the head light sight distance criterion for determination of minimum length of sag curve from the point of view that it is more logical for general use and especially in connection to safety on roads.

Sight Distance at Undercrossings – the Policy on Geometric Design of highways and Streets recommends that sight distance on a highway through a grade separation should be at least as

long as the minimum stopping sight distance and preferably longer (Figure 4.9). The GHA RDG gives vertical clearances under grade-separated structures, however there is no mention of line of sight under highway structures.

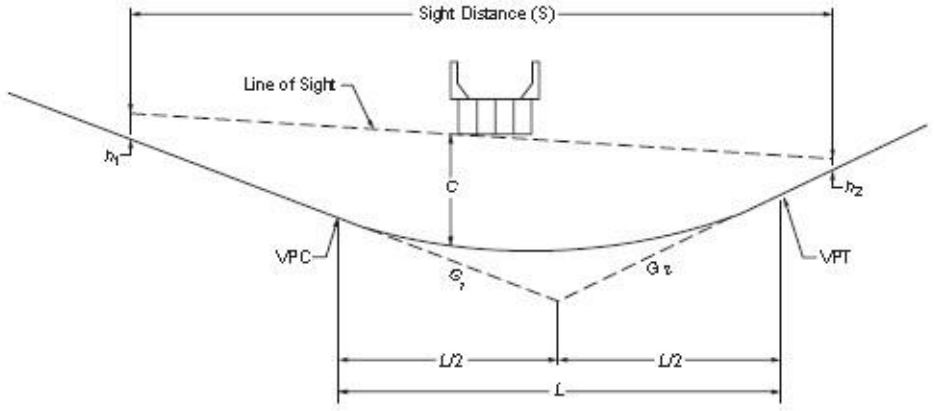

Figure 4.9. Sight Distance at Undercrossings (Source: AASHTO, 2011)

Climbing Lanes – the GHA RDG recommends the introduction of climbing lanes under the following necessary conditions:

i) Traffic volume as well as the proportion of large vehicles and trailers or commercial vehicles must be more than 20%. ii) The critical lengths must be exceeded.

The GHA RDG then gives entry and exit runoff lengths of 45m and 60m respectively, and a width of 3.5m. Although the Guide gives speed and gradient related critical lengths there is no mention of what traffic volumes are considered to be ‘high’. The entry and exit widths are also not speed related. This makes the introduction of climbing lanes subjective, and also there is the likelihood that entry and exit runoffs will be unmatched with operating speeds, leading to reduced capacity or overdesign. The Ugandan manual gives threshold traffic volumes for the introduction of climbing lanes. For example climbing lanes will not be necessary on (i) roads with AADT < 2000 pcu in design year 10, and (ii) on all design class III, A, B and C roads even if the AADT exceeds 2000 pcu in design year 10. The Ugandan manual also gives speed related entry and exit runoffs as shown in Table 4.20. Higher speeds are given longer runoffs.

Table 4.20. Runoff lengths (Source: Ugandan Manual)

Speed limit (km/h)	Entry taper (m)	Exit taper (m)
80	150	200
100	200	300

Phasing of Horizontal and Vertical curves – although the importance of proper phasing and methods of achieving same are treated no visual illustrations are given to aid the designer to grasp the concept. The Ugandan manual gives illustrations of correct and incorrect phasing as shown in Figure 4.10.

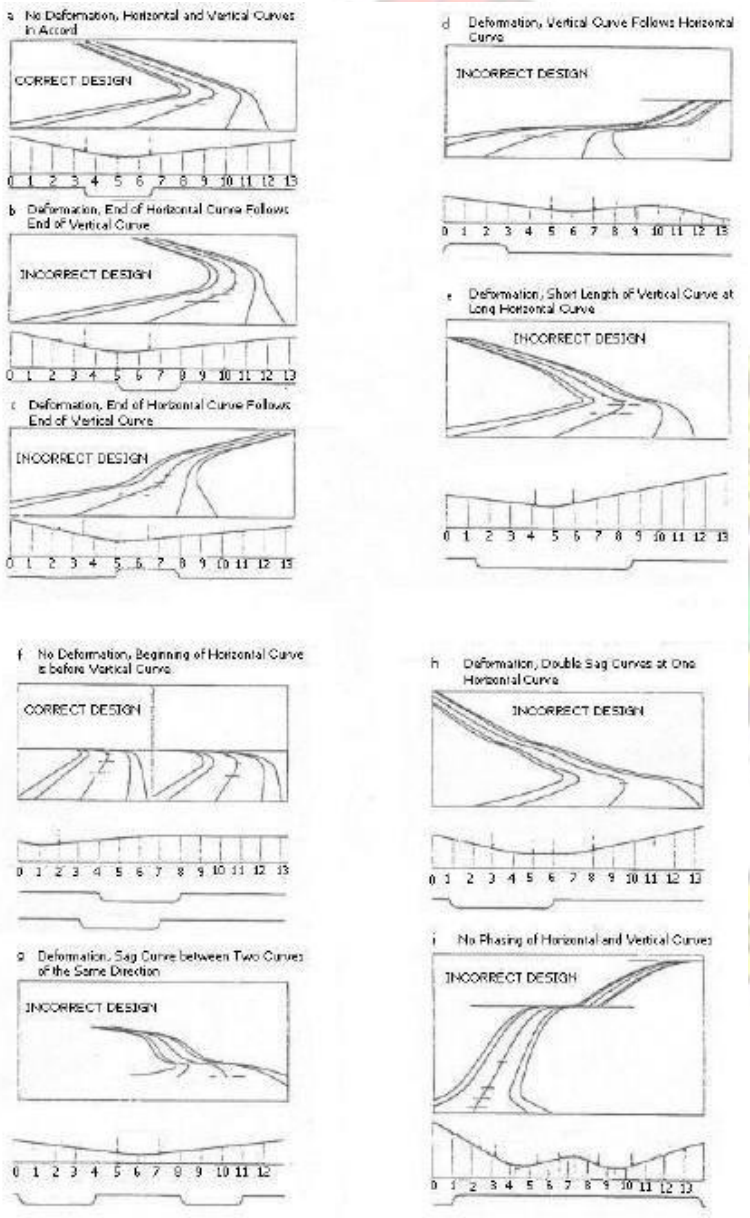

Figure 4.10. Phasing of horizontal and vertical curves (Source: Ugandan Manual) **Summary of Findings**

- The GHA RDG gives a brief description of what to consider in order to achieve a good alignment, but does not give a stepwise procedure for achieving a good alignment in harmony with its environment.
- The GHA RDG makes no mention of broken-back curves (curves in the same direction with relatively short straight in between them) although they are a threat to road safety. There is inconsistency between the minimum desirable curve radius in Table 4.2.1 (420m) and that in the table in Appendix A, page 116 (458m) for a design speed of 80km/h and a superelevation rate of 5%.
- Meeting sight distance (a necessary control on narrow two-lane rural roads) is not discussed in the GHA RDG.
- The GHA RDG recommends that sag curves are designed using driver comfort instead of headlight condition (which would give longer and possibly safer curve lengths).
- The GHA RDG does not mention line of sight under highway structures.
- There is no mention of what threshold traffic volumes are warrants for climbing lanes. Entry and exit widths given are also not speed related.
- No visual illustrations are given to aid the designer to grasp the concept of Phasing of Horizontal and Vertical Curves.

4.1.6 Chapter 5: At-grade Intersection

The GHA RDG covers many essential areas of at-grade intersection design such as planning (procedure and required data), intersection layout, intersection spacing, visibility, channel and island design, cross-section composition, left-turn lane design and lane shift run-off. There are however certain omissions in the GHA RDG in the area of at-grade intersection design that are discussed as follows:

Junction Design Speed – Although speeds through an intersection are expected to affect capacity and safety the GHA RDG does not employ junction design speed as a parameter required for the design of at-grade intersections. According to the Ugandan manual economy demands that the Junction Design Speed be no more than 20 km/h higher than the average design speed of the major road. Additionally, for safety reasons, the Junction Design Speed should never be less than 20 km/h lower than the average design speed for the major road.

Selection of Intersection Category and Type – The GHA RDG gives examples of good and bad intersection configurations and for the bad ones, recommends applicable corrective measures. It however does not give any guidelines for the selection of interchange type. According to the Ugandan Geometric Manual the selection of intersection category should mainly be based on safety, and this can be done by using diagrams with the relationships between the safety levels and the average annual daily approaching traffic volumes (AADT in veh/day) based on accident statistics. Figures 4.11 to 4.13 show considerations for T-intersections on 2-lane roads with 50km/h speed limit. The traffic volumes on major and minor roads determine what control type is required (Figure 4.11), whether acceptable capacity will be achieved (Figure 4.12), or whether the intersection should be chanelised. Generally, higher volumes require higher levels of control, or grade separation.

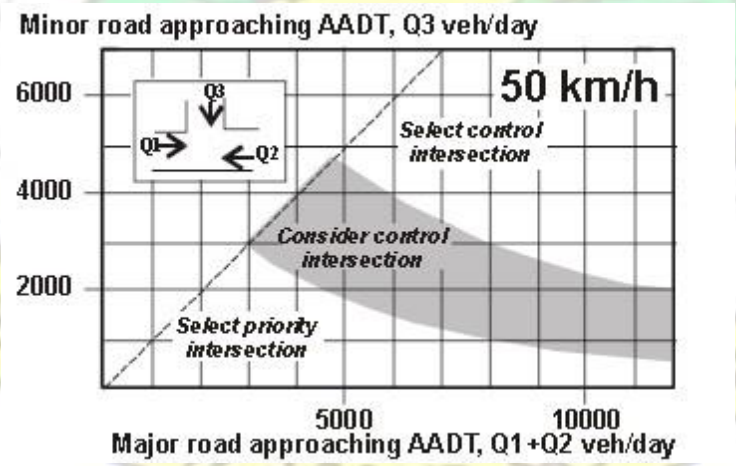

Figure 4.11. Intersection category selection - Safety (Source: Ugandan Manual)

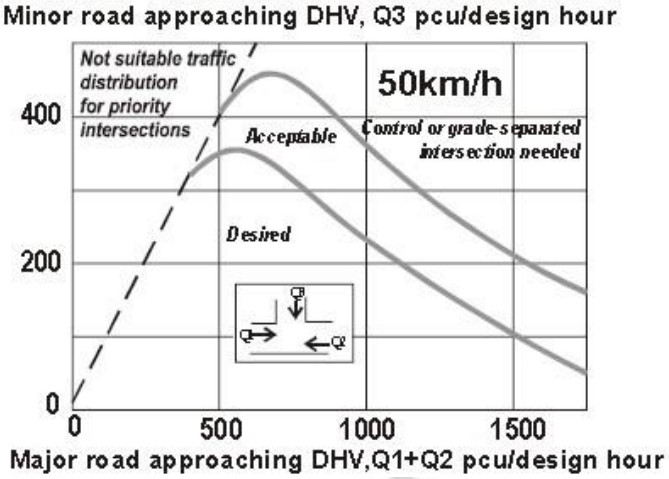

Figure 4.12. Intersection category selection - Capacity (Source: Ugandan Manual)

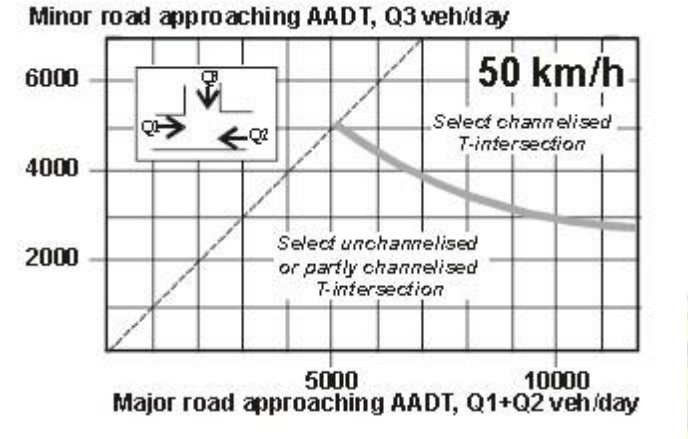

Figure 4.13. Priority intersection type selection - Safety (Source: Ugandan Manual)

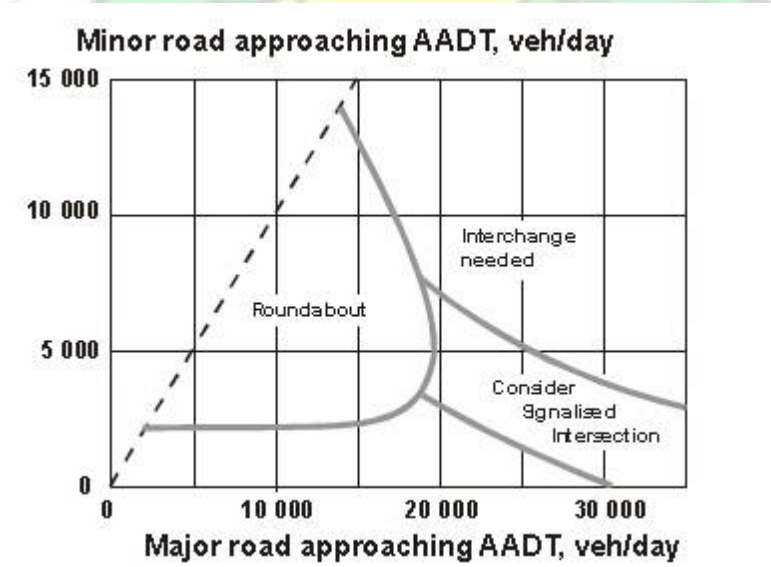

Figure 4.14. Intersection type selection - Control (Source: Ugandan Manual)

Figure 4.14 shows whether a roundabout, signalized intersection or interchange would be required. From the table a roundabout is recommended when there is low-medium traffic on the major road combined with low-high traffic on the minor road. A signalised intersection is recommended for medium-high traffic on the major road combined with low-medium traffic on the minor road. An interchange is recommended when medium-high traffic levels on the major road combine with low-high traffic in the minor road.

Roundabout design – The GHA RDG does not cover roundabouts and their design, although research has shown that there are fewer conflict points in roundabouts than signalized intersections and roundabouts tend to have accidents of a less severe nature (RoundaboutsUSA, 2016). The Ugandan manual and the Policy provide ample guidance for the design of roundabouts.

Signalised intersections – The GHA RDG gives minimum distance required for recognising signalised and unsignalised intersections. It however does not cover the design of signalised intersections. The treatment of signalised intersections is hence incomplete. The Ugandan manual amply covers the topic in terms of control strategy and layout, visibility, lane design, signal location advice, spacing of signalized intersections, and pedestrian and cyclist facilities.

Level Crossings – The GHA RDG does not give any guidelines to cover designs for highwayrailroad intersections, contrary to what pertains in the Policy.

Capacity - The GHA RDG does not treat highway capacity as a design control as done in the Policy and also the Ugandan Manual. It also does not give any guidelines on how to ensure that a designed intersection can adequately handle design traffic demand. It is hence difficult to determine whether an intersection has been overdesigned or underdesigned.

Summary of Findings

- The GHA RDG does not employ junction design speed as a parameter required for the design of at-grade intersections.
- The GHA RDG does not give any guidelines for the selection of interchange type.
- The GHA RDG does not cover roundabouts and their design.
- The GHA RDG does not cover the design of signalised intersections.
- The GHA RDG does not treat highway capacity as a design control.
- The GHA RDG does not give any guidelines to cover designs for highway-railroad intersections.
- The GHA RDG does not give any guidelines on how to ensure that a designed intersection can adequately handle design traffic demand.

4.1.7 Chapter 6: Road Drainage

Chapter 6 of the GHA RDG is devoted to road drainage. The subject of road drainage however falls outside the scope of this study. The GHA RDG chapter on road drainage was therefore not reviewed.

4.1.8 Chapter 7: Accessories to Road

In this chapter the GHA RDG discusses bus-bays, parking, road marking and safety fence. Howbeit, the topics of Road Marking and Safety Fence would be better placed with other road safety related topics in a separate chapter. They must however be mentioned in the chapter on cross-section elements, when they constitute such. In the Policy the topics of Bus-bays and Safety Fences are treated under Bus Turnouts and Traffic Barriers in the chapter for CrossSection Elements. Toll plazas and rest stops are becoming everyday design features, but the GHA RDG does not cover them. Although the GHA RDG gives numerous configurations for parking it does not give guidelines for how traffic data can be used to design for parking.

Summary of Findings

- The topics of Road Marking and Safety Fence would be better placed with other road safety related topics in a separate chapter.
- The GHA RDG does not cover toll plazas and rest stops although they are becoming everyday design features on Ghanaian roads.
- Although the GHA RDG gives numerous configurations for parking it does not give guidelines for how traffic data can be used to design for parking.

4.1.9 Chapter 8: Presentation of Drawing

The GHA RDG gives details of requirements for presenting road design drawings. It covers size of drawing and margin, cover sheet, title column, table of contents, location map, key plan, cross-section, other drawings (junction details, structural details, and drainage details). The list of required drawings however does not include expropriation/right-of-way and road furniture. The horizontal title column gives more usable space for drawings, especially for A3 sized sheets. The GHA RDG features only the vertical title column.

Summary of Findings

- The list of required drawings does not include expropriation/right-of-way and road furniture.
- The GHA RDG does not feature the horizontal title column

4.2 Assessment of Responses to Questionnaire

4.2.1 Respondents' Personal Data

Out of 15 questionnaire sent out 8 responses were received. Seven respondents failed to fill out and return their questionnaire in spite of numerous reminders to do so. For the questionnaire received all Respondents were Highway Designers or Road Safety Engineers working as

Highway Consultants or with Client/Supervision Agencies. Respondents' work experience ranged from up to 5years to 10 years and above. All respondents had worked on GHA or DUR road design projects as Team Leaders, Consultants or Highway Designers.

4.2.2 Respondents' Limited Use of the GHA RDG

All respondents indicated that they refer to the GHA Road Design Guide in their highway design practice. They indicated that they select the following design controls and criteria from the GHA Road Design Guide:

Controls/Criteria

1. Road Classification
2. Design Speed
3. Design Vehicle
4. Access Control
5. Pedestrian Accommodation
6. Vertical Clearance
7. Stopping Sight Distance
8. Passing Sight Distance
9. Horizontal Curvature
10. Vertical Curvature
11. Phasing of Curves
12. Cross sectional features
13. At-grade intersections
14. Parking lots
15. Lay-by
16. Superelevation rates
17. Spiral curve length

All respondents stated that the GHA Road Design Guide was not sufficient for all their highway designs, and indicated that they were not able to use the GHA Road Design Guide for the following design elements/controls/criteria/features:

Elements/Controls/Criteria/Features

1. Speed Calming
2. Level of Service
3. Roundabout
4. Grade separated intersections
5. Highway capacity analyses
6. Freeways
7. Lane balancing
8. Parking Studies
9. Phasing of Curves
10. Design Vehicle
11. Channelisation
12. Broken back curves
13. Tunneling
14. Toll plaza design
15. Pedestrian Footbridges/underpass
16. Turning radius for different design vehicles
17. Design of ferry landing ramp
18. Features for Vulnerable Road Users
19. Speed and traffic related horizontal clearances
20. Terrain Classification by grades
21. Determination of design vehicle
24. Basis for terrain classification

4.2.3 Respondents' Recommendations for Modification of the GHA RDG

Respondents recommended the following changes/additions/omissions in the GHA Road Design Guide:

(i) **Respondents**: *A dedicated chapter should be created for traffic calming devices in communities along the highway.*

Researcher: As earlier observed in this study, settlements along trunk roads are getting more and more populated and that traffic volume is on the increase, resulting in an increased need for designs to handle higher levels of traffic and traffic conflicts with a view to safety and economy. Additionally, according to NDOT (1999) safety is the principal design consideration. The researcher is of the view that for sufficient emphasis on road safety a chapter should be devoted to road safety installations including traffic calming devices in communities along the highway.

(ii) **Respondents**: *A dedicated chapter should be created for the design of interchanges and rotary intersections.*

Researcher: An interchange is an efficient and safe way of minimizing conflicts generated by crossing roads with high speeds and volumes (AASHTO, 2011). Roundabouts provide many significant safety advantages over signalized intersections and have the same capacity to cater for a significant volume of traffic (up to 7000 entering vehicles per hour - 60,000 vehicles/day). Additionally there are fewer conflict points in roundabouts than signalized intersections and roundabouts tend to have accidents of a less severe nature (RoundaboutsUSA, 2016). As indicated in Table 2.5 roundabouts, and interchanges are not treated in the GHA RDG. In the researcher's opinion they are necessary should be incorporated with the revised manual, howbeit in separate chapters since they are each voluminous and belong to two different categories, namely at-grade and grade-separated intersections.

(iii) **Respondents**: *The classification of the trunk roads into National Roads, Interregional Roads and Regional Roads should be included. The functional classification of roads based on mobility and access control should be considered. The classification of roads into freeways, collector roads, access roads, etc. should be considered.*

Researcher: The GHA RDG features six functional classes of roads, namely Motorways, Primary Roads and Secondary Roads, Feeder Roads, Town/Residential Roads and Service Roads in Town. In the year 2000, however, the Ministry of Roads and Highways adopted a new classification nomenclature for roads. There are now three functional classes for trunk roads, namely Primary Roads, Interregional Roads and Regional Roads. Although roads in urban areas are referred to only as 'Town/Residential Roads' and 'Service Roads in Town' in the GHA RDG the new system functionally classifies urban roads as Major Arterial, Minor Arterial, Collector/Distributor and Local Roads. Since the selection of highway design controls, criteria and elements such as design speed, road width, intersection type and other elements depend on a road's functional class the researcher recommends that these functional classes be adopted in the revised manual.

(iv) **Respondents**: *The classification of vehicles should include dimensions of all parts relevant for design.*

Researcher: The GHA RDG features three design vehicles (small vehicle, large vehicle and trailer), and for each one dimensions of length, width and height are given. In other manuals like the Ugandan Geometric Design Manual and the Policy on Geometric Design of Highways and Streets other dimensions like overhang and minimum turning radius are given. These additional dimensions are crucial especially when designing parking areas and intersections (swept path

analysis). The researcher recommends the inclusion of these relevant design vehicle dimensions in the revised manual.

(v) **Respondents**: *The classification of terrain should go with numerical figures to clearly define the various terrain types.*

Researcher: In the GHA RDG terrain types are categorised into Flat, Hilly and Mountainous and design speeds are stipulated for each terrain type of a functional road class. It is however not stated what ranges of slope define a terrain category.In the Ugandan Geometric Design Manual, however a terrain is deemed Flat when transverse terrain slope is around 5%; Rolling when transverse terrain slope is greater than 5%, but not over 20%; Mountainous when transverse terrain slope is greater than 20%, but not more than70% ; Escarpment when transverse terrain slope is greater than 70%. This definite and numerical categorization makes selection of terrain types for the application of design speeds objective (rather than subjective). The researcher recommends the adoption of such terrain type categorization.

(vi) **Respondents**: *Horizontal Curves per kilometer and Vertical Curves per kilometer should be included.*

Researcher: According to Ulfarsson and Shankar (2003) the number of horizontal curves per kilometer on a road has a negative effect on accident frequencies. It has also been shown that there is also a correlation between number of vertical curves per kilometre and multiple-vehicle accidents (AlMasaeid, 1997). The GHA RDG is silent on the issue of curves per kilometre thus omitting an important road safety consideration. The researcher finds it necessary to include number of curves per kilometre as a design control in the revised document.

(vii) **Respondents**: *Revision should consider incorporating traffic into selection of design parameters.*

Researcher: The GHA RDG considers traffic characteristics in determining climbing lanes, exclusive turning lanes, storage lane lengths, intersection turning radii, lane widening in curve sections. For example, one warrant for the inclusion of a climbing lane is for the proportion of large vehicles to be in excess of 20%. The GHA RDG also shows how various sizes of design vehicles should be used as controls for width composition, widening of curve section, vertical gradient, sight distance, clearance, and design of intersection. Again, the Guide recommends curve section widening for roads with high proportion of large vehicles, although what constitutes 'high proportion of large vehicles' is not stated. The researcher recommends that incorporating traffic into selection of design parameters be continued, however, definite threshold proportions should be given where required to make design decision making more objective.

(viii) **Respondents**: *A checklist for geometric design and vetting should be included.*

Researcher: A checklist is a quality assurance tool that helps to confirm whether all requirements for a task have been met. They are employed in industry to guide users through accurate task completion (Hales et al.). Design and vetting checklists therefore help ensure uniformity of performance, output while minimizing the incidence of omissions. The researcher recommends the inclusion of checklists for route selection, survey, geometric design, safety installations and documentation.

(ix) **Respondents**: *Revision should cover broken-back curves (for example to use broken back curves some manuals allow a minimum length of 6V where V is the design speed).*

Researcher: According to AASHTO (2011), most drivers (except when driving on circumferential highways) do not expect successive curves to be in the same direction and hence "broken-back" or "flat-back" configuration of curves (with

a short tangent between two curves in the same direction) should be avoided. An exception is where very unusual topographical or right-of-way conditions make other alternatives impractical. The Ugandan Geometric Design Manual observes that broken-back curves also create problems with superelevation and drainage. In the researcher's opinion, for reasons of functionality and safety the revised manual should limit the use of broken-back curves and give a minimum length of straight acceptable between successive curves in the same direction.

(x) **Respondents**: *Revision should cover capacity analysis.*

Researcher: As earlier stated, design standards are a source of capacity additions (Chen et al., 2012). This implies that a road or intersection design must ensure adequate capacity to meet traffic demand. Although the GHA RDG includes the use of service flow rate in determining the number of lanes for carriageways it does not treat the subject of capacity analysis. There is therefore no means of using the Guide to ensure adequate capacity. It is recommended that guidelines for undertaking capacity analysis be provided in the revised Manual.

(xi) **Respondents**: *Revision should cover tunneling.*

Researcher: Although tunnel construction has not been chosen as the preferred option for any road in Ghana, in the face of increasing land take because of urbanization, tunnel design and construction could soon become necessary. The researcher recommends the inclusion of tunnel design in the revised manual.

(xii) **Respondents**: *Revision should cover toll plaza design.*

Researcher: In response to the Ghana Road Fund's policy of having a road toll station every 50km on trunk roads there are numerous temporary and permanent toll plazas in Ghana with attendant safety and operational problems. The GHA

RDG does not cover the design of toll stations. It is recommended that toll plaza design, rest stop and security checkpoint design be included with the revision.

(xiii) **Respondents**: *It may be necessary to consider developing separate Guide for the Highway Design and that for Roads in built up areas as it is the common practice in many countries.*

Researcher: Highway Design by definition involves the geometric design for all categories of public roads. This therefore embraces roads in built up areas as well. Treating and presenting the geometric design for built-up areas in a the same manual is logical since often built-up areas occur on sections of longer routes and must be considered in connection with the rest of the alignment. The researcher is of the opinion that presenting design for built-up areas in a separate manual would not augur well for coherence and economy. It should therefore be discouraged.

(xiv) **Respondents**: *Make adequate details for road furniture that is sensitive to the physically challenged*

Researcher: Current applicable laws in Ghana make it mandatory for all designs for public infrastructure to be friendly to the aged and physically challenged. The researcher recommends that all road furniture, pedestrian crossings, and the like, be made considering their use by the aged and the physically challenged.

(xv) **Respondents**: *Give adequate information for grade separation on Horizontal Alignment Design*

Researcher: Grade separations including overpasses and interchanges come with requirements for alignment design for approaches, crossings, conflict areas and ramps. The researcher recommends that a chapter be devoted to the design

of grade separations that will give guidelines for all alignments pertaining to grade separations

(xvi) **Respondents***: Show Bike traffic where it is obvious on Typical-Cross Section Composition*

Researcher: Typical cross-sections in the GHA RDG already show cycle tracks next to walkways in urban areas. The provision of cycle tracks in typical crosssections for urban areas should be continued in the revised manual.

(xvii) **Respondents**: *The design guide should be explanatory*

Researcher: For all topics treated in the GHA RDG an explanatory approach is employed. For instance, it is explained why transition curves are introduced between circular curves and straights, before computational formulas are presented. This should be continued in the revised manual. In the researcher's opinion the textbook approach of delving into extensive theoretical discussions only serve to make reading laborious and will add unnecessary production cost without increasing the quality of the manual.

(xviii) **Respondents**: *Illustrations for superelevation and its application on off-ramps, etc should be expanded.*

Researcher: The GHA RDG features superelevation and its application. However since the Guide does not cover grade separations there is no mention of the application of superelevation on off-ramps. In the researcher's opinion the chapter in the revised manual on grade separations as mentioned in (ii) above will cover this identified need

4.2.4 Respondents' Use of Other Design Manuals for Road Design

All respondents indicated that they refer to other standards and manuals/guides apart from the GHA Road Design Guide for geometric design.

The other standards and manuals/guides referred to and the design elements/issues for which they are referred to are as shown in Tables 4.21 and 4.22.

Table 4.21. Other design manuals used by respondents for road design

Design Manual/Guide	Design Element/Issue											
	Typical Cross Sections	*Roundabouts*	*Interchanges*	*Other Intersections*	*Auxiliary Lanes*	*Broken Back Curves*	*Horizontal Curves per Kilometre*	*Vertical Curves per Kilometre*	*Phasing of Curves*	*Pedestrians*	*Bicycles*	*Physically Challenged*	*Signs and Markings*
AASHTO Green Book	√	√	√	√	√	√	√	√	√				
SANRAL Design Manual									√				
Standard Details for Urban and Trunk Roads (MRH)	√												√
Ugandan Geometric Design Manual	√	√	√	√	√	√	√	√	√				
Overseas Road Note 6									√				
MASS Highway. Highway Design Manual	√	√	√	√	√	√	√	√	√				
MASS Highway. Intersection Designs		√	√										
Guidance for Pedestrian &Bicycle Traffic in African Cities										√	√		
Recommendation for Traffic Provisions for Built Up Areas (ASVV) (ROW, The Netherlands)		√								√	√	√	

Freeway and Interchange Geometric Design Handbook (Joel P. Leisch, P.E.)			√		√							

Table 4.22. Other design manuals used by respondents for road design (Cont'd)

Design Manual/Guide	***Design Element/Issue***											
	Typical Cross Sections	*Roundabouts*	*Interchanges*	*Other Intersections*	*Auxiliary Lanes*	*Broken Back Curves*	*Horizontal Curves per Kilometre*	*Vertical Curves per Kilometre*	*Phasing of Curves*	*Pedestrians*	*Bicycles*	*Road Humps*	*Rumble Strips and Jiggle Bars*
Traffic Calming Measures: Design Guidelines												√	√

It can be seen from Tables 4.21 and 4.22 that several other design manuals and standards are referred to by respondents for geometric design. However, the most referenced manuals are A Policy for Geometric Design of Highways and Streets, the Ugandan Geometric Design Manual and the Massachusetts Highway Design Manual.

4.3 Recommended Table of Contents for Revised Design Guide

Based on findings from the literature review and analysis of respondents' recommendations a table of contents has been proposed to guide the revision of the GHA RDG. In doing so, the original contents of the GHA RDG have been expanded to cover topics that were omitted, such as Route Corridor Selection, Road Survey Procedure and Requirements, Grade Separations and

Interchanges, and Design of Roundabouts. Topics already covered have also been covered in more detail.

Chapter 1: Introduction

- 1.1 Background
- 1.2 Highlights of Current Revision
- 1.3 Departure from Standards
- 1.4 Definitions and Abbreviations

Chapter 2: Road Classification

- 2.1 Concept of Classification
- 2.2 Classification Types and Applications
- 2.3 Functional and Design Classification of Roads

Chapter 3: Route Corridor Selection

- 3.1 Factors of Route Corridor Selection
- 3.2 Desk Study for Identification and Feasibility
- 3.3 Preliminary Identification of Potential Corridors and Comparison
- 3.4 Site Visit and Survey
- 3.5 Route Corridor Recommendation

Chapter 4: Road Survey Procedure and Requirements

- 4.1 General
  - 4.1.1 Units of Survey Measurement
  - 4.1.2 Datum and Distance Measurement
  - 4.1.3 Survey Reference Pillars
  - 4.1.4 Survey Data
- 4.2 Methods of Data Collection
  - 4.2.1 Photogrammetry
  - 4.2.2 Ground Survey
- 4.3 Road Survey Procedures
  - 4.3.1 Location
  - 4.3.2 GPS Survey
  - 4.3.3 Levelling

4.3.4 Detailing
4.3.5 Bridge Site Survey
4.3.6 Town Section Survey

Chapter 5: Design Controls and Criteria

5.1 Road Classification
5.2 Design Vehicles
5.3 Speed
5.4 Terrain
5.5 Safety
5.6 Driver Performance and Human Factors
5.7 Traffic Characteristics
5.8 Highway Capacity
5.9 Access Control and Access Management
5.10 The Pedestrian
5.11 Bicycle Facilities
5.12 Environment
5.13 Economic Analysis
5.14 Determination of Service Volume
5.15 Weaving Sections and Ramp Terminals

Chapter 6: Cross-section Elements

6.1 Introduction
6.2 Road and Lane Width
6.3 Headroom and Lateral Clearance
6.4 Shoulders
6.5 Side Slope and Back Slopes
6.6 Cross Fall
6.7 Drainage Channels
6.8 Side Roads and Culverts
6.9 Right-of-way
6.10 Median
6.11 Traffic Barriers
6.12 Cross-section Over Bridges and Culverts
6.13 Footways and Cycle Ways
6.14 Service Roads

6.15 Outer Separations
6.16 Curbs
6.17 Noise Control
6.18 Tunnels
6.19 On-street Parking 6.20
Bus Lay-Bys
6.21 Roadside Control

Chapter 7: Elements of Design
7.1 Horizontal Alignment
7.2 Vertical Alignment
7.3 Gradients
7.4 Climbing and Overtaking Lanes
7.5 Sight Distances
7.6 Phasing of Horizontal and Vertical Curves

Chapter 8: At-grade Intersections
8.1 Introduction
8.2 Intersection Types
8.3 Design Requirements
8.4 Selection of Intersection
8.5 Principles of Junction Design
8.6 Junction Design Procedure
8.7 Design of Roundabouts
8.8 Design of Signalised Intersection
8.9 Railroad-highway grade crossings

Chapter 9: Grade Separations and Interchanges
9.1 Interchange Warrants
9.2 Interchange Types
9.3 Weaving
9.4 Location and Spacing of Interchanges
9.5 Basic Lanes and Lane Balance
9.6 Auxiliary Lanes
9.7 Ramp Design
9.8 Collector–Distributor Roads

9.9 Other Interchange Design Features Chapter 10: Speed Management

10.1 Speed Management Principles

10.2 Speed Control Measures

10.2.1 Gates

10.2.2 Speed Control Zone

Chapter 11: Other Road Facilities

11.1 Toll Plazas

11.2 Axle Load Control Stations

11.3 Rest Areas, Information Centers, and Scenic Overlooks

Chapter 12: Road Furniture, Safety and Miscellaneous Design Items

12.1 Traffic Signs and Road Markings

12.2 Safety Barriers

12.3 Curbs

12.4 Rumble Strips

12.5 Bridge Parapets

12.6 Traffic Islands

12.7 Pedestrian Barrier

12.8 Ramp Design

12.9 Lighting

12.10 Erosion Control and Landscape Development

12.11 Utilities

12.12 Traffic Management Plans for Construction

12.13 Document Preparation

12.14 Checklists

12.14.1Route Selection

12.14.2 Survey

12.14.3 Geometric Design

12.14.4 Safety Installations

12.14.5 Documentation

Table Table 4.23 presents a brief first level comparison of the existing table contents of the GHA Road Design Guide and that proposed for a revised Guide/Manual. The table of contents

for the revised Guide now contains chapters such as Introduction, Design Controls and Criteria, Route Corridor Selection, Grade Separations and Interchanges, Speed Management, Other Road Facilities Road Furniture, Safety and Miscellaneous Design Items. Existing chapters of Design Vehicles, and Classification of Roads and Design Speed will be combined under the chapter 'Design Controls and Criteria'.

Table 4.23. Comparison of Contents of Existing and Revised Manuals

Existing GHA RDG	Revised GHA RDG
Chapter 1: Design Vehicles	Chapter 1: Introduction
Chapter 2: Classification of Roads and Design Speed	Chapter 2: Road Classification
Chapter 3: Composition of Cross-section	Chapter 3: Route Corridor Selection
Chapter 4: Alignment	Chapter 4: Road Survey Procedure and Requirements
Chapter 5: At-grade Intersection	Chapter 5: Design Controls and Criteria
Chapter 6: Road Drainage	Chapter 6: Cross-section Elements
Chapter 7: Accessories to Road	Chapter 7: Elements of Design
Chapter 8: Presentation of Drawing	Chapter 8: At-grade Intersections
	Chapter 9: Grade Separations and Interchanges
	Chapter 10: Speed Management
	Chapter 11: Other Road Facilities
	Chapter 12: Road Furniture, Safety and Miscellaneous Design Items

Table 4.24 compares the contents of an existing and revised chapter, namely the chapter on atgrade intersections. **The existing chapter has been expanded to include Introduction, Design of Roundabouts, Design of Signalised Intersection, Railroad-highway Grade Crossings, and Capacity Analysis.**

Table 4.24. Comparison of Chapters of Existing and Revised Manuals

Existing GHA RDG	Revised GHA RDG
Chapter 5: At-grade Intersection	Chapter 8: At-grade Intersections
5.1 Planning and Design	8.1 Introduction
5.2 Layout of At-grade Intersections	8.2 Intersection Types
5.3 Visibility	8.3 Design Requirements
5.4 Cross-section Composition	8.4 Selection of Intersection
5.5 Channel and Island	8.5 Principles of Junction Design
5.6 Stop Line and Pedestrian Crossing	8.6 Junction Design Procedure
	8.7 Design of Roundabouts
	8.8 Design of Signalised Intersection
	8.9 Railroad-highway Grade Crossings
	8.10 Capacity Analysis

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

After careful review and assessment of the road design guide and other manuals and having made consultations and received responses from practitioners, the following conclusions and recommendations have been arrived at for the study:

5.1 Conclusions

- The results of this study indicate that the Ghana Highway Authority Road Design Guide does not meet several of the requirements for the geometric design of modern trunk and urban roads. Highway designers working for the GHA and DUR in the last ten years have had to consult eleven other design manuals, especially AASHTO's A Policy on Geometric Design of Highways and Streets, the Ugandan Geometric Design Manual and the Massachusetts Highway Design Manual.

- Designers consult these other manuals for such main areas as the selection or design of design controls, elements and features like access control, sight distance, at-grade intersections, grade-separated intersections, freeways and toll plazas.
- The study has assessed some of the other commonly used standards for road element design in other manuals together with respondents' recommendations and has established the basis for their inclusion (or otherwise) in the revised GHA RDG.
- Finally, the study has presented a proposed detailed table of contents highlighting main design elements and requirements that if employed would greatly improve on the GHA RDG's capability to facilitate safe, functional and economic highway designs.

5.2 Recommendations

It is recommended that:

- the GHA Road Design Guide should be revised and updated as a matter of urgency
- the revision would need to consider the local best practices, research in academia and other observations to ensure that it reflects the local conditions and driver behavior.
- illustrations in the revised manual should as much as possible be drawn from local practice and infrastructure examples.
- the findings of this study are to assist in the formulation of terms of reference for the updating of the road design guide.
- the Ministry of Roads and Highways could constitute a working group consisting of academics, consultants, road agency staff and a few Ghanaian transportation professionals in the Diaspora to look at the proposed content and the results of this study and arrive at a terms of reference for a revised and updated road design manual for Ghana.

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APPENDIX

QUESTIONNIARE (BLANK)

An Appraisal of the Ghana Highway Authority Road Design Guide

Dear Sir/Madam,

I am carrying out a study to help **appraise the Ghana Highway Authority Road Design Guide**. I would be grateful if you could spend a little time to fill out this questionnaire. All information provided here would be treated as purely academic and strictly confidential.

Thank you for your assistance.

Please Note: Indicate your answer by ticking the appropriate box, and/or writing PART 1 – Personal Data

1. What Organisation Type do you represent?

   ☐ Client/Supervision Agency ☐ Highway Consultant ☐ Road Contractor

2. What is your Profession?

   ☐ Highway Designer ☐ Road Safety Engineer Other (specify).....

3. How many years of Experience in Highway Design do you have?

   ☐ (1 – 5) ☐ (6 – 10) ☐ (10 – Above)

4. Have you worked on any GHA/DUR road design project as a technical professional?

   ☒ Yes No ☐ .

5. What was the Implementing Agency for the highway design project(s) you worked on?

   ☐ GHA ☐ DUR ☐ OTHER please state……..

6. You worked as a..... (State the role you played)

PART 2 – Information on design standards and manuals/guides used A **Road Design Guide** is a document that ensures minimum levels of safety and comfort of road users, helps the designer arrive at an economic design, helps to maintain uniformity in alignments, drainage and other road facilities.

7. Do you use or refer to the GHA Road Design Guide in your highway design practice?

Yes ☐ No ☐

8. What design controls and criteria do you select from the GHA Road Design Guide? (Please write and tick as appropriate)

C ɔntrols/Criteria					
1.	Road Classification		10.	Vertical Curvature	
2.	Design Speed		11.	Phasing of Curves	
3.	Design Vehicle		12.		
4.	Access Control		13.		
5.	Pedestrian Accommodation		14.		
6.	Vertical Clearance		15.		
7.	Stopping Sight Distance		16.		
8.	Passing Sight Distance		17.		
9.	Horizontal Curvature		18.		

9. Do you consider the GHA Road Design Guide sufficient for all your highway designs?

Yes ☐ No ☐

10. What design elements/controls/criteria/features are you not able to use the GHA Road Design Guide for? (Please write and tick as appropriate)

Elements/C ɔntrols/Criteria/Features					
1.	Speed Calming		8.		
2.	Level of Service		9.		
3.			10.		
4.			11.		
5.			12.		
6.			13.		
7.			14.		

11. What specific changes/additions/omissions do you recommend in the revision of the GHA Road Design Guide?

i) .....

ii) .....

iii).....

iv).....

12. Do you use or refer to any standards and manuals/guides apart from the GHA Road Design Guide? Yes ☐ No ☐

13. If you answered "Yes" in (12) kindly complete the form below by stating those other standards/manuals/guides and checking to indicate your reason for referring to them. You may add more information as required

Design Manual/Guide	***Design Element/Issue***												
	Typical Cross Sections	*Roundabouts*	*Interchanges*	*Other Intersections*	*Auxiliary Lanes*	*Broken Back Curves*	*Horizontal Curves per Kilometre*	*Vertical Curves per Kilometre*	*Phasing of Curves*				
AASHTO Green Book													

QUESTIONNAIRE (FILLED OUT)

QUESTIONNIARE

An Appraisal of the Ghana Highway Authority Road Design Guide

Dear Sir/Madam,

I am carrying out a study to help **appraise the Ghana Highway Authority Road Design Guide**. I would be grateful if you could spend a little time to fill out this questionnaire. All information provided here would be treated as purely academic and strictly confidential.

Thank you for your assistance.

Please Note: Indicate your answer by ticking the appropriate box, and/or writing

PART 1 – Personal Data

1. What Organisation Type do you represent?

   ☐ Client/Supervision Agency ☑ **Highway Consultant** ☐ Road Contractor

2. What is your Profession?

   ☑ **Highway Designer** ☐ Road Safety Engineer Other (specify).....

3. How many years of Experience in Highway Design do you have?

   ☐ (1 – 5) ☐ (6 – 10) ☑ **(10 – Above)**

4. Have you worked on any GHA/DUR road design project as a technical professional?

   ☑ **Yes** ☐ No .

5. What was the Implementing Agency for the highway design project(s) you worked on?

   ☑ **GHA** ☐ DUR ☐ OTHER please state... ... ...

6. You worked as a *Consultant* (State the role you played)

1

PART 2 – Information on Design Standards and Manuals/Guides used

A **Road Design Guide** is a document that ensures minimum levels of safety and comfort of road users, helps the designer arrive at an economic design, helps to maintain uniformity in alignments, drainage and other road facilities.

7. Do you use or refer to the GHA Road Design Guide in your highway design practice?

   Yes ☑ No ☐

8. What design controls and criteria do you select from the GHA Road Design Guide? (Please write and tick as appropriate)

Controls/Criteria					
1.	*Road Classification*	✔	**10.**	**Vertical Curvature**	✔
2.	*Design Speed*	✔	11.	Phasing of Curves	
3.	Design Vehicle		12.		
4.	Access Control		13.		
5.	Pedestrian Accommodation		14.		
6.	Vertical Clearance		15.		
7.	*Stopping Sight Distance*	✔	16.		
8.	Passing Sight Distance		17.		
9.	*Horizontal Curvature*	✔	18.		

9. Do you consider the GHA Road Design Guide sufficient for all your highway designs?

   Yes ☐ **No** ☑

10. What design elements/controls/criteria/features are you not able to use the GHA Road Design Guide for? (Please write and tick as appropriate)

Elements/Controls/Criteria/Features					
1.	Speed Calming		8.		
2.	Level of Service		9.		
3.	*Parking Studies*	✔	10.		
4.	*Phasing of Curves*	✔	11.		
5.	*Design Vehicle*	✔	12.		
6.	*Channelization*	✔	13.		
7.			14.		

11. What specific changes/additions/omissions do you recommend in the revision of the GHA Road Design Guide?

    i) *It may be necessary to consider developing separate Guide for the Highway Design and that for Roads in built up areas as it is the common practice in many countries.*

    ii) *Address function of the Road (i.e. Flow Distributor/Collector/Local Streets)*

    iii) *Make adequate details for road furniture that is sensitive to the physically challenge.*

    iv) *Give adequate information for grade separation on Horizontal Alignment Design.*

    v) *Show Bike traffic where it is obvious on Typical-Cross Section Composition.*

12. Do you use or refer to any standards and manuals/guides apart from the GHA Road Design Guide? **Yes** ☑ No ☐

13. If you answered "Yes" in (12) kindly complete the form below by stating those other standards/manuals/guides and checking to indicate your reason for referring to them. You may add more information as required

Design Manual/Guide	***Design Element/Issue***												
	Typical Cross Sections	*Roundabouts*	*Interchanges*	*Other Intersections*	*Auxiliary Lanes*	*Broken Back Curves*	*Horizontal Curves per Kilometre*	*Vertical Curves per Kilometre*	*Phasing of Curves*	*Pedestrian*	*Bicycle*	*Physically Challenge*	
AASHTO Green Book	✔	✔	✔		✔	✔							
Guidance for Pedestrian & Bicycle Traffic in African Cities										✔	✔		
Recommendation for Traffic Provisions for Built Up Areas (ASVV) (ROW, The Netherlands)		✔								✔	✔	✔	
Freeway and Interchange Geometric Design Handbook (Joel P. Leisch, P.E.)			✔		✔								