JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

CIVIL ENGINEERING DEPARTMENT

HIGHWAY ENGINEERING STREAM

The Effect of Raised Median on Traffic Flow and Its Remedial Measures: Case Study in Jimma Town

A thesis submitted to the School of Graduate Studies of Jimma University in Partial fulfillment of the requirements for the Degree of Master of Science in Highway Engineering.

By:

Anteneh Worku

October, 2016

Jimma, Ethiopia

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BY

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DECLARATION

I, the undersigned, declare that this thesis entitled "**The Effect of Raised Median on Traffic Flow and Its Remedial Measures: Case Study in Jimma Town.**" is my original work, and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material used for theses have been dually acknowledged.

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As Master research Advisors, we hereby certify that we have read and evaluate this MSc research prepared under our guidance, by Mr. Anteneh Worku entitled: "**The Effect of Raised Median on Traffic Flow and Its Remedial Measures: Case Study in Jimma Town**."

We recommend that it can be submitted as fulfilling the MSc Thesis requirements.

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ABSTRACT

The development of raised medians is an important access management technique commonly used in urban settings. It can be used to control or restrict mid-block left turns, U-turns or crossing maneuvers for implementing of alternative left-turn and U-turn movements.

The insufficient design and installation of raised medians with respect of median width, spacing of median opening and length of median opening has an effect on the effective traffic operation by causing delay in travel time of through traffic movements as well as on traffic safety which generates traffic accidents between road users of both vehicles and pedestrians

The objective of this research project is to develop guidelines that supplement the ERA manual for the design of operationally effective and safe raised medians and the use of alternative movements on urban roadways.

To fulfill this goal the researcher has reviewed and synthesized national and international practices, conducted survey of traffic characteristics of both vehicular and pedestrian and field studies, explored the design issues relating to raised medians and alternative movements, and developed guidelines for future implementation of raised medians and representative alternative movements in Ethiopia.

The results of this study provide recommendations on some critical design issues in the use of raised medians, including median widths, the techniques of landscaping and fencing of the medians, placement of median openings, and the median opening length.

Key words: Accident, Delay, Left turn movement, Medians, Median width, Median opening spacing, Median opening length, Traffic operation, Traffic safety, U-turn movements.

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ACRONYMS

AASHTO	American Association of state Highway and Transportation Officials
ERA	Ethiopia Road Authority
DOT	Department of Transport
TxDOT	Texas Department of Transport
NCHRP	National Cooperative Highway Research Program
ASTM	American Society for Testing and Materials
TRL	Transport Research Laboratory
TWLTL	Two Way Left Turning Lane
RCUT	Restricted Crossing U-Turn
MUT	Median U-Turns
CFI	Continuous Flow Intersections
RTOR	Right-Turn-On-Red
AADT	Annual Average Daily Traffic
ADT	Average Daily Traffic
VPD	Vehicles per day
CTR	Centerline Turning Radius
LHS	Left Hand Side
RHS	Right Hand Side
P	Passenger car
SUT	Single Unit Truck

CHAPTER ONE

INTRODUCTION

1.1 Background

The problem of applying access control to a developed major type of asphalt road is one of the greatest challenges to the traffic manager. Many studies have documented the damaging effects that access points have on the quality of traffic flow provided by a roadway. The official responsible for safe, efficient movement of traffic is certainly aware of increasing crash rates and reduced levels of service that occur with an increase in traffic, an increase in access points, or, as is usually the case, both.

Implementation of access control techniques on existing roadways is commonly very difficult. Right-of-way limitations and development in close proximity to the right-of-way are commonly encountered. Opposition by the owners of the adjacent properties and the affected businesses often makes it difficult to obtain the necessary political acceptance. (Oregon State University, 1996)

In many instances, however, congestion is evidenced by long queues at intersections, traffic crashes, and extensive travel delays often result in a public demand that improvements be made to existing major streets.

The installation of a non-traversable (restrictive) median provides positive control of left turns and therefore have been found to be very effective in improving traffic safety.

According to the study of Oregon State University, 1996 it has been demonstrated that medial access control results in a substantial reduction in the number of crashes together with a reduction in the associated social and economic costs of deaths, injuries, and property damage. Other benefits include time saving and reduced fuel consumption. Furthermore, air quality improvement can be obtained through the implementation of access management techniques, which will reduce vehicular emissions by improving traffic flow and reducing idling delay. Median access control is also an effective congestion mitigation strategy as part of the Congestion Management Systems required by the 1991 Intermodal Surface Transportation Efficiency Act.

Median access control measures include both modifications of route segments and point improvements. Route segment changes, which are applicable to major roadways, include the following: (Oregon State University, 1996)

1. Installation of a non-traversable median.
2. Replacement of a continuous two-way left-turn lane with a non-traversable median.
3. Closure or re-design of a median opening along an entire section of roadway.

Point improvements/changes include:

1. Closure of a median opening
2. Redesigning a median opening so as to permit a selected movement(s) only
3. Adding a left-turn bay at a median opening is sufficient right of way exists
4. Increasing the length of an existing turn bay to provide adequate queue storage and reduce the speed differential between turning vehicles and through traffic.

Although the installation of a median or replacement of a TWLTL with a non-traversable median may be expensive, it is commonly much less expensive than adding a lane in each direction of travel. Moreover, it is much less disruptive to the abutting development. (Oregon State University, 1996)

1.2 Statement of the Problem

The development of raised medians is an important access management technique commonly used in urban settings. A raised median can be used on urban streets where it is desirable to control or restrict mid-block left turns, U-turns, or crossing maneuvers to improve operational and safety performance. Alternative movements, such as right turns followed by U-turns as an alternative to direct left turns, are increasingly used on urban streets to mitigate congestion, reduce conflicts, and improve safety along arterial roads.

Globally, there are a lot of guidelines and manuals prepared by different states and countries for the design and construction of raised medians which is one of the most commonly used access management techniques. These guidelines and manuals have different minimum design criteria from one another for the installation of raised medians, median width, and the spacing and length of median openings are based on the classification of functionality of roads, economic status of states and country, available right of way, property of adjacent land use, characteristics of both vehicular and pedestrian traffic.

Nationally, there is no detailed design and implementation procedure of raised medians to be used as a guideline in Ethiopia. ERA manual declares the installation of raised medians with a minimum width of 5m as one part of cross sectional elements for four lane town section of design standard DS1 and DS2. The manual only specifies the minimum width of the median but other design components like minimum median opening spacing and opening length are not imbedded where the research gap is shown.

Locally, according to the field observation made around the study area of Jimma town and during the design review stage of this thesis, the prepared preliminary design during planning phase and the working drawing design templates during construction phase shows that the minimum criteria is not fulfilled with respect to the guidelines and manuals prepared globally and nationally.

Due to these insufficient design and construction practice of raised medians which is below the minimum criteria as compared to different guidelines and manuals, the functionality of the road with respect to the traffic operation and safety is impaired. The qualitative effect of improper design and construction of already installed raised medians in Jimma town on the traffic operation and safety have been observed in terms of delay in travel time on through vehicles and turning vehicles as well as the types of traffic accident to be occurred respectively.

1.3 Research Questions

1. What are the effects of the provision of improperly designed raised median on the traffic operation and safety of asphalt roads in town section?
2. What is the characteristic of traffic flow on existing asphalt roads with both roads asphalt road with and without median curb?
3. How the presences of median curbs have a contribution for the traffic delay?
4. What are the causes of traffic accident on asphalt roads with insufficient raised median in town section?

1.4 Objectives

1.4.1 General objectives

The main objective of the study is to evaluate the effect of insufficient design and construction of raised medians in asphalt roads on the traffic operation and safety in town section with respect to traffic delay and traffic accident.

1.4.2 Specific objectives

- To investigate the existing practice of design and construction of raised medians of different countries and Jimma town through review of design manuals and prepared working designs as well as through field observation and measurement.
- To determine the qualitative effect of improperly designed raised median on the traffic operation in terms of the traffic pattern and delay occurred on asphalt road.
- To analyze the types of possible traffic accident of road users to be incurred on similar types of road.

1.5 Scope of the study

This study shall cover the effect of raised median curbs on traffic operation in terms of traffic operational impact and safety aspect, which may result in traffic delay, and traffic accident in urban sections of asphalt roads with divided four lane with raised median, which means it may not be recommended to provide inadequately designed raised median at the center of the road with insufficient right of way possession, even though it has its own advantage of safety of pedestrian.

In this study all urban and suburban asphalt roads with four or more lanes divided by raised medians will be investigated for further recommendation whether raised median is really necessary with the available to date and future traffic volume and right of way problem.

To achieve the objectives, all the necessary data related to the road geometry of typical cross section elements of selected routes, both vehicular and pedestrian traffic characteristics and the characteristic of the adjacent land use on both sides of the road will be collected around Jimma town, and comparison will be made with ERA, AASHTO and similar design manuals and likewise a recommendation shall be drawn and formulated.

1.6 Significance of the study

- To collect and review the design data of preliminary design prepared during the planning phase.
- To collect and review the design data of working drawing prepared during the construction phase which is approved by the Engineer.
- To conduct field study through observation and measurement to collect as-built data of the selected routes as well as to study the characteristics of traffic flow and identify the types of accident to be occurred.
- To further identify issues related to design and implementation of raised medians through field observation.

- To understand the benefits and shortcomings of closely spaced median openings shorter than AASHTO and similar standards.
- To develop guidelines for operationally effective raised medians based on the results from the study.
- Summarize the operational and safety impacts of raised through a review of best practices manuals.

CHAPTER TWO

LITERATURE REVIEW

2.1 Concepts, definitions, and backgrounds

2.1.1 Access Management

Access management represents a very general principle to improve safety and mobility by managing the access to and from abutting properties along streets and highways. So far, there are more than 100 individual access management techniques that have been identified (NCHRP Report 420, 1999). Among them, raised medians and alternative movements are recognized as representative techniques that may help preserve capacity, maintain mobility, and improve safety.

2.1.2 Access Point

An access point defines all unsignalized access locations, which can be either a driveway or a public street approach. Access point density typically means the total number of access points on both sides of the major-street segment (i.e., a two-way total) divided by the length of the segment (in miles). Driveway density and public street approach density are defined in a similar manner.

2.1.3 Median Types

A. Flush Medians

A flush median is defined where the surface is constructed as a smooth plane in conjunction with the adjacent roadway pavement. Flush medians are used most often on low-speed urban highways and streets. The following discusses the various types of flush medians:

I. <u>Painted Flush Median</u>: - Widths for painted flush medians can range from 4 ft (1.2 m) to 14 ft (4.2 m). Such medians serve as a buffer between opposing traffic, or for the development of dedicated left-turn lanes at median crossovers.

II. Two-Way Left-Turn Lanes (TWLTL):- TWLTL are also considered flush medians. Operating speeds, truck and bus volumes, number and spacing of entrances and intersections, availability of right-of-way, character of abutting property, parking facilities, etc., should be considered when determining appropriate TWLTL widths for specific projects.

III. Flush Median with Concrete Barrier: - A flush median with a concrete barrier may be used on urban freeways and expressways where the right-of-way does not allow for the use of a depressed median.

B. Traversable TWLTL Medians

Where an M-2 (M-5) curb is used to delineate the edges of a median, this median is designated as a traversable median and traffic is allowed to turn left across the median. On certain streets in large metropolitan areas where traffic volumes and mid-block left turns are unusually high, the traversable median with an M-2.12 (M-5.30) CC&G, although having a slightly higher initial cost than a flush TWLTL median, may be the appropriate design option. This median type eliminates the frequent and somewhat hazardous striping operations and yet provides for TWLTL movements. Because the traversable TWLTL median was developed as a direct substitute for the flush TWLTL, the M-2.12 (M-5.30) CC&G is not designed to be a physical barrier nor is it intended to impede left-turn movements across the median.

C. Raised-Curb Medians

A median is defined as a raised-curb median if it contains a curb height greater than 2 in (50 mm) within its limits. Usually, a raised-curb median is proposed when the Department needs to manage access to the street and to control left-turn movements.

D. Depressed Medians

Wherever practical, use a depressed median on rural freeways, expressways, and other designated arterials. Depressed medians have better drainage and snow storage characteristics and, therefore, are preferred on high-speed arterial highways. In addition, they provide the driver with a greater sense of comfort and freedom of operation.

2.1.4 Raised Median

Raised median defines raised, non-traversable dividers in the center of a roadway, as shown in Figure 2-1. It is generally concluded that a properly designed raised median can bring a series of benefits, including:

- Better safety performance over other median treatments, e.g., TWLTL, or undivided cross-section. Raised medians concentrate turning movements at appropriate locations, and separate left turns and U-turns from through traffic movements, which contributes to a reduction in conflict points.
- Providing crossing pedestrians with refuge areas at mid-blocks and intersections.
- Providing space for control devices at mid-blocks and intersections.
- Opening up landscaping opportunities for urban aesthetic benefits.

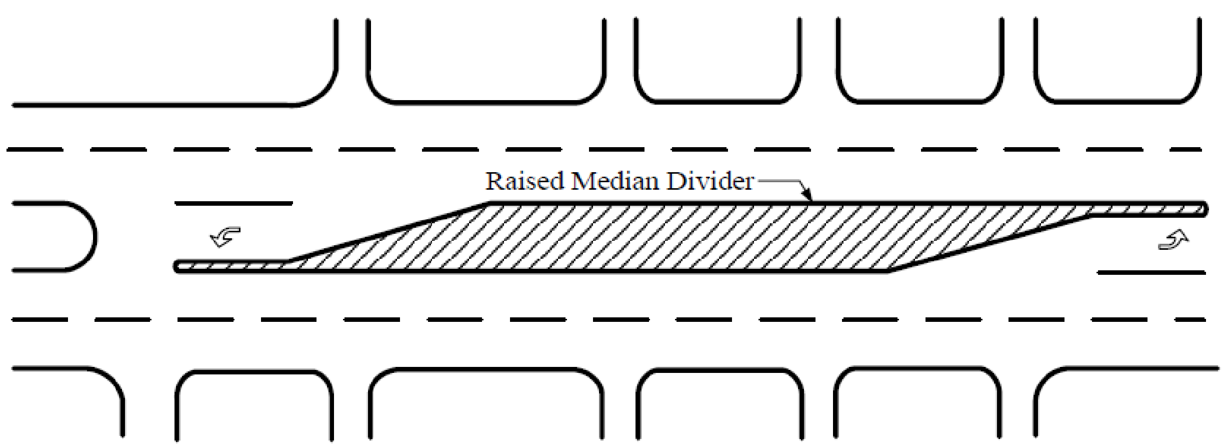


Figure 2-1: Illustration for Raised Medians

Besides DOT standards, a set of detailed guidelines were derived by Bonneson and McCoy based on benefit-cost comparisons. NCHRP Report 395, indicates undivided cross-sections or TWLTLs should be converted to raised medians for business-office and residential land uses.

It can be noticed that the guideline assumed a median opening spacing of 1,320 ft, while number of travel lanes, ADT level, access density, and left-turn volumes were taken into account in the development of the guidelines.

The "undivided cross-section" treatment has the highest expected accident frequency over the range of traffic volumes. The model results indicated 30 to 35% accident reduction can be achieved by converting from an undivided cross section to either a TWLTL or non-traversable median

This study contributed a series of useful findings as follows:

- Raised-curb medians and TWLTLs experience similar delays to arterial drivers; an undivided cross section yields significantly higher delays than the two mentioned above.
- Any of the median treatment types can function without creating congestion within the major-street movements at ADT demands of 40,000 vpd or less.
- The performance of an unsignalized access point often is degraded by the close proximity of another intersection.

The operational analysis indicated that the undivided cross section could result in significantly higher delay than either the raised-curb median or TWLTL. This result is due to the turbulence caused by left turns from the inside through lane.

Additionally, it can be generally concluded that roadway safety can be improved by replacing full median openings with directional median openings in typical urban roadway settings (Levinson et al., 2005; Castronovo et al., 1995).

Raised medians and TWLTLs experience similar delay levels to arterial drivers (NCHRP Report 395, Bonneson and McCoy 1998); undivided cross section yields significantly higher delays than the two mentioned above, particularly under high traffic volume conditions (NCHRP Reports 395 and 420). Raised median treatments may result in slightly lower speeds compared with the TWLTL treatments (Eisele and Frawley, 2005).

2.1.5 Raised Median Design Elements

With regard to the design of raised medians, there is a series of design elements to be determined based on the geometric, environmental, and traffic conditions. Typically, the elements include (1) median opening placement, (2) median opening spacing, (3) median width, a major contributing factor to U-/left-turn radii, (4) median opening length, and (5) pocket turn lane composed of taper, deceleration, and storage sections. These design elements are illustrated in Figure 2-2.

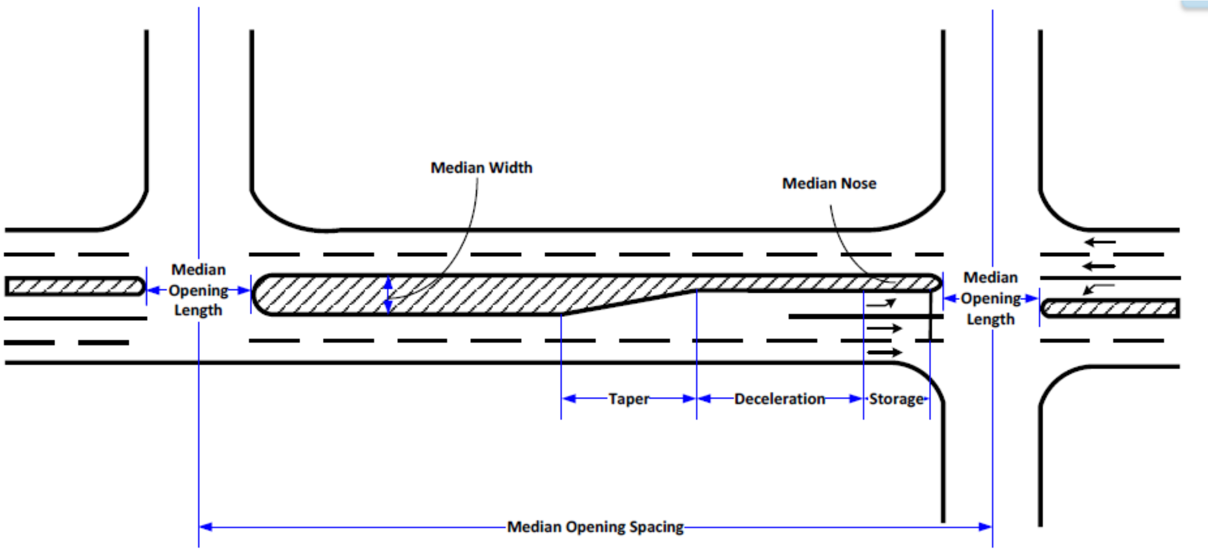
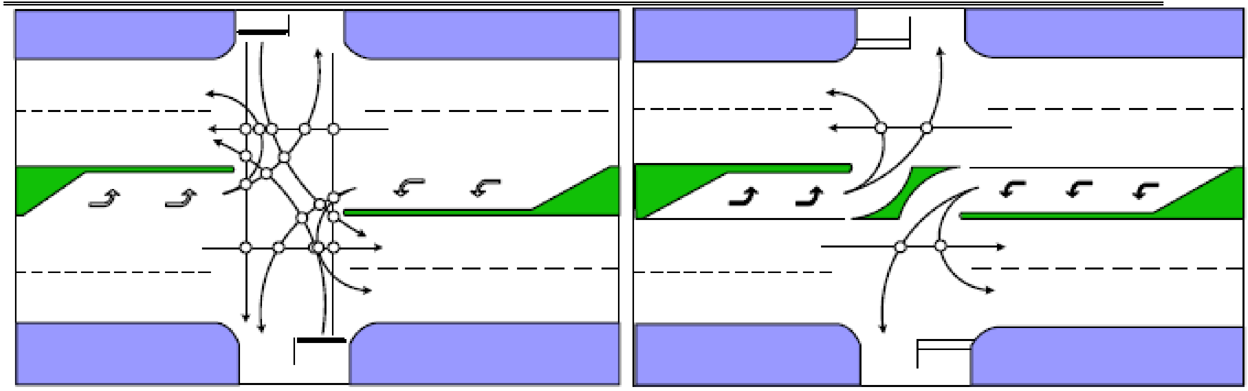
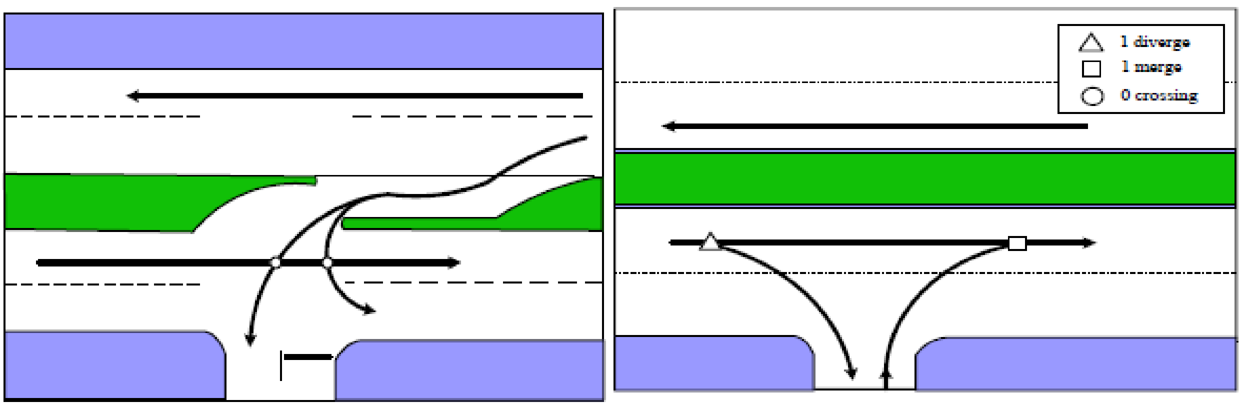


Figure 2-2: Major Raised Median Design Elements

Median openings are sometimes referred to as "crossovers." The placement and frequency of median openings is critical for the efficient operation of the roadway. Figure 2-3 illustrates the traffic conflict distributions with various median opening settings. A full median opening allows all turns and has 18 major conflict points (see Figure 2-3 (a)). By providing restrictive medians it can reduce the number of conflict points along arterial roads as shown in Figures 2-3 (b)-(d).



(a)Full Median Opening, 18 Major Conflicts (b) Directional Median Opening, 4 Major Conflicts



(c) Left-in Only Opening, 2 Major Conflicts (d) Restrictive Median, and 2 Minor Conflicts

Source: Median Handbook, Florida Department of Transportation, 1997.

Figure 2-3: Conflict Zones with Different Median Opening Settings

2.2 Cross Sectional Elements in ERA Manual

2.2.1 Introduction

A cross-section will normally consist of the carriageway, shoulders or curbs, drainage features, and earthwork profiles. These terms are defined in the Definition portion of the manual text; major elements are repeated here for clarity:

- Carriageway- the part of the road constructed for use by moving traffic, including traffic lanes, auxiliary lanes such as acceleration and deceleration lanes, climbing lanes, and passing lanes, and bus bays and lay-byes.

- Roadway- consists of the carriageway and the shoulders, parking lanes and viewing areas

- Earthwork profiles- includes side slopes and back slopes

For urban cross-sections, cross-section elements may also include facilities for pedestrians, cyclists, or other specialist user groups. These include curbs, footpaths, and islands. It may also provide for parking lanes. For dual carriageways, the cross-section will also include medians. Typical Cross Sections are illustrated in Appendix E of this manual. Bus lay-byes, parking lanes, passing lanes, and viewing areas are presented in Chapter 14 of the ERA Manual.

Lane and shoulder widths should be adjusted to traffic requirements and characteristics of the terrain. The cross-section may vary over a particular route because these controlling factors vary. The basic requirements are, however, that changes in cross-section standards shall be uniform within each sub-section of the route and that any changes of the cross-section shall be effected gradually and logically over a transition length. Abrupt or isolated changes in cross-section standards lead to increased hazards and reduced traffic capacity and complicate construction operations.

In certain cases, however, it may be necessary to accept isolated reductions in cross-section standards, for example when an existing narrow structure has to be retained because it is not economically feasible to replace it. In such cases a proper application of traffic signs and road markings is required to warn motorists of the discontinuity in the road. However, all such narrow structures must be widened or replaced however when the width across the structure is less than the adjacent carriageway width.

2.2.2 Lane Widths

A feature of a highway having great influence on safety and comfort is the width of the carriageway. Lane widths of 3.65m are used for Design Classes DS1 and DS2. The extra cost of 3.65 m above that for 3.0 m 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. The wider 3.65m lane also provides desired clearances between large commercial vehicles on two-way rural highways.

Narrower lanes are appropriate on lower volume roads. Standards for carriageway widths are shown in Table 2-1 for all Road Design Standards.

Table 2-1: Design Standards Vs Road Classification and AADT

Road Functional Classification	Design Standard	Design Traffic Flow (AADT)*	Surface Type	Width (m)		Design Speed (km/hr)				Urban/Peri-Urban
				Carriageway	Shoulder	Flat	Rolling	Mountainous	Escarpment	
	DS1	10000–**15000	Paved	***Dual 2 x 7.3	See T.2-2	120	100	85	70	50
	DS2	5000–10000	Paved	7.3	See T.2-2	120	100	85	70	50
TRUNK	DS3	1000–5000	Paved	7.0	See T.2-2	100	85	70	60	50
MAIN LINK	DS4	200–1000	Paved	6.7	See T.2-2	85	70	60	50	50
	DS5	100– 200	Unpaved	7.0	See T.2 -2	70	60	50	40	50
COLLECTORS ACCESS	DS6	50–100	Unpaved	6.0	See T.2-2	60	50	40	30	50
	DS7	30–75	Unpaved	4.0	See T.2-2	60	50	40	30	50
FEEDER	DS8	25–50	Unpaved	4.0	See T.2-2	60	50	40	30	50
	DS9	0–25	Unpaved	4.0	See T.2-2	60	40	30	20	40
	DS10	0–15	Unpaved	3.3	See T.2-2	60	40	30	20	40

2.2.3 Shoulders

A shoulder is the portion of the roadway contiguous to the carriageway for the accommodation of stopped vehicles; traditional and intermediate non-motorized traffic, animals, and pedestrians; emergency use; the recovery of errant vehicles; and lateral support of the pavement courses. Shoulder widths vs. design standards, terrain type, and urban/rural environment are presented in Table 2-2. They vary from no shoulder on minor rural roads where there is no surfacing, to a 1.5-3.0m or even greater sealed shoulder on major roads depending on the terrain and design classification. Wider configurations cater to the need for a parking lane in urban/sub-urban areas where paved carriageways exist. For unpaved carriageways, the shoulders are included in the carriageway width given in Table 2-2.

Table 2-2: Shoulder Widths

Design Standard	Rural Terrain/Shoulder Width (m)				Town Section Widths (m)			
	Flat	Rolling	Mountainous	Escarpment	Shoulder	Parking Lane***	Foot way	Median'
DS1	3.0	3.0	0.5 – 2.5	0.5 – 2.5	n/a	3.5	2.5 (min)	5.0 (min)
DS2	3.0	3.0	0.5 – 2.5	0.5 – 2.5	n/a	3.5	2.5	Barrier'
DS3	1.5 - 3.0++	1.5 - 3.0++	0.5 – 1.5	0.5 – 1.5	n/a	3.5	2.5	n/a
DS4	1.5	1.5	0.5	0.5	n/a	3.5	2.5	n/a
DS5*	0.0	0.0	0.0	0.0	n/a	3.5+++	2.5	n/a
DS6**	0.0	0.0	0.0	0.0	n/a	3.5+++	2.5	n/a
DS7	1.0 (earth)	1.0 (earth)	1.0 (earth)	1.0 (earth)	n/a	n/a +	n/a +	n/a
DS8**	0.0	0.0	0.0	0.0	n/a	n/a +	n/a +	n/a
DS9**	0.0	0.0	0.0	0.0	n/a	n/a +	n/a +	n/a
DS10**	0.0	0.0	0.0	0.0	n/a	n/a +	n/a +	n/a

2.2.4 Clear Zone

Once a vehicle has left the roadway, an accident may occur. The end result of an encroachment depends upon the physical characteristics of the roadside environment. Flat, traversable, stable slopes will minimize overturning accidents, which are usually severe. Elimination of roadside furniture or its relocation to less vulnerable areas is options in the development of safer roadsides. If a fixed object or other roadside hazard cannot be eliminated, relocated, modified, or shielded, for whatever reason, consideration should be given to delineating the feature so it is readily visible to a motorist.

For adequate safety, it is desirable to provide an unencumbered roadside recovery area that is as wide as practical on a specific highway section. The cleared width should be a minimum of 15 meters each side from the edge of the roadway for the higher road standards.

For lower standard roads, the clear zone can be reduced as practical. It should extend beyond the toe of the slope. Lateral clearances between roadside objects and obstructions and the edge of the carriageway should normally be not less than 1.5 meters. At existing pipe culverts, box culverts and bridges, the clearance cannot be less than the carriageway width; if this clearance is not met, the structure must be widened. New pipe and box culvert installations, and extensions to same, must be designed with a 1.5-meter clearance from the edge of the shoulder.

2.2.5 Right-of-Way

Right-of-ways, or road reserves, are provided in order to accommodate road width and to enhance the safety, operation and appearance of the roads. The width of right-of-way depends on the cross section elements of the highway, topography and other physical controls together with economic considerations. Although it is desirable to acquire sufficient right-of-way to accommodate all elements of the cross section and appropriate border areas, right-of-way widths should be limited to a practical minimum in both rural and developed areas affecting the economy of the inhabitants.

Right of ways will be equidistant from the centerline of the road to the left and to the right of the carriageway. It should always be determined and shown on the final design plans of road projects.

Road reserve widths applicable for the different road classes are given in Tables 2-3 through2-12 in Appendix A. In mountainous or escarpment terrain, a cut section may be of such depth that the right-of-way width is exceeded from the top of cut on one side to the other top of cut.

Additional areas required for outlets etc., should be provided in a manner that will not endanger the future integrity of the drainage facility and will provide adjoining landowners restricted use of this land after completion of the road.

Reduced widths should be adopted only when these are found necessary for economic, financial or environmental reasons in order to preserve valuable land, resources or existing development or when provision of the desirable width would incur unreasonably high costs because of physical constraints. In such cases, it is recommended that the right-of-way should extend a minimum of a nominal 3 meters from the edges of the road works. However, where this occurs, it is advisable to restrict building activity along the road to prevent overcrowding, to preserve space for future improvements, and to provide for sight distances at curves. The distance across the carriageway from building line to building line should be a minimum of 15m.

For dual carriageway roads it may be necessary to increase the road reserve width above the given values.

2.2.6 Four-Lane and Divided Roads

Mention was made in Chapter 5 regarding traffic volumes and the need to increase the roadway to a four-lane facility when a certain volume is reached.

It is also the case that some cities and villages have included a four-lane roadway as a feature in their master plans.

Four lane and divided roads are required when the design traffic volume is sufficient to justify their use. They are also frequently used in urban/sub-urban areas.

A minimum median width of 5.0 meters is required to allow the provision of left-turning lanes outside of the adjacent carriageway, and to avoid having a turning passenger vehicle from the minor road protrude into the through lanes. Geometric Standards for four lane roads are given in Tables 2-1, 2-2, and 2-3.

2.2.7 Single Lane Roads

For low traffic volume roads (<100ADT), single lane operation is adequate as there will be only a small probability of vehicles meeting, and the few passing maneuvers can be undertaken at very reduced speeds using either the shoulder (DS6 and DS7) or passing bays(DS8 to DS10). Provided sight distances are adequate for safe stopping, these maneuvers can be performed without hazard, and the overall loss in efficiency brought about by the reduced speeds will be small, as only a few such maneuvers will be involved.

The lowest design standards (DS8, DS9 and DS10) will not allow passing and overtaking to occur on the carriageway and passing bays must be provided. The increased width at passing bays should be such as to allow two design vehicles to pass, i.e. a minimum of 5.0 meters width, and vehicles would be expected to stop or slow to a very slow speed.

Normally, passing bays should be located every 300 to 500 meters depending on the terrain and geometric conditions. However, adjacent passing bays must be inter-visible. Account should be taken of sight distances, the likelihood of vehicles meeting between passing bays and the potential difficulty of reversing. In general, passing bays should be constructed as the most economic locations as determined by terrain and ground conditions, such as transitions from cuttings to embankment, rather than at precise intervals.

The length of individual passing bays will vary with local conditions and the type of design vehicle but, generally, a length of 20 meters including tapers will cater for most commercial vehicles.

Significant cost savings may be realized in mountainous and escarpment terrain by incorporating short lengths of DS8 standard within a DS6 road. This Departure from Standard may be economically justified, especially in escarpment terrain, for design traffic flows of less than 100 vehicles per day. However, appropriately placed, inter-visible passing bays are essential to ensure the free flow of traffic.

2.2.8 Typical Cross Sections & standard cross sections

Typical cross sections are illustrated in ERA Standard Detail Drawings-2002 and Standard cross sections for the 10 standard classes of roads are illustrated in Appendix E of this manual.

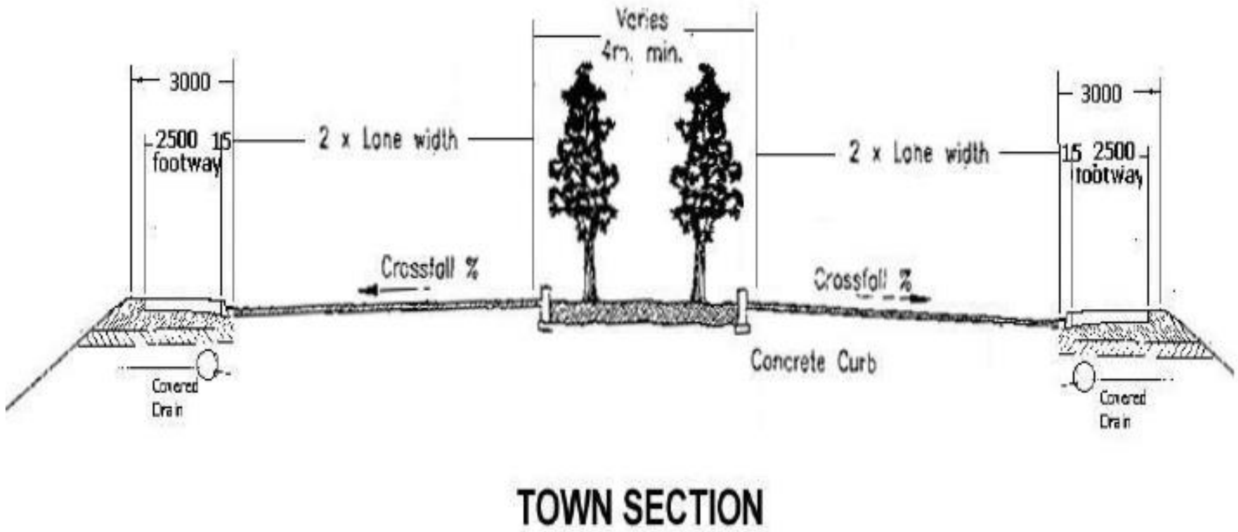


Figure 2-4: Four Lane Town Section

2.3 Research Gaps

From the revised literature, the design and construction of raised median at the center of urban asphalt roads in general in Ethiopia had not been given due emphasis since there is no detailed design of raised median mentioned in ERA manual for different situation.

2.4 Research output

- Study the common type of medians used in Ethiopia
- Discuss the geometric property of raised median constructed in the study
- Adopt the design and construction of raised median from other design manual to be included in ERA manual.

CHAPTER THREE

METHODOLOGY

The core objective of this research is to evaluate the effect of the construction of raised median on asphalt roads on the traffic operation in urban section in Jimma town asphalt road projects with respect to traffic delay and traffic accident.

Jimma town asphalt road is the study route selected to take the necessary data about the cross sectional elements of the road to evaluate the types of median used, the width of the median and median spacing or opening length of median. The types of plant used in the median which are meant to provide architectural function to beautify the town are gathered along with their plant property and the spacing of plantation. The types of median barrier used in the median to reduce the severity of accident on pedestrian and crash with opposite lane traffic are collected.

In order to achieve the objective of the research goal it requires review of different guidelines of urban road design manuals, applicable practices, research findings, information on the design of raised median and other types of median related study and relevant literatures on current design approaches.

1. The methodologies adopted to achieve the objectives are outlined as follows: Review of applicable practices, research findings and other relevant information on design of raised median.
2. Relevant literatures on current design and construction practices of medians and functionality approach of various types of medians and their impact on traffic flow have been reviewed.
3. Data collection has been carried out in the study area of Jimma asphalt road projects and the necessary data collected were:
    - Types of median used
    - Median width.
    - median opening length
    - median opening spacing

4. The types of median used the width of the median and median spacing or opening length of median had been taken through field review of design data and onsite field measurement. The types of plant inside the median including their growth property and dimensions are gathered along with the spacing of plantation. The types of median barrier used in the median to reduce the severity of accident on pedestrian and crash with opposite lane traffic are collected.

The classification and measurement of median types used on Jimma town asphalt projects like the types of median preferred and the width of chosen median are surveyed by observation and measurement continuous for the certain length of the major road network and those data were used to estimate the present road design and construction trend of the urban section of the road.

Finally the design and construction trend of cross sectional elements consideration of medians data collected from the field measurement and analysis of design data at office was reviewed in correlation with different guidelines of urban road design manuals, applicable practices, research findings, information on the design of raised median and other types of median related study and the strength and drawbacks of the current design and construction practices of median types used on asphalt road with respect to traffic flow and traffic accident and report were prepared on the finding.

To achieve the objectives of this thesis as stated above, the knowledge of certain applicable design manuals and guidelines is in sighted. The knowledge and experience gained during this period helped the writer of this paper in developing reliable, efficient and effective study approach to focus on stated goals.

Before data collection was carried out, training was provided to enumerators to arm them with knowledge on how to gather reliable data on median types and their characteristics and some basic measurement training were given to get accurate measurement values using the tape meter during data gathering.

3.1 Data collection

Data collected for the analysis were obtained from design documents prepared during the design phase of road project and through field measurements. The types of median, the width of median and opening length of median at intersections and at mid-block were well collected in the site for the analysis of the safety and operational performance level of the asphalt road network of the study route.

The types of data gathered during field data collection were:

- ⇒ Lane width,
- ⇒ Carriageway width
- ⇒ Shoulder width
- ⇒ Right of way width
- ⇒ Adjacent land use
- ⇒ Road side features
- ⇒ Types of median used
- ⇒ Width of median
- ⇒ Opening length of median at mid-block and intersections

First the preliminary design data prepared during the planning stage is collected and major routes are identified with large roadway width and length. Then some routes are selected among the total routes mentioned on the preliminary design where some of the routes are designed with an enclosure raised medians at the center whereas some are not.

Then the approved working design templates for the selected routes which are prepared during the construction stage of the road projects were collected and compared with that of the preliminary design data.

Data was also collected through field investigation of these selected routes which is composed of observation and measurement of as-built roads. The types of data collected on the field include the characteristic of traffic flow, the location of junctions, and the adjacent land use.

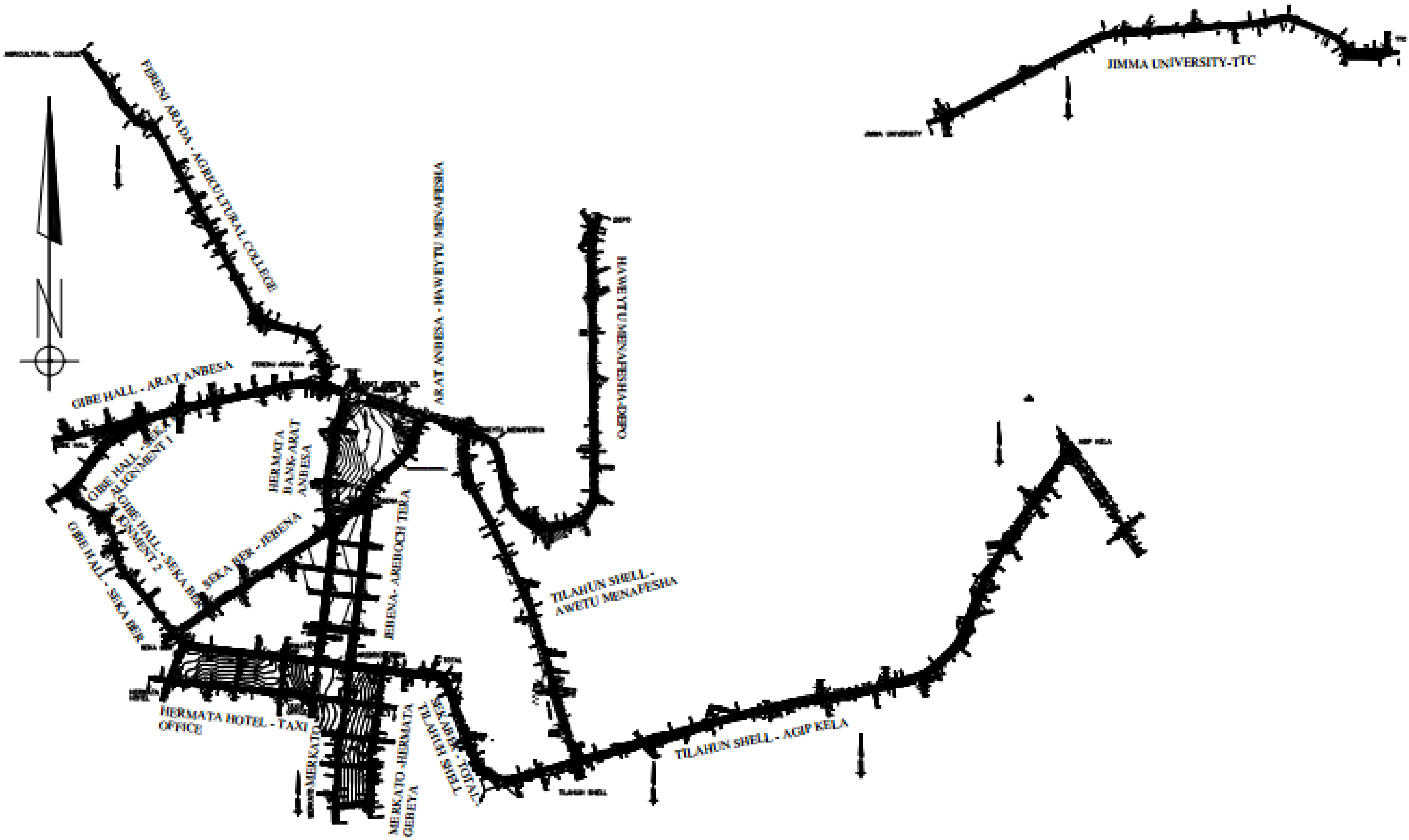


Figure 3-1: Plan of the All Routes in Jimma Town Asphalt Project

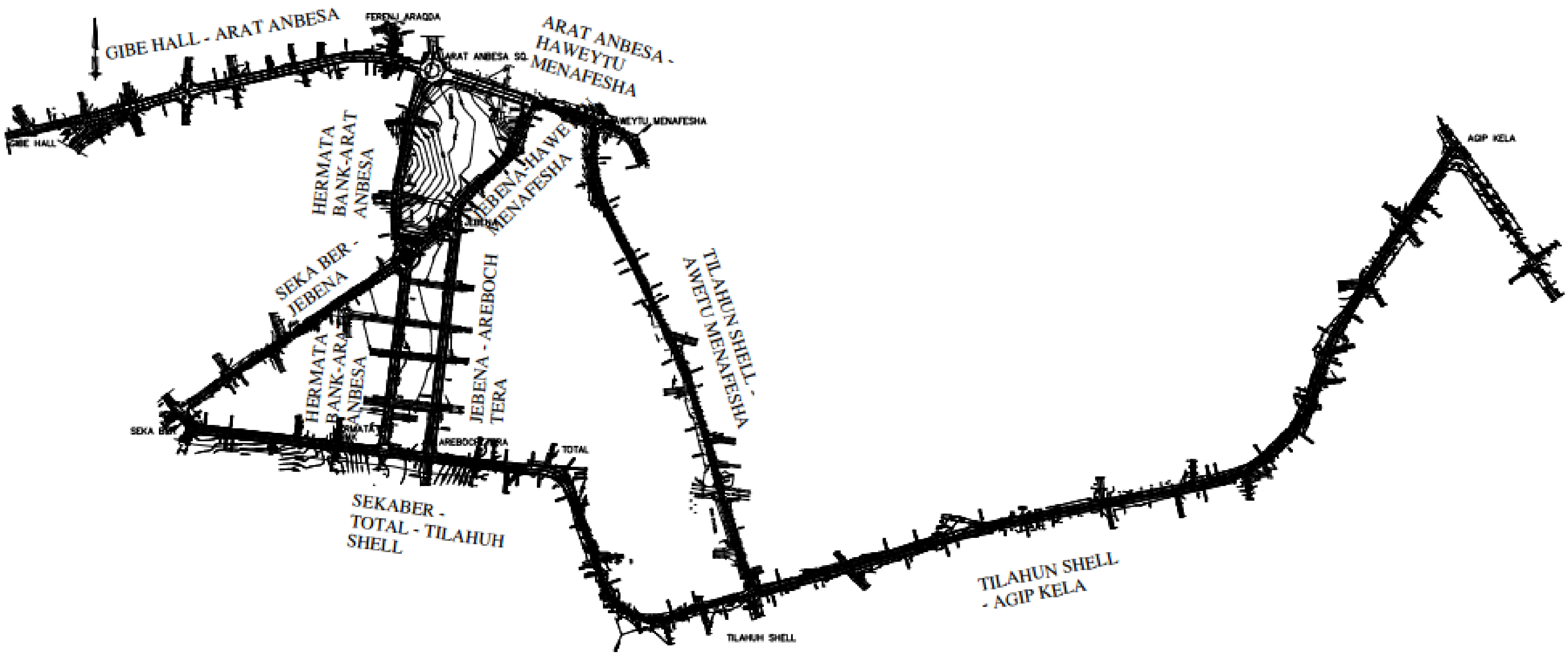


Figure 3-2: Plan of the Selected Routes in Jimma Town Asphalt Project

3.2 General Description of selected routes

3.2.1 Route 1: Hermata Bank-Arat Anbesa

Section 1: Station 0+000 - 0+380

This route is considered as urban section and it is administered by the Jimma City Admiration. It starts at station 0+000 which is at Hermata Branch of Commercial Bank of Ethiopia and passes through the Roundabout in front of the Main Branch of Commercial Bank of Ethiopia which is at station 0+380 from the start. This section of the route has congested traffic flow since it is found near the center of market place and this place is used as a taxi station on both sides of the road. Besides the majority of the adjacent land use on both sides of the road are used as commercial propose composed of shops of clothing construction material and electronics. Besides the number of pedestrian using the road is enormous with a characteristic movement of irregular pattern.

Section 2: Station 0+380 - 0+750

The second section of the route starting from 0+380 up to 0+750 which is the end station of this route at Arat Anbesa Roundabout do not have a congested traffic flow as that of the first section. One reason behind this is the adjacent land use of the road on both side is not much of a commercial area and the number of pedestrian along this section is few. The typical section of this route approved by the Engineer during the construction phase is shown in Figure 3-3 below.

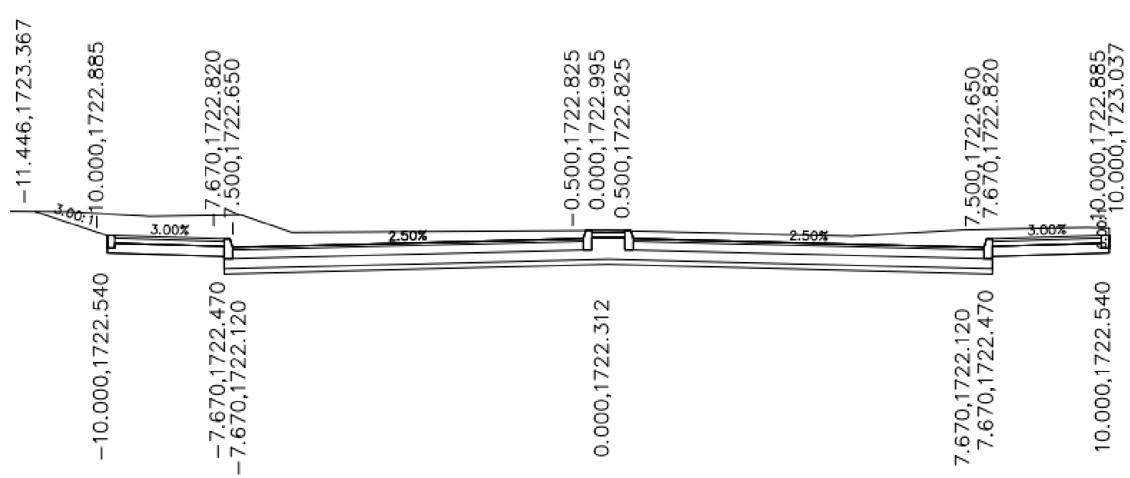


Figure 3-3: Cross Section for Hermata Bank-Arat Anbesa

3.2.2 Route 2: Areboch Tera–Jebena

Areboch Tera is the start of the project road at station 0+000 which is around the building of Jimma City Center and ends at Yegna Le Yegna Hotel at station 0+460.This section of the route is experiencing a highly congested traffic flow because it is found at the center of business area of different merchandise where a lot of large vehicles park on both side of the road to load and unload commodities for distribution. The outer lane of both sides of the road is used as a parking lane leaving one effective lane on each direction for through and turning traffic movements. As a result the operation and safety of the traffic movement is obstructed. As described earlier the majority of the adjacent land use on both sides of the road is used as commercial propose not only the volume of large vehicles but also the number of pedestrian for commercial purpose is high.

The prepared design template approved by the Engineer during construction which was used as a working drawing for the typical cross section of Areboch Tera – Jebena is shown below on Figure 3-4.

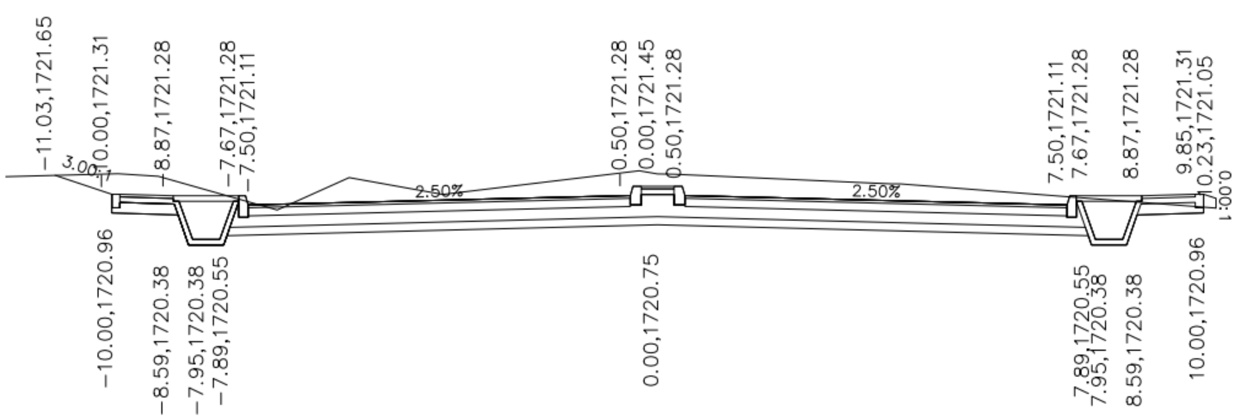


Figure 3-4: Cross Section for Areboch Tera–Jebena

3.2.3 Route 3: Jebena-Awetu Menafesha

This section of the route is the continuous route of Seka Ber-Jebena where it starts at Seka Ber which was the old exit road to Seka. By now this road is blocked due to the upgrading project of Jimma Aba Jifar Airport and a new exit road is constructed to Seka. Anyways the old exit road of Seka is found at intersection road to Jimma Preparatory School where the project starts at station 0+000. This road is now under construction by the name of governmental contractor Ethiopian Construction Works Corporation under the division of Transport Infrastructure Construction (ECWC).

However the route Jebena-Awetu Menafesha which has already been constructed is the next part of Seka Ber-Jebena where it starts at Roundabout fount in front of the Main Brach of Commercial Bank of Ethiopia at station 0+510 and ends Awetu Menafesha at station 0+915 in front of Bemnet Café adjacent to Awetu Bridge. The typical section of the road is shown below in Figure 3-5 which was approved by the Engineer.

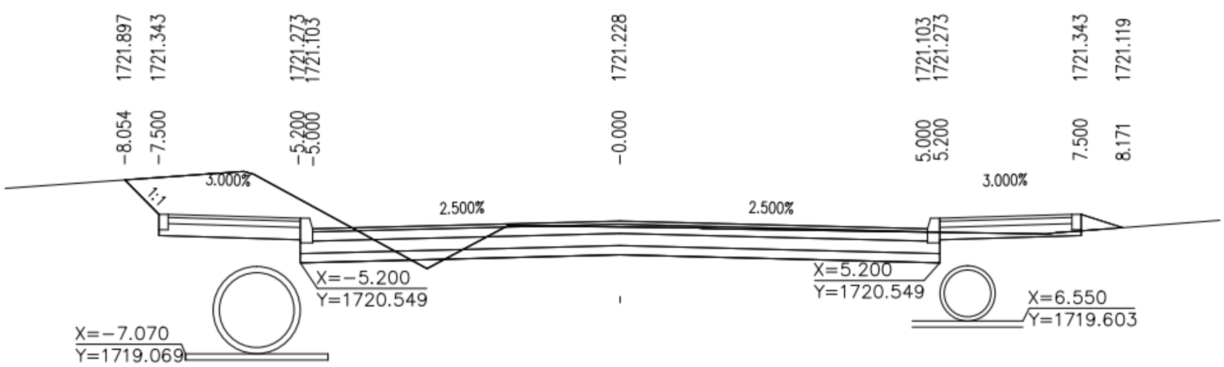


Figure 3-5: Cross Section for Jebena-Awetu Menafesha

3.2.4 Route 4: Seka Ber - Total - Tilahun Shell

The start of the project is at Seka Ber at station 0+000 runs in the direction of Munir Mosque passing through the intersection of roads at Hermata Bank at station 0+420 towards Getachew Total found at Legehar Bridge at station 0+800. At this point taking the road to the right side from Y intersection, it leads in the direction of Roundabout found at Tilahun Shell at station 1+370. The approved typical section of the road is shown below in Figure 3-6.

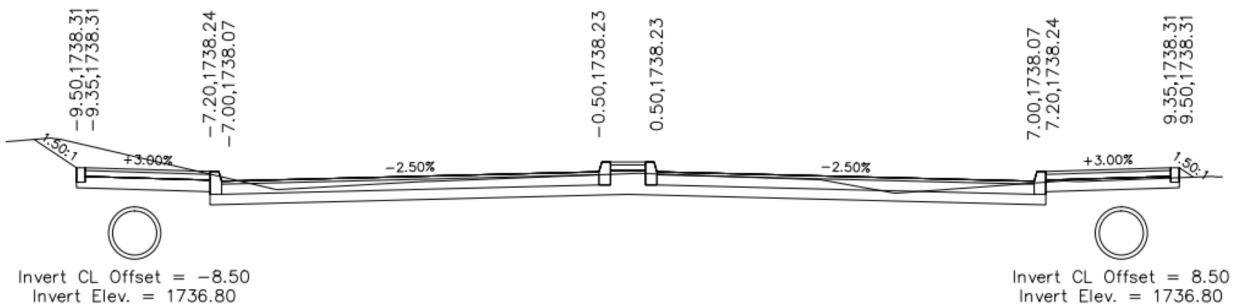


Figure 3-6: Cross Section for Seka Ber - Total - Tilahun Shell

3.2.5 Route 5: Arat Anbesa - Top View Café

The project starts at station 0+000 at Arat Anbesa Roundabout runs in the direction Awetu Bridge passing through it and ends at Top View Café at station 0+400. The typical section of the road prepared during construction is shown below in Figure 3-7. The capacity of this road is satisfactory since wider road width is provided due to sufficient Right of Way width. As a result of this there is less probability of congestion of traffic flow when compared to the other routes found in Jimma in general. The adjacent land use of this road is used as a green area with recreation spot.

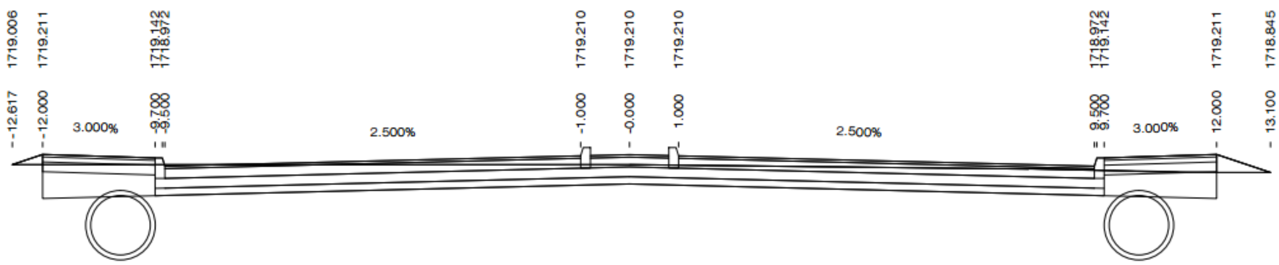


Figure 3-7: Cross Section for Arat Anbesa - Top View Café

3.2.6 Route 6: Tilahun Shell – Awetu Menafesha

Tilahun Shell is the start of the project at station 0+000 goes in the direction of Jimma Bus Station and meets with the intersection at Coffee Land Hotel at station 0+180. Passing the intersection in the way to Central Hotel, the road leads to the end of the project at Awetu Menafesha at station 0+980. The first 500m of this road is somewhat congested section as it is nearby the bus station and the adjacent land use of the road is for commercial purpose composed of recreational places as Hotel. Thus a lot of parked vehicles are observed on both sides of the road. The section of the road after the 500m length is with a calmed traffic flow because there are no special activities undergoing on both adjacent side of the road. The typical section of the road in the approved design template by the Engineer is shown below in Figure 3-8.

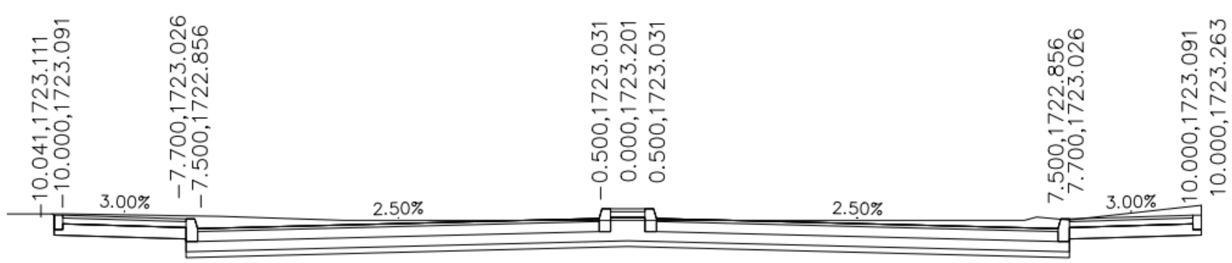


Figure 3-8: Cross Section for Arat Anbesa - Top View Café

3.2.7 Route 7: Tilahun Shell-Agip Kela (Jimma Connectivity Road)

As the name indicates two names were given to this route because of the reason it had two planning stages. The first plan was prepared along with the other road network shown above in Figure 3-1. This road network was planned for construction under the ownership of Jimma City Administration and this route was included in the plan.

According to the plan the road is the continuity of the route Seka Ber-Total-Tilahun Shell mentioned above where Tilahun Shell being the end of Seka Ber-Total-Tilahun Shell and the start of Tilahun Shell-Agip Kela at station 1+370. The end of this route was planned to be at roundabout found in front of Honey Land Hotel at station 3+200 with a total length of 1.83km starting from Tilahun Shell up to Honey Land Hotel. As a whole the combined route Seka Ber-Total-Tilahun Shell-Agip Kela from station 0+000 to 3+200 a total length of 3.2km was planned.

Thus taking station 1+370 at Tilahun Shell as the start of this route and heading in the direction of St. Mikael Church and then towards Honey Land Hotel where it ends. The typical section of the road according to the plan by Jimma City Administration is shown below in Figure 3-9.

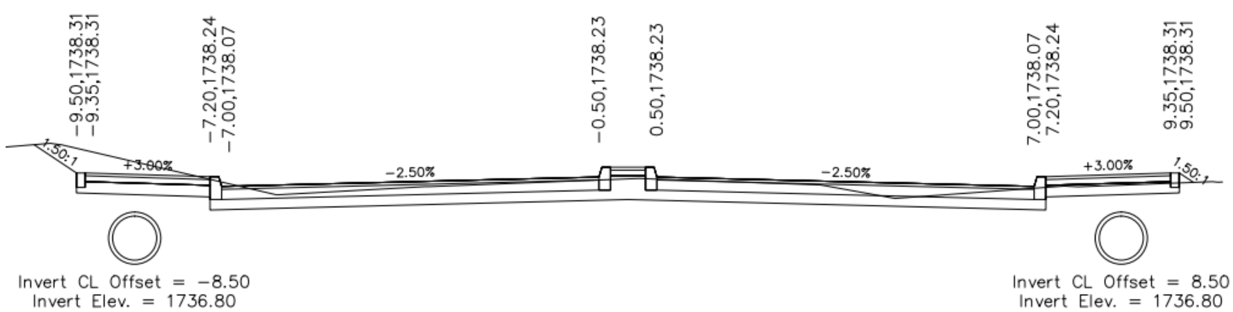


Figure 3-9: Cross Section for Tilahun Shell-Agip Kela

However the Administration was not able to implement the road project of this route due to termination of agreement with the contractor. This is when the second plan for this route was prepared after two years by Ethiopian Road Authority and given to another contractor.

According to the new plan the start station 0+000 of this asphalt road project is at Ethiopian Commodity Exchange Jimma Branch found at the exit road to Addis Abeba local name called Agip. Starting from Agip going towards to Honey Land Hotel a small Roundabout is found at station 0+460. The road turns to the left leaving the road to Jimma University and goes in the direction to gas station called Abera Total at station

0+900. After this station the road goes forward for about 1.3 km towards the end of the project at station 2+260 at Tilahun Shell besides the roundabout.

All the other asphalt roads mentioned in this paper are monitored by Jimma City administration where are this asphalt project is under the ownership of Ethiopian Road Authority. Since this is the main road used as an exit road to Addis Ababa, the composition and volume of the traffic flow is very high. Besides most of the road length is occupied by parked vehicles of different types on both sides of the road. The typical section as it was used in the design template approved during construction phase after the second planning stage is shown below in Figure 3-10.

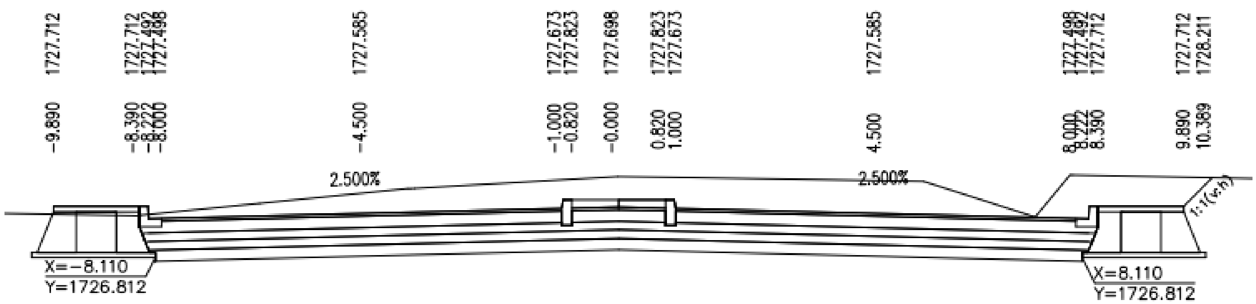


Figure 3-10: Cross Section for Jimma Connectivity Road

3.3 Cross Sectional Elements of Selected Routes during Planning Phase

The dimensions and characteristics of typical cross sectional elements of all of the above selected routes have been investigated during the field study. The data collection result from both the design data during planning stage and construction stage as well as the field measurement has been compared for analysis.

During the preliminary design stage, the typical sections of the selected routes of Hermata-Arat Anbesa, Areboch Tera – Jebena, Jebena-Awetu Menafesha and Seka Ber-Total-Tilahun Shell were planned to have total of 4 lanes having a 3.5m width for each lane. As an opposite traffic separator a 0.3m width curb stone was designed at the median of the road as shown in Figure 3-11 below. Thus, adding up all together the carriageway width including the median curbstone was 14.30m. The shoulder on both sides of the road was provided for the purpose of pedestrian walkway had a width of 2m on each side.

The design of pedestrian walkway with their corresponding dimensions is shown below on Figure 3-12. The roadway width which is the sum of the carriageway width including the median and both sides of the shoulder width gives 20m.

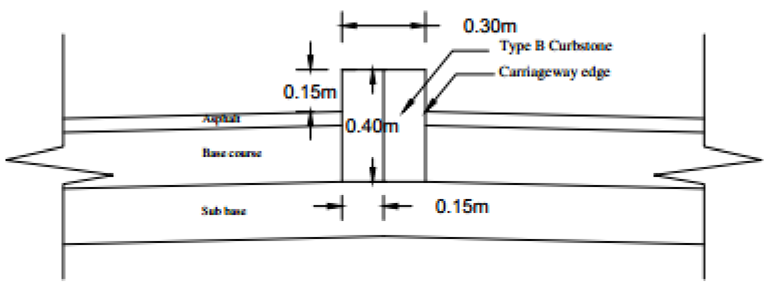


Figure 3-11: Design of Raised Median for Most Routes during Planning

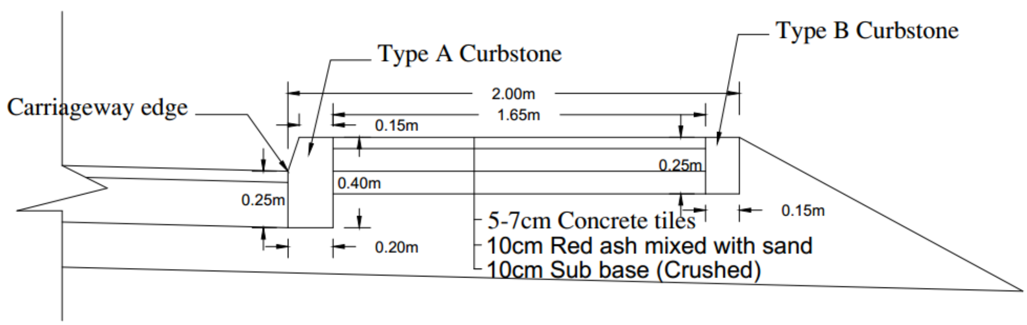


Figure 3-12: Design of Pedestrian Walkway during Planning

The other selected routes discussed above having similar typical cross sectional elements during the preliminary design stage are Seka Ber – Jebena, Top View-Awetu and Tilahun Shell - Awetu Menafesha. These routes were planned to have a total of 2 lanes i.e. one lane in each direction of the road with a 3.5m width for each lane. In this case there is no dedicated median opposite traffic separator as that of the previously mentioned routes rather paint is used as delineation for the centerline of the road. Thus, the carriageway width was only 7m. The pedestrian walkway had a width of 1.35m on each side. The roadway width which in this case consists of carriageway width and the walkway on both sides width gives 9.7m.

The only route having a wider typical cross section from the selected routes is Awetu - Arat Anbesa. This routes was planned to have a total of 4 lanes i.e. two lane in each direction of the road with a 3.5m width for each lane. As an opposite traffic separator a 2m width median including the curbstone was designed at the center of the road as shown in Figure 3-13 below. When compared with other selected routes this route was designed to have the wider median width of 2m. Thus, adding up all together the carriageway width including the median curbstone was 16m. The shoulder road used as a pedestrian walkway had a width of 2.5m on both side. Thus the roadway width which is the sum of the carriageway width including the median and both sides of the shoulder width gives 21m.

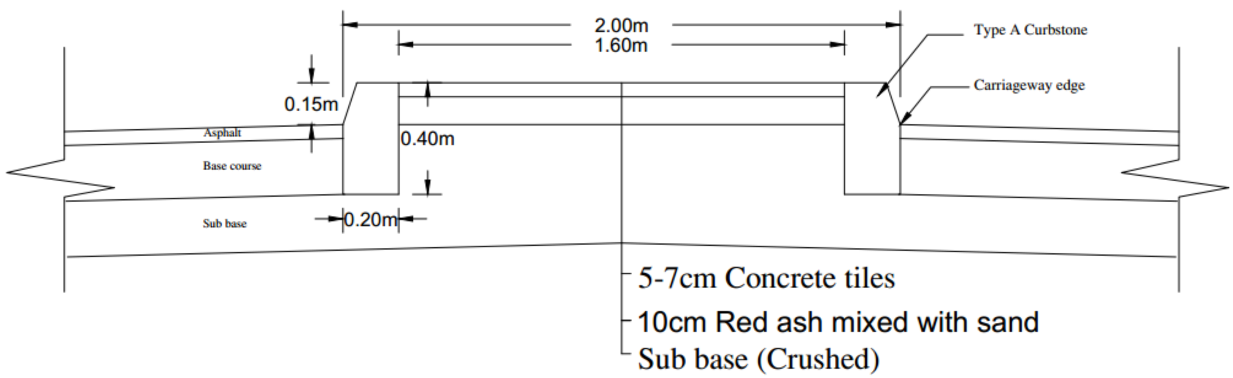


Figure 3-13: Design of Raised Median for Jimma Connectivity during Planning

Table 3-1: Typical Cross Sections during Planning Stage

No.	Route name	Route length	No. of lane	Lane width(m)	Median width(m)	Pedestrian Walkway(m) (Both sides)	Roadway width(m)
1	Hermata Bank-Arat Anbesa	0+000-0+751.48	4	3.5	0.3	2	18.3
2	Areboch Tera-Jebena	0+000-0+440.647	4	3.5	0.3	2	18.3
3	Jebena-Awetu Menafesha	0+450-0+915.93	4	3.25	0.3	2.5	18.3
4	Seka beer-Total-Tilahun Shell	0+000-1+350	4	3.25	0.3	2.5	18.3
5	Top View-Awetu	0+000-0+160	2	3.5	0	1.35	9.7
6	Awetu - Arat Anbesa	0+160-0+361.07	4	3.5	2	2.5	21
7	Tilahun Shell - Awetu Menafesha	0+000-0+985.388	2	3.5	0	1.35	9.7
8	Tilahun Shell - Agip Kela	0+000-0+2+260	4	3.5	0.3	2	18.3

3.4 Cross Sectional Elements of Selected Routes during Construction Phase

As discussed above, during the preliminary design phase the design data for the routes Hermata Bank-Arat Anbesa, Areboch Tera – Jebena, Jebena-Awetu Menafesha and Seka beer-Total-Tilahun Shell showed the same typical cross section characteristic that all dimensions of the cross section elements of the routes are equal. However; during the construction phase the design data approved by the Engineer shows that the typical section is different from that of the preliminary design during planning stage.

Hermata Bank-Arat Anbesa and Areboch Tera – Jebena, routes changed their typical cross section during the construction phase that the roadway width i.e. from the edge of the pedestrian walkway to the other edge of the pedestrian walkway was increased from 18.3m to 20m which requires additional right of way possession. This increment was caused by provision of additional median width from 0.3m which is double curbstone placed side to side without space between them as shown in Figure 3-11 above to 1m median width including the median curbstone of 0.2m on the left and the right leaving an effective width of the median of 0.6m. A 1m width median is shown in the Figure 3-15 below. The other increment of the road width was caused due to the change in dimension of the pedestrian walkway from 2m to 2.5m. Figure 3-12 shown above is the design for a pedestrian walkway of 2m width whereas the same characteristic of walkway elements for 2.5m width is shown in Figure 3-14 below.

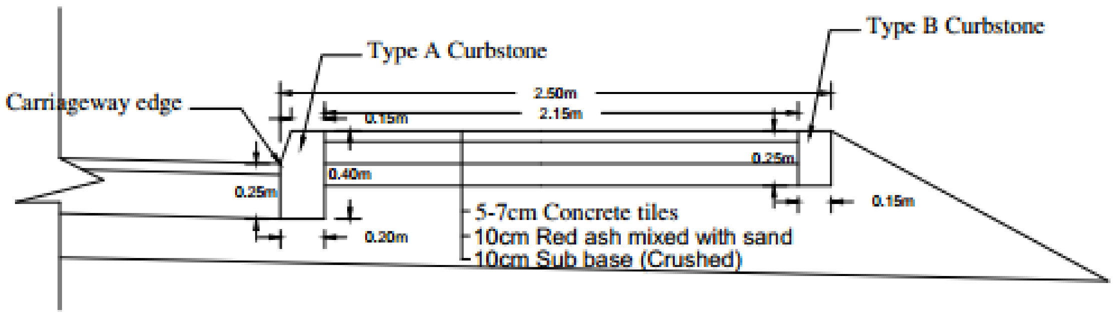


Figure 3-14: Design of Pedestrian Walkway during Construction

The typical cross section of the routes of Jebena-Awetu Menafesha and Seka beer-Total-Tilahun Shell was the same as that of Hermata Bank-Arat Anbesaand Areboch Tera – Jebena. But during the construction phase there was a change in design of cross section of Jebena-Awetu Menafesha and Seka beer-Total-Tilahun Shell. The roadway width of Jebena-Awetu Menafesha was decreased from 18.3m to 15m due to insufficient right of way possession. The carriageway width of this route including a 0.3m median with double curbstone was 13.3m during the planning stage but during the construction stage the carriageway width was decreased to 10m where there is no median provided for this route. This is the main reason that the typical section decreased since the pedestrian walkway width has not changed for both during the planning stage and construction phase and kept the same on 2.5m.On the other hand, the typical cross section of the route Seka beer-Total-Tilahun Shell was changed by an increment from 18.3m to 20m during construction. Even though the number of lane was kept to 4 in number one of the cause for this change was the width of one lane was widened from 3.25m to 3.5m besides the median width was also increased from 0.3m of double curbstone to 1m median as shown in the Figure 3-15 below. Thus the width of the carriageway has changed from 13.3m to 15m. Here again the width of the pedestrian walkway was the same for both phases to 2.5m.

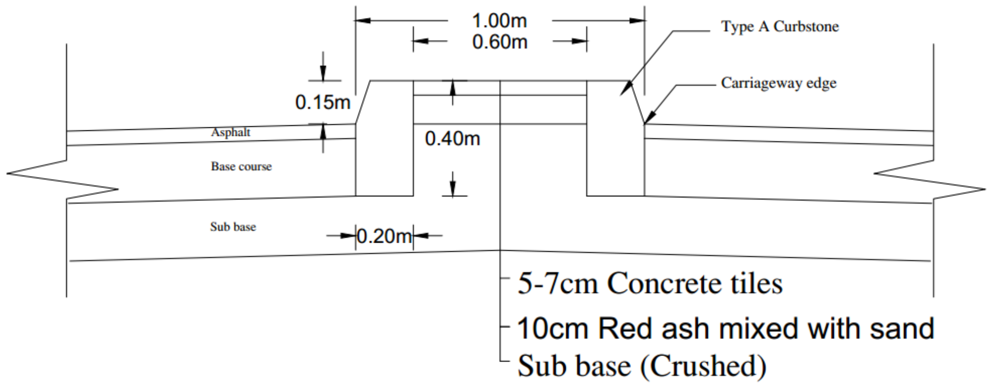


Figure 3-15: Design of 1m Width Raised Median during Construction

The same is true for the routes Top View-Awetu and Tilahun Shell - Awetu Menafesha that previously they had the same roadway width of 9.7m. But during the construction phase the roadway width of the typical cross section of Top View-Awetu was changed to 24m while Tilahun Shell - Awetu Menafesha was changed to 20m. In Top View-Awetu route the number of lane was increased from 2 to 4 with a corresponding increment of one lane width from 3.5m to 4.25m. In addition to this a 2m median width was provided even though no median was included in the preliminary design stage. This means the carriageway width has increased from 7m to 19m. besides the pedestrian walkway width also increased from 1.35m during planning stage to 2.5m during construction stage. Summing up together the roadway width showed difference from 9.7m to 24m due to the reasons mentioned above.

Whereas the route Tilahun Shell - Awetu Menafesha changed the roadway width to 20m which was an increment from 9.7m. This is mainly due to the increment of the number of lane from 2 to 4 with the same width of lane. Again median width of 1m was included during construction stage as it was not part of the typical cross section during planning stage. This implies a change in carriageway width of 7m to 15m. Moreover the walkway on both sides of the road has changed from 1.35m to 2.5m indicating an increment of roadway width from 9.7m to 20m.

Awetu - Arat Anbesa route was also showing difference of typical cross section during both phases. The only reason for the change was the increment of a single lane width for one from 3.5m to 4.25m with a total of 4 lanes and the same median width of 2m for both phases an increment of carriageway width was observed from 16m to 19m. there was no difference in pedestrian walkway width for both cases that a2.5m width was reserved for both stages concluding the roadway width varies from 21m to 24m.

Table 3-2: Typical cross sections during Construction

No.	Route name	Route length	No. of lane	Lane width(m)	Median width(m)	Pedestrian Walkway(m) (Both sides)	Roadway width(m)
1	Hermata Bank-Arat Anbesa	0+000-0+751.48	4	3.5	1	2.5	20
2	Areboch Tera-Jebena	0+000-0+440.647	4	3.5	1	2.5	20
3	Jebena-Awetu Menafesha	0+450-0+915.93	4	2.5	0	2.5	15
4	Seka beer-Total-Tilahun Shell	0+000-1+350	4	3.5	1	2.5	20
5	Top View-Awetu	0+000-0+160	4	4.25	2	2.5	24
6	Awetu - Arat Anbesa	0+160-0+361.07	4	4.25	2	2.5	24
7	Tilahun Shell - Awetu Menafesha	0+000-0+985.388	4	3.5	1	2.5	20
8	Tilahun Shell - Agip Kela	0+000-0+2+260	4	3.5	2	1.5	19

Therefore according to the comparison discussed above, most of the roadway width of the selected route in the preliminary design during planning stage and the roadway width in the approved design by the Engineer during construction phase show that there is an additional right of way requirement due to the increment of different cross sectional elements.

3.5 Cross Sectional Elements of Selected Routes during Field Study

This stage of the research tries to investigate the persistence of actually constructed design elements of cross section with that of the designs prepared during the planning stage and construction stage. The field study of this research made an observation and measurement on the selected routes examines the actual physical characteristic of the typical cross sections on site and discusses the missed part when compared it with design during the construction stage after gaining the approval by the Engineer.

3.5.1 Route 1: Hermata Bank-Arat Anbesa

The actual filed observation showed that a 1m median including the curbstone was left unconstructed and this space which was reserved for the median was covered with asphalt to be used as a flush median. Actually the flush median is not painted to be reserved as median thus it seems it is part of the carriageway left for the full access of motorized traffic. This suggested that there is no dedicated median facility provided for this route.

On the other hand, pedestrian walkway of 2.5m width which was approved by the Engineer during construction phase was not secured due to different reasons. At some random stations there is an indication of limitation of right of way possession which was the responsibility of the Jimma City Administration to clear out and secure the right of way with due compensation process. Even though some stations have sufficient right of way, the characteristic of the adjacent land use of the route provoke the pedestrian walkway to give its intended purpose by blocking the walkway with commodities of the shops on the walkway. Figure 3-16 shown below is an evidence for this situation.

Figure 3-16: Obstruction on walkway with commodities by shop owners

Not only shop owners but also illegalized markets of different types is allowed on both sides of the pedestrian walkway making congestion of non-motorized traffic force them to use the traffic lane as a walkway. Figure 3-17 below shows pedestrian walkway congestion due to this reason.

Figure 3-17: Illegal Market Place on Walkway

In order avoid the congestion of pedestrians on the walkway and block the accessing of pedestrians from using the traffic lane, the City Administration proposed the placing simple type of barrier made of vertical posts about 1.5m height buried in some intervals a chain connected to the posts horizontally at both edges of outer traffic lanes. This does not assure the separation of the pedestrian from the motorized traffic lane due to the above mentioned reasons. Figure 3-18 below shows the barrier described above and the figure captured evidence still the pedestrian is not interested to use the walkway for their safety.

Figure 3-18: Barrier at the Road Side of Pedestrian Walkway

3.5.2 Route 2: Areboch Tera – Jebena

The typical cross section of this route is almost the same as that of the approved design data during construction phase except a slight change in the width of pedestrian walkway. As it was discussed above a 2.5m width walkway as shown in the Figure 3-14 above was approved by the Engineer on the design template. This type of walkway was introduced with a composition of a trapezoidal ditch constructed with concrete and a ditch cover on top the ditch covered as pedestrian walkway. The ditch cover had a width of 1.4m including "Type A curbstone" as discussed earlier and the rest of space adjacent to the ditch would be paved as a walkway.

However during the field investigation, the part of the walkway adjacent to the ditch is missed as shown in the Figure 3-19 below due to probably the insufficient right of way. In addition to this, the route has a very congested traffic characteristic as the adjacent land use on both sides of the route is commercial to half of its length and half is old residents with front door of the house right near to the ditch. Thus concluding the walkway is not fully functional as the space is invaded by the adjacent land use of the commercial and residential purposes.

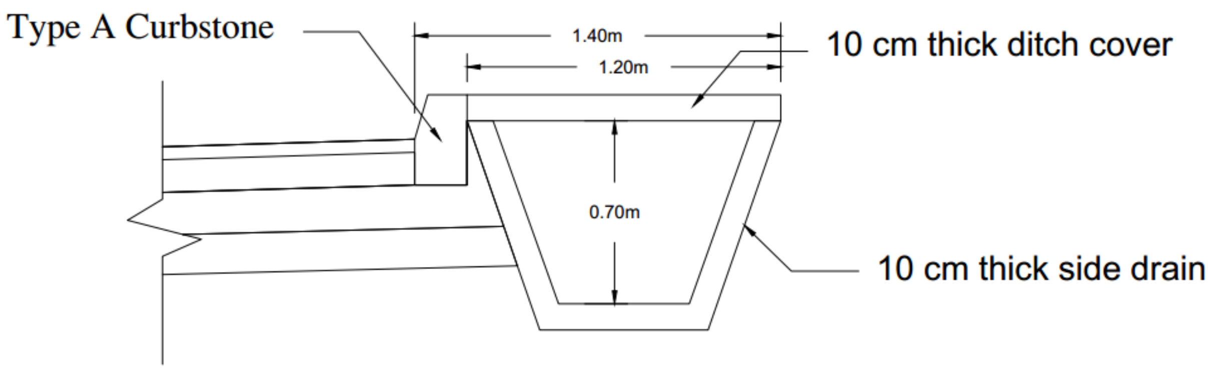


Figure 3-19: Trapezoidal Ditch at Areboch Tera – Jebena

The field study has confirmed the installation of raised medians of 1m width including the two sides of curbstone of 0.2m width on both sides leaving an effective space of 0.6m as shown in the Figure 3-15 above. Now, the researcher wants to give a strong emphasis on the design of raised medians with respect to their types of median and components inside the median (e.g. properties of plantation and barriers placed inside the median), the width of the media, spacing of the median opening and length of median opening.

As mentioned above a median width of 1m is introduced of which only 0.6m free space is excluding the curbstones. The simple barrier as shown in the Figure 3-20 below on the median made of welded rectangular hollow section (RHS) is used. A single barrier has a length of 9mand about 1.5m high is installed one after the other having a space of ranging from 1.1m to 1.86m between them. These spaces are provided meant as a refugee area for pedestrian crossing the road. Inside the median barrier trees with about 0.4m diameter and 2.5m high are planted within 1.5m interval.

Figure 3-20: Trapezoidal Ditch at Areboch Tera – Jebena

Along this route, there are four minor junctions on both sides of the road where the junctions are in front of each other. On all locations of the junctions, median openings are provided allowing all movements for the traffic including left turn, U turn and crossing movement. The location of junctions are 0+040 both sides, 0+140 both sides, 0+200 both sides and 0+290 both sides from the start 0+000 which is found at major intersection.

Table 3-3: Junctions location in Areboch Tera-Jebena route

No.	LHS	Remark	RHS	Remark
1	0+000	Major Junction	0+000	Major Junction
2	0+040	Minor Junction	0+040	Minor Junction
3	0+140	Minor Junction	0+140	Minor Junction
4	0+200	Minor Junction	0+200	Minor Junction
5	0+290	Minor Junction	0+290	Minor Junction
6	0+460	Y Junction	0+460	Y Junction

The spacing of median opening can be found from the location of junctions that the first opening is at 40m from the start the second opening is 100m away from the first opening, the next opening 60m from the previous and the next one 90m from the preceding.

On the other hand, the respective median opening length on the location of junctions are 12m at station 0+040, 9m at station 0+140, 10m at station 0+200 and 10m at station 0+290.

Table 3-4: Areboch Tera – Jebena Medain Opening Spacing and Length

Intersection/ Junction Station	Median Opening Spacing(m)	Median Opening Length(m)
0+000		
0+040	40	12
0+140	100	9
0+200	60	10
0+290	90	10
Average Spacing/ Length	**72.5**	**10.25**

3.5.3 Route 3: Jebena-Awetu Menafesha

The carriageway property and dimension of this route was constructed the same way as it was approved by the Engineer during construction phase. Even though as discussed earlier on the design of pedestrian walkway 2.5m was provided, the field observation has confirmed that the facility has no definite space the pedestrian use and it is not paved with smooth surface indicating its unsuitability to be selected as a walkway. Especially on the right side of the pedestrian walkway is not prepared well even though there is sufficient right of way.

3.5.4 Route 4: Seka Ber - Total - Tilahun Shell

There is no change in the construction of carriageway and the median where both element of the road has been built according to the design template approved by the Engineer during the construction phase. However a variable width of pedestrian walkway was provided that a sufficient amount of right of way width was not secured for this purpose. As a result 2.5m walkway width was reduced to values ranging from 0m to 1m.

In addition to this, the route has a very congested traffic characteristic as the adjacent land use on both sides of the route is commercial starting from the station 0+000 at Seka Ber up to station 0+700 found near Legehar Bridge. As a result the walkway is not fully functional as the space is invaded by the adjacent land use of the commercial and residential purposes. The other type of invasion of walkway was observed due to fencing of a construction site right at the edge carriageway that all the walkway is in the inside part of the fence in addition to that a vehicle stopped on the traffic lane for the purpose of unloading construction materials on the vehicle as shown in the Figure 3-21(c) and thus the pedestrian is forced to use the traffic lane.

(a) (b) (c)

Figure 3-21: Obstruction of Pedestrian Walkway at Seka Ber - Total - Tilahun Shell

Installation of raised medians of 1m width including the two sides of curbstone of 0.2m with an effective width of 0.6m was observed beginning from the start of the road at Seka Ber up to the end of the road at Tilahun Shell at station 1+370.

As mentioned above a median width of 1m is introduced of which only 0.6m free space is excluding the curbstones. The simple barrier similar to the Figure 3-20 shown above on the median made of welded rectangular hollow section (RHS) is used. A single barrier has a length of 9m and about 1.5m high is installed one after the other having a space of ranging from 1.1m to 1.86m between them. These spaces are provided meant as a refugee area for pedestrian crossing the road. Inside the median barrier trees with about 0.4m diameter and 2.5m high are planted within 1.5m interval.

Along this route, there are five major junctions and seven minor junctions on left side of the road and six major junctions and six minor junctions on right sides of the road. The location of junctions is shown in the Table 3-5 below.

Table 3-5: Junctions location in Seka Ber-Total-Tilahun Shell route

No.	LHS	Remark	RHS	Remark
1	0+000	Major Junction	0+000	Major Junction
2			0+040	Major Junction
3			0+210	Minor Junction
4	0+250	Minor Junction		
5	0+340	Minor Junction	0+340	Minor Junction
6	0+430	Major Junction	0+430	Major Junction
7	0+520	Major Junction	0+520	Major Junction
8	0+620	Minor Junction	0+620	Major Junction
9	0+655	Minor Junction		
10			0+690	Minor Junction
11	0+765	Minor Junction		
12	0+800	Major Junction		
13	0+975	Minor Junction		
14			1+000	Minor Junction
15			1+195	Minor Junction
16	1+265	Minor Junction	1+265	Minor Junction
17	1+370	Major Junction	1+370	Major Junction

The locations of median opening with their corresponding opening spacing and opening length have been investigated for this route and it is shown in the Table 3-6.

Table 3-6: Spacing and Length of Median opening at Seka Ber-Total-Tilahun Shell route

Intersection/ Junction Station	Median Opening Spacing(m)	Median Opening Length(m)
0+050		start
0+250	200	10
0+430	180	30
0+520	90	30
0+620	100	10
0+655	35	end
Legehar Bridge		
0+800		start
0+965	165	16
1+265	300	13
1+355	90	end
Average Spacing/ Length	**145**	**18.17**

3.5.5 Route 5: Arat Anbesa - Top View Café

The construction of carriageway and the median was built according to the design template approved by the Engineer during the construction phase. And also the width of pedestrian walkway provided was somehow preserved even more than 2.5m (i.e. the approved pedestrian width on design template) on both sides due to sufficient amount of right of way in this route better than the other routes mentioned earlier except some problem of paving the walkway with smooth surface on the stretch starting from the Awetu Bridge at station 0+245 up to the end of the road at Top View Café station 0+400.

Raised median of 2m width with 0.2m width curbstone on both sides was installed giving an effective width of 1.6m from in to in. this much width of median is recommended if sufficient right of way is available for many purposes that it will be discussed later. The simple barrier on the median made of welded rectangular hollow section (RHS) is used.

These spaces are provided meant as a refugee area for pedestrian crossing the road. Inside the median barrier, small trees and beatifying flowers are planted.

Along this route, there are two major junctions and two minor junctions on left side of the road and three major junctions and one minor junction on right sides of the road. The location of junctions is shown in the Table 3-7 below.

Table 3-7: Spacing and Length of Median opening at Seka Ber-Total-Tilahun Shell route

No.	LHS	Remark	RHS	Remark
1	0+000	Major Junction	0+000	Major Junction
2	0+140	Minor Junction	0+140	Minor Junction
3			0+200	Major Junction
4	0+315	Minor Junction		
5			0+335	Major Junction
6	0+400	Major Junction		

The locations of median opening with their corresponding opening spacing and opening length have been investigated for this route and it is shown in the Table 3-8 below.

Table 3-8: Spacing and Length of Median Opening at Arat Anbesa - Top View Café

Intersection/ Junction Station	Median Opening Spacing(m)	Median Opening Length(m)
0+000		start
0+200	200	30
Awetu Bridge		
0+245		start
0+335	90	-
Average Spacing/ Length	**145**	**30**

3.5.6 Route 6: Tilahun Shell – Awetu Menafesha

The carriageway was constructed with no change in width from that of the design template but the median installation was left unconstructed and the 1m width of the median was paved with asphalt incorporating it with the carriageway to make it 15m without a median facility. If it were supposed to be a flush median, the 1m width would have been painted to give function as flush median. A variable width of pedestrian walkway was observed due to insufficient amount of right of way width as it was not secured to fully function for this purpose. As a result 2.5m walkway width was reduced to values ranging from 0m to 1m. Even though this much amount of width is available, it is not smoothed and paved to attract the pedestrian traffic to use them.

3.5.7 Route 7: Tilahun Shell-Agip Kela (Jimma Connectivity Road)

This route was supposed to be constructed under the ownership of Jimma City Administration as a client. That is why during the planning stage the road plan was prepared along with other road networks according the road network plan shown above in Figure 3-1. However the road was constructed under new ownership of Ethiopian Road Authority (ERA) as a client.

The carriageway was constructed with no change in width from that of the design template but the median installation was left unconstructed and the 2m width of the median was paved with asphalt incorporating it with the carriageway to make it 16m without a median facility. If it were supposed to be a flush median, the 2m width would have been painted to give function as flush median. A constant of 1.5m width of pedestrian walkway was observed on both sides of the road made of 1.5m width concrete ditch cover. Even though this much amount of width was provided, the walkway on the ditch cover is not smooth because of the undulating placement. Thus the pedestrian is not attracted to use them. Not only this, but also construction materials being obstacles have been observed placed on the walkway which are placed by construction sites adjacent to the road side. Some photos have been captured for evidence on Figure 3-21 as shown below.






Figure 3-22: Obstruction of Pedestrian Walkway at Jimma Connectivity Road

CHAPTER FOUR

ANALYSIS AND DISCUSSION

4.1Design analysis

Data collected for the analysis were obtained from design documents and through field observation and measurements of the classification of types of median, determining median width and opening length of medians at mid-block and at intersection. Before detail analysis of the data for the collected data were dimensions of cross sectional elements includes Lane width, Carriageway width, Shoulder width, Right of way width, Adjacent land use, Road side features, Types of median used, Width of median Opening length.

In order to determine the operational and safety performance due to the design and construction of median, summary of the collected data was prepared in order to make it easy for the analysis. The evaluation analysis of the characteristics of medians and dimensions was examined in comparison with different countries design manual, guidelines, principles and study results for the design and construction of medians and recommendation was given on remedial solutions how to design and construct for effective operation and safety considerations.

4.1.1 Median Width of Different DOT's

Median width from different Department of Transports (DOT's) were analyzed for the sake of measuring accuracy of design and implementation of raised medians during planning and construction phase of Jimma town asphalt road projects.

4.1.1.1 Delaware (DelDOT Road Design Manual, 2004)

Typical widths of raised medians range from 4 to 22 ft (1.2 to 6.7m). A raised median of 4 to 6 ft (1.2 to 1.8m) in width with a paved surface may be used under restricted conditions on urban streets, but they have limited advantages. Although they provide a positive separation between opposing traffic and an opportunity to collect drainage, they offer no opportunity to introduce left turn lanes, are too narrow to provide a desirable pedestrian refuge and do not adequately serve as an area for installing traffic control devices.

The absolute minimum median width is 12 ft (3.65m) for introducing left-turn lanes on low speed arterial streets with restricted conditions and minimal truck use. Any size truck (as well as many passenger car drivers) could not use this lane without invading on the adjacent travel way.

A median width of 16 ft (4.8m) is the normally accepted minimum in urban areas to adequately serve a mix of drivers and vehicles without having erratic movements. This width provides for a 10 ft (3m) turn lane and a 6-ft (1.8m) raised median. This width does not provide any curb offset, so there will be a tendency for drivers to keep away from the median into the adjacent travel lane.

The two preferred urban median widths, where frequent left turns are to be accommodated with a diverse traffic mix, are 20 ft (6m) or 22 ft (6.7m). A 20 ft (6m) median width allows for a 12 ft (3.65m) left turn lane, 2 ft(0.6m) clearance from the edge of traffic lanes to the face of the curbed island, and a 4 ft(1.2m) wide island to provide space for traffic control devices. However, in high pedestrian use areas, the preferred width is 22 ft (6.7m), which will allow for a 6-ft (1.8m) raised median for pedestrian refuge.

4.1.1.2 Connecticut (CTDOT Highway Design Manual, 2009)

The width of a raised median should be sufficient to allow for the development of a channelized left-turn lane. Therefore, the typical width is 22 ft (6.7m), which provides for a 12-ft (3.65m) left turn lane, a 2-ft (0.6m) shoulder between the turn lane and raised island, a 2-ft (0.6m) shoulder between the opposing traveled way and the raised island, and a minimum 6-ft (1.8m) raised island.

If practical at an unsignalized intersection, a raised median should be 25 ft (7.6m) in width to permit storage of a vehicle crossing or turning left onto the mainline.

Under restricted conditions, the recommended minimum width of a raised median should be 8 ft. This assumes a minimum 4-ft (1.2m) raised island with 2-ft (0.6m) shoulders on each side adjacent to the through travel lanes.

4.1.1.3 Florida (FDOT Median Handbook, 2006)

Table 4-1: Summary for Florida DOT Median Width Recommendation.

		Minimum Width in Feet	Minimum Width in Meters
Guidance from Plans Preparation Manual	Reconstruction Projects , speed = 40 mph or less	15.5	5
	Reconstruction Projects, Speed >45 mph	19.5	6
	45 mph <Speed < 55 mph	22	7
	Speed> =55 mph	40	12
Recommended	4 lane highways with median expecting significant U-turns and directional median openings with excellent positive guidance	30 for single left turns and 42 for dual lefts	9 for single left turns and 12.6 for dual lefts
	6 lane highways with median expecting significant U-turns and directional median openings with excellent positive guidance	22 for single left turns and 34 for dual lefts	7 for single left turns and 10.6 for dual lefts

Source: Median Handbook. Florida Department of Transportation, 2006.

The minimum width of a median traffic separator "nose" has commonly been 4 ft (1.2m). Where the right-of-way is limited, 2 ft (0.6 m) and even as little as 18 in. (460 mm) can be used. The American Association of State Highway Transportation Officials(AASHTO) indicates that "the minimum narrow median width of 4 ft(1.2m) is recommended and is preferably 6 to 8 ft(1.8 to 2.4m) wide" (AASHTO Greenbook).

U-turns should not be permitted from through traffic lanes because of the potential for high speed, rear-end crashes and serious detrimental impact on traffic operations. Rather, all left turns and U-turns should be made from a left-turn/U-turn lane.

4.1.1.4 South Carolina (SCDOT Access and Roadside Management Standards, 2008)

As shown in Figure 4-1, the part of the median within the right-of-way shall have a minimum width of 4 ft (1.2m) and a maximum width of 12 ft (3.65m). When the median width is larger than 4 ft (1.2m), the nose shall be defined with a 2-ft (0.6m) radius and the control turning radius. The median nose shall be offset a sufficient distance so that the median does not encroach into the normal shoulder width of the roadway. Landscape plants on the median and within 25 ft (7.6m) of the roadways should be limited to low growing plants not exceeding 2.5 ft (0.76m) in height. These plants shall not negatively affect sight distance.

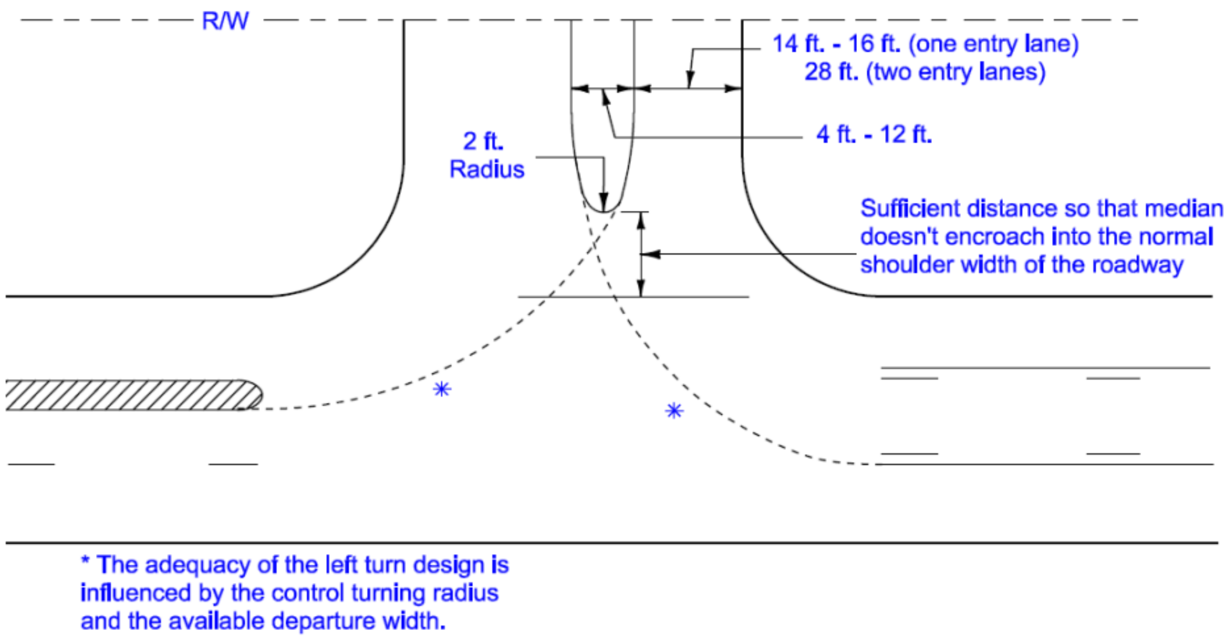


Figure 4-1: South Carolina DOT Guidelines on Raised Median and Median Nose Design.

4.1.1.5 Ohio (ODOT State Highway Access Management Manual, 2001)

Urban Roadways: The minimum median width for a four-lane urban freeway should be 10 ft (3m), which provides for two 4-ft (1.2m) shoulders and a 2-ft (0.6m) median barrier. For freeways with six or more lanes, the minimum width should be 22 ft (6.7m), preferably with a 26 ft(7.92m) wide median when the directional design hourly volume for truck traffic exceeds 250 vehicles per hour to provide a wider median shoulder to accommodate a truck.

Rural Roadways: In flat or rolling terrain, the desirable median width for rural freeways is 60 to 84 ft (18 to 25.6m). The 84-ft (25.6m) wide median allows for a future 12-ft (3.65m) wide lane in each direction of travel, and the 60-ft (18.3m) median. The minimum median width is normally 40 ft (12.2m). However, in rugged terrain, narrower medians ranging from 10 to 30 ft (3 to 9m) may be used.

4.1.1.6 Maine (Maine DOT Highway Design Guide, 2007)

The designer should consider several factors when determining the median width:

- The median width should include the width of left-turn lane where it is applicable for providing left-turn bays at the median openings.
- Should be approximately 25-ft (7.62m) wide to allow a crossing passenger vehicle to stop between the two roadways.
- Turning movements at median openings depend on the median width and the width of the opening for cross traffic.
- A uniform median width is desirable; however, variable-width medians may be advantageous where right-of-way is restricted, at-grade intersections are widely spaced (0.5 mile (0.8km) or more), or an independent alignment is practical.
- In general, the widths of the other roadway cross section elements should not be reduced to provide additional median width.

Raised medians, typically with sloping curbs, are often used where it is desirable to control left turns. Desirably, the width of a raised median will be sufficient to accommodate left turn lanes at intersections. The minimum width of the median nose is 4 ft (1.2m).

4.1.1.7 Georgia (GDOT Design Policy Manual Version 2.0, 2010)

A 24-ft (7.3m) raised median will require a sloped curb inside the median, and a 2-ft (0.6m) additional paved shoulder offset from the edge of the inside travel lane to the edge of the gutter (for a total of 4-ft (1.2m) inside shoulder width from the edge of travel lane to the face of the curb).

4.1.1.8 Colorado (CDOT Roadway Design Guide, 2005)

The primary determinant of required median width is the type of facility. Width may be limited by aesthetic concerns, economics, right of way limitations, topography, and at-grade intersection signal operations. Median widths less than 4 ft (1.2m) should be considered separators, not medians. Sign width and location should be considered, and sign placement should be discussed with the region traffic Engineer.

4.1.1.9 Nevada (NDOT Access Management System and Standards, 1999)

The minimum width for a raised median (edge of gutter pan to edge of gutter pan) is 4 ft (1.2m).If an existing median is of sufficient width to accommodate the proposed left turn lane(s), the existing median may be used without further widening. When it is necessary to widen the roadway to accommodate left turn lanes, the roadway will be widened symmetrically on both sides of the roadway.

Table 4-2: Minimum Median Widths for Left Turn Lanes.

Single Left Turn Lane	16 ft
Dual Left Turn Lanes	28 ft
Triple Left Turn Lanes	40 ft
Two Way Left Turn Lanes (TWLTL)	14 ft (max)

Source: Access Management System and Standards. Nevada Department of Transportation, July 1999

4.1.1.10 Wisconsin (WisDOT Facilities Development Manual, 2006)

The nose of the median end may be either circular or bullet shaped. The bullet nose is preferred in most instances where the median is wide enough to provide it. The radius used to form the end of the bullet nose should be between 1 ft (0.3m) and 5 ft (1.5m) but desirably should be as near to 3 ft (0.9m) as possible.

4.1.1.11 Summary for Existing Median Width Guidelines

Collectively, the primary determinant of required median width is the type of facility, although the standards may vary state by state. For example, some representative results are shown as follows:

- A shoulder (or shoulders), as a part of the median width, usually has a width of 2 ft (0.6m) each (Georgia and Connecticut), and can be 4 ft (1.2m) each (Ohio).
- A median width of 16 ft (4.78m) is the normally accepted minimum in urban areas (identical recommendations as the TxDOT Roadway Design Manual), while the width include the width of a dedicated left-turn lane. This standard is particularly applicable when dedicated left-turn lanes are considered for intersections or openings (Delaware).
- A raised median of 4 to 6 ft (1.2 to 1.8m) in width with a paved surface may be used under restricted conditions on urban streets, which are too narrow to introduce dedicated left-turn lanes (Delaware).
- In high pedestrian use areas, the median width shall allow for at least a 6-ft (1.8m) raised median for pedestrian refuge (Delaware).
- A median width of 25 ft (7.62m) usually allows a crossing passenger vehicle to stop between the two roadways while keeping away from the travel lanes (Ohio and Maine).

4.1.2 Median width in Jimma Town

The installed raised median of the routes Areboch Tera – Jebena and Seka Ber - Total - Tilahun Shell have a width of only 1m including 0.2m width curbstone on both sides with a clear space of 0.6m inside. This clear space is left for planting trees and flowers. None of the routes have left turning lanes which are used to introduce a safe and sound left turn maneuver without causing any delay and accident.

This median width is even below the minimum width of 1.2m suggested by many of the guidelines discussed above. Rather than paving the median with smooth surface as it is used as pedestrian refugee, all the medians are planted with trees having heights of 2m and above and fences are made to protect these green plants leaving small amount of area as a pedestrian crossing in 6 to 9m interval.

A raised median of 1.2m in width might be allowed with a paved surface under restricted conditions on urban streets, but they have limited advantages. Although they provide a positive separation between opposing traffic and an opportunity to collect drainage, they offer no opportunity to introduce left turn lanes, are too narrow to provide a desirable pedestrian refuge and do not adequately serve as an area for installing traffic control devices. This clearly indicates that there were right of way restrictions in order to provide wider medians.

Relative to the routes Areboch Tera – Jebena and Seka Ber - Total - Tilahun Shell the route Arat Anbesa- Top View Café has a wider median width and also lane width of 2m and 4.5m respectively. Out of the 2m median width, 0.2m is the width of curbstone on both sides leaving a clear space of 1.6m inside. This free space is left for landscaping composed of short height trees and flowers. No left turning lane was introduced for this route as it was not used to the other routes which is provided for the sake of safe and sound left turn maneuver without causing any delay and accident.

According the guidelines of state DOT's about median width discussed earlier a 2m median width would be sufficient for high pedestrian use areas as pedestrian refuge. Even though it is not paved with smooth surface to be used as pedestrian refugee, the median is planted with short trees and flowers and fenced with rectangular sections of iron bars as a barrier to protect these green plants leaving small spaces for pedestrian crossings in 6 to 9m interval.

According to Yi Qi et al 2012 on their simulation-based studies for evaluating the operational and safety impacts of raised median treatments they developed minimum median and ROW widths to provide operationally effective urban roadways for different types of design vehicles.

The TxDOT Roadway Design Manual suggests a minimum median width of 16 feet or 4.87 meter (17 feet or 5.18 meter if a pedestrian refuge is needed). The use of this minimum median width on a four-lane curbed roadway does not provide adequate space for mid-block U-turn movements by large size vehicles, such as pick-up trucks, SUVs or vans. To make this type of movement, larger vehicles have to conduct a 3-point turn into the oncoming lanes or detour through private parking lots, resulting in operational and safety issues.

The objective of this part of the study is to investigate the types of vehicles that can be accommodated by the provided median width with restricted ROW through a swept path analysis in Jimma town asphalt projects. The result led to recommendations for minimum median width to provide operationally effective urban roadways.

The swept path analysis was conducted according to AASHTO Green Book (A Policy on Geometric Design of Highways and Street, 2011, 6th Edition). The guidebook provides minimum turning path requirements for different types of design vehicles in Chapter 2—"Design Controls and Criteria." Minimum median widths for accommodating U-turn movements were calculated for typical four-lane divided highways on urban arterials. In addition, typical dimensions (e.g., lane width, borders, and offsets) were assumed for the cross-section, as shown in Figure 4-2 below.

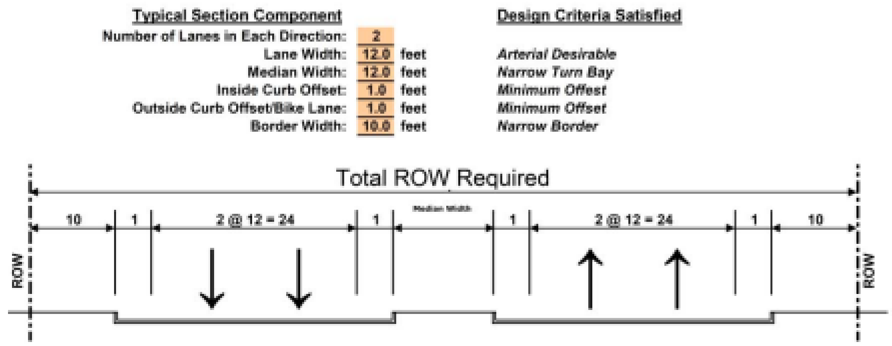


Figure courtesy of Mr. Jim Heacock, P.E., TxDOT

Figure 4-2: Urban Arterial Typical Section Design.

The minimum widths of medians to accommodate U-turns were calculated for different types of design vehicles based on the assumption that U-turn vehicles turn from the lane adjacent to the median to the outer lane on a typical four-lane divided highway.

Four types of opening designs are considered. These designs are 1) openings without dedicated left-turn bay, without loon; 2) openings without dedicated left-turn bay, with loon; 3) openings with dedicated left-turn bay, without loon; and 4) openings with dedicated left-turn bay, with loon.

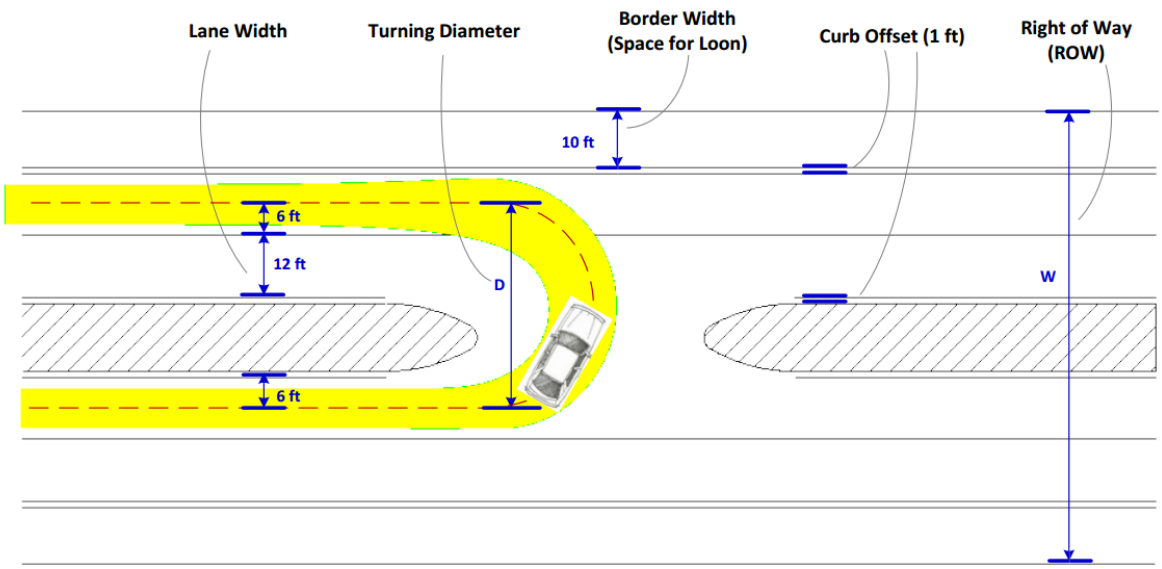


Figure 4-3: Right-of-Way to Accommodate U-Turns with No Dedicated Left-Turn Bay, No Loon.

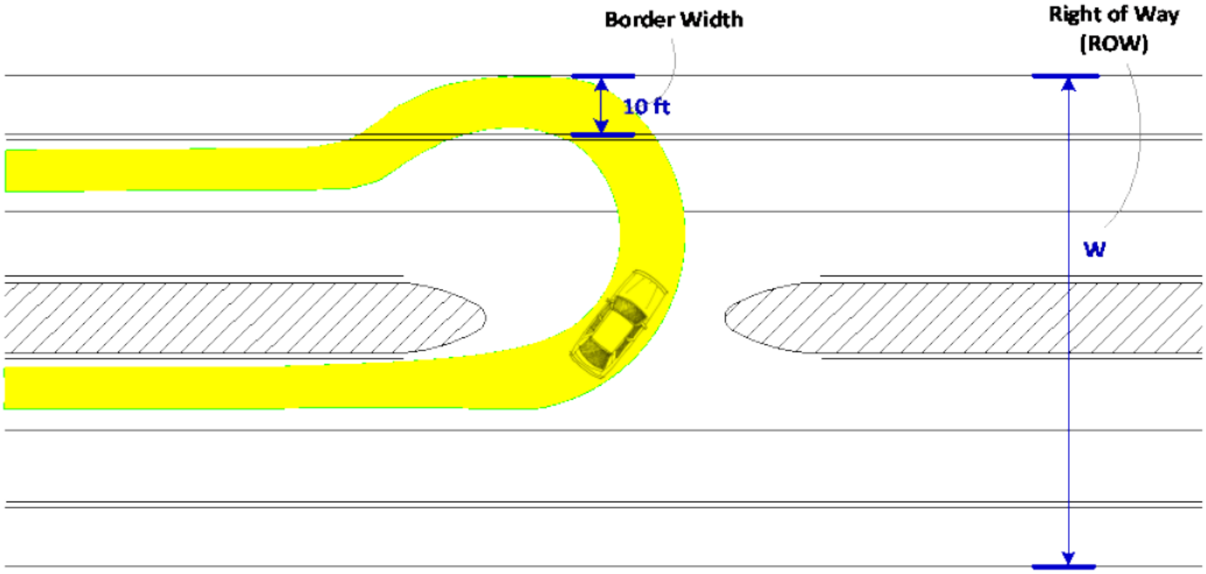


Figure 4-4: Right-of-Way to Accommodate U-Turns with Loon but No Dedicated Left-Turn Bay.

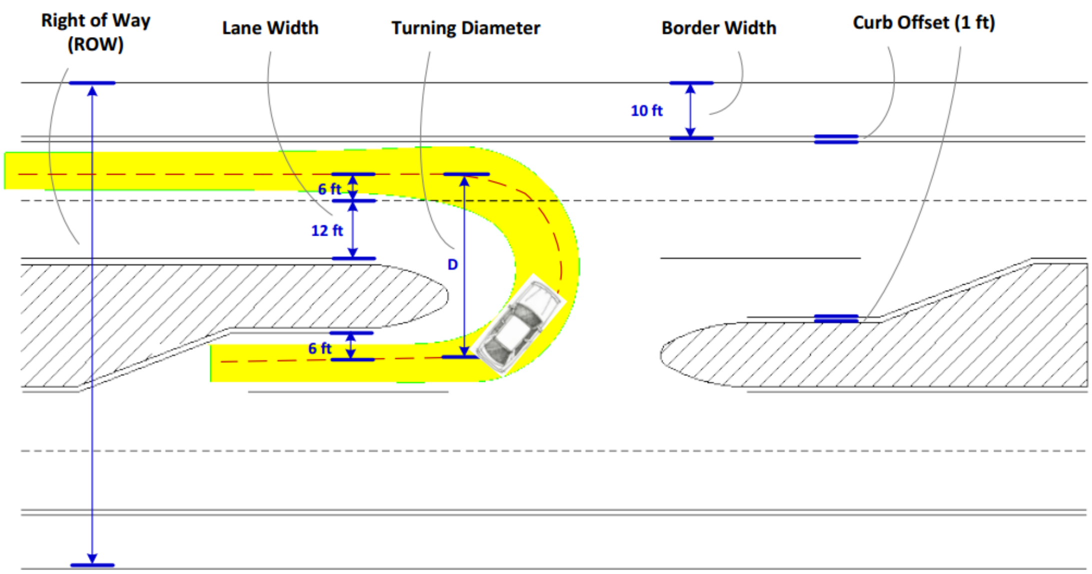


Figure 4-5: Right-of-Way to Accommodate U-Turns with Dedicated Left-Turn Bays but No Loon.

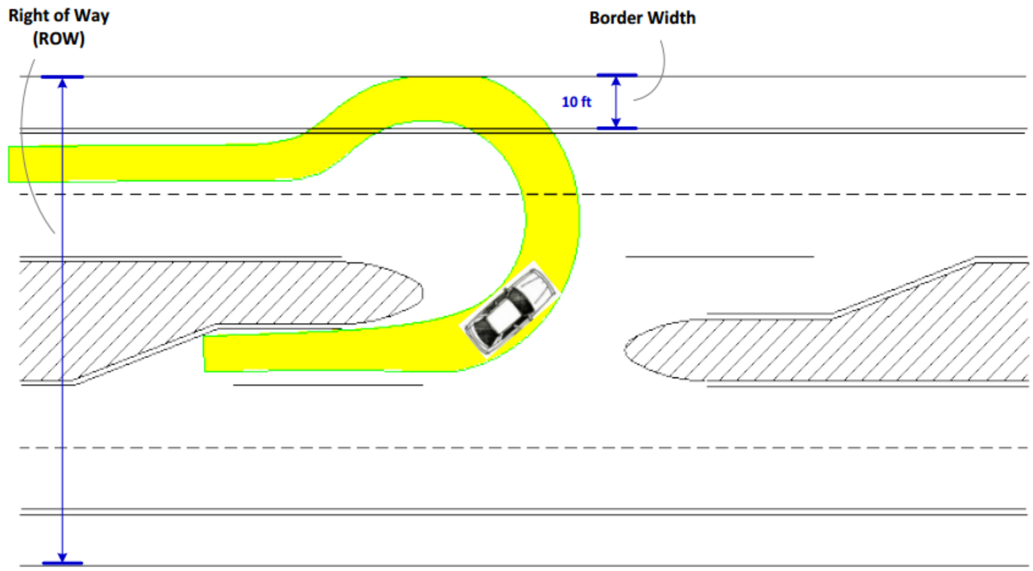


Figure 4-6: Right-of-Way to Accommodate U-Turns with Dedicated Left-Turn Bays and Loon.

According to Yi Qi et al 2012 on their simulation-based studies the equations for calculating the minimum median widths for all of the four types of roadway designs have been formulated but in this study only the first type of median will be analyzed because it is the only type of median used in Jimma town.

No Dedicated Left-Turn Bay, No Loon

The minimum median width can be estimated as

$$W = D - 2 * 6 - 12 \qquad (5)$$

where D is the centerline turning diameter, 12 ft is the typical width of a lane assumed in the calculation, as shown in Figure 5-16(a) above.

For the case of the typical cross section used for Jimma town asphalt roads there is a slight change in the equation shown above due to the difference in lane width . Thus:

$W = D - 2 *$ half of lane width – lane width General Equation

Route 2: Areboch Tera – Jebena and Route 4 Seka Ber-Total-Tilahun Shell

$W = D - 2 * 1.75 – 3.5$…………………………Equation for Route 2 and Route 4

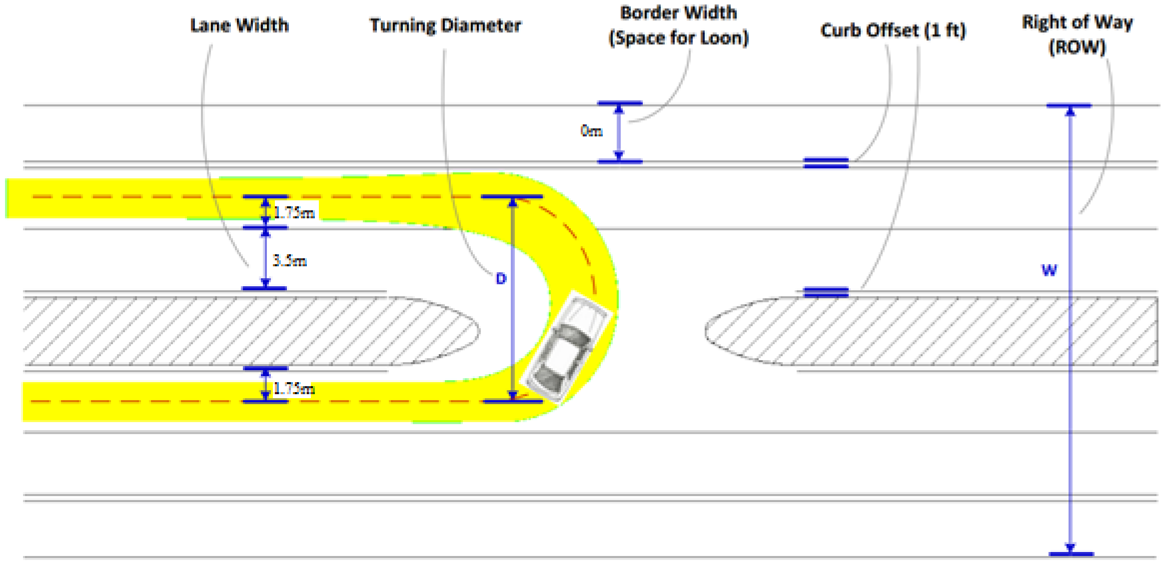


Figure 4-7: Adjusted U-Turns with No Dedicated Left-Turn Bays and Loon for Route 2 and 4

As it is shown in the modified minimum median equation for these routes, one lane width is 3.5m and half of it will be 1.75m. According to the equation median width of these routes are evaluated whether U turn is possible for different design vehicle with various length and width as shown in the Table 4-3 below.

Table 4-3: Minimum Median Width Requirement for U Turn with No Left Turn Bay and Loon

Design Vehicle Type	**Centerline Turning Radius(m) (CTR)**	**Length of vehicle(m)**	**Width of Vehicle(m)**	**W=D – 2*1.75 – 3.5 (m)**	**Remark**
Passenger car (P)	6.4	5.79	1.83	-0.6	<1m, U turn possible
Single-unit truck (SU)	11.6	9.15	2.44	4.6	>1m, U turn impossible
Inter-city Bus (Motor Coach) (BUS-40)	12.4	12.2	2.59	5.4	>1m, U turn impossible
Inter-city Bus (Motor Coach) (BUS-45)	12.4	13.72	2.59	5.4	>1m, U turn impossible
City transit bus (CITY-BUS)	11.5	12.2	2.59	4.5	>1m, U turn impossible
Conventional school bus (S-BUS-36)	10.6	10.91	2.44	3.6	>1m, U turn impossible
Large school bus (S-BUS-40)	10.8	12.2	2.44	3.8	>1m, U turn impossible
Articulated bus (A-BUS)	10.8	18.29	2.59	3.8	>1m, U turn impossible
Intermediate semitrailer (WB-40)	11	13.87	2.44	4	>1m, U turn impossible
Intermediate semitrailer (WB-50)	12.5	16.77	2.44	5.5	>1m, U turn impossible

The evaluation concludes that the only vehicle type that can perform U turn safely and without delay is Passenger car (P) with a length of 5.79m and width of 1.83m and can complete the turning with only 6.4m radius. The other types of vehicles with greater length and width and larger turning radius cannot perform the U turn at once or even at all, suggesting the demand for the increment of median width greater than 1m.

This result a delay on the travel time for through traffic while a vehicle performing U turn trying the maneuver until it succeed. Thus the through traffic waits making a queue behind until the lane is free of vehicle making the U turn maneuver as it was observed during the field study.

Route 5 Arat Anbesa-Top View

$W = D - 2 * 2.125 - 4.25$………………….. Equation for Route 5

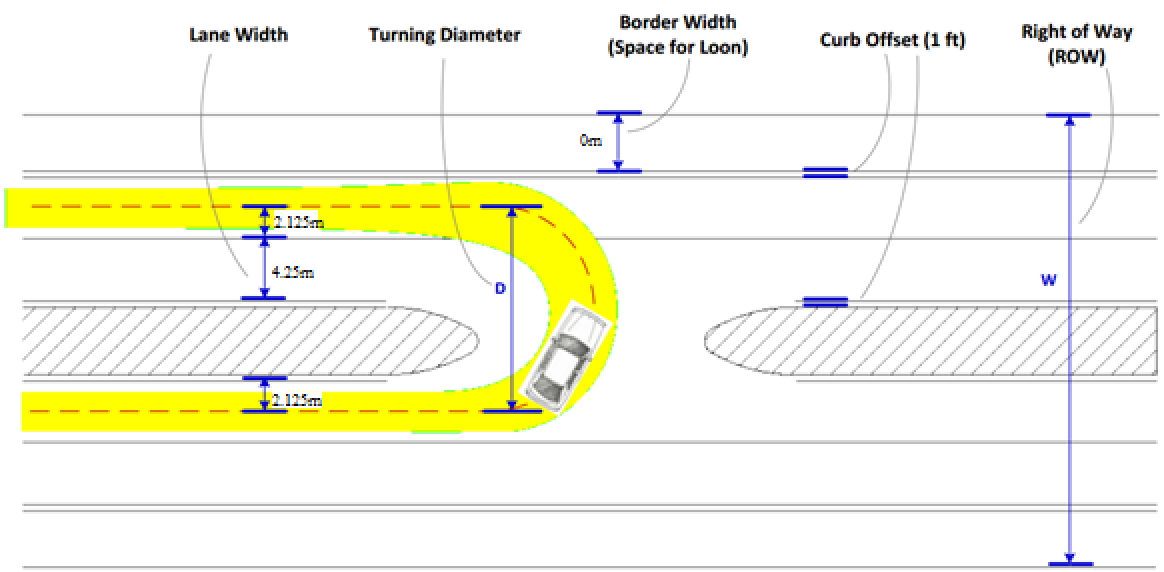


Figure 4-8: Adjusted U-Turns with No Dedicated Left-Turn Bays and Loon Route 5

The same is true for this route as the equation is modified according to the lane width for this route, having one lane width of4.5m and half of it will be 2.125m. According to the adjusted equation median width, this route is evaluated whether U turn is possible for different design vehicle with various length and width as shown in the Table 4-4 below.

Table 4-4: Minimum Median Width Requirement for U Turn with No Left Turn Bay and Loon

Design Vehicle Type	Centerline Turning Radius(m) (CTR)	Length of vehicle(m)	Width of Vehicle(m)	W=D − 2*2.125 − 4.5	Remark
Passenger car (P)	6.4	5.79	1.83	-2.6	<1m, U turn possible
Single-unit truck (SU)	11.6	9.15	2.44	2.6	>1m, U turn impossible
Inter-city Bus (Motor Coach) (BUS-40)	12.4	12.2	2.59	3.4	>1m, U turn impossible
Inter-city Bus (Motor Coach) (BUS-45)	12.4	13.72	2.59	3.4	>1m, U turn impossible
City transit bus (CITY-BUS)	11.5	12.2	2.59	2.5	>1m, U turn impossible
Conventional school bus (S-BUS-36)	10.6	10.91	2.44	1.6	<1m, U turn possible
Large school bus (S-BUS-40)	10.8	12.2	2.44	1.8	<1m, U turn possible
Articulated bus (A-BUS)	10.8	18.29	2.59	1.8	<1m, U turn possible
Intermediate semitrailer (WB-40)	11	13.87	2.44	2	<1m, U turn possible
Intermediate semitrailer (WB-50)	12.5	16.77	2.44	3.5	>1m, U turn impossible

According to the result of the analysis as shown in the Table 4-4 above the vehicle types that can perform U turn safely and without delay are vehicles like Intermediate semitrailer (WB-40) with vehicle length of 13.87m and width of 2.44m and turning radius of 11m and smaller vehicles.

Thus when compared with the above analysis made for Areboch Tera – Jebena and Seka Ber-Total-Tilahun Shell, this analysis for Arat Anbesa-Top View shows a better performance of U turn possibility for majority of vehicle types. Therefore a 2m median width is somewhat sufficient relative to the lane width.

This result a delay on the travel time for through traffic will be reduced while a vehicle performing U turn trying the maneuver succeeds easily and effectively. Thus the through traffic will not wait without making a queue behind until the lane is open with vehicle making the U turn maneuver.

4.1.3 Median Opening Spacing of Different DOT's

The median opening spacing refers to the distance between the centerlines of two adjacent median openings, as shown in Figure 4-9 below.

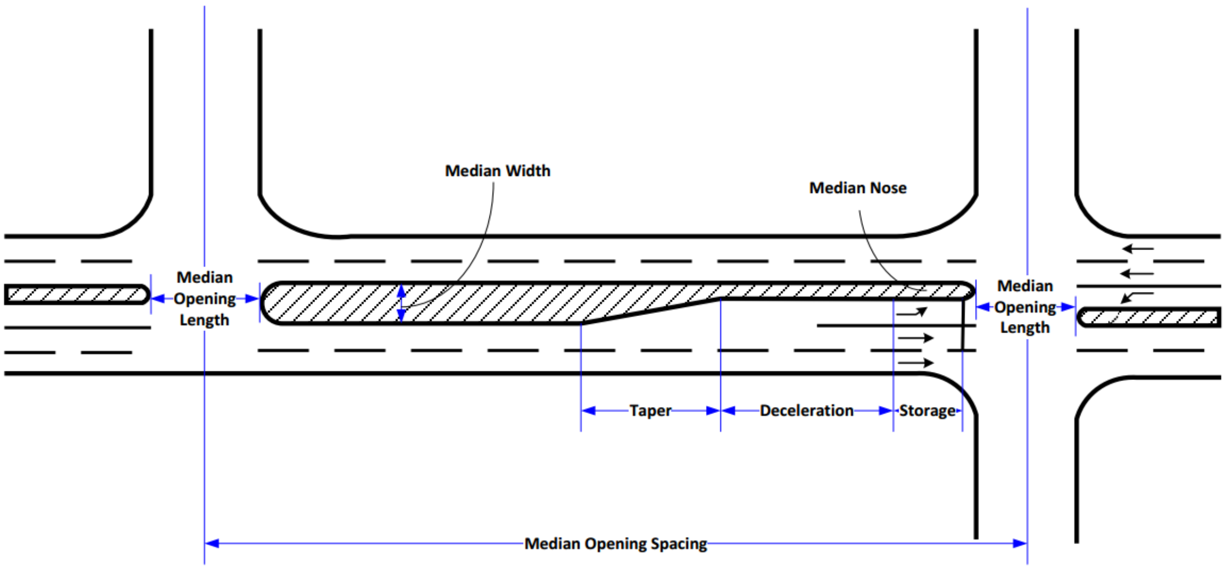


Figure 4-9: Major Raised Median Design Elements.

4.1.3.1 Florida (FDOT Median Handbook, 2006)

Table 4-5: Florida DOT Median Opening Spacing Standards.

Access Class	**Minimum Median Opening Spacing (Directional)**		**Minimum Median Opening Spacing (Full)**	
Interstate Highway	1,320 ft	400 m	2,640 ft	800 m
Principal Arterial	1,320 ft	440 m	2,640 ft	800 m
Minor Arterial	660 ft	200 m	2,640 ft over 45 mph 1,320 ft 45 mph or less	800 m over 70 km/h 400 m 700 km/h or less
Collector	330 ft	100 m	660 ft	200 m

Source: Median Handbook. Florida Department of Transportation, 2006

4.1.3.2 Missouri (MODOT Access Management Guidelines, 2003)

Table 4-6: Missouri DOT Median Opening Spacing Standards.

Roadway Classification	In Current and Projected Urban Areas	In Rural Areas
Interstate/Freeway	No median openings allowed	No median openings allowed
Principal Arterial	1,320 to 2,640 ft 1,320 to 660 ft (directional)	2,640 ft (full) when posted speed is over 45 mph 1,320 ft (full) when posted speed is under 45 mph
Minor Arterial	1,320 ft (full) 660 ft (directional)	1,320 ft (full) at all speeds
Collector	Medians generally not used	Medians generally not used

Source: Access Management Guidelines. Missouri Department of Transportation. 2003.

4.1.3.3 Montana (MDT Road Design Manual, 2006)

In no case may the number of median openings exceed three per 1000 ft (300 m).

4.1.3.4 *North Dakota (NDDOT Design Manual, 2003)*

Table 4-7: North Dakota DOT Median Opening Spacing Standards.

	Functional Purpose	Median Openings
Freeways	High Mobility, Low Access	• Public-use openings not allowed • U-turn median openings for use by authorized vehicles only when need is justified
Expressways	High Mobility, Low to Moderate Access	• Allowed • Alternatives to all-movement openings encouraged Minimum spacing between all-movement openings • 2,000 ft (posted speed limit of greater than 45 mph) or 1,200 ft (posted speed limit of 45 mph or less)
Boulevards	Moderate Mobility, Low to Moderate Access	• Allowed Minimum spacing between all-movement openings • 2,000 ft (posted speed limit of greater than 45 mph) or 1,200 ft (posted speed limit of 45 mph or less)
Thoroughfares	Moderate to Low Mobility, High Access	• Not Applicable

Source: North Dakota DOT Design Manual, 2003

4.1.3.5 South Dakota (SDDOT Roadway Design Manual)

The spacing of median openings for signalized intersections should reflect traffic signal coordination requirements and the storage space needed for left turns. Ideally, spacing of openings should be conducive to future signalization, if it is ultimately needed.

4.1.3.6 Wisconsin (WisDOT Facilities Development Manual, 2006)

Table 4-8: Wisconsin DOT Median Opening Spacing Standards.

Spacing between midblock median openings for a design speed of:	**Minimum**	**Desirable**
25 mph	140 ft	910 ft
30 mph	190 ft	780 ft
35 mph	240 ft	670 ft
40 mph	300 ft	530 ft
45 mph	360 ft	670 ft
50 mph	430 ft	780 ft
55 mph	510 ft	910 ft

Source: Facilities Development Manual. Wisconsin Department of Transportation, 2006.

4.1.3.7 Illinois (IDOT Bureau of Design and Environment Manual, 2001)

The following recommended minimum spacing should be evaluated when determining the location for a median opening:

- Urban Facilities: The desirable minimum spacing between median openings should be approximately one-quarter mile (1,320 ft, 400m). However, this may not always be practical. Ata minimum, the spacing of median openings should be far enough apart to allow for the development of exclusive left-turn lanes with proper lengths.
- Rural Facilities: Median openings should be at least 0.5 mile (2,640 ft, 800m) apart and, desirably, 1 mile (5,280 ft, 1600m) apart, subject to public service requirements and as determined by an Engineering study.

For both rural and urban facilities, the available sight distance in the vicinity of a median opening is also a factor in the determination of its location. In addition, on some facilities, commercial establishments with heavy truck traffic may dictate the location of median openings.

4.1.3.8 Michigan (Michigan DOT Road Design Manual, 2004)

On the premise that an extra travel distance of up to 1/4 mile (1,320 ft, 400m) is not excessive when crossing a free access divided highway, the following criteria for opening spacing should apply:

- Medians Less Than 30 ft (9m) in Width: Openings may be constructed, as determined by the Traffic and Safety Division, opposite driveways and side roads or streets.
- Medians 30 ft (9m) or More in Width: Openings may be provided every 1/8 mile (660 ft, 200m) in urban areas and every 1/4 mile (1,320 ft, 400m) in rural areas. They may be adjusted 100 ft (30m) either way to conform to existing street or road returns or driveways. No two openings should be closer than 500 ft (150m) apart. Public roads should take priority over private drives in the event of a location conflict.

4.1.3.9 Mississippi (Mississippi DOT Access Management Manual, 2010)

Table 4-9: Mississippi DOT Median Opening Spacing Standards.

		Minimum Median Opening Spacing (Directional)	**Minimum Median Opening Spacing (Full)**
Urban Areas	Speed >45 mph	1,760 ft	1,760 ft
	Speed <45 mph	880 ft	1,760 ft
Rural Areas		1,760 ft	1,760 ft

Source: Access Management Manual. Mississippi Department of Transportation, 2010

4.1.3.10 Kentucky (Access Management Implementation in Kentucky, 2008)

Table 4-10: Kentucky DOT Median Opening Spacing Standards.

Access Classification			Speed ≥45		Speed <45	
			minimum spacing (full, ft)	**minimum median (directional, ft)**	**minimum spacing (full, ft)**	**minimum spacing (directional, ft)**
Freeway			N/A			
Urban	Principle Arterial	Volume≥10,000	2400	1200	2400	1200
		Volume<10,000	2400	1200	2400/1200	1200/600
	Minor Arterial	Volume≥10,000	2400	1200	2400/1200	1200/600
		10,000>Volume≥5000	2400/1200	1200/600	2400/1200	1200/600
		Volume<5000	2400/1200	1200/600	600	300
	Collector	Volume≥5000	2400/1200	1200/600	600	300
		Volume<5000	600	300	600	300
	Local		N/A			
Rural	Principle Arterial	Volume≥5000	2400	1200	2400	1200
		Volume<5000	2400	1200	2400	1200
	Minor Arterial	Volume≥5000	2400	1200	2400	1200
		5000>Volume≥2500	2400	1200	2400	1200
		Volume<2500	2400	1200	900	450
	Collector	Volume≥2500	2400	1200	900	450
		Volume<2500	900	450	900	450
	Local		N/A			

Source: Access Management Implementation in Kentucky, University of Kentucky, 2008.

4.1.3.11 Oregon (Oregon DOT Access Management Classification and Spacing Standards, 1996)

Table 4-11: Oregon DOT Median Opening Spacing Standards.

Functional Class	Level of Importance	Area	Typical Speed	Median Opening Spacing (ft)
Full Control (Freeway)	Interstate or statewide	Fully developed urban	55 mph	10,559
		Suburban developing urban	55–65 mph	15,839
		Rural	60–65 mph	31,678
Expressway	Statewide	Urban	45–55 mph	2640
		Rural	55 mph	2640
Major Arterial	Multi-lane	Urban	55 mph	2640
		Rural	45 mph	1320
		Fully Developed	35 mph	N/A
	Two-lane	Urban	45 mph	N/A
		Rural	45 mph	N/A
		Fully Developed	35 mph	N/A
Minor Arterial	Multi-lane	Urban	55 mph	660
		Rural	45 mph	330/ N/A
		Fully Developed	35 mph	N/A
	Two-lane	Urban	55 mph	N/A
		Rural	45 mph	N/A
		Fully Developed	35 mph	N/A
Major Collector	Multi-lane	Urban	45 mph	330/ N/A
		Rural	40 mph	N/A
		Fully Developed	35 mph	N/A
	Two-lane	Urban	45 mph	N/A
		Rural	40 mph	N/A
		Fully Developed	35 mph	N/A

Source: Access Management Classification and Spacing Standards, Oregon Department of Transportation, 1996.

4.1.3.12 Summary for Existing for Median Opening Spacing Guidelines

Collectively, the primary determinants of median opening spacing include the type of facility, posted speed limit, traffic volume (e.g., ADT) level, and rural or urban settings. Since this research project focuses on urban roadways, some representative guidelines are listed in Table 4-12, with differentiated spacing values for full and directional median openings, respectively.

Table 4-12: Summary for State DOT Median Opening Spacing Standards

<table>
<tr><th></th><th colspan="2"></th><th colspan="2">Minimum Median Opening Spacing (Directional)</th><th colspan="2">Minimum Median Opening Spacing (Full)</th></tr>
<tr><td rowspan="10">Speed Limit Based</td><td rowspan="2">Mississippi</td><td>Speed >45 mph</td><td colspan="2">1,760 ft</td><td colspan="2">1,760 ft</td></tr>
<tr><td>Speed <45 mph</td><td colspan="2">880 ft</td><td colspan="2">1,760 ft</td></tr>
<tr><td rowspan="2">North Dakota</td><td>Speed >45 mph</td><td colspan="2">N/A</td><td colspan="2">2,000 ft</td></tr>
<tr><td>Speed <45 mph</td><td colspan="2">N/A</td><td colspan="2">1,200 ft</td></tr>
<tr><td rowspan="2">Kentucky</td><td>Speed >45 mph</td><td colspan="2">1,200/600/300 ft
(depends on ADT level)</td><td colspan="2">2,400/1,200/600 ft
(depends on ADT level)</td></tr>
<tr><td>Speed <45 mph</td><td colspan="2">1,200/600/300 ft
(depends on ADT level)</td><td colspan="2">2,400/1,200/600 ft
(depends on ADT level)</td></tr>
<tr><td rowspan="2">Oregon</td><td>Speed >45 mph</td><td colspan="2">N/A</td><td colspan="2">2,640 ft</td></tr>
<tr><td>Speed <45 mph</td><td colspan="2">N/A</td><td colspan="2">330 ft</td></tr>
<tr><td rowspan="2">Wisconsin</td><td>Speed >45 mph</td><td colspan="2">N/A</td><td colspan="2">430 to 510 ft
(depends on detailed speed)</td></tr>
<tr><td>Speed <45 mph</td><td colspan="2">N/A</td><td colspan="2">360 to 140 ft
(depends on detailed speed)</td></tr>
<tr><td rowspan="3">Rule of Thumb</td><td>Michigan</td><td>N/A</td><td colspan="2">N/A</td><td colspan="2">500 ft</td></tr>
<tr><td>Illinois</td><td>N/A</td><td colspan="2">N/A</td><td colspan="2">1,320 ft</td></tr>
<tr><td>Montana</td><td>N/A</td><td colspan="2">N/A</td><td colspan="2">1,000 ft</td></tr>
<tr><td rowspan="6">Roadway Functionality Based</td><td rowspan="2">Missouri</td><td>Principal Arterial</td><td colspan="2">1,320 to 660 ft
(dependent variables are not mentioned)</td><td colspan="2">1,320 to 2,640 ft
(dependent variables are not mentioned)</td></tr>
<tr><td>Minor Arterial</td><td colspan="2">660 ft</td><td colspan="2">1,320 ft</td></tr>
<tr><td rowspan="4">Florida</td><td>Interstate Highway</td><td colspan="2">1,320 ft</td><td colspan="2">2,640 ft</td></tr>
<tr><td rowspan="2">Principal Arterial</td><td>Speed >45 mph</td><td>1,320 ft</td><td>Speed >45 mph</td><td>2,640 ft</td></tr>
<tr><td>Speed <45 mph</td><td>660 ft</td><td>Speed <45 mph</td><td>1,320 ft</td></tr>
<tr><td>Minor Arterial or Collector</td><td colspan="2">330 ft</td><td colspan="2">660 ft</td></tr>
</table>

4.1.4 Median Opening Spacing in Jimma Town

Route 2 Areboch Tera – Jebena has median opening spacing of 40m, 60m, 90m and 100m in ascending order with an average opening spacing of 72.5m as shown in the Table 3-4 above. These median openings were located on every minor junction without the consideration of minimum criteria for median opening spacing from similar guidelines as it was discussed above.

Route 4 Seka Ber-Total-Tilahun Shell has median opening spacing of 35m, 90m, 90m,100m, 165m, 180m, 200m and 300m in ascending order with an average opening spacing of 145m as shown in the Table 3-6 above. From the above Table 3-6 listing the location of junctions, some junctions was not provided with median opening in order to limit the number of opening within short distance. Accordingly, the junctions at 0+250 LHS, 0+340 LHS and 0+340 RHS were not provided with median opening otherwise if opening is provided, opening spacing will be less or if no median is provided and left open in between nearly located junctions, the opening length will be more.

Route 5 Arat Anbesa- Top View Café has median opening spacing of 200m and 90m with an average opening spacing of 145m as shown in the Table 3-8 above. In this route the junctions found at station 0+140 LHS and RHS have no median opening available thus a 200m median length was gained and after station 0+335 there was no median provided until the end of the project at station 0+400 since the road is divided in to two to make Y junction at the end that the median would have short length of less than 65m and due to the junction it would be difficult to manage.

According to the summarized table of all the above mentioned guidelines of different state department of transport as shown in Table 4-12 above based on the primary determinants of median opening spacing include the type of facility, posted speed limit, traffic volume (e.g., ADT) level, and rural or urban settings.

Since this research project focuses on urban roadways, these representative guidelines will be compared with the actual conditions of median opening spacing in Jimma town asphalt roads.

In comparison with speed limit ground, all the routes mentioned earlier were designed based on a speed limit of 50km/h which is equivalent to 31 mph according to the data collected from design office of the Engineer and the contractor as well. Thus the summarized table suggests a minimum full median opening spacing which allows all types of movement like left turn, U turn and crossing for a speed limit less than 45 mph are 1760ft (536m), 1200 ft (365m), at least 1200 ft (365m) for volume 5,000-10,000 vpd, 330 ft (100m), 190ftor 58m (780ft or 238m desirable) according to DOT's of Mississippi, North Dakota, Kentucky, Oregon and Wisconsin respectively.

By the rule of thumb where the location of median opening might be determined by the Traffic and Safety Division, opposite driveways and side roads or streets and commercial establishments with heavy truck traffic may dictate the location of median openings. The available sight distance in the vicinity of a median opening is also a factor in the determination of its location. Keeping this in mind the guidelines of state DOT's of Michigan, Illinois and Montana suggest for the spacing of median opening to be 500 ft (152m), 1320 ft (402m) and 1000 ft (304m) respectively.

Based on the road functionality for Minor Arterials, the DOT's of Missouri and Florida recommend a median opening spacing of 1320 ft (402m) and 600 ft (182m).

Being stated by the State DOT's about different spacing length, AASHTO Green Book (A Policy on Geometric Design of Highways and Street, 2001, 4th Edition) suggests a preferred spacing at 400 to 800 m [0.25 to 0.50 mi] is suitable in most instances. Fixed spacing is not necessary, nor is it fitting in all cases because of variations in terrain and local service needs.

After all these guidelines make for spacing of median openings being flexible due to different condition like traffic composition, road geometric characteristic, adjacent land use etc… it is better to take a good look before deciding the location of median opening, because the density of median opening has an impact on the operation and safety on the management of traffic flow.

When median openings are spaced closely beyond the necessity which allows all types of movements like left turn, U turn and crossing maneuvers, the route would fall in to operational issues like delay in travel time due to all movements are granted on each median opening. These movements will cause a delay for through traffic by making unnecessary stops at every median opening to give a chance for these movements.

On the other hand, when the openings are distantly located with each other, all movements of left turns, U turns and crossing maneuvers will be made at other locations far away from desired locations and will be accommodated at few openings or major intersections which will cause even more congestion.

4.1.5 Median Opening Length of Different DOT's

4.1.5.1 Florida (FDOT Median Handbook, 2006)

Median opening length is commonly governed by the turn radii, side street geometrics, median (traffic separator) width, intersection skewness, and intersection legs. An excessively wide median opening will store two or more vehicles in an unsignalized full median opening while they are waiting to complete a maneuver, which results in multiple conflicts for both the turning vehicles and through traffic. This may present both safety and operational problems.

4.1.5.2 California (Caltrans Highway Design Manual, 2006)

For any three or four-leg intersection on a divided highway, the length of the median opening should be at least equal to the width of the crossroads pavement, median width, and shoulders. An important factor in designing median openings is the path of the design vehicle making a minimum left turn at a speed of 8 to 15 km/h. The length of median opening varies with width of median and angle of intersecting road.

Usually a median opening of 18 m (60 ft) is adequate for 90-degree intersections with median widths of 6.6 m (22 ft) or greater. When the median width is less than 6.6 m (22 ft), a median opening of 21 m (70 ft) is needed. When the intersection angle is other than

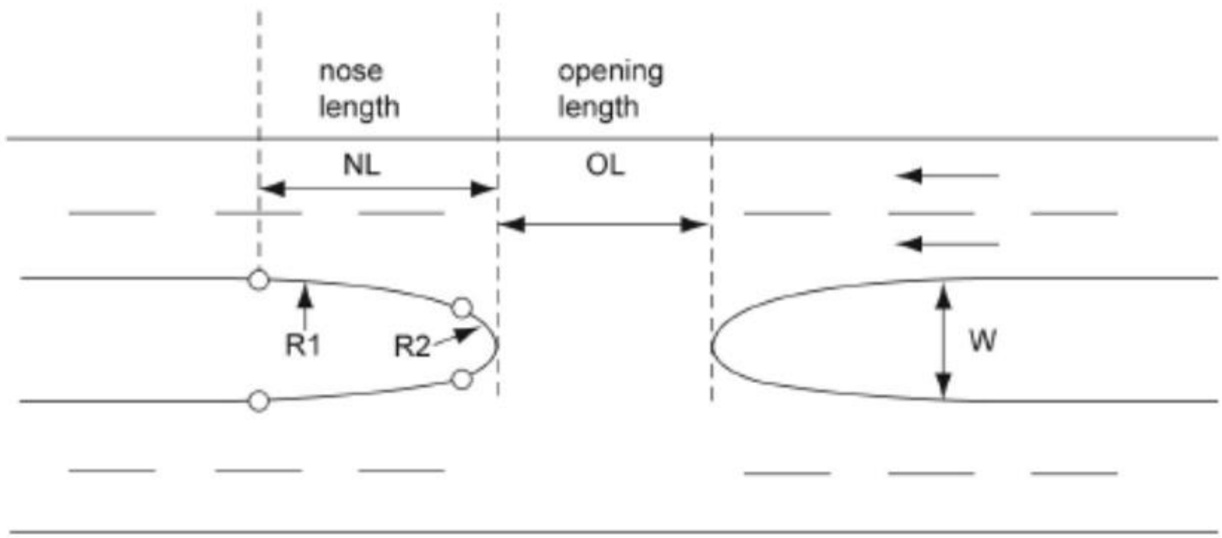
90 degrees, the length of median opening should be established by using truck turn templates.

4.1.5.3 Illinois (IDOT Bureau of Design and Environment Manual, 2001)

The median opening length should properly accommodate the turning path of the design vehicle. The minimum length is the largest of the following: (a) approach width plus 8 ft (2.44m) including crossroad median width; (b) approach width plus the width of shoulders, including crossroad median width; (c) the length based on the selected design vehicle; or (d) 40 ft.

4.1.5.4 Massachusetts (MassDOT Project Development & Design Guide, 2006)

Exhibit 6-29
Median Openings



Length of Median Opening (OL, feet)

Width of median (W, feet)	Passenger Car (P)		Single Unit Truck (SU)		Tractor/Trailer Truck (WB-50)	
	Semicircular	Bullet nose	Semicircular	Bullet nose	Semicircular	Bullet nose
4	76	76	96	96	146	122
6	74	60	94	76	144	115
8	72	53	92	68	142	110
10	70	47	90	62	140	105
12	68	43	88	58	138	100
14	66	40 min	86	53	136	96
16	64	40 min	84	50	134	92
20	60	40 min	80	44	130	85
24	56	40 min	76	40 min	126	78
28	52	40 min	72	40 min	122	73
32	48	40 min	68	40 min	118	67
36	44	40 min	64	40 min	114	62
40	40 min	40 min	60	40 min	100	57
50	40 min	40 min	50	40 min	95	48
60	40 min	40 min	40 min	40 min	90	40 min
70	40 min	40 min	40 min	40 min	80	40 min
80	40 min	40 min	40 min	40 min	70	40 min
100	40 min	40 min	40 min	40 min	50	40 min
110	40 min	40 min	40 min	40 min	40 min	40 min
120	40 min	40 min	40 min	40 min	40 min	40 min

Note: R1, R2 and NL determined by design vehicle turning paths.
Source: Adapted from A Policy on the Geometric Design of Streets and Highways, AASHTO, 2004. Chapter 9 Intersections

Source: Project Development & Design Guide, Massachusetts Highway Department, 2006.

Figure 4-10: Massachusetts DOT Guidelines on Raised Median and Median Nose Design.

4.1.5.5 Minnesota (MnDOT Roadway Design Manual, 2004)

The minimum median opening at any crossing should be 40 ft (12.2m). A school bus shall be the design vehicle for the turning template method at minor roadways with an ADT less than400 vpd. The same geometric design can be applied to median openings at crossroads with an ADT up to 1000 vpd, if a traffic study shows that the presence of large trucks is only a rare occurrence (5 or fewer per day).

Table 4-13: Lengths of Minimum Median Openings (Minnesota DOT standards).

Median width (ft)	12	14	16	18	20	22	24	26	28	30	greater than 30
Minimum median opening length (ft)	112	96	83	73	65	58	53	47	43	40	40 minimum

Source: Roadway Design Manual. Minnesota Department of Transportation, 2004

4.1.5.6 Nevada (NDOT Access Management System and Standards, 1999)

The turning template method shall be used based on a single unit truck (SUT) and occasional semi-trailer/trucks (WB-50) for perpendicular intersections. The length must be increased for skewed intersections and predominant semi-trailer/truck usage.

Table 4-14: Nevada DOT Standards for Minimal Lengths of Median Openings.

Median Width (ft)	Semicircular (ft)	Bullet Nose (ft)
4	96	96
6	94	76
8	92	68
10	N/A	62
12	N/A	58
14	N/A	53
16	N/A	50
20	N/A	44
24	N/A	40 (min.)
>24	N/A	40 (min.)

Source: Access Management System and Standards. Nevada Department of Transportation, July 1999

4.1.5.7 New Mexico (NMDOT State Access Management Manual, 2002)

Median openings should be designed to accommodate the largest design vehicle anticipated to use the opening. A median opening may be designed to permit U-turn movements. If the opening is too narrow to safely permit a U-turn, based upon storage and vehicle turning characteristics, U-turns should be addressed in design or restricted through signage. Sign use and placement requires the department approval.

4.1.5.8 Nebraska (Nebraska Department of Roads, Roadway Design Manual, 2006)

The median opening length should be a minimum of 72 ft (22m). The turning templates for the appropriate design vehicle shall be used for the final opening width determination.

4.1.5.9 Utah (UDOT Roadway Design Manual, 2007)

Minimum length of median openings is 40 ft (12.2m). To calculate the need, measure the crossroad pavement width plus 8 ft. Use that measurement if it is greater than the 40 ft (12.2m) minimum. Do not use a 40-ft minimum length of opening without regard to the width of median or control radius except at very minor crossroads. The 40 ft (12.2m) minimum length of opening does not apply to openings for U-turns.

4.1.5.10 Wisconsin (WisDOT Facilities Development Manual, 2006)

The length of a median opening should be determined by the control radii for left-turn movements of vehicles turning into a driveway or making a U-turn. A 40-ft (12.2m) length should be used as a minimum length.

4.1.5.11 Summary for Existing Median Opening Length Guidelines

A number of states provide, in their roadway design manuals, the minimal median opening length, such as 40 ft(12.2m) proposed by Utah, Wisconsin, Massachusetts, Illinois, Minnesota, and Nevada, and 60 ft(18.3m) by California, and 72 ft(22m) by Nebraska.

Particularly, Massachusetts, Minnesota, and Nevada present look-up tables for minimum median openings as a function of median widths. It should be noticed that turning template with appropriate design vehicles should be used for the final decisions on both median width and opening length.

4.1.6 Median Opening Length in Jimma Town

Route 2 Areboch Tera – Jebena has median opening length of 9m, 10m, and 10mand 12m in ascending order with an average opening spacing of 10.25m as shown in the Table Table 3-4 above.

Route 4 Seka Ber-Total-Tilahun Shell has median opening spacing of 10m, 10m,13m, 16m,, 30m and 30m in ascending order with an average opening spacing of 18.17m as shown in the Table 3-6 above.

Route 5 Arat Anbesa- Top View Café has median opening spacing of only 30m with an average opening spacing of 30m as shown in the Table 3-8 above.

As it is known the shape of median end treatment has an impact on the turning radius of design vehicles in such a way that semicircular end and bullet nose end do not have the same turning characteristic. All the medians constructed in Jimma town are with a width of 1m having ends that are treated with a shape of semicircular nose.

An important factor in designing median openings is the path of each design vehicle making a minimum left turn at 15 to 25 km/h [10 to 15 mph]. The paths of design vehicles making right turns are given in Chapter 2of AASHTO Green Book (A Policy on Geometric Design of Highways and Street, 2001, 4th Edition). Any differences between the minimum turning radii for left turns and those for right turns are small and are insignificant in highway design. Minimum 90-degree left-turn paths for design vehicles are shown in Figure 4-11. Figure 4-11A shows these paths positioned as they would govern median end design for vehicles leaving a divided highway. Figure 4-11B shows them positioned for left turns to enter a divided highway. In both cases it is assumed that the inner wheel of each design vehicle clears the median edge and centerline of the crossroad by 0.6 m [2 ft] at the beginning and end of the turn. For comparison, circular arcs of 12-, 15-, and 23-m [40-, 50-, and 75-ft] radii and tangent to the crossroad centerline and the median edge are also shown.

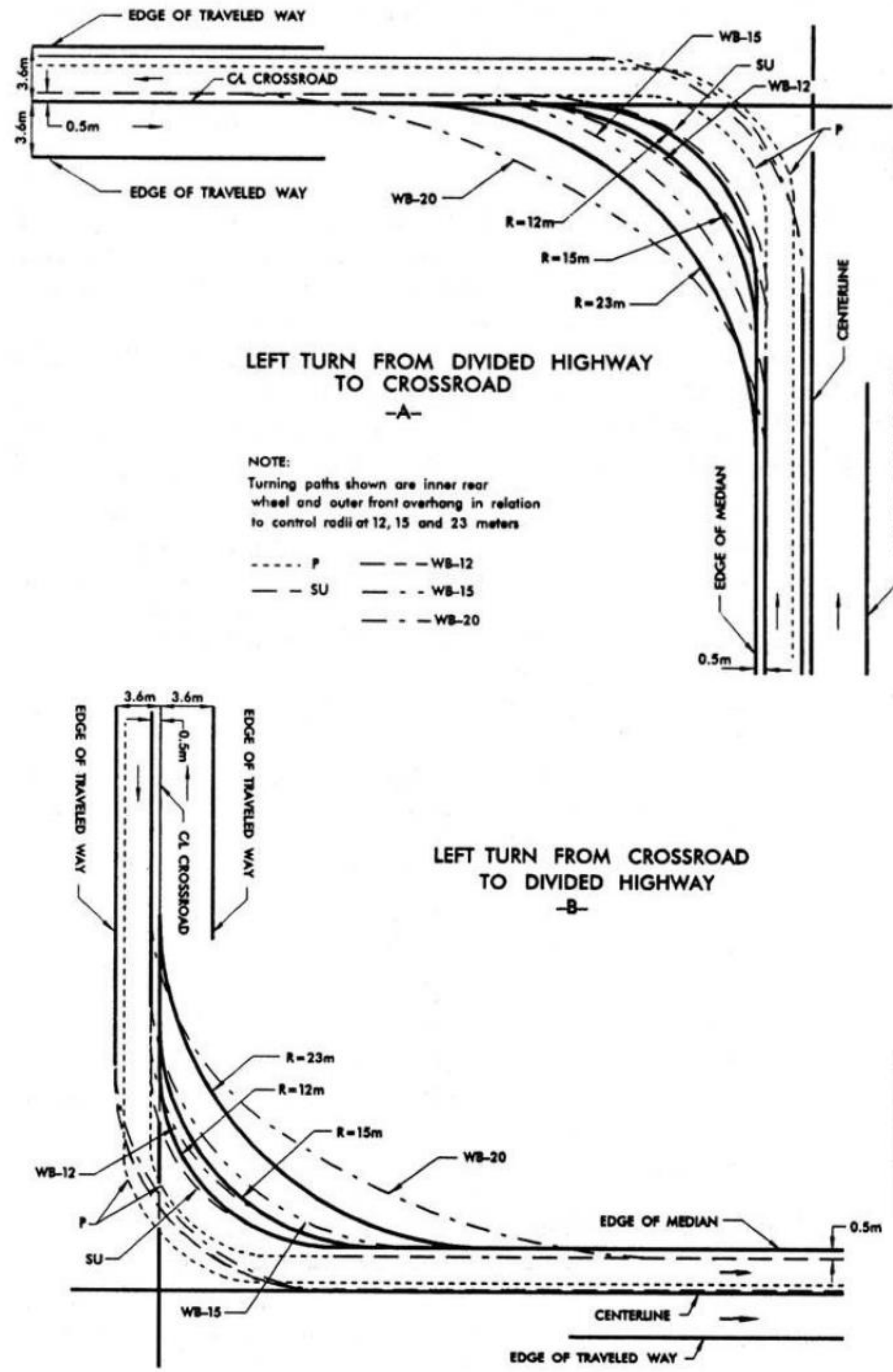


Figure 4-11: Control Radii at Intersections for 90-Degree Left Turns

By considering the range of radii for minimum right turns and the need for accommodation of more than one type of vehicle at the usual intersections, the following control radii can be used for minimum practical design of median ends: a control radius of 12 m [40 ft] accommodates P vehicles suitably and occasional SU vehicles with some swinging wide; one of 15 m [50 ft]accommodates SU vehicles and occasional WB-12 [WB-40] vehicles with some swinging wide; and one of 23 m [75 ft] accommodates WB-12 [WB-40] and WB-15 [WB-50] vehicles with only minor swinging wide at the end of the turn. These relations are shown generally in Table 4-15 through Table 4-17.

Table 4-15: Minimum Design of Median Openings (P Design Vehicle, Control Radius of 12 m)

Metric		
M Width of median (m)	L = Minimum length of median opening (m)	
	Semicircular	Bullet nose
1.2	22.8	22.8
1.8	22.2	18.0
2.4	21.6	15.9
3.0	21.0	14.1
3.6	20.4	12.9
4.2	19.8	12.0 min
4.8	19.2	12.0 min
6.0	18.0	12.0 min
7.2	16.8	12.0 min
8.4	15.6	12.0 min
9.6	14.4	12.0 min
10.8	13.2	12.0 min
12.0	12.0 min	12.0 min
15.0	12.0 min	12.0 min
18.0	12.0 min	12.0 min

Table 4-16: Minimum Design of Median Openings (SU Design Vehicle, Control Radius of 15 m)

Metric		
M Width of median (m)	L = Minimum length of median opening (m)	
	Semicircular	Bullet nose
1.2	28.8	28.8
1.8	28.2	22.8
2.4	27.6	20.4
3.0	27.0	18.6
3.6	26.4	17.4
4.2	25.8	15.9
4.8	25.2	15.0
6.0	24.0	13.2
7.2	22.8	12.0 min
8.4	21.6	12.0 min
9.6	20.4	12.0 min
10.8	19.2	12.0 min
12.0	18.0	12.0 min
15.0	15.0	12.0 min
18.0	12.0 min	12.0 min
21.0	12.0 min	12.0 min

Table 4-17: Minimum Design of Median Openings (WB-12 [WB-40] Design Vehicle, Control Radius of 23 m)

Metric		
M Width of median (m)	L = Minimum length of median opening (m)	
	Semicircular	Bullet nose
1.2	43.8	36.6
1.8	43.2	34.5
2.4	42.6	33.0
3.0	42.0	31.5
3.6	41.4	30.0
4.2	40.8	28.8
4.8	40.2	27.6
6.0	39.0	25.5
7.2	37.8	23.4
8.4	36.6	21.9
9.6	35.4	20.1
10.8	34.2	18.6
12.0	30.0	17.1
18.0	27.0	12.0 min
24.0	21.0	12.0 min
30.0	15.0	12.0 min
33.0	12.0 min	12.0 min
36.0	12.0 min	12.0 min

Jimma town asphalt roads have used a median width of 1m for majority of routes which is even below the minimum median width mentioned in the above tables. For this much of median width, they shall have an opening length of more than 22.8m in order to make a successful left turn from the crossroad to divided highway or vice versa for a design vehicle type of passenger car (P) with a control radius of 12m. Whereas more than 28.8m opening length shall be provided for single unit trucks (SU) to make the left turn with control radius of 15m. For a design vehicle type of Intermediate Semitrailer (WB-12 [WB-40]) needs an opening length of 43.8m for this maneuver with a control radius of 23m.

Only one route found out of all Jimma town asphalt roads have used a median width of 2m for route 5 of Arat Anbesa- Top View Café for the stretch less than 400m. thus according to recommendation given above on the tables mentioned above taken from AASHTO Green Book, opening length of 22m (i.e. found by linear interpolation of opening length for median width between 1.8m and 2.4m) in order to make a successful left turn from the crossroad to divided highway or vice versa for a design vehicle type of passenger car (P) with a control radius of 12m. Whereas 28m (i.e. similar interpolation with earlier) opening length shall be provided for single unit trucks (SU) to make the left turn with control radius of 15m. For a design vehicle type of Intermediate Semitrailer

(WB-12 [WB-40]) needs an opening length of 43m (i.e. similar interpolation with earlier) for this maneuver with a control radius of 23m.

Accordingly, route 2 of Areboch Tera-Jebena does not satisfy these criteria as the maximum opening length provided along this route is only 12m which is not even sufficient for a passenger car (P) to make successful left turn with one chance from the crossroad to the divided highway or vice versa.

Along route 4 named Seka Ber-Total- Tilahun Shell only two median openings with 30m length are provided adequately to perform a successful left turn for design vehicle types of passenger cars (P) and single unit trucks (SU). These openings are located at located at major intersections of Hermata Bank at station 0+430 and at Areboch Tera with station of 0+520. This is a clear indication that the majority of large sized vehicles chose to perform the left turn to gain access into or out of the main divided highway and this situation is the main reason for a congestion to happen at the intersections. This congestion at intersection would in return affect the characteristics of traffic flow by causing operational and safety problems which is not desired.

Whereas on route 5 Arat Anbesa- Top View Café, for design vehicles of passenger cars (P) and single unit trucks (SU) have the chance of completing a fruitful left turn maneuver because the 2m median width give more guarantee for the opportunity of safe and outstanding operational left turn maneuver within an opening length of 30m at station 0+200 where the route Seka Ber-Jebena make a T-junction at this station.

For Route 2 Areboch Tera – Jebena with a median width of 1m having median opening lengths of 9m, 10m, 10m and 12m listed in ascending order with an average opening spacing of 10.25m as shown in the Table 3-3 above.

Route 4 Seka Ber-Total-Tilahun Shell has median opening spacing of 10m, 10m, 13m, 16m,, 30m and 30m in ascending order with an average opening spacing of 18.17m as shown in the Table 3-6 above.

Route 5 Arat Anbesa- Top View Café has median opening spacing of only 30m with an average opening spacing of 30m as shown in the Table 3-8 above.

As it is known the shape of median end treatment has an impact on the turning radius of design vehicles in such a way that semicircular end and bullet nose end do not have the same turning characteristic. All the medians constructed in Jimma town are with a width of 1m having ends that are treated with a shape of semicircular nose.

4.2 Safety analysis

The safety problems at all these study routes were analyzed based on the collected traffic conflicts and historical crash data.

Traffic conflicts are defined as the interaction between two or more road users (e.g., vehicles, pedestrians, and bicycles), where one or more users take evasive action to avoid a collision. For this study route, observation was made on different days for different purpose of the study including quantitative data like field measurement of the dimensions of Lane width, Carriageway width, Shoulder width, Right of way width, Width of median and Opening length of median at mid-block and intersections as well as qualitative data like types of median used, adjacent land use and road side features along the route. After the field observation and measurement has been taken the researcher recorded the different types of conflicts that occurred.

Type 1—Conflict between through vehicles &through pedestrian occurs when a through pedestrian traffic moving in the direction parallel to the road which was supposed to use only the pedestrian walk way provided on both sides of the road starts tousle the traffic lane prepared for the use of vehicles only.


Figure 4-12: Illustration of Type 1 Traffic Conflicts.

The occurrence of Type 1 traffic conflicts pinpoints the need for refuge space at pedestrian walkway on both sides of the road e.g., providing a dedicated pedestrian walkway with sufficient width as it was approved on the design during construction phase. This is to prevent the pedestrian traffic from accessing the traffic lane for their movement parallel to the direction of traffic flow and to avoid possible traffic accident between the pedestrian and the vehicles.

Type 2—Conflict between through vehicles & crossing pedestrian occurs when a pedestrian traffic make an aggressive crossing to move from one side of the road to the other side in the direction perpendicular to the road and the trough traffic is impeded due to non-uniform crossing of pedestrians with undefined location and time.

Figure 4-13: Illustration of Type 2 Traffic Conflicts.

The occurrence of Type 2 traffic conflicts may indicate that problems may appear where either there is no defined location of pedestrian crossing facilities like Zebra at suitable intervals or else as is it known there is no enforcing rules and regulation of traffic law for pedestrians that oblige them to use crossing facilities like Zebra for crossing movements.

Type 3—Conflict between through vehicles & left turn from junction or driveway at median opening occurs (a) when a leading left-turn vehicle from the mainline slows down at an opening without a dedicated left-turn lane (shown as Type 3.A), or (b) when a left-turn vehicle from either mainline or driveway stops at an opening, waiting to cross, but the opening cannot fully accommodate the length of the left-turn vehicle (shown as Type 3.B). Both of these situations place a follow-up mainline vehicle in danger of a rear-end collision.

Type 3.A Type 3.B

Figure 4-14: Illustration of Type 3 Traffic Conflicts.

The occurrence of Type 3 traffic conflicts pinpoints the need for refuge space at a median opening, e.g., providing a dedicated left-turn lane at the opening or sufficient median width to shelter the left-turn vehicles from the mainline traffic.

Type 4—Conflict between junction (driveway) left turns & mainline left turns occurs when a left turn vehicle from the mainline and a left-turn vehicle from the driveway at a median opening are turning at the same time. Conflicts of this type are a result of unclear priority between the two left turn movements inside the median opening. Under heavy traffic conditions, the excessive waiting time at the median opening may cause this type of traffic conflict. The occurrence of Type 4 traffic conflicts may indicate that problems may appear where a full median opening is provided to allow all the movements. More importantly, drivers' sight distance will be impaired if two left-turn vehicles appear at the opening at the same time and block each other's view.

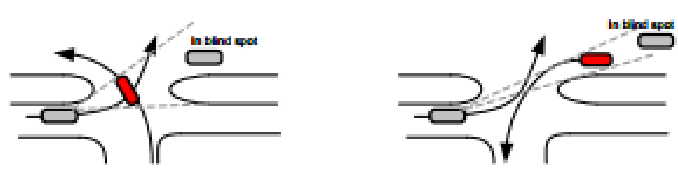


Figure 4-15: Impaired Sight Distance When Two Left-Turn Vehicles Appear at a Full Opening at the Same Time.

Type 5—Conflict between left turns & opposing through traffic on the mainline occurs when a left-turn vehicle from the mainline or a left-turn vehicle from the driveway makes an aggressive turn at a median opening by taking risky gaps. The occurrence of a Type 5 traffic conflict is generally a result of aggressive left-turn drivers. The excessive waiting time at a driveway under heavy traffic conditions may be a cause of this type of aggressive left-turn maneuver.

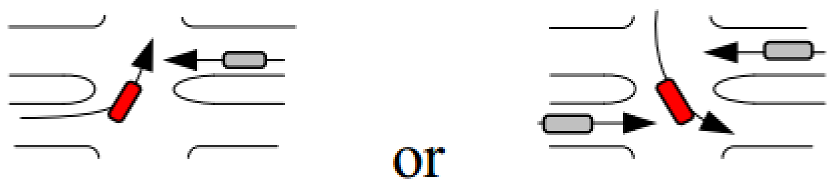


Figure 4-16: Illustration of Type 5 Traffic Conflicts.

Type 6—Gridlock due to aggressive left turns from a driveway (peak hours) occurs under heavy traffic conditions where a driveway and the aligned median opening are within the functional area of a signalized intersection. When the egress left turns from the driveway have to cross the queue of the downstream signalized intersection, the mainline traffic normally stops during a red interval to keep the driveway clear. However, when the signal of the downstream intersection turns green, the egress left turns, which aggressively enter the mainline but cannot be cleared, may block the mainline traffic and cause gridlock in the middle of the road (see Figure 4-16). The occurrence of a Type 6 traffic conflict indicated that operational problems may appear where a median opening is located in the functional area of a signalized intersection.

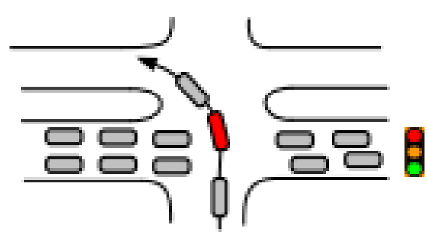


Figure 4-17: Illustration of Type 6 Traffic Conflicts.

Type 7—Weaving conflict occurs where there are no full openings that are aligned to the driveways, and thus no direct left-turn maneuvers can be made from the two driveways. As a result, left-turn maneuvers have to quickly weave to the most left side lane to make left turns at a closely spaced opening downstream (see Figure 4- 16).

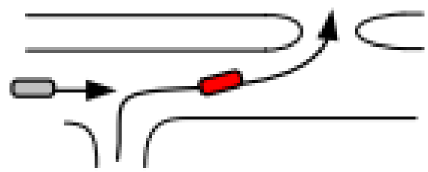


Figure 4-18: Illustration of Type 7 Traffic Conflicts.

4.3 Safety Implications of the Data Collected

At these routes, based on traffic conflicts observed in the field three major safety issues associated with raised median design were identified and summarized as follows.

4.3.1 Narrow Median Opening Width

The insufficient median width is a major issue that caused conflicts and crashes in these routes. The observed traffic conflicts occurred due to the median opening being too narrow to accommodate a left-turning vehicle, and the others were associated with the narrow medians width. As illustrated in Figure 4-19, the left-turn vehicle No. 1 from the driveway on the first figure and the left-turn vehicle No. 2 from the mainline on the second figure stopped in the opening and waited a gap to turn left. The insufficient median width, which blocked the mainline traffic and caused the conflicts with through vehicles, was unable to refuge the whole vehicle.

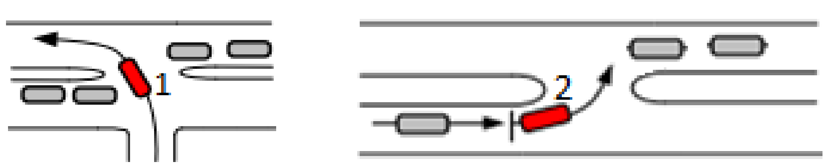


Figure 4-20: Two Types of Conflicts Caused by the Narrow Median Width.

4.3.2 High Driveway Density

There are a lot of driveways or junctions on both sides along the selected routes within short interval of the roads, and most of the driveways are not directly aligned to the median openings. This issue resulted in two other issues like weaving conflicts and right-turn queue spillback. Figure 4-20 indicates how weaving conflicts occurred. The left-turn vehicle No.1 in the first figure exited from the driveway that is very close to the downstream of the opening, which merged to the most inside lane leading to a possible weaving conflict with through traffic. On the other hand in the second figure the left-turn vehicle No.2 exited from the narrow driveway that is very close to the opening, which tries to merge to the most inside lane leading to a possible weaving conflict with through traffic. But before the vehicle merges it stops until it get a gap. During this time right turning vehicles starts to queue on the most outer lane of the road until the left turning vehicle leave a space for them.

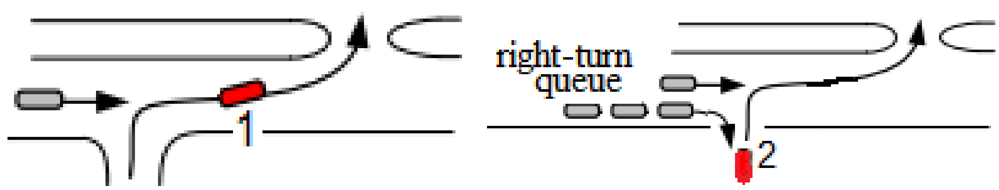


Figure 4-21: Weaving Conflict and Right-Turn Queue Spillback.

4.3.3 Median Opening within Functional Area of a Signalized Intersection

When the median is very near from the major intersection, during peak hours, the right-turn queue will spillback to the driveway at this opening. As a result, the egress left turns from the driveway have to cross the queue to reach the opening. Because their view is blocked by the vehicles in the queue, they may fail to detect the through vehicle approaching from the most left through lane, which will result in T bone crashes. This traffic conflict of this type was observed during the field study. In addition, the gridlock events observed at this location were caused by this problem as we discussed before (see the Type 6 conflicts in Figure 4-16).

4.3.4 Result

- Narrow medians have significant, negative effects on traffic safety. Insufficient median width that is unable to refuge the whole vehicle will cause crashes/conflicts between through and turning vehicles at the median openings.
- High driveway density will increase the weaving traffic conflicts. Consolidating driveways can be a safety countermeasure for reducing weaving conflicts due to left turns at openings.
- It should be avoid placing a median opening within the influence area (queue length) of a signalized intersection, which will cause T-bone crashes between egress vehicles from the driveway and the through vehicles on the mainline and will cause gridlock problems.
- Short left-turn bays did not compromise the safety along the studied roadway section. Given a short left-turn bay, left-turn vehicles were observed to decelerate on the mainline travel lanes before entering the taper, which reduced the risk of rear-end crashes.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This researcher has identified both major and minor design changes among preliminary design, construction working design and As-built design from field investigation which may both positive and negative impact on the function, operation and safety of traffic flow. Some of the changes that are detected during design review are listed below.

- An increment or reduction in number of lanes, or in width of lanes or median or pedestrian walkway was witnessed on the process of design review of the prepared design document before the construction during planning stage, the design template at construction period and the As-built design document along with field observation after construction of the roads.
- The design change which was generated by the increment of roadway width in general at the construction period beyond the width provided during planning stage has an impact on the trend of traffic flow in many ways.
- Additional right of way was needed due to theses increment on both sides of adjacent land use which most of them are of commercial purposes. The unexpected cost of buying additional right of way which the City Administration would pay or the interest of business owners to leave the place partially or completely influenced the land acquisition for full access of right of way.
- The provision of restricted right of way had caused the following major impacts on the smooth traffic flow.
    1. The capacity of the some roads is much affected due to the reduction in number and width of lanes even though the demand of traffic flow for wider carriageway width is noticeable.
    2. Wider medians could not be installed or even not installed at all either by replacing the space reserved for median with paving asphalt or by completely omitting the median space to save sufficient right of way.
    3. On some routes even though the number and width of lane, and somewhat narrow median was installed, the shoulder width kept for pedestrian

walkway was not given emphasis to provide adequate width as a result irregular widths below the approved design template where at some places it can be said width of less than 0.5m is available.

Installation of Raised Medians

Median width

Most of the roads are designed with 1m median width which is below the minimum median width recommended by different countries and states design manuals and guidelines prepared for the design of medians. In addition to the provision of narrow median, the median is fenced with densely welded metal grills made of RHS with a height ranging from 1m up to 1.5m from the raised curbed median and the middle space is landscaped with trees and flowers. The spacing at which these trees planted did not consider the properties of the trees with respect to their height, diameter of their trunk and the amount of leaf it will produce during their growth span. Due to these reasons the follows effects has been observed on the traffic flow:

1. The narrower median width has a negative impact on turning maneuvers like left turn and U-turn movements in such a way that the turning vehicles cannot make a safe and operationally effective turns because minimum centerline turning radius needed for large sized vehicles cannot be achieved due to narrow medians. This would in return cause a delay in travel time for both vehicle making the turn and the through traffic since the turning vehicles takes long time trying many chances to succeed the turn while the through traffic on both directions retards their speed or stops completely until the turning vehicles evacuate the traffic lanes and make the turn.
2. The densely welded fences and the setup of the landscape inside a 0.6m width free space of medians become an obstruction for the traffic by creating short sight distance and increasing the probability of accident occurrence. The through traffic with impaired sight distance due to poor landscape design inside the median would be exposed to crash with vehicles making left turn or U-turn from the opposite direction of main road. Concerning the accident between the through

traffic and the pedestrian crossing the main road, both the through traffic and the pedestrian standing on the median to make the next crossing movement transversely do not have a clear sight distance to avoid the accident.

Median Opening Spacing

The majority of provision of median openings was correlated on the presence of major and minor junctions. For almost all junctions found on both sides of the road are granted a full access for all types of directions even though the junctions are closely spaced along the road.

Unless otherwise optimum spacing between successive median openings is provided, being more closely or remotely spaced has negative effect on increasing travel time either for the through traffic or for the turning as well as crossing traffic.

As in the case of Jimma town asphalt roads, more closely spaced median openings that allows especially left turn movements from junctions to main road or vice versa influences the travel time by hindering the through traffic from getting an access due to interruption of left turning, U-turning or crossing maneuvers at every median openings along the route.

Whereas median opening located faraway from each other would cause a longer travel time in order to make left turn into or out of the main road, or crossing maneuver across the main road. This is because no median opening is provided right at the junction and the vehicle should use the next median opening found at some distance from the junction and make U-turn to return to the opposite direction of the original place.

Median Opening Length

For all median openings no matter how far the spacing is located along the route, appropriate opening length should be provided unless otherwise both turning movements (i.e. left turn and U-turn) and crossing maneuvers will be jeopardized.

An excessively wide median opening will store two or more vehicles in an unsignalized full median opening while they are waiting to complete a maneuver, which results in multiple conflicts for both the turning vehicles and through traffic. This may present both safety and operational problems.

Similar to the situation of Jimma town asphalt roads, on the other hand, the shorter length of median opening become insufficient to make safe and operationally effective movements of vehicles to turn to the left from the junctions to the main road or vice versa or to do U-turns on the main road. The narrow median opening forces all the conflict points created due to the path of vehicles to be followed during the turning and crossing movement to move towards the center of the influence zone at the intersection.

Since the ends of the medians terminated for the purpose of providing a median opening are so close to the intersection of the main road and the junction(s), for instance, in order to perform U-turn on the main road, a vehicle is forced to inter into the influence zone of the intersection where the vehicle was supposed to make the maneuver away from the intersection if wider median opening was provided. Thus the ends of medians should have been located away from the influence zone of intersections which in other words would guarantee the provision of wide median openings.

Pedestrian walkway

Walkway width

The approved design template prepared during the construction period included a pedestrian facility to be used as walkway on both sides of all the roads with a width ranging from 2m up to 2.5m. The template also designed the surface of walkway to be smoothed by paving materials like terrazzo.

However, the actual situation during field investigation, it can be said that emphasis was not given to the provision of proper walkway as pedestrian facility according to the approved design template.

The main reason behind this is the required amount of walkway width could not be maintained due to restricted right of way width along both road sides. The city administration failed to possess the necessary right of way probably due to a lot of reasons which clearly shows lack of knowledge about the advantage of providing pedestrian facility. Thus the available walkway width is fluctuating where the majority is much below the width specified on the template.

The other reason for the deficiency of pedestrian facility is the invasion of available width by the commercial shops adjacent to the road sides by placing their commodities on the walkway near the veranda. On the other hand, illegal traders have occupied partially or completely the walkway by putting all their commodities.

In addition, ongoing construction sites adjacent to the road side fences their border approaching the edge of the carriageway where the pedestrian walkway is part of the site partially or completely this in return leads to malfunction of the facility.

Hence this condition of failure to provide the proper design during construction takes away the interest and willingness of the pedestrian traffic to use the facility with comfort rather they use the edge of the outer traffic lanes to move along the road. Consequently conflict between vehicle and pedestrian is demonstrated which aggravate the possibility of the occurrence of accidents.

5.2 Recommendations

- The preliminary design which is prepared during planning stage should be managed to reflect the actual physical characteristics of the routes with respect to the available right of way possession and the property of traffic flow (i.e. motorized and non-motorized traffic flows)prior to the construction stage.
- Contradictory problems would have to be reviewed and the appropriate measurements would be decided among the stake holders and concerned bodies in order to eliminate the occurrence of major design changes after the construction stage are started.
- If change in design is needed due to the desire for increment or reduction in number or width of traffic lanes, or widening, reducing, omitting or replacing the median width with asphalt, or increment or reduction of pedestrian walkway width from that of the preliminary design, available right of way and characteristics of both vehicular and pedestrian traffic flow should be investigated and appropriate mitigation measurement should be taken by freeing up the obstructions such as residential and commercial buildings and utilities like electric, water and telephone supplies which come across within the right of way by means of compensating the victims with financial and replacement of land ownership.
- In the routes of Tilahun Shell – Awetu Menafesha and Tilahun Shell-Agip Kela (Jimma Connectivity Road) where the 1m and 2m median width respectively is replaced with paved asphalt to make a flush median, even though it is not feasible to demolish the paved median and reinstall the curbed raised median by this time, at least the median should be painted with the appropriate marking of flush medians which is used to show the presence of median space. This delineation of the flush median has advantages for managing the traffic flow of both vehicular and pedestrian.
    - ✓ The vehicular traffic flow will be channelized on both direction of the road in which unnecessary access of vehicles to the median space and also to the opposite direction of traffic lanes for the purpose of overtaking slower

vehicles will be prohibited by traffic laws unless allowed. This reduces the probability of head-on crashes with the traffic in the opposite direction.

- ✓ The demarcation of the flush median will give a chance for a safe and secure crossing movement of the pedestrians as they will use the median as a refugee area before making the next crossing on the other side of the carriageway.

- ➢ Due to the insufficiently installed median opening spacing and length of some routes, large sized vehicles incapable of making left turn, U-turn or crossing movement safely and efficiently should be prohibited by using traffic signs.
- ➢ The spacing between the planted trees, the dimensions (i.e. the diameter and height) and the characteristic of the leaf should be considered before choosing for landscaping because these properties has an impact on the sight distance other than giving good architectural view of the road and beatifying the town.
- ➢ The fences used as a protection for the plants from endangering the growth by human and others actions and also used to avoid indiscriminate pedestrian crossings on random places should be well designed. The height and the density of metal bars welded together should be specified in order to contribute for better sight distance.
- ➢ The fences are not continuous throughout the median length from the start to the end rather in order to allow pedestrian to cross the road in traverse direction, there are closely spaced openings provided having a width of ranging 1m up to 1.5m with in spacing of ranging from 4m up to 9m. This much number of openings should be restricted to at least 20m in order to reduce the conflict between the pedestrian and vehicles.
- ➢ Since the carriageways are meant to serve motorized traffic movements and exceptionally for pedestrian crossing movements, all other pedestrian movements should be restricted on pedestrian walkway designed and constructed for this purpose. So in order to avoid the pedestrian longitudinal direction movement to be on the carriageway, sufficient walkway width should be provided by the City Administration by any means necessary to free up right of way restrictions through:
  - ✓ Buying additional right of way possession from the adjacent land use.

- ✓ Forbidding legal business owners from blocking the walkway by putting their commodities near or adjacent to the walkway.
- ✓ Eliminating illegal trading on the walkway as well as on the edge of carriageway.

- ➢ During the construction period of the asphalt project before 4 or 5 years ago, the City Administration could have got a least cost right of way possession because the center of Jimma town was established with old buildings having low salvage value. The Administration failed to do so instead it chose to change the design to be according to the available right of way in which this was the major problem to happen as mentioned earlier. However, these old buildings are being replaced with multistory buildings by this time and these buildings should be located in such a way that wide space should be preserved between the border of the building and the edge of the road already constructed. Even though this space would not be used to widen the already constructed cross sectional elements of the road, it will be used to provide wide pedestrian walkway on both sides which will be a relief to reduce the crash rate due to the conflict between the pedestrian and motorized traffic.
- ➢ In order to avoid the possession of restricted of right of way for future road construction in Jimma town as a whole, the City Administration should prepare a the Master Plan for the town clearing showing the right of way width of the roads to be constructed in far future.
- ➢ According to the new Mater Plan to be prepared which will prioritize the conservation of wide right of way for future road construction, the remaining land should be partitioned as residential, commercial, recreational etc… with their respective land area according their intended purpose.
- ➢ During the preparation of a new master plan, the future development of the town should be put in to mind that it must be consisting of all types of infrastructure including road infrastructure to be built within at least 20 years. This plan should secure the provision of wider carriageway, median and pedestrian walkway as well as the spacing and the length of median openings should be suitably matched with the regularly spaced junctions.

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APPENDIX

Table 2-3: Geometric Design Parameters for Design Standard DS1 (Paved Dual Carriageway)

Design Element	Unit	Flat	Rolling	Mountainous	Escarpment	Urban/Peri-Urban
Design Speed	km/h	120	100	85	70	50
Min. Stopping Sight Distance	m	285	205	155	110	55
Min. Passing Sight Distance	m	425	375	340	275	175
Min. Horizontal Curve Radius	m	630	395	270	175	85
Transition Curves Required		Yes	Yes	Yes	No	Yes
Max. Gradient (desirable)	%	3	4	6	6	6
Max. Gradient (absolute)	%	5	6	8	8	8
Minimum Gradient	%	0.5	0.5	0.5	0.5	0.5
Maximum Superelevation	%	8	8	8	8	4
Crest Vertical Curve	k	210	105	60	31	10
Sag Vertical Curve	k	74	51	36	25	12
Normal Crossfall	%	2.5	2.5	2.5	2.5	2.5
Shoulder Crossfall	%	4	4	4	4	4
Right of Way	m	50	50	50	50	50

Table 2-4: Geometric Design Parameters for Design Standard DS2 (Paved)

Design Element	Unit	Flat	Rolling	Mountainous	Escarpment	Urban/Peri-Urban
Design Speed	km/h	120	100	85	70	50
Min. Stopping Sight Distance	m	285	205	155	110	55
Min. Passing Sight Distance	m	425	375	340	275	175
% Passing Opportunity	%	50	50	25	0	20
Min. Horizontal Curve Radius	m	630	395	270	175	85
Transition Curves Required		Yes	Yes	Yes	No	yes
Max. Gradient (desirable)	%	3	4	6	6	6
Max. Gradient (absolute)	%	5	6	8	8	8
Minimum Gradient	%	0.5	0.5	0.5	0.5	0.5
Maximum Superelevation	%	8	8	8	8	4
Crest Vertical Curve	k	210	105	60	31	10
Sag Vertical Curve	k	74	51	36	25	12
Normal Crossfall	%	2.5	2.5	2.5	2.5	2.5
Shoulder Crossfall	%	4	4	4	4	4
Right of Way	m	50	50	50	50	50

Table 2-5: Geometric Design Parameters for Design Standard DS3 (Paved)

Design Element	Unit	Flat	Rolling	Mountainous	Escarpment	Urban/Peri-Urban
Design Speed	km/h	100	85	70	60	50
Min. Stopping Sight Distance	m	205	155	110	85	55
Min. Passing Sight Distance	m	375	340	275	225	175
% Passing Opportunity	%	50	33	25	0	20
Min. Horizontal Curve Radius	m	395	270	175	125	85
Transition Curves Required		Yes	Yes	No	No	No
Max. Gradient (desirable)	%	3	4	6	6	6
Max. Gradient (absolute)	%	5	6	8	8	8
Minimum Gradient	%	0.5	0.5	0.5	0.5	0.5
Maximum Superelevation	%	8	8	8	8	4
Crest Vertical Curve	k	105	60	31	18	10
Sag Vertical Curve	k	51	36	25	18	12
Normal Crossfall	%	2.5	2.5	2.5	2.5	2.5
Shoulder Crossfall	%	4	4	4	4	4
Right of Way	m	50	50	50	50	50

Table 2-6: Geometric Design Parameters for Design Standard DS4 (Paved)

Design Element	Unit	Flat	Rolling	Mountainous	Escarpment	Urban/Peri-Urban
Design Speed	km/h	85	70	60	50	50
Min. Stopping Sight Distance	m	155	110	85	55	55
Min. Passing Sight Distance	m	340	275	225	175	175
% Passing Opportunity	%	25	25	15	0	20
Min. Horizontal Curve Radius	m	270	175	125	85	85
Transition Curves Required		Yes	Yes	No	No	No
Max. Gradient (desirable)	%	4	5	7	7	7
Max. Gradient (absolute)	%	6	7	9	9	9
Minimum Gradient	%	0.5	0.5	0.5	0.5	0.5
Maximum Superelevation	%	8	8	8	8	4
Crest Vertical Curve	k	60	31	18	10	10
Sag Vertical Curve	k	36	25	18	12	12
Normal Crossfall	%	2.5	2.5	2.5	2.5	2.5
Shoulder Crossfall	%	4	4	4	4	4
Right of Way	m	50	50	50	50	50

Table 2-7: Geometric Design Parameters for Design Standard DS5 (Unpaved)

Design Element	Unit	Flat	Rolling	Mountainous	Escarpment	Urban/Peri-Urban
Design Speed	km/h	70	60	50	40	50
Min. Stopping Sight Distance	m	110	85	55	45	55
Min. Passing Sight Distance	m	275	225	175	125	175
% Passing Opportunity	%	25	25	15	0	20
Min. Horizontal Curve Radius	m	175	125	85	50	85
Transition Curves Required		No	No	No	No	No
Max. Gradient (desirable)	%	4	5	7	7	7
Max. Gradient (absolute)	%	6	7	9	9	9
Minimum Gradient	%	0.5	0.5	0.5	0.5	0.5
Maximum Superelevation	%	8	8	8	8	4
Crest Vertical Curve	k	31	18	10	5	10
Sag Vertical Curve	k	25	18	12	8	12
Normal Crossfall (Paved)	%	2.5	2.5	2.5	2.5	2.5
Shoulder Crossfall (Paved)	%	4	4	4	4	4
Normal and Shoulder Crossfall (Unpaved)	%	4	4	4	4	4
Right of Way	m	50	50	50	50	50

Table 2-8: Geometric Design Parameters for Design Standard DS6 (Unpaved)

Design Element	Unit	Flat	Rolling	Mountainous	Escarpment	Urban/Peri-Urban
Design Speed	km/h	60	50	40	30	50
Min. Stopping Sight Distance	m	85	55	45	30	55
Min. Passing Sight Distance	m	225	175	125	75	175
% Passing Opportunity	%	20	20	15	0	20
Min. Horizontal Curve Radius	m	125	85	50	30	85
Transition Curves Required		No	No	No	No	No
Max. Gradient (desirable)	%	6	7	10	10	7
Max. Gradient (absolute)	%	8	9	12	12	9
Minimum Gradient	%	0.5	0.5	0.5	0.5	0.5
Maximum Superelevation	%	8	8	8	8	4
Crest Vertical Curve	k	18	10	5	3	10
Sag Vertical Curve	k	18	12	8	4	12
Normal and Shoulder Crossfall (Unpaved)	%	4	4	4	4	4
Right of Way	m	30	30	30	30	40

Table 2-9: Geometric Design Parameters for Design Standard DS7 (Unpaved)

Design Element	Unit	Flat	Rolling	Mountainous	Escarpment	Urban/Peri-Urban
Design Speed	km/h	60	50	40	30	50
Min. Stopping Sight Distance	m	85	55	45	30	55
Min. Passing Sight Distance	m	225	175	125	75	175
% Passing Opportunity	%	20	20	15	0	20
Min. Horizontal Curve Radius	m	125	85	50	30	85
Transition Curves Required		No	No	No	No	No
Max. Gradient (desirable)	%	6	7	10	10	7
Max. Gradient (absolute)	%	8	9	12	12	9
Minimum Gradient	%	0.5	0.5	0.5	0.5	0.5
Maximum Superelevation	%	8	8	8	8	4
Crest Vertical Curve	k	18	10	5	3	10
Sag Vertical Curve	k	18	12	8	4	12
Normal and Shoulder Crossfall (Unpaved)	%	4	4	4	4	4
Right of Way	m	30	30	30	30	30

Table 2-10: Geometric Design Parameters for Design Standard DS8 (Unpaved)

Design Element	Unit	Flat	Rolling	Mountainous	Escarpment	Urban/Peri-Urban
Design Speed	km/h	60	50	40	30	50
Min. Stopping Sight Distance	m	85	55	45	30	55
Min. Passing Sight Distance	m	225	175	125	75	175
Min. Horizontal Curve Radius	m	125	85	50	30	85
Transition Curves Required		No	No	No	No	No
Max. Gradient (desirable)	%	6	7	10	10	7
Max. Gradient (absolute)	%	8	9	12	12	9
Minimum Gradient	%	0.5	0.5	0.5	0.5	0.5
Maximum Superelevation	%	8	8	8	8	4
Crest Vertical Curve	k	18	10	5	3	10
Sag Vertical Curve	k	18	12	8	4	12
Normal and Shoulder Crossfall (Unpaved)	%	4	4	4	4	4
Right of Way	m	20	20	20	20	20
Max. Spacing of Passing Bays	m	500	500	500	500	500
Design Vehicle	DV 2/3					

Table 2-11: Geometric Design Parameters for Design Standard DS9 (Unpaved)

Design Element	Unit	Flat	Rolling	Mountainous	Escarpment	Urban/Peri-Urban
Design Speed	km/h	60	40	30	20	40
Min. Stopping Sight Distance	m	85	45	30	20	45
Min. Passing Sight Distance	m	225	125	75	50	125
Min. Horizontal Curve Radius	m	125	50	30	15	50
Transition Curves Required		No	No	No	No	No
Max. Gradient (desirable)	%	6	7	13	13	7
Max. Gradient (absolute)	%	8	9	15	15	9
Minimum Gradient	%	0.5	0.5	0.5	0.5	0.5
Maximum Superelevation	%	8	8	8	8	8
Crest Vertical Curve	k	18	5	3	2	5
Sag Vertical Curve	k	18	8	4	2	8
Normal and Shoulder Crossfall (Unpaved)	%	4	4	4	4	4
Right of Way	m	20	20	20	20	20
Max. Spacing of Passing Bays	m	500	500	500	500	500
Design Vehicle	DV 2/3					

Table 2-12: Geometric Design Parameters for Design Standard DS10 (Unpaved)

Design Element	Unit	Flat	Rolling	Mountainous	Escarpment	Urban
Design Speed	km/h	60	40	30	20	40
Min. Stopping Sight Distance	m	85	45	30	20	45
Min. Passing Sight Distance	m	225	125	75	50	125
Min. Horizontal Curve Radius	m	125	50	30	15	50
Transition Curves Required		No	No	No	No	No
Max. Gradient (desirable)	%	6	7	14	14	7
Max. Gradient (absolute)	%	8	9	16	16	9
Minimum Gradient	%	0.5	0.5	0.5	0.5	0.5
Maximum Superelevation	%	8	8	8	8	8
Crest Vertical Curve	k	18	5	3	2	5
Sag Vertical Curve	k	18	8	4	2	8
Normal and Shoulder Crossfall (Unpaved)	%	4	4	4	4	4
Right of Way	m	20	20	20	20	20
Max. Spacing of Passing Bays	m	500	500	500	500	500
Design Vehicle	DV 1					