JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

HIGHWAY ENGINEERING STREAM

Road Safety Audit In Relation To Road Geometric Design Parameters: Case Study on Shashemene-Wendogenet-Gemeto Road

A Thesis Submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Highway Engineering.

By

Rena Dedefo

June/2017,
Jimma, Ethiopia

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June, 2017

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SCHOOL OF POST GRADUATE STUDIES
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As member of the examining board of the final MSc open defense, e certify that we have read and evaluated the thesis prepared by Rena Dedefo entitled: Road Safety Audit In Relation to Road Geometric Design parameters: Case study on Shashemene-Wendogenet-Gemeto Road, recommended that it be accepted as fulfilling the thesis requirements for the degree of masters of science in highway engineering.

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Declaration

I, the undersigned, declare that this thesis entitled “Road Safety Audit In Relation To Road Geometric Design Parameters: A Case Study of Shashemene-Wendogenet-Gemeto road .” is my original work, and has not been presented by any other person for an award of a degree in this or other University, and all sources of material used for thesis have been duly acknowledged.

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As Masters research advisors, we hereby certify that we have read and evaluated this MSc.

Research prepared under our guidance, by RENA DEDEFO BUTA entitled Road Safety Audit In Relation To Road Geometric Design Parameters: A Case Study of Shashemene-Wendogenet-Gemeto road.

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

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Abstract

One of the factors that cause road traffic accident is geometric elements of road. Even though there is a big concern on the issue there are no enough studies taken place on evaluating the safety of road. So as to be safe enough or improve the safety of existing road there should be road safety audit. But so far the road safety audit on the existing road of Shashemene-Wendogenet-Gemeto has not been conducted.

This study focus on proactive approach rather than reactive one; which is conducting road safety audit. The aim of this study was to conduct the road safety audit of an existing road Shashemene-Wendogenet-Gemeto road, road segment located between West Arsi Zone of Oromia And Sidama Zone of South Nation Nationalities and Peoples Region and assessing the existing road facilities with respect to geometric design elements.

The study has taken as built data from ERA as population. The as built document has been gathered and then site inspection have been conducted. After analyzing the primary and secondary data the road safety audit report in general and relating with geometric elements of the road have been prepared. After assessing the hazardous condition of the geometric elements that could be risk of accident recommendations have been given.

The Audit Report revealed that there is inadequate shoulder width, lack of pedestrian facility and non-motorized vehicles use the main road way. There is also lesser (SSD) and (PSD) at two curves against required Stopping Sight Distance (SSD) and Passing Sight Distance (PSD). As a whole, this corridor is assessed as hazardous mainly due to 85th percentile speed, significant variance of speed between locations and also within the same type of vehicles (average speed of bus, truck, small standard motorized vehicles and non-standard vehicles was found to vary observance of motorized vehicles' . As site audit shows various hazardous conditions at built-up areas and at rural. There is lack of implementation of sign post as it is stated on as built data. On two bridges guardrails have not provided and as a whole no sign post for bridge approaching

In this study attempts are made to assess safety hazards of a selected highway section of Ethiopia i.e. Shashemene-Wendogenet-Gemeto Highway using road safety auditing approach. Based on findings of the study, conclusion and recommendation of the researcher have been stated.

Keywords: Design speed, Road Alignment, Road Safety Audit, Sight Distance

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ACRONYMS

AADT	Annual Average Daily Traffic
ECA	Economic commission for Africa
ERA	Ethiopian road authority
EMSB	Environmental monitoring safety branch
FHWA	Federal highway administration
IFRC	International federation of Red Cross
IHT	Institution of Highways & Transportation
NMV	Non-Motorized Vehicle
NZTA	New Zealand transport agency
PSD	Passing Sight Distance
RSA	Road safety audit
RSARs	Road safety audit review
SSD	Stopping Sight Distance
SNNP	South Nation Nationalities people
UN	United nation

CHAPTER- ONE
INTRODUCTION

1.1 Background

Roads are one way of transportation of goods and people from one place to another. As it plays a great role in economic growth, it also has become the main health issue of mankind and cause of economic loss.

Road traffic injuries are a leading cause of preventable death. Globally, road traffic crashes are a leading cause of death among young people, and the main cause of death among those aged 15–29 years (WHO 2015).

In developed countries the rate of road traffic accident is decreasing as compared to developing one. For instance in the first decades of the 21st century most member countries of the International Transport Forum saw the lowest level of fatalities due to road traffic accident. Overall, the number of people killed on road in 2013 declined by 5% in the 34 countries. Only one of those countries reported an overall increase of its fatalities from 1995 to 2013 (International Road Transport Forum, 2014).

Road accidents do not cause only losses in lives of productive members of the population and a substantial number of disabilities and injuries but also generate a gigantic loss to the country's economy, the total national economic loss resulting from road accidents to be estimated as 1.87 Billion Birr which is equivalent to 145.07 Million USD considering the exchange rate of the same year, or approximately 0.49 percent of the gross domestic product of the country in the same year (Murad, 2011).

Six years (July 2005 - June 2011) of police-reported crash data were analyzed, consisting of 12,140 fatal and 29,454 injury crashes on the country's road network. The 12,140 fatal crashes involved 1,070 drivers, 5,702 passengers, and 7,770 pedestrians, totaling 14,542 fatalities, an average of 1.2 road user fatalities per crash. An important and glaring trend that emerges is that more than half of the fatalities in Ethiopia involve pedestrians (Getu, 2013).

Implementation of road safety activities, though generally perceived as important, was not always given the priority it deserved. It is not uncommon that in some countries, the lead implementing agency is more concerned with completing the road works portion of the project and neglects implementation of the safety subcomponents until it is too late to complete them before project closure (World Bank, 2014). Road safety audits help to improve the number of high severity crashes that occur because of design deficiency and make self-explaining safe road.

1.2 Statement of the Problem

Road safety crisis have become a global concern. Currently estimated to be the ninth leading cause of death across all age groups globally, road traffic crashes lead to the loss of over 1.2 million lives and cause nonfatal injuries to as many as 50 million people around the world each year. Nearly half (49%) of the people who die on the world's roads are pedestrians, cyclists and motorcyclists. Road traffic crashes are the main cause of death among people aged between 15 and 29 years (WHO, 2017).Organizations like WHO and IFRC are calling every country for an action to decrease the fatalities caused by road traffic accident and make roads safer for everyone.

Some studies have been done on identifying the cause of traffic accident generally but emphasis is on the road user and effects of road geometry have been shadowed by driver behavior and other factors although geometric design parameters have a big impact on number of accidents there is no much study conducted in our country. As Shashemene-Wendogenet-Gemeto road is a part of highway segment that starts from the city of market province, destination city from four direction and the way to tourist destination Wendogenet there is huge traffic with leading number of vehicle from other roads under ERA Shashemene district but in contrast the safety subcomponents are very less when compared to other road segments which would increase the risk of accident.

Most of the time studies conducted on traffic accident try to use black spot identification method to know the risk area but the available data from police station have lack of recording the place of accident occurrence this make the quality of data lower than expected. The road safety audit which is conducted on this study is advantageous in that there is no need of black spot data to conduct it. These study cross check the geometric design parameters with the data gathered from primary and secondary sources.

1.3 Research questions

1. What safety considerations have been included during design of Shashemene-Wendogenet-Gemeto road?
2. What are the safety conditions and adverse effects of geometric design elements on safety of the existing road?
3. What are the possible safety considerations to be included in relation to geometric parameters to enhance safety performance of the road?

1.4 Objective

1.4.1 General objective

The main objective of this study is to evaluate the safety of Shashemene-Wendogenet-Gemeto Road with respect to geometric parameters.

1.4.2 Specific objectives

The specific objectives of the study include:

1. To identify safety considerations during design of the road;
2. To assess the safety condition and adverse effect of geometric design on the safety of existing road; and
3. To recommend the possible safety measures to be taken.

1.5 Scope of the Study

These studies give emphasis on evaluating the road safety audit of existing road from the perspective of geometric design parameters. The study only focused on the geometric design elements that affect the safety of the existing road and it is not about checking the detail design of the road as per the standard. The study was focused on evaluating the safety of only Shashemene-Wendogenet-Gemeto road without including access roads as a case.

1.6 Significance of study

The concern of safety of road is globally and nationally very high. Therefore this study would help to evaluate the safety of specific road Shashemene-Wendogenet-Gemeto as a case.

This study identified that whether existing road is safe enough by cross checking the geometric design parameters by using road safety audit. The study helps Ethiopian Roads Authority to take counter measure on the existing safety problem of the study area and improve the safety state of the road. As it is known to have safer road is beneficial locally and nationally to decrease future accident, life lose and economic lose.

1.7 Organization of the research

The report paper is organized in to five chapters. The first chapter is introduction to the paper and it includes background, statement of problem, research question, general and specific objectives, scope of the study, significance of the study, organization of the research and limitation of the study.

Chapter two reviewed literatures of previous researchers, guidelines and standards. The chapter included definition of road safety and its benefit, the concept of proactive approach, process of road safety audit and other related topics which reinforce the research paper.

The third chapter is about methods and materials used on the research paper. First the chapter briefly describes study area and then Methodological Consideration in the Research have been described. Collected data is described depending on its type. Used materials are also stated on this chapter. The fourth chapter is result and discussion which include potential hazards observed during site inspection, comparison of ERA design parameter and existing condition of road geometry, shoulder width in percentage, obstruction less than 1.5 meter from inner lane and discussion about road alignment and cross section.

The final chapter, chapter five discuss the conclusion and recommendation of the researcher. In this chapter from the result and conclusion recommendation of possible counter measures have been stated in order to give a direction for the stakeholders.

1.8 Limitations of the study

As the aim of this study is evaluating the road safety in relation to geometric design parameters; the problem faced during the study is lack of data. There is very limited road data i.e. only a hard copy of as built drawing and few progress reports; this made the data analysis very tedious. The other challenge faced during site surveying is corresponding as built data with handy GPS data to calculate sight triangle with distance of obstruction.

CHAPTER-TWO

LITERATURE REVIEW

2.1 Introduction

Road accidents are complex events involving a variety of factors, including highway geometry, driver behavior, weather conditions, speed limits and human factors (Watters, 2007). The African Region remains the least motorized of the six world regions, but suffers the highest rates of road traffic fatalities, with 37 of 44 surveyed countries having death rates well above the global average of 18.0 deaths per 100,000 population. While the regional average is 24.1 deaths per 100, 000 population, for the 19 countries in the middle-income category, covering 44 percent of the Region's population, the rate is 27.8 deaths per 100 000 population. By comparison, the global average for middle-income countries is 20.1 deaths per 100 000 population. Democratic Republic of Congo , Ethiopia, Kenya, South Africa, Tanzania, and Uganda, are responsible for 64 percent of all road deaths in the region (The Facts, 2013).

Road traffic accident remains to be one of the critical problems of the road transport of Ethiopia without due consideration. Although the traffic accident death rate per ten thousand motor vehicles (95 in 2007/8) is showing a decreasing trend in recent years, it still puts Ethiopia on the extreme high side of the international road safety scene. In the last Ethiopian fiscal year (2007/8), for example, police reported 15,086 accidents which caused the losses of 2,161 lives. Up to 2005/6, traffic accidents and fatalities increased at 17 percent and 10 percent per year respectively, but in the recent couple of years there is a sudden drop (Economic Commission for Africa, 2009). Roads designed to standards are not safe, not unsafe, nor are they appropriately safe; roads designed to standards have an unpremeditated level of safety (Hauler, 1999).

One of the most important measures for the reduction of fatalities is to put in place a good infrastructure regime. By comparing desirable standards for Safe Road Infrastructure Design with undesirable standards for each of the key elements, engineers can play a crucial role in building safer roads. Uniformity of standards is a key element in design of safe roads (Kapila, 2013).

Getu (2013) states that crashes occurred by category of age, sex, road environment, day time. Inter-state and city roads accounted for 70.5 percent of fatal crashes. Most of these are paved two-way two-lane roads. The road environment data is putted on table 2.1;

Table 2.1 Crash occurred by category due to road environment

Alignment,Junction Type and illumination conditions	fatal	%	injury	%
lane/medians				
one way	3020	24.88	6391	21.7
undivided two way	7278	59.95	16631	56.46
double carriageway(median)	1482	12.21	5335	18.11
two-way (divided with solid lines road marking)	236	1.94	727	2.47
two-way (divided with divided with broken line road	124	1.02	259	0.88
Total	12140	100	29454	100
road alignment				
Tangent road with flat terrain	7,913	65.18	19832	67.33
Tangent road with mild grade and flat terrain	1,166	9.6	2797	9.5
Tangent road with mountainous terrain and	348	2.87	816	2.77
Tangent road with rolling terrain	337	2.78	909	3.09
Gentle horizontal curve	587	4.84	1,325	4.5
sharp reverse curve	525	4.32	1,069	3.63
steep grade up ward with mountainous terrain	515	4.24	990	3.36
steep grade down ward with mountainous terrain	669	5.51	1,478	5.02
other	80	0.66	238	0.81
Total	12,140	100	29,454	100

2.2 Some Basic Fundamentals about Road Safety Auditing

2.2.1 Background of Road Safety Audit

The road safety audit process was initiated when road safety engineers realized that they were carrying out accident remedial schemes on relatively new roads. Adopting the principle of "prevention is better than cure", they decided to use some of the safety experience they had gained from the remedial work, and design safety into new road schemes. Highways and Transportation (IHT) Guidelines on Accident Investigation and

Prevention produced during this time included a section on “safety checking", suggested as an accident prevention mechanism (NRA, 2007) in subsequent articles, some basic fundamentals are discussed to gain comprehensive knowledge on road safety auditing.

2.2.2 Definition of Road Safety Audit

A Road Safety Audit is a formal, systematic, independent assessment of the potential road safety problems associated with a new road scheme or road improvement scheme (IHT 2008). The RSA is a formal systematic road safety assessment or “checking” of a road or a road scheme. It is a systematic procedure that brings traffic safety knowledge into the road planning and design process to prevent traffic crashes(ERA , 2004). Road safety manual for Africa (2014) states that ‘’RSAs are a valuable tool to review the features or character of a new road or improvement scheme during its development and help identify aspects of the design that may have an adverse impact of the safety of anyone who will use the road after it is completed’’.

2.2.3 Benefits of a Road Safety Audit Program (ERA, 2005)

The benefit-cost ratio of implementing RSA is found to be as high as about 15 to 20:1 in developed countries and it is believed that the ratio could be even higher if properly implemented in developing countries. Experiences show that the maximum cost for RSA is in the order of 4 percent of the total road project cost. However, this has to be set against the potential benefits such as:

i) Savings in the time and cost by changing project details at the planning and design stage rather than the more expensive option of removing or changing road infrastructure once installed;

ii) Reductions in the number of accidents and the consequent savings in road accident-related costs; and

iii) Reductions in possible litigation costs.

In general, available evidence suggests that the costs of changes introduced as a result of the RSA are significantly outweighed by the benefits accruing from such work.

2.3 Related Issues of Safety Audit

Some important issues related to road safety audit are discussed in the subsequent articles.

2.3.1 Breaking the Accident Chain

Human, road environment and vehicle factors often combine in a chain of events which result in accidents. Figure 2.1 shows 'accident chain'. Addressing the road environment factors through road safety audit allows breaking such a link in the chain of events in accidents (AUSTROADS, 2002).

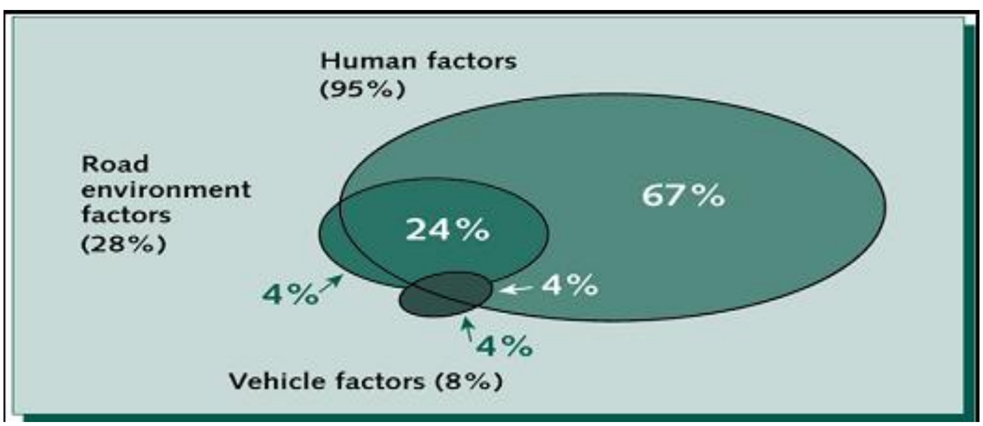

Figure 2.1: Accident Chain

2.3.2 Application of Road safety Audit

The RSA can be applied to all kinds of road projects – new road construction as well as rehabilitation of existing roads. It can be applied to small and large projects and used on rural as well as urban roads. The RSA can be applied to specific operating and maintenance activities on existing roads as well as for systematic assessment or road safety aspects on existing roads and road networks.

2.3.3 The Proactive Approach Concept

Proactive approaches can be useful where crash data are not yet available or where details such as precise crash coordinates are not recorded. While proactive approaches are useful, they do not replace the need for good quality crash data to guide and direct road safety practices. They can be used while the quality and availability of crash data is improved, or as a complementary approach to those described in the existing roads. Road Safety Audit is a Part of a Road Safety Strategy (Road safety manual for Africa, 2014)

2.3.4 RSA and the Safe System

The Safe System needs to ensure that road users that enter the 'system' (in an overall sense) are com-patent, alert and compliant with traffic laws. This is achieved through road user education, managing the licensing of drivers and taking action against those who break the rules. Once drivers enter the Safe System, there are three core elements that need to work together to protect human life:

- Safe vehicles: Vehicles that have technology that can help prevent crashes (for example electronic stability control and Anti-lock Braking System (ABS) brakes) and safety features that protect road users in the event of a crash (for example airbags and seatbelts). This requires the promotion of safety features to encourage consumers and fleet operators to purchase safer vehicles.
- Safe roads: Roads that are self-explaining and forgiving of mistakes to reduce the risk of crashes occurring and to protect road users from fatal or serious injury. This requires roads and road-sides to be designed and maintained to reduce the risk and severity of crashes.
- Safe speeds: Vehicles travel at speeds that suit the function and the level of safety of the road to ensure that crash forces are kept below the limits where fatal or serious

injury results. This requires the setting of appropriate speed limits supplemented by enforcement and education.

The Safe System philosophy requires a shift in thinking away from blaming the driver for the mistakes they make. The Safe System challenges those responsible for designing the road transport system to share the responsibility so as to manage the interaction between road users, vehicles, travel speeds and roads.

2.3.5 Road Safety Audit as a solution

The RSA is only a check of road safety aspects and is not concerned with monitoring whether a certain road standard has been followed or checking whether drainage, structural strength, and other elements are appropriate for that road and location. Essential Elements of a Road Safety Audit. The RSA is also focused only on "accident prevention" and does not usually address the separate issue of "accident reduction". For safe road networks to exist, it is necessary to carry out both accident prevention (using the RSA) and accident reduction (using hazardous location improvement programs). The RSA alone cannot solve all safety concerns but can play an important part in preventing the circumstances that can lead to road accidents(ERA, 2004).

2.4 Review of guide lines

According to ERA (2004), the process typically consists of various steps or stages described below.

i. Initiating the Audit : The ERA (client) will usually commission an RSA but in some cases (where it may have been written into the design contract) this may be done by the designer or even by donors or an external funding agency directly. The EMSB within ERA may organize the audit, audit themselves or if they may find it more convenient, subcontract such work to specialist consultants.

ii. Gathering the Project Reports and Plans

The designer must supply the auditor with the necessary information for a thorough audit. This will include feasibility study, Environmental Impact Assessment, engineering design reports, drawings, etc. The information needed for each RSA stage is listed in Appendix 3 at the top of the checklists for each audit stage.

iii. Studying the Plans

The auditor reviews the plans and makes a preliminary assessment of potential safety concerns and issues based on the information provided, together with his/her knowledge and experience. Some preliminary discussions with designers during the commencement meeting can help clarify reasons for particular design decisions and allow the auditor to explain his/her role and the audit process.

iv. Undertaking the Audit

Using appropriate checklist (depending upon the stage), the auditor first reviews the plans and documents. The auditor then visits the site and carries out an audit, identifies any road safety concerns (referenced by chainage), and suggests ways of minimizing them. The audit findings are recorded in a formal report and given to the designer and to the client. Although the report should give a clear indication of what needs to be done and possible alternatives, it is not necessary for the auditor to provide detailed designs-that is the designer's job. However, appropriate diagrams, sketches, and annotated copies of plans can be included in the report.

v. Completion

The designer will now need some time to review the problems and issues raised in the auditor's report to see which of the recommendations to adopt and identify those that might be difficult to implement. At this stage, it may be beneficial for the designer and the auditor to meet and see whether all issues can be resolved to both parties'

Satisfaction. If any issues remain unresolved, the designer presents the area of disagreement to the client, who makes the final decision. The designer then describes and records any modifications to the project and the audit is then complete. The recommendations made and agreed changes are rechecked at the commencement of the next stage of the RSA.

NRA (2007) categorize Road safety audit process as follows:

1. **Audit Team Make-up:-** A Road Safety Audit Team should comprise at least two people who are independent of the Design Team. This independence is vital to ensure that the Design Team does not influence the recommendations of the road safety audit and therefore compromise safety at the expense of another issue. Team members should have recent relevant experience of undertaking road safety audits and should also have more general road safety engineering experience. In most situations the Audit Team will comprise a senior person who will adopt the role of Audit Team Leader. The second person in the team will be the Audit Team Member.
2. **Audit Team Approval:-** Applications for approval of audit teams must be submitted on the standard form
3. **Site Visits Including Stage 3:-** A site visit must be carried out at the first audit stage being undertaken by an audit team. Site visits must also be carried out at Stage 2 unless otherwise agreed with the Scheme Project Manager, and always at Stage 3. These should be carried out by all members of the audit team together at every stage requiring a site visit. They should take into account the topography, local amenities, tie-ins of the scheme and any other relevant details. Photographs should be collected and stored for future reference.
4. **Checklists: -** Road safety auditors should use when carrying out their work. However, checklists should be used intelligently, and not simply as a “tick box” system. It is recommended that they are used at the end of the process, to ensure that no major potential safety issue has been overlooked.
5. **Road User Role Play: -** One of the most important checks carried out involves assessing the safety of the scheme from different potential road users' perspectives. The road safety auditor should always be asking the question: “What is it about this scheme that will lead road users to fail to cope with the road environment?” During the design stages the auditor has to imagine what it would be like to walk, cycle and drive the scheme. "Driving" should include cars, vans, trucks and buses. "Walking" should be considered from the perspective of the elderly, the child, the wheelchair user and those with sight impairment. Cycling includes children, leisure cycling, and utility or

commuter cycling. Where appropriate, the needs of the equestrian should be considered.

6. **Stages of Audit -**A road safety audit can be undertaken at one or more stages as a design proceeds from concept to implementation. The background, necessity, requirements, significance and implementation of various stages of audits differ considerably. Absence of thorough discussion on each stage of audits deprived all concerned especially potential safety auditors in gaining appropriate knowledge. Stages of audits, being followed are more or less similar amongst various organizations. At Table 2.2, a tabular representation of audits at various stages followed by recognized organizations is shown:

Table 2.2: Audits at Various Stages Followed by Recognized Organizations

FHWA(2006)	**AUSTROADS(2002)**	**IHT(1996)**
Planning Stage Audit(not discussed but prompt list	The feasibility stage audit	The feasibility stage audit
The preliminary design stage audit	The preliminary design stage audit	The preliminary design stage audit
The detailed/ final design stage audit	The detailed design stage audit	The detailed design stage audit
Work zone traffic control plan audit	The pre-opening stage audit	The pre-opening stage audit
Existing road audit	Existing road: Road safety audit	-
Land use development proposals audit	Audit of land use development(prompt list not	-
-	Specialist audits for road user groups (prompt list not	-

2.5 Road Safety Audit of Existing Road

View of FHWA is that traditional safety reviews and investigations of crash history rely primarily on crash data to determine what safety issues are occurring at the site. They are reactive as they mainly identify safety issues after a crash or pattern of crashes have occurred. In contrast, road safety audits of existing roads rely mainly on the site visit, as-built design drawings (if kept up to date), and other project data (e.g., previous reports) to determine what safety issues are expected to arise at the site. For this reason, road safety audits are proactive as they can identify where crashes will likely occur and what will be their resultant severity. According to FHWA, crash data, if available, should be used to supplement any findings made as a result of the site visit and review of project data. However, the road safety audit team may choose not to examine the crash history until after the project data review and site visit have been completed so that their evaluation is not biased by the crash data. Also, crash data is often dated and does not always help in determining emerging operational trends or safety issues at a location.

2.6 The purposes of RSA on existing roads are:

a. Evaluate all roadway and roadside features, design elements and local conditions (glare, night visibility, adjacent land uses, etc.) that would increase the likelihood and severity of a crash.
b. Review firsthand the interaction of the various design elements with each other and the surrounding road network.
c. Observe how road users are interacting with the road facility.
d. Determine if the needs of all road users have been adequately and safely met.
e. Explore emerging operational trends or safety issues at that location.

RSAs of existing roads rely mainly on the site visit, as-built design drawings (if kept up to date), and other project data (e.g., previous reports) to determine what safety issues are expected to arise at the site. This will provide the RSA team with an accurate picture as to the level of safety on the road. Another feature of RSAs of existing roads is that, at the outset, the RSA team will want to consider whether the road facility under review has the same function and classification as it did when it was originally designed and constructed. Changes in traffic volume, vehicle mix, increased presence of vulnerable road users, or adjoining land use developments may have rendered the original classification and design of the facility obsolete. Standards, policies and guidelines may be a starting point for the RSA team in identifying roadway/roadside elements or features that are no longer consistent with the function and classification of the road, and are potentially posing a risk to road users (FHWA, 2006).

2.7 Road safety audit Checklists/Prompt Lists (FHWA 2006)

2.7.1 Purpose of Prompt Lists

The purposes of RSA prompt lists are to help the RSA team identify potential safety issues and to ensure that they do not overlook something important. The prompt lists may also be used by designers to help them identify potential safety issues proactively as they develop their design. RSA prompt lists, even the most detailed ones, should be viewed as a prompt only. They are not a substitute for knowledge and experience; rather, they are an aid in the application of knowledge and experience. The RSA high-level prompt lists appended to this guideline are not all-inclusive, nor will they cover all potential issues and circumstances.

2.7.2 When to Use the Prompt Lists

The prompt lists are for use during RSAs when:

- Reviewing project data, in particular, when project drawings are being examined.
- Conducting site visits.
- Conducting the RSA analysis.
- Writing the RSA report.

During project data and plan review, prompt lists may assist the RSA team in identifying missing information relevant to the scope of the RSA. During pre-construction phase RSA site visits, a review of prompt lists may assist the RSA team in visualizing and assessing how the proposed design will integrate with existing road and environmental features.

During construction phase and post-construction phase RSA site visits, the prompt lists provide a means of ensuring no safety-related elements are over looked. When filled out during project data and plan review, and during the field visits, the information contained in the comment fields of the prompt lists may subsequently be used to facilitate writing the audit report more rapidly and accurately. Prompt lists should not be appended to the RSA report. The written RSA report should contain a sufficient explanation of the identified safety issues, the extent of safety concern, and the resulting suggestions, without any need to refer to notes or prompt lists.

2.7.3 Observing Road User Behavior

When conducting road safety audits of existing roads, the safety audit team will not only observe the various road features and how they complement each other but also see how road users are interacting with the road facility. They may observe incidents of driver behavior that suggest something inherently wrong, misleading, or absent in the road design. Vulnerable road users may be observed having particular difficulty negotiating through a site being investigated.

Alternatively, they may observe motorists committing traffic offenses and may suggest an enforcement or education-based treatment (FHWA, 2006).

2.8 Safety and geometric design parameters

Some of the road geometric design elements that affect the safety of existing road include speed, sight distance, shoulder width, carriage way width, horizontal curve, vertical curve, sign and markings.

2.8.1 Sight distance

Many RTAs occur due to information errors (e.g. the view was obstructed by a tree or the driver didn't perceive the oncoming vehicle due to an incline). In order to minimize the likelihood that such errors occur "the sight distance must be sufficient for a driver to perceive potential hazards which may or may not be conspicuous (Basacik et al., 2007, cited in Dr. phil). Hedman (1990) found that accident rates decrease with increasing sight distance. But if the sight distances are above the stopping sight distance but below the overtaking sight distance drivers may start overtaking maneuvers even though the sight distance is too short for passing.

2.8.2 Shoulder width

Shoulders are the other important factors in road safety. Use of road restraints, signs and sign boards especially in mountainous areas and high density accident areas is vital. Also the effect of road environment is significant in accidents in a way that mountainous roads are 13 times more unsafe than other roads. Moreover, in his study it was shown that adverse weather conditions and the number of cross roads per kilometer do not have major effects in safety of rural roads (Elvik, 2004).

There are several purposes in providing shoulder along the highway; these include accommodating stopped vehicles so that they do not encroach on the travel lane, to make maintenance work, to facilitate access by emergency vehicles and to protect the structural integrity of the pavement. About the impact of shoulder width or shoulder in general there are various opinions in the literature several positive as well as negative aspects are discussed (Hocherman, 2001). Increasing the shoulder width is associated with a decline of accidents. 21% reduction of total accidents was determined on road with shoulders of 0.9m-2.7m compared to road without shoulders (Zegeer, 1981).

Based on experience, drivers are wary of un-stabilized shoulders, especially on high-volume highways, such as suburban expressways. Such experience has led to the replacement of un-stabilized shoulders with some form of stabilized or surfaced shoulders (AASHTO, 2001).

2.8.3 Lane width and number of lane

A feature of a highway having great influence on safety and comfort is the width of the

Carriageway (ERA, 2002). On the other hand, very little has been found on the safety implications of wider lanes. It is reasonable to assume that wider lanes may provide additional space to the driver to correct potential mistakes and thus avoid crashes. However, a driver could be expected to adapt to the available space, and the positive safety effects from the wider lanes may be offset by the higher speeds(Jerry et.al ,2009)

2.8.4 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 are 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 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 (ERA, 2002).

2.8.5 Effect of road Alignment on safety

Various studies show road alignment have a great impact on safety of the road some of them are discussed below

2.8.6 Horizontal alignment

Horizontal curves are causes for concern in all countries. A study in Denmark has found that about 20 per cent of all personal injury accidents and 13 percent of all fatal accidents occur on curves in rural areas; and in France, over 20 percent of fatal accidents occur on dangerous curves in rural areas. Accidents on bends are major problems in many developing countries, although the proportion of such accidents is dependent on both topography and demography of each country(ECA,2009). Association for safe international road travel (2013) reviewed various studies and confirm that there are several elements of horizontal alignment which are associated with horizontal curve safety. The safety of a horizontal curve- its accident frequency and severity- is partly determined by features internal to it (radius or degree of curve, super elevation, etc.) and partly by features external to it (density of curves upstream, length of the connecting tangent sections, sight distance, etc.) that influence driver expectation and curve approach speed.

2.8.7 Vertical alignment

The two major aspects of vertical alignment are vertical curvature, which is governed by sight distance criteria, and gradient, which is related to vehicle performance and level of service. Vertical curves are required to provide smooth transitions between consecutive gradients (ERA ,2002). It may be difficult for driver to appreciate the sight distance available on crust curve and he may overtake when it is insufficient for him to do so safely(Silcock, 1994). This can be extremely expensive to provide safe overtaking sight distances on crust curves. However, a complete ban on overtaking would be difficult to enforce because of the presence of very slow moving vehicles, the lack of driver discipline in selecting places, poor maintenance of road marking and signs. Successive short vertical curves on straight section of road may produce misleading forward visibility(Getu,2007).

Glennon et al (1987) after examining the results of a number of studies in the United States, concluded that grade sections have higher accident rates than level sections, steep gradients have higher accident rates than mild gradients and down gradients have higher accident rates than up gradients.

2.8.8 Safety Barriers

Many accidents on high-speed roads involve vehicles leaving the road and coming into collision with hazardous obstacles such as trees, bridge supports, or simply rolling down a high embankment. Similarly, a vehicle leaving a lane on a dual carriageway runs the risk of collision with an oncoming vehicle. Barriers may also protect roadside facilities from vehicle impact. The risk of these types of accidents can be reduced by the use of safety barriers (guardrails). The purpose of the barrier is to absorb or deflect the impact with as little severity as possible (ERA, 2002). Guard rails are longitudinal barriers placed on the outside of sharp curves and at sections with high fills. Their main function is to prevent vehicles from leaving the roadway. They are installed at embankments higher than 8 ft and when shoulder slopes are greater than 4:1(Gaber, 2009).

CHAPTER-THREE

MATERIALS AND METHDOS

3.1 Description of Study setting/area

The study area is located in between Oromia Region West Arsi Zone and SNNP Region Sidama zone the road segment was built by ERA. The length of the road section is 39 km including access road towards Wondogenet Wabeshebele resort hotel which is 2.72km from Wendo Wesha town. It starts at Shashemene town and passes through Wendo Wesha, Wendo Kella, Basha Teferi, Meribu and finally connected to Gemeto at the main road of Addis-Hawassa-Dilla route junction. The towns and villages section found at chainage 0+0000, 13+000, 17+000, 20+000, 23+000, 25+000 and 36+000 respectively. The design standard of the road segment is DS4 and traffic class of T5.

The climate condition of study area is broadly divided in two climatic zones. The area around Shashemene fall under tropical rainy climate; whereas the area around Wondogenet and Gemeto falls under warm temperature rainy climate. Shashemene have mean annual temperature 10-18°C with annual rainfall 680mm-2000mm and Wendogenet-Gemeto have mean annual temperature greater than 18°C with annual rain fall of 1000mm-2800mm. The study area has long rainy period from the beginning of June to the end of October.

The terrain is 76.32 percent flat, 7.89 percent mountainous, 15.79 percent rolling and the elevation is 1700m-1950m above sea level.

Table 3.1 terrain classification of Shashemene-Wendogenet-Gemeto Road (Source: ERA as built drawing)

STATION		TERRAIN CLASS	DESIGN SPEED
FROM	TO		
0+000	1+000	URBAN	50
1+000	2+000	FLAT	85
2+000	3+000	FLAT	85
3+000	4+000	FLAT	85
4+000	5+000	FLAT	85
5+000	6+000	FLAT	85
6+000	7+300	ROLLING	70
7+300	7+900	MOUNTAINOUS	60
7+900	8+100	ROLLING	70
8+100	9+000	MOUNTAINOUS	60
9+000	11+000	ROLLING	70
11+000	12+000	FLAT	85
12+000	13+000	URBAN	50
13+000	14+000	URBAN	50
14+000	16+400	FLAT	85
16+400	18+100	URBAN	50

18+100	18+820	FLAT	85
18+820	20+748	URBAN	50
21+600	22+600	FLAT	85
22+600	26+200	URBAN	50
26+200	35+000	FLAT	85
35+000	36+042	URBAN	50

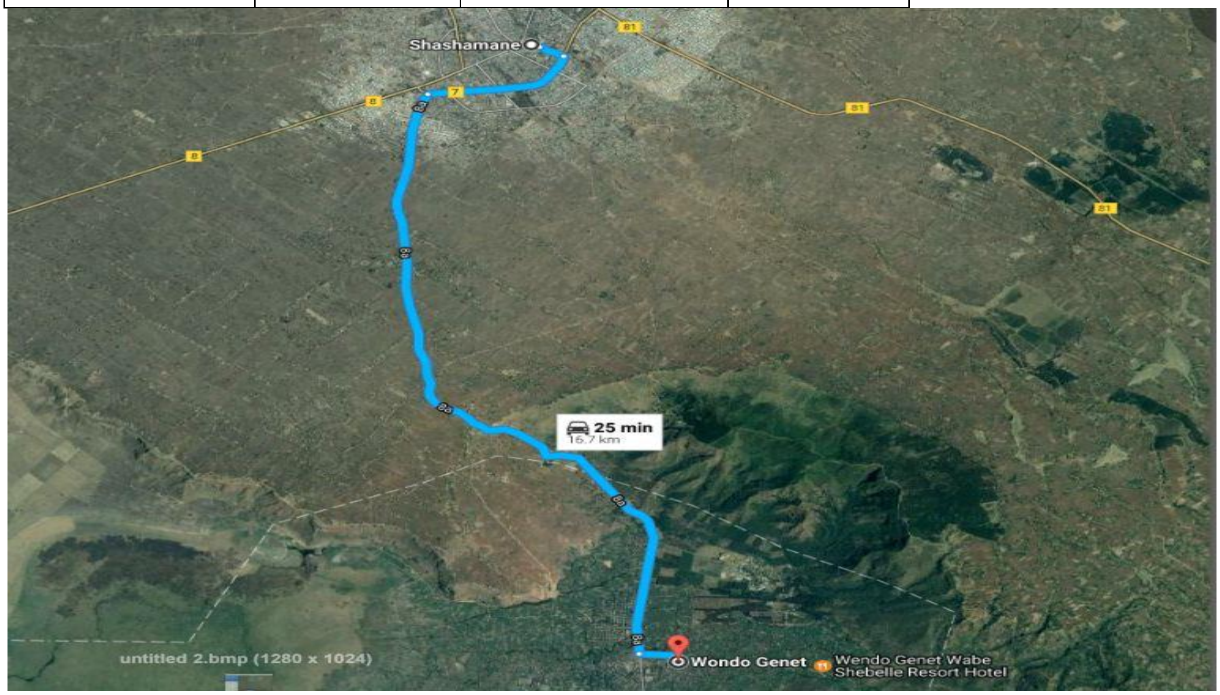

Figure 3.1 Study areas from Google earth maps

3.2 Methodological Consideration in the Research

3.2.1 Road Safety Auditing

Limitation of the Audit Team

The audit team was supposed to be a multi-disciplinary team consisting of experts from various fields. This is a research audit which is done by the researcher and two audit team; one civil engineer and one with other profession (as observer) assigned by the researcher have been involved as an audit team. To compensate for the knowledge of the audit team, the researcher made attempts to gain and develop sufficient knowledge in road safety audit, road safety engineering, accident investigation, traffic management, high way design standards, road user behavior, enforcement, local knowledge etc. and give awareness to the auditors. The research is an attempt to conduct safety audit of an existing road using modified checklists and following the procedures as suggested in various guidelines keeping in view local conditions by relating to road geometric design parameters.

Fig 3.2 audit team on field auditing

Methodology followed for Road Safety Auditing

Collection of Background Information- At first background information about the highway was collected. Design standards, existing policies and guidelines was collected by reviewing literatures and data on Annual Average Daily Traffic (AADT), Statement of Road Condition and as built data was collected from ERA Shashemene area district.

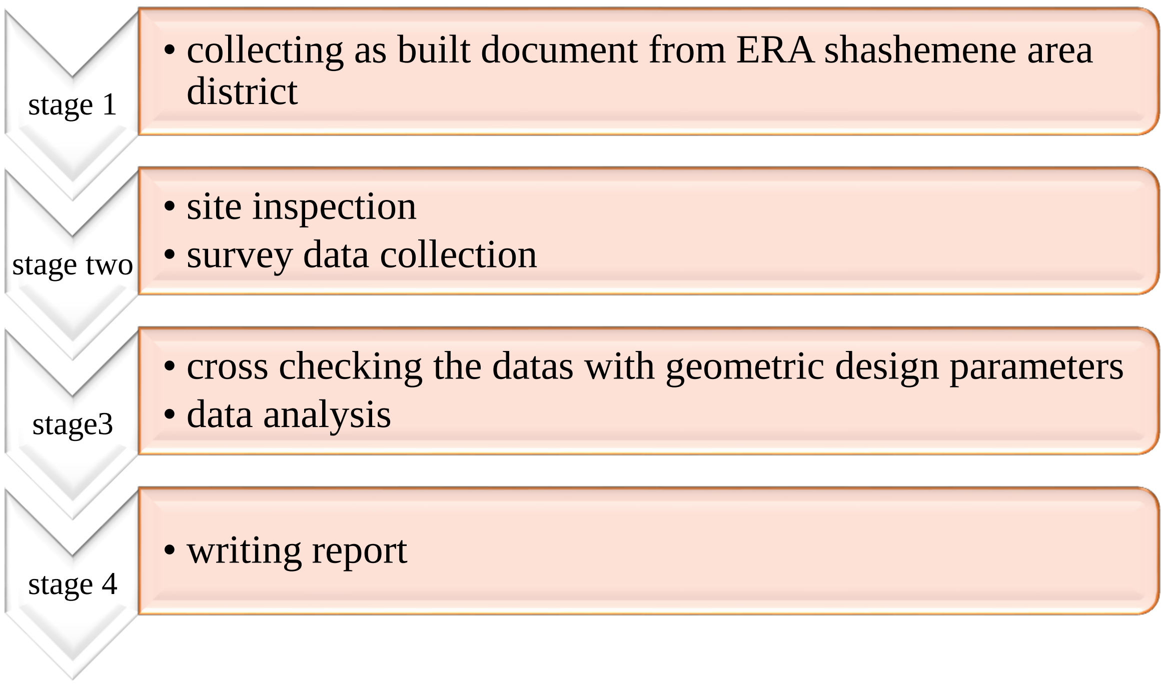

Figure 3.3 research design stage

Review of Data- The review of design drawings and other information regarding the highway was conducted prior to and after the field review. Reviews of the project data and design drawings were normally performed individually by the researcher. Reference to the checklists was made in the process which served as a means of reminding the researcher of relevant aspects of the road safety audit. As a result, during the field review, it was possible to verify identified issues and identify additional safety issues that might not be evident from the design drawings/available data. As built drawing and other data was reviewed to familiarize with the location.

Site Inspection/ Field Review- Inspection of the site was carried out to identify safety deficiencies/ hazards as per the modified checklists. Site inspections included visit to the adjacent sections of the road, collection of data on roadway geometry, operating conditions and other road side features through field survey. Issues identified in the review of project data were verified in the field. Photographs were taken that was reviewed while writing the road safety audit report at later stage. During the field review, all possible movements were considered. On highway, both directions of travel were considered. At intersections, right, through, and left-turning movements on each approach was considered. Pedestrian facilities were also investigated, particularly at points where they came into conflict with vehicular traffic. The interaction of the road users with road environment was observed.

Conduct Audit Analysis and Prepare Report of Findings- Road safety audit analysis was carried out to concisely report the findings of the audit through identification and prioritization of safety issues. Upon completion of the road safety audit analysis, the road safety audit report was written. During field visits, a number of safety issues were identified. Where necessary, the report included pictures and diagrams as may be considered useful to further illustrate points made. References to other reports, standards, policies or published research on road safety are sometimes made within the road safety audit report. The main body of the report contains all of the identified safety issues. Safety issues are sometimes grouped into broad topics that are further broken down into subtopics. Items are listed in the order in the checklists and also grouped by common issues.

Writing the Road Safety Audit Report - Each safety issue identified in the report has a brief description of why it poses a risk under the head ‘problem’. The audit findings and recommendations are written in simple descriptive and tabular formats are used to support the facts. The recommendations usually indicated the nature or direction of a solution, rather than precise details; responsibility for that was left with concerned authority. When framing recommendations, considering the severity of the problem and the cost, feasible solutions were provided. Issues identified are described in terms of where they are located and how they represent a safety risk.

Presenting the finding of the research-Based on the written audit report and as built data review; the finding of the researcher have been discussed. The results of finding and recommendation of the researcher were clearly defined.

3.3 Data Collection Approach

3.3.1 Primary Data

Primary data have been collected from site surveying by visiting the highway segment using checklist or prompt list and in order to emphasize on safety of road with geometric design parameters point of view. Survey data have been gathered for spot speed at three segments which are one at straight section, one around a curve and one at urban section having curve to do the spot speed study.

3.3.1.1 Spot speed survey

The time-mean speed (spot speed) is the average spot speed of several vehicles measured at a given spot. Spot speed data have been gathered systematically by manual method taking 100m road segment at rural and urban at three locations ;both at straight section and at curves were conducted with 10 sampled vehicles at each section from a cross section of the driving public in and around Wendo genet and Shashemene. The study includes bus, Land rover, passenger car, police pickup, minibus and a Bajaj. Tape, notebook and stop watch are used to record spot seed of the segments.

Modal Speed: which is the speed value that occurs most frequently in a sample of spot speeds.

The ith- percentile: Spot Speed which is the spot speed value below which i percent of the vehicles travel; for example, 85th- percentile spot speed is the speed below which 85 percent of the vehicles travel and above which 15 percent of the vehicles travel

Frequency: the rate at which the speed value occurs in the sample of spot speeds.

Cumulative frequency: the increase in frequency in every speed group

3.3.2 Secondary Data

Secondary data have been gained from literature review, by reviewing previous data from revising documents of the existing road from ERA Shashemene district and the consultant TCDSC main office.

3.3.2.1 Traffic Volume Counts

The traffic count was taken from ERA shashemene area district .Twelve - hour classified traffic volume counts were undertaken by two ERA enumerators by the format ordered from ERA head office in three directions, namely Wendo genet Junction to Shashemene, Wendogenet junction to Hawassa and Wendogenet junction to wendogenet. The counts were tabulated and traffic patterns developed using Microsoft Excel spreadsheet. The count includes one market day and one non market day conducted at both day time and night time as ordered by the head office.

Date	Car	L/rover	S/ Bus	L/Bus	S/truck	M/truck	H/truck	T/truck	Total
01/02/17 At day time*	422	463	645	139	452	484	264	246	3115
01/02/17 At night*	85	94	123	19	109	122	29	24	605
02/02/17	451	572	747	111	520	491	242	258	3400
03/02/17	410	579	698	133	540	470	440	347	3617
04/02/17	572	696	792	231	659	577	255	127	3910
05/02/17	557	613	763	151	597	530	240	262	3733
06/02/17	513	574	738	127	587	556	311	254	3660
07/02/17	100	75	132	25	117	111	29	35	624

At night**									
07/02/17 At day time**	527	623	774	166	665	552	371	305	3983
Total	3643	4289	5432	1102	4246	3896	2181	1858	26647
* Market day ** non market day									

Table 3.2 traffic count of wendogenet shashemene (location: w/genet junction, direction: Shashemene)

Shashemene Wendogenet traffic count is the second biggest count following the Wendogenet Hawassa traffic count under ERA Shashemene district roads.

3.4 Data Collection for Road Safety Audit

During field visits, audit data was collected through observation. Data collection approach for road safety audit is discussed below according to the chronology of the headings as appeared in the 'audit report':

Road Alignment and Cross Section

Visibility; Sight Distance: During field visits, data /information was collected through observation. The sight distance along the road was obtained by calculating the values gained from as built data and sight line have been checked by using GPS to obtain the point of tangency and point of curve corresponding with the as built data by compensating the accuracy. The GPS also used to obtain the location of sight obstruction with respect to curve point. The accuracy of the GPS is then compensated to decrease the error.

Vegetation, roadside activities, corner shops, inherent geometric faults were observed which causes inadequate visibility and sight distance.

Fig.3.4 Handy GPS used during site survey

Curve Information: Data regarding curvature radius, various sight distances, road sign, road marking, guide posts, roadside hazards, etc. were obtained from as built data to gain information about possible safety deficiencies. After taking the curvature radius, available sight distance was computed and then compared with standard Stopping Sight Distance (SSD) and Passing Sight Distance (PSD).

Formulas used for SSD and PSD

$$SSD = (0.278)(t)(V) + \frac{V^2}{254f+g}$$ ………………………………..……….Equation no.1

Where

SSD= stopping sight distance in meter

t= driver reaction time, generally taken to be 2.5 seconds

V= initial speed (km/h)

f= coefficient of friction between tires and roadway

g= gradient (the higher of the two i.e back grade and fore grade)

The passing sight distance is generally determined by a formula with four components, as follows:

d_1= initial maneuver distance, including a time for perception and reaction

d_2= distance during which passing vehicle is in the opposing lane

d_3= clearance distance between vehicles at the end of the maneuver

d_4= distance traversed by the opposing vehicle

The formulae for these components are as indicated below:

$$d_1 = 0.278t1(v - m + \frac{at1}{2})$$ ………………………………………………….… Equation 2

Where

t_1= time of initial maneuver, s

a = average acceleration, km/h/s

v = average speed of passing vehicle, km/h

m = difference in speed of passed vehicle and passing vehicle, km/h

$$d_2 = 0.278vt_2$$ ……………………………………………………………Equation 3

Where

t_2= time passing vehicle occupies left lane, s

v = average speed of passing vehicle, km/h

d_3= safe clearance distance between vehicles at the end of the maneuver, is dependent on ambient speeds as per ERA manual 2002 Table 7-2

Table 3.3 clear distance (d3) vs. Ambient speeds ; source ERA ,2002

Speed Group (km/h)	50-65	66-80	81-100	101-120
d_3 (m)	30	55	80	100

d_4= distance traversed by the opposing vehicle, which is approximately equal to d_2 less the portion of d2whereby the passing vehicle is entering the left lane, estimated at: $d_4 = \frac{2d_2}{3}$ ……………………………………………………………..……Equation4

The minimum Passing Sight Distance (PSD) for design is therefore:

$PSD = d1 + d2 + d3 + d4$ ....Equation 5

The values t1,t2 and a gained From AASHTO manual Exhibit 3-5 and m=speed of passing vehicle-speed of passed vehicle (which are gained from AASHTO manual Exhibit 3-7 Passing distance for design of two lane highways)

To calculate sight line, distance of obstruction at a given segment have been measured by tape and the easting and northing of the point at which obstruction restrict the visibility is checked and recorded by using handy GPS. The following Equations have been used to calculate the available sight distance at a specific section.

S=R/28.65[cos-1(R-O/R)]……………………………………………………Equation 6

For s≤ the length of circular curve

Ms=Rv[1-cos 90(SSD)/ΠRv]…………………………………………………...Equation 7

Where

S=sight distance

Rv=radius of vehicles traveled path (usually measured to the center of inner most lane of the road (m)

Ms= middle ordinate necessary to provide adequate sight distance (in meters)

Junctions/ Built-up area /Bus-stand Investigation

These places were critically examined considering location characteristics, visibility, sight distance, controls and delineation, layout and readability (perception) by drivers, pedestrian crossing facilities and other miscellaneous aspects.

Signs

Inventory of existing traffic signs for sign type, size, mounting position, clear height, color, visibility, readability, reflectivity, condition at various locations were made. At various locations, general sign issues, sign legibility, sign supports and appropriate sign for various speed limits were investigated. This enabled to identify sign related safety issues.

Road Marking and Delineations Investigation

Road marking and delineations were investigated at various locations for general issues, centerlines, edge lines, lane lines and other markings, guideposts, reflectors and curve delineation.

Crash Barriers and Guideposts Condition

At various locations especially at curves and bridges including approaches, condition and location of delineator post, guide posts, crash barriers etc were assessed for safety impacts.

Bridge Investigation

Various features related to bridges such as approach alignment, carriageway widths, warning and other signs, control and delineation, footway, pedestrian and Non-Motorized Vehicle (NMV) facilities were examined for safety assessment.

Side Road without any Engineering Treatment

Side roads joining the highways were observed to identify potential safety hazards. Sight distance, level of side roads in comparison to highway, road sign and marking, design standards and requirements were examined in this regard. Necessity of appropriate engineering treatment was identified.

Behavior Observation of Various Road Users

Behavior of various road users' i.e. motorized vehicles, Non-motorized vehicles and pedestrians was observed at mid-block locations, intersections, built-up areas, bridges, curves etc. to assess the safety aspects.

Checklists used in this research

1. Road alignment, cross section and signs
    - Visibility, sight distance
    - Design speed
    - Curves
    - Shoulders
    - Walkway
    - Signs
2. Marking and delineation
    - Centerlines, edge-lines, lane lines
    - Curve warning and delineation

3.5 Study variables

3.5.1 Dependent Variable:

- Road safety audit

3.5.2 Independent Variable:

- Visibility
- Design speed, Spot speed
- Road alignment, cross section ,sign and marking

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1Potential hazards observed during site inspection

Hazardous conditions that can increase the risk of accident have been observed and recorded in two main groups; road alignment and cross section hazards and road side environment hazards as shown in the preceding headings

4.1.1 Road alignment and cross section hazards

During field visit potential hazards have been identified in two subdivisions the first is road alignment and cross section hazard as shown on table 4.1 and the other one is road side environment as shown on subsequent section.

Table 4.1 road alignment and cross section hazards

Hazard number	Description of hazard
1	Absence of shoulder
2	Shoulder less than the required
3	Combination of Sharp curve and bridge
4	Small radius with inadequate widening
5	Absence of pedestrian walkway
6	Unpaved shoulder
7	Absence of bridge guardrail
8	Absence of pedestrian crossing
9	Absence of centerline and edge line delineation
10	Absence of barrier at mountainous areas with non-recoverable slop
11	Absence of sign at curves and bridge approach

4.1.2 Road Side Environment Hazards

Road side environment have been also investigated. The gained result from field visit reveals hazardous conditions as shown on table 4.2

Table 4.2 Road side hazards

Hazard number	Description of hazard
1	Road side vegetation near carriage way restricting sight line
2	Road side development on shoulder
3	Dumping of materials on carriageway
4	Wrong placing of Bajaj station on a curved carriage way
5	Inappropriate commercial activities adjacent to carriage way
6	Random usage of carriage way as Bajaj and taxi station

4.2 Discussion of findings

4.2.1 Visibility; Sight Distance

The sight distance along the road is inadequate or restricted when plantation on the edges of embankments; especially at the inner edge of horizontal curves obstruct the sightlines to stationary objects or oncoming vehicles. At the straight sections, visibility and sight distance is restricted at built-up areas / bus-stands due to parked vehicles and road side developments and activities. Inadequate sight distance results in a shorter reaction and response time available to the driver when the change is sighted which results in a higher crash risk. Road side obstructions restricting visibility occur greatly on rolling and mountainous area having 64.3 percent and 57.6 percent from the given terrain class road length. Obstruction cover which restrict sight distance in urban area appeared to be 2 percent of the length 11.27 as shown on figure 4.1.

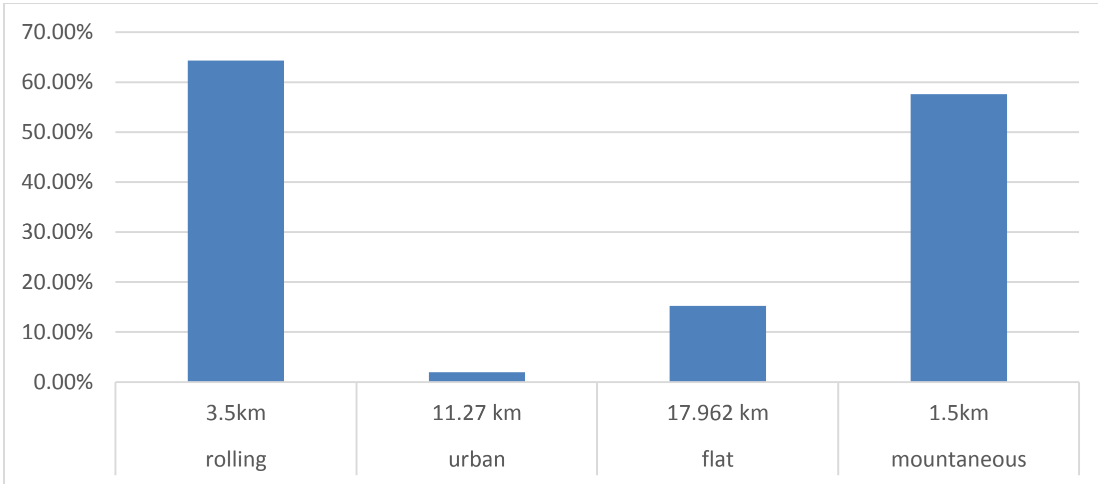

Fig.4.1 percentage of obstruction less than 1.5m form the edge of the lane

4.2.2 Design speed

Design speed cannot be maintained along this highway. According to ERA manual the design Speed of the highway is 85 km/h for flat terrain. Based on 'traffic volume survey and speed study' carried out to determine the speed characteristics along with vehicle composition, at straight section with flat terrain (between Wendogenet Junction and Shashemene at 11+881 up to 11+980), 98^{th} and 85^{th} percentile speed was found to be 69 and 67 km/h [Figure 4.5]. Considering the same vehicle composition, at the curve Wendo werda at station 10+560 up to 10+720, 98th and 85^{th} percentile speed was found to be 64 and 57 km/h [Table 4.3 (below) and Figure 4.4]. Another 'traffic volume survey and speed study' carried out to determine the speed characteristics along with the same vehicle composition at a curve with the terrain class flat at 6+880 up to 6+990 revealed 98^{th} and 85^{th} percentile speed to be 67 and 63 km/h [Table 4.2, 4.3 and Figure 4.6] .

Table 4.3 Spot Speed Calculation at curve Section (from station 10+560 up to 10+720)

Vehile No.	Time coverage to finish the distance in seconds	type of vehicle	spot speed
1	16	bus	36
2	12.177	minibus	47.3
3	13.51	minibus	42.61
4	10.79	Isuzu	53.34
5	15.226	Bajaj	37.83
6	13.016	motor cycle	44.25
7	14.152	Isuzu	40.7
8	11.29	land rover	51.02
9	9.049	Pickup	63.65
10	11.697	Passenger car	49.24

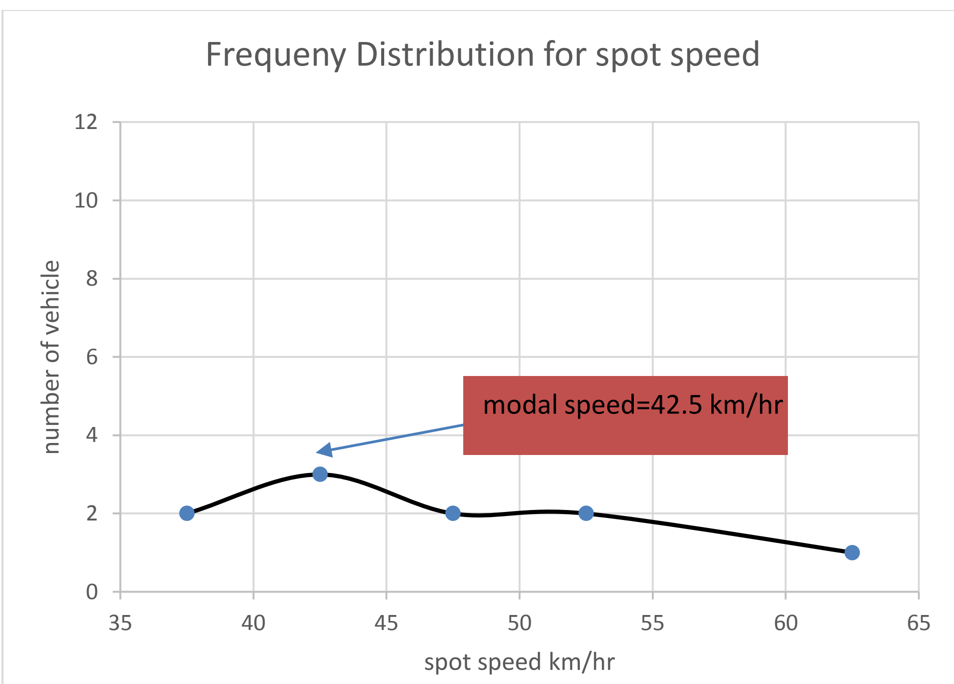

Figure 4.2 Frequency Distribution for Spot Speed at Curve Section

At station 10+560-10+720 from sample of 10 vehicles 30 percent falls under the speed range 40-45 as stated on figure 4.2 and 98 percent of the vehicles travel below 64km/hr as shown on figure 4.3

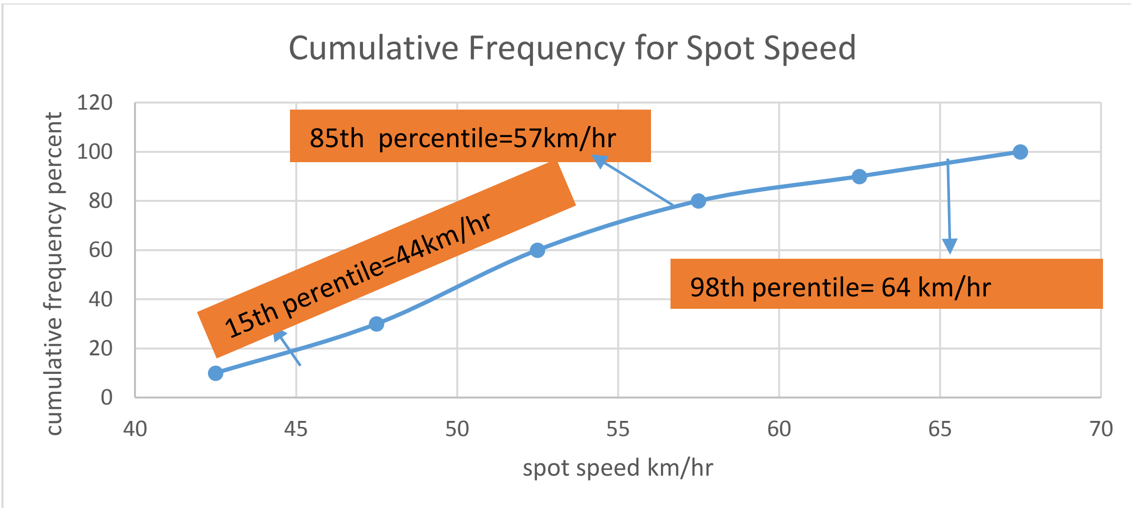

Figure 4.3 Cumulative Frequency Distribution of Spot Speed at curve Section

Spot speed on a straight section reveals that most of the vehicles travel with speed ranging between 65 up to 70 km/hr as shown on table 4.4.

Table 4.4 Spot Speed Calculation at straight Section (Wendo from 11+881 up to 11+980)

Speed range (Km/h)	No. of vehicle observed (f)	Mid-speed, V	percent Frequencies	Cumulative percent frequencies
35-40	2	37.5	20	20
40-45	1	42.5	10	30
45-50	1	47.5	10	40
50-55	1	52.5	10	50
55-60	1	57.5	10	60
60-65	1	62.5	10	70
65-70	3	67.5	30	100
Total	10			

The study shows that 20 percent of the sampled vehicles travels below 40 km/hr speed and 30 percent of them travels with speed ranging from 65-70 km/hr.

From the survey data gathered the modal speed along the straight section is 67.5 as shown on figure 4.4

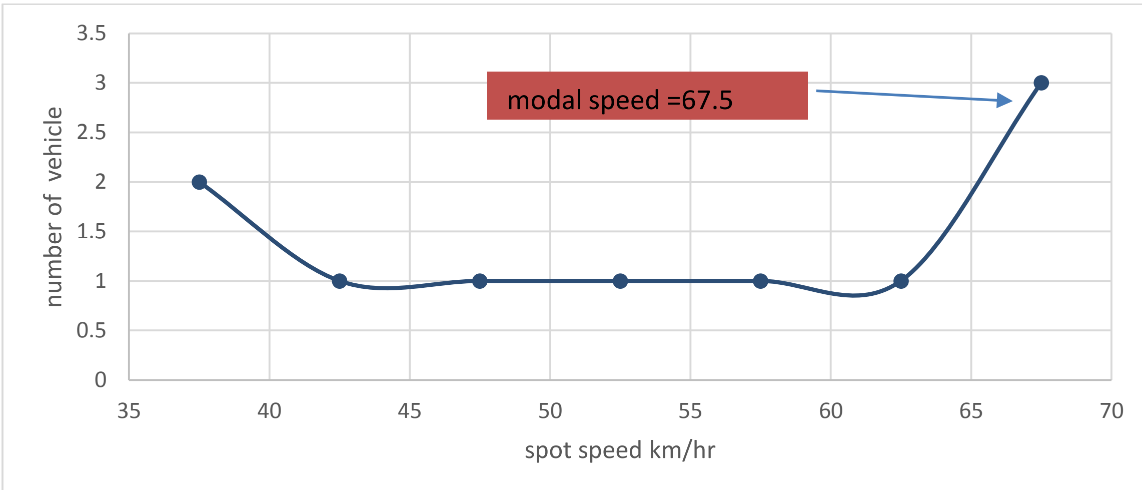

Figure 4.4 Frequency Distribution for Spot Speed at straight Section

From the samples taken, 70 percent of the vehicles travel with speed below 65 km/hr and the 98th percentile speed is 69 km/hr as shown on figure 4.5.

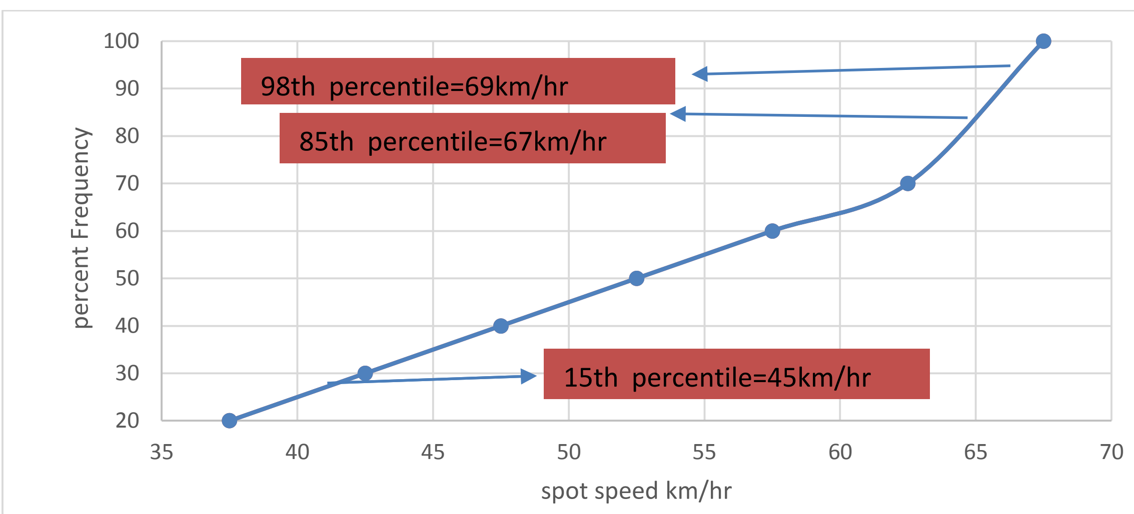

Figure 4.5 Cumulative Frequency Distribution of Spot Speed at straight Section

According to spot speed done on straight section from station 11+881 up to 11+980 the result shows 20 percent of the sampled vehicles travel in the speed range 35-40 and 30 percent of them travels in the speed range 65-70 having modal speed of 67.5 as shown on figure 4.4. 98 percent of the sample vehicles travel under 69km/hr as shown on figure 4.5.

During the study different types of vehicle have been taken as a sample and the time cover to ravel the length is recorded by using stopwatch as shown on table 4.5.

Table 4.5 Spot speed taken at straight section

Vehicle No	Time coverage to finish the selected distance in seconds	Type of vehicle	Spot speed km/hr
1	6.92	Pickup	51.502
2	5.10	Passenger car	69.882
3	6.5	Minibus	54.830
4	6.25	Minibus	57.024
5	8.16	Isuzu	43.676
6	9.25	Bajaj	38.529
7	5.51	Isuzu	64.68
8	7.13	Motor cycle	49.98
9	6.14	Land rover	58.04
10	9.41	Passenger car	37.87

At the second curved section, station 6+880-6+990 the spot speed calculation shows that most of the vehicles travel in the speed range 50-55 and 40-45 as shown on table 4.6.

Table 4.6 Spot Speed Calculation at Curve (between 6+880 and 6+990)

Vehile	Time coverage to	type of vehicle	spot speed
1	6.32	Pickup	62.58
2	9.065	Passenger car	43.68
3	9.228	Minibus	42.91
4	7.552	Minibus	52.43
5	5.921	Isuzu	66.87
6	11.092	Bajaj	35.7
7	7.173	Isuzu	55.2
8	7.471	Motor cycle	53
9	6.870	Land rover	57.64
10	7.294	Passenger car	54.29

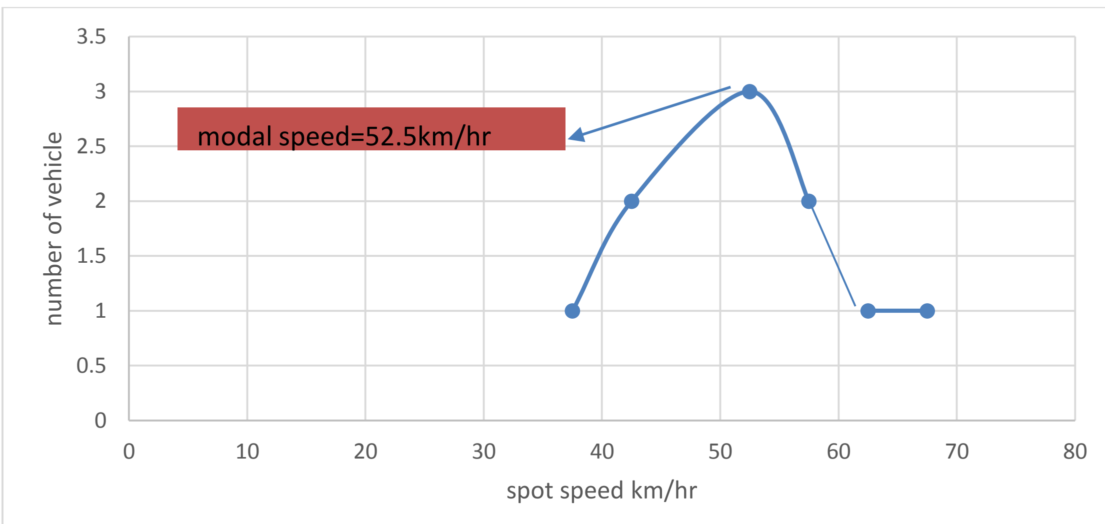

Figure 4.6 Frequency Distribution for Spot Speed at Curve 6+880-6+990

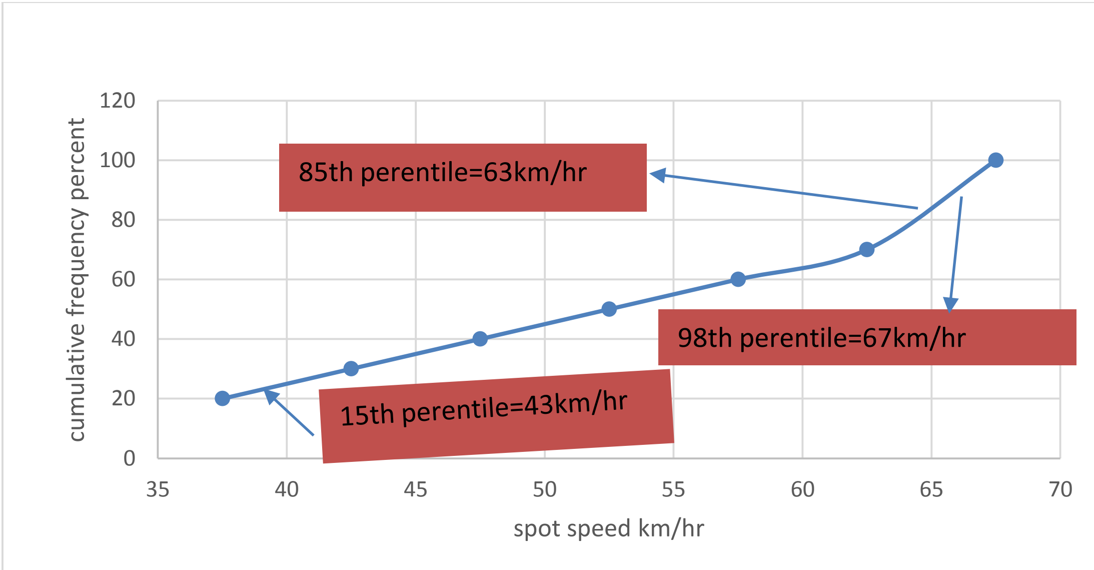

Figure 4.7 Cumulative Frequency Distribution of Spot Speed at Curve (6+880-6+990)

From the speed study, it is found that along this highway, 98th percentile speed varies between 64 to 69 km/h and 85th percentile speed varies between 63 to 67 km/h. This implies that the highway is not capable of maintaining its intended design speed. At present condition, segment-specific speed limit/zoning needs to be applied for safety reasons.

Again modal speeds at curve from 10+560 up to 10+720 (Figure 4.2), at straight section between 11+881 up to 11+980 (Figure 4.4), at curve station between6+880 and 6+990 (Figure 4.6), and were found to be 42.5 km/h, 67.5 km/h and 52.5 km/h respectively.

The speed studies were carried out at free flow condition. The abovementioned speed and vehicle composition analysis reveals significant speed differential arising from heterogeneous vehicle composition

4.2.3 Curves

Adequate clear zone is not provided at any curves. Roadside hazards/objects exist within 1m of the carriageway at Wereda of Goto Anoma, Busa, Wendo Wereda Medo Buanba and Meribu. This observation essentially suggests that drivers of the corridor need extra attention while negotiating these geometric constraints. 43% of radius of horizontal curves are less than 250 m as shown on figure 4.8

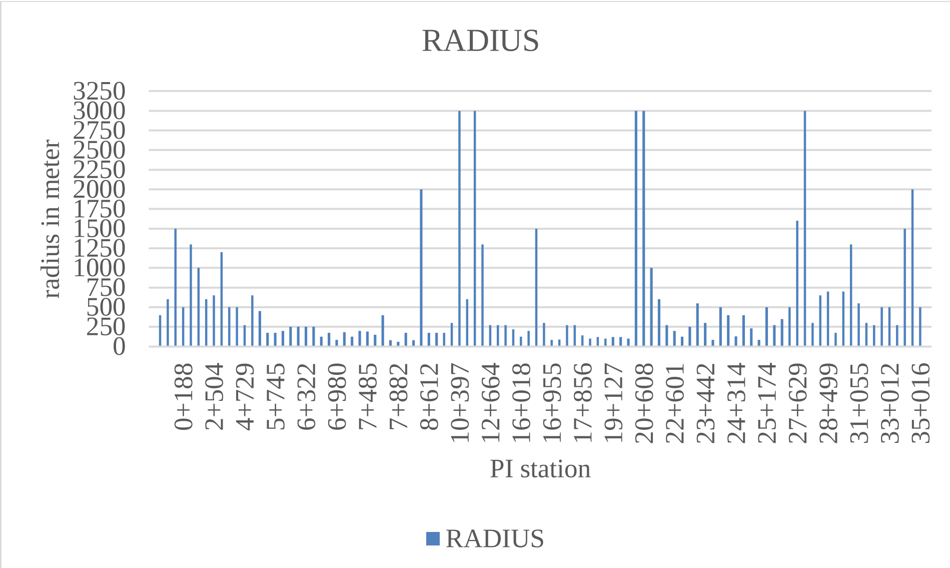

Fig 4.8 Radius of horizontal curve

Determination of Stopping Sight Distance (SSD) and Passing Sight Distance (PSD)

In order to check adequacy of sight distance, at curves, Stopping Sight Distance (SSD) and Passing Sight Distance (PSD) was computed using as built data. At first, required SSDs and PSDs was determined based on data which was then compared with available sight line (determined based on calculation of sight triangle by measuring distance of obstruction gained from field). Detail calculations are shown. The field measurements and calculated sight distances at two curves are shown.

- For kella town at (PI Station 17+725)

The terrain class is urban and the corresponding design speed is 50km/hr and have Radius of 85m .From AASHTO manual for design speed 50km/hr ; the speed of passed vehicle wiil be speed =44 and the speed of passing vehicle =59 (Exhibit 3-7 Passing distance for design of two lane highways)

The stopping sight distance is calculated by using Equation 1 (ERA, 2002 page 7-1)

SSD= (0.278)*(t)*(v) +v2/254f

t=2.5 sec from ERA manual usually considered value from table 7-2 of ERA manual f=0.35 for 50km/hr

SSD= 0.278*2.5*50+ (50^2/254*0.35)

The required stopping sight distance for driver to have clear vision oncoming vehicle or stationary object is 62.878 m

To calculate the passing sight distance Equation 2, 3, 4 and Equation 5 are used as follows

From AASHTO manual Exhibit 3-5 for speed 50-65 average acceleration =2.25

t1=3.6, d1=45, t2=9.3, d2=145, d3=30, d4= 317 or by calculating d1 = 0.278t1 (v-m+at1/2)

d1=0.278*(3.6)*(50-(59-44)+2.25(3.6)/2)

=1.0008(50-15+8.1/2) = 39.3624

d2= 0.278vt2 t2=9.3 =0.278*50*9.3

=129.27

d3= from ERA manual for 50-65 is 30

d4=2d2/3

=2*129.27/3 =86.18

Therefore from Equation 5 the passing site distance calculated is as follows

PSD=d1+d2+d3+d4

=39.3624+129.27+30+86.18=284.812

For Radius 85m and offset length=9.3

Obstruction length at (GPS station Easting= 456993.58, northing= 778641.9 Accuracy =±2m) = 3.3

Beginning of curve=17687.14 and End of curve=17758.39

SSD=ΠRsΔ/180

Rs = R-w/2; Where w is width of inner lane

Rs=85-1.75=83.25

SSD=29.14448 which is less than the required SSD=62.878

- R=500 offset length=14.3(from as-built data), Length of obstruction = 3.5, PI station = 2+237

S=R/28.65[cos-1(R-O/R)]

For s≤ the length of circular curve

S= 500/28.65[cos-1(500-14.3/500)]

=239.720672

Ms=Rv[1-cos 90(SSD)/ΠRv]

SSD for speed of 85km/hr (table 7-2 ERA) =150

Ms=5.6341 should be provided for adequate stopping sight distance but due to vegetation obstruction 3.5 meter from the edge of the inner lane should be removed

Fig 4.9 (a)Goto Anoma restricted sight due due to road side obstruction

Fig 4.9 (b)Lomicha bridge ; restricted site to obstruction

Sample taken from the calculation is tabulated as follows

Table 4.7 calculated sight distance

PI station	radius	Deflection Angele(°)	distance from obstruction	Speed	SSD required	Rs*	SD calculted	Remark
6+811	250	170.8669	2	70	108.65	248.25	740	Sufficient
6+980	250	158.7856	0.3	70	108.65	248.25	687	Sufficient
7+126	125	168.8783	8	60	83.7	123.25	363	Sufficient
7+254	175	168.8783	6.7	70	108.65	173.25	510	Sufficient
7+347	85	38.4794	3	50	62.75	83.25	55	Insufficient
7+485	180	20.05833	4	60	83.7	178.25	62	Insufficient
7+590	125	29.3125	2.3	60	83.7	123.25	63	Insufficient
7+694	200	11.158	1.3	60	83.7	198.25	38	Insufficient
7+787	190	20.356	3.4	60	83.7	188.25	66	Insufficient
7+882	150	10.5747	2.7	60	83.7	148.25	27	Insufficient
8+023	400	176.316	3.7	70	108.65	398.25	1225	Sufficient
8+213	80	40.34972	9	50	62.75	78.25	55	Insufficient
8+417	60	85.50277	1	40	44.8	58.25	86	Sufficient

8+612	175	19.5725	5.6	60	83.7	173.25	59	Insufficient
8+849	80	47.04972	0.5	50	62.75	78.25	64	Sufficient

* Rs= radius of horizontal curve minus half of inner lane width

4.2.4. Shoulders

Along the route inadequacy of shoulder is highly observed the detailed data is shown in table as follows from the 39 km length route only 11.7 percent have adequate shoulder 43.5 percent from0.7- 1m,21 percent 0.3-0.6m shoulder, 23.8 percent no shoulder as shown on figure 4.10

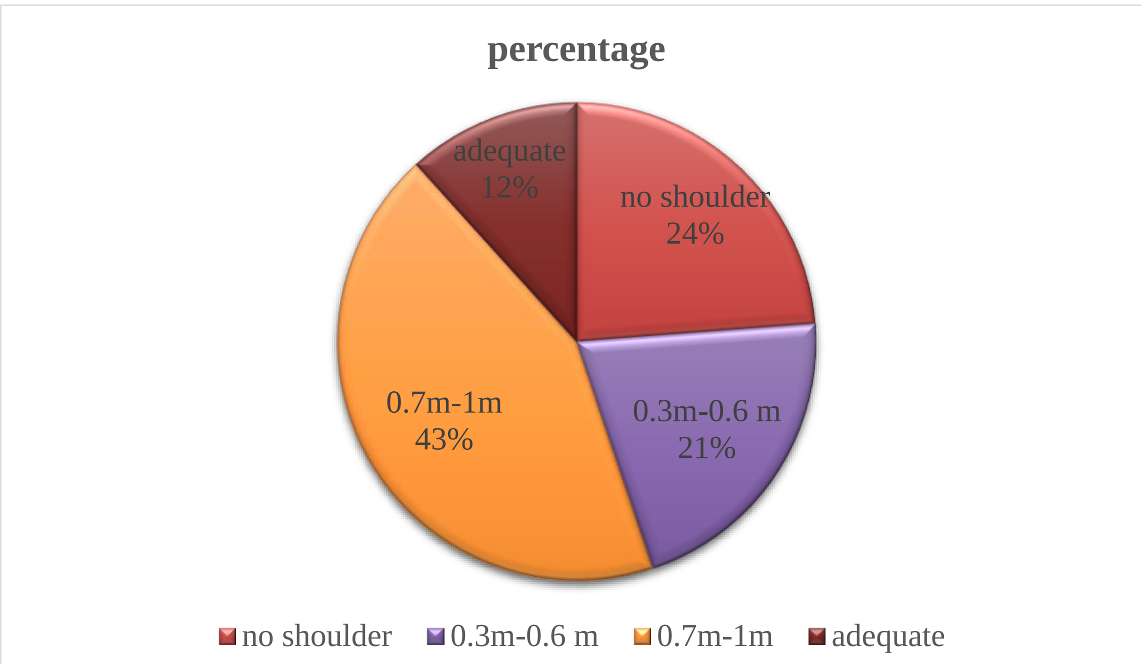

Fig.4.10 percentage of shoulder by width

At some places, due to roadside vegetation and obstructions, effective shoulder width is reduced and as a result, Non-Motorized Vehicles (NMVs) using shoulder comes to the carriageway.

Figure 4.11 Inadequate shoulder width

Figure 4.12 shoulder absent due to vegetation

Fig 4.13 obstructions dumped on the carriage way

4.2.5 Walkway

This highway required 1.5 m wide walkway on each side. Except very rare occasions, walkway is either not available or existing walkway is covered with roadside vegetation or damaged due to soil erosion thus not useable almost throughout the length of the highway. It is observed that at areas with high pedestrian concentration such as built-up area there exists no raised footpath.

Figure 4.14 shoulder is not walk-able or absent due to vegetation

Fig 4.15 No enough space for pedestrians

Fig 4.16 No enough space for Non-motorized vehicle

4.2.6 Markings and Delineations

Lack of delineating edge line, centerline and zebra crossing at 47.3 percent of the rout excluding the 2.7km access road towards Shebele.

Fig 4.17 No center and edge line and zebra crossing near round about

Specific area-wise discussions for other locations are avoided as the nature of problem and recommended measures are similar in nature. Built-up areas located within/prior/after a curve or having bridges within/prior/after the location will be needed an integrated marking and delineation system.

Some common characteristics of built-up areas are presence of narrow side roads making non-engineered junctions with the highway. This makes marking and delineation very challenging if appropriate engineering treatments are not given to the side roads.

Sign

Guide post schedule have been mentioned on the as built data; 47 guide post for curves and 60 guide posts for culvert as shown in the table but there is only 23 guide posts including guide post for reverse curve, slope, narrowing road, approach to circle, stop sign, end sign, left turning curve, right turning curve; there is no bridge or culvert guide post along the route. Some of guide post schedule mentioned on as built drawing are shown on table 4.7.

Table 4.8 some of guide post schedule mentioned on the as built drawing

NO.	STATION		SPACING	DIRECTION
	FROM	TO		
1	0+125	0+252	30	BOTH
2	2+027	2+306	35	BOTH
3	4+897	5+035	35	BOTH
4	5+068	5+377	35	BOTH
5	5+444	5+622	24	BOTH
6	5+727	5+913	33	BOTH

Fig 4.18 no guide post for culvert

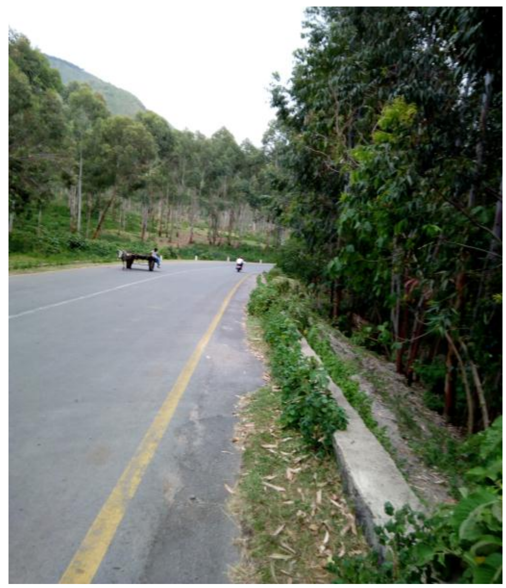

Fig 4.19 no guide post for curve

Junctions/ Built-up area /Bus-stand Investigation

At Wesha town there is a bajaj station at a curve and the road have become very narrow for the passage of huge traffic between Kella and Wesha town.

Fig 4.20 wesha bajaj station at curve

There is round about when going from basha town towards meribu and gemeto which doesn’t have any aproaching sign, zebra crossing, center line and edge line delineation and at the edge of the round about there is road side development (tire repairing station)

Fig 4.21 round about with no delinetion

Other observations are:

- Vehicle paths and splitter nose at junctions are not marked or delineated and pedestrian crossing sites (zebra) are not well marked (figure 4.22 and figure 4.23).
- Edge line markings are faded out or invisible due to dust, mud and weather effects.
- Along the highway, painted "Edge line" and "Center line" markings are not observed.

Figure 4.22 No center line between the two directions

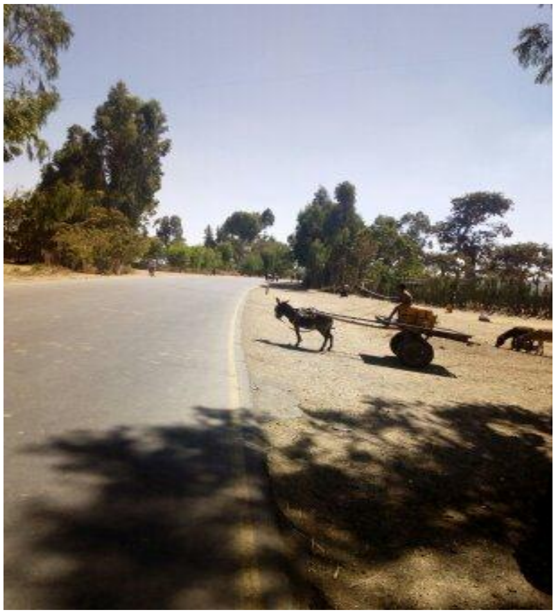

Figure 4.23 No zebra crossing

Fig 4.24 zebra crossing not visible

4.2.7 Guard rail

There are two bridges without guardrail namely wesha bridge 264.1km away from Addis Ababa and werka bridge 265.4 km from Addis Abeba. Wesha Bridge was used previously by the localities to wash clothes and throw garbage in the river. It is constructed as the situation is and no measures have been done before the construction of the bridge

Fig 4.25 Werka Bridge needs maintenance and guardrail should be provided

Fig 4.26 Wesha bridge guardrail should be provided

Existing verses geometric design standard

Cross checking existing road safety condition with geometric design parameters have been done as stated on table 4.8.

Table 4.9 Comparison of ERA design parameters with existing condition

No	Design element	ERA design parameter	Existing condition
1	AADT	DS4 is from 200-1000 v/day	200-3980 vehicle/day
2	Shoulder width	For rural 0.5-1.5 depending on terrain	0-1 m

		For town section parking lane 3.5 and footway 2.5	Absence of delineated parking lane with carriage width 9m 1.2m gutter at each side
3	Minimum horizontal curve radius	Flat=270,rolling=175,mounteneous=125, escarpment=85,urban=85	There are four curves with radius less than minimum
4	Design speed	Flat=85,rolling=70,mountaneous=60, escarpment=50,urban=50	98% of the vehicle travel less than 67km/hr(76% flat terrain)
5	Bridge width	At least full approach traveled width or plus 0.6 m clearance way width on each side	Equal to the approach travel or lesser by 0.5-0.7m
6	Clear zone	Not less than 1.5 from the edge of the carriage way	75% of the road segment have less than 1m clear zone
7	Minimum vertical curve	Equal to k value as minimum	Out of 79 curves 23 length of curves are less than k value
8	Guard rail	Guard rails should be provided for all bridges	Two bridges with out guardrail
9	Curve Guide posts	For radius 30-500 should provide with 5-35 meter spacing	Absence of guide posts at most of the curves

The comparison of existing condition with the standard geometric parameter of Ethiopian road Authority indicates that there are hazardous geometric conditions that adversely affect the safety of the studied area which include inadequate shoulder width, using curve radius less than acceptable minimum radius , ignoring provision of guard rails to bridges and so on. The other finding is the AADT of the study area have raised from the designed standard DS4 to AADT which is categorized as DS3 on ERA design manual. This have an impact on the design speed not to be attainable.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this study attempts are made to assess safety hazards of a selected highway section of Shashemene-Wendogenet-Gemeto Highway using road safety auditing approach. Guidelines for Road Safety Audit of FHWA have been modified and used in the way it suits the local condition. Based on the findings of the research the following conclusion has been drawn.

- According to count made during the second month of 2017 Shashemene – Wendogenet- Gemeto road is a road with highest traffic count among roads under ERA Shashemene district and at current situation the AADT is 250-3900 which upgraded the classification from the designed DS4 to DS3 and it have an impact on the attainability of design speed
- The road segment have high vegetation cover which will restrict the sight of the driver along the consecutive curves of the road mainly in the rural part of the highway
- Around towns on-road dumping of construction materials like sand, crashed stone and soil is very common and could remain on the road for more than three weeks
- During design of highway no consideration of guard rails at two bridges namely Werka bridge and Wesha bridge
- The route under study have highly problem of implementation of road signs as stated on as-built drawing and the one implemented like zebra crossing have most likely wiped out.
- The shoulder width of rural roads along the study area are very inadequate and there is no enough space for high number of non-motorized vehicles along the route which made the design speed unattainable.
- There is random use of road by pedestrians without bothering to use the road side and shoulder and also animals standing on the roads especially in towns.

- The studied road segment Shashamene –Wendogenet-Gemeto road is unsafe due absence of shoulder, pedestrian facility, guardrail at bridges and sharp curves with non -recoverable embankment slope , absence of road marking and guide posts.

5.2 Recommendation

- Routine follow up should be done by the client and obstructions like vegetation must be removed.
- Future upgrading of the road should be considered because the AADT have become higher than the standard of the road.
- Sign posts should be implemented as mentioned and scheduled on the as built drawing.
- Guardrails should be provided to the two bridges werka and wesha according to the standard.
- Obstructions covering shoulder should be removed and shoulder should be provided where it is possible to provide enough space for pedestrians and non-motorized vehicles.
- Stakeholders should give awareness to road users about road sharing and safety.
- It is essential to consider road safety audit in planning, construction and on existing road not only for this route but for all road projects that are being constructed, and will be constructed in the future.
- Safety considerations done during the design of highway should be followed up and implemented.
- Road sign should not be separated and ignored from main construction of the road.
- There is a huge lack of data on road segments older than seven years and this makes researches and studies to be implemented the road very difficult. Ethiopian Road Authority as it is the client of the roads it should improve its data storing system.

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Appendix A: Prompt list of FHWA

PROMPT LIST 6 (1 OF 2)

Existing Road Audit

Road Function, Classification, Environment	Road Alignment and Cross Section	Auxiliary Lanes	Intersections	Interchanges	Signs and Lighting	Marking and Delineation	Barriers and Clear Zones	Traffic Signals	Pedestrians and Bicyclists
	1 Visibility, sight distance	1 Tapers	1 Location	1 Visibility, sight distance	1 Lighting	1 General issues	1 Clear zones	1 Operations	1 General issues
	2 Design speed	2 Shoulders	2 Visibility, sight distance	2 Lanes, shoulders	2 General signs issues	2 Centerlines, edge-lines, lane lines	2 Barriers	2 Visibility	2 Pedestrians
	3 Speed limit/speed zoning	3 Signs and markings	3 Signing and marking	3 Signing, marking, delineation	3 Sign legibility	3 Guideposts and reflectors	3 End treatments /Crash cushions	3 Placement of signal heads	3 Bicyclists
	4 Passing	4 Turning traffic	4 Layout and 'read-ability' (perception) by drivers	4 Pedestrians, bicyclists	4 Sign supports	4 Curve warning and delineation	4 Pedestrian railing		4 Public transport
	5 'Readability' (perception) of the alignment by drivers		5 Pedestrians, bicyclists	5 Lighting			5 Visibility of barriers and fences		
	6 Human factors		6 Lighting						
	7 Widths								
	8 Shoulders								
	9 Cross slopes								
	10 Side slopes								
	11 Drains								
	12 Combinations of features								

Prompt list 6(1of 2) of FHWA

PROMPT LIST 6 (2 OF 2)

Existing Road Audit

Older Drivers	Bridges and Culverts	Pavement	Parking	Provision For Heavy Vehicles	Floodways and Causeways	Other Safety Issues
1 Turning operations (receiving lane widths, radii)	1 Design features	1 Pavement defects		1 Design issues	1 Ponding and flooding	1 Landscaping
2 Channelization, opposing left turn lanes	2 Barriers	2 Skid resistance		2 Pavement/shoulder quality	2 Safety of devices	2 Temporary works
3 Sight triangles	3 Pedestrian and recreational facilities, delineation	3 Ponding/icing/snow accumulation				3 Headlight glare
4 Signing, marking and delineation		4 Loose stones/material				4 Roadside activities
5 Traffic signals		5 Manholes				5 Signs of possible problems (pavement, roadside)
						6 Rest areas
						7 Environment
						8 Median curbing

Prompt list 6(2of 2) of FHWA

Appendix B: Road safety audit

Reference	Location	Images	Result, problem and recommendation
#1	Wendo wereda medo buanba area (5km from shashemene		Result: lane width 3.7m, obstruction 5m from the edge of the lane(not include shoulder) Problem: no zebra crossing and delineation Recommendation:
#2	wereda of Goto anoma		Result :lane width 3.5 and distance of obstruction is 1m Problem: obstruction restricts driver sight of

#3	**Area around Bele**		No sign for curve approaching
#4	**In front of wendo genet forestry collage**		Un paved shoulder,absence of delineation and zebra crossing is not clearly visible

#5	**Shesha wereda area (shasha qaqasi**		**Vegetation near the carriageway(1m-0.5m away from the edge of the lane)**
#6	**10+480 km from the start**		**High drop-off at shoulder, inadequate shoulder and road side obstruction restricting sight of driver**

#7	**10+500-10+790**		**Absence of shoulder, obstruction near carriageway, narrow carriageway with sharp curves**
#8	**Wesha town**		**Damaged shoulder, random usage of carriageway as Bajaj and taxi station**

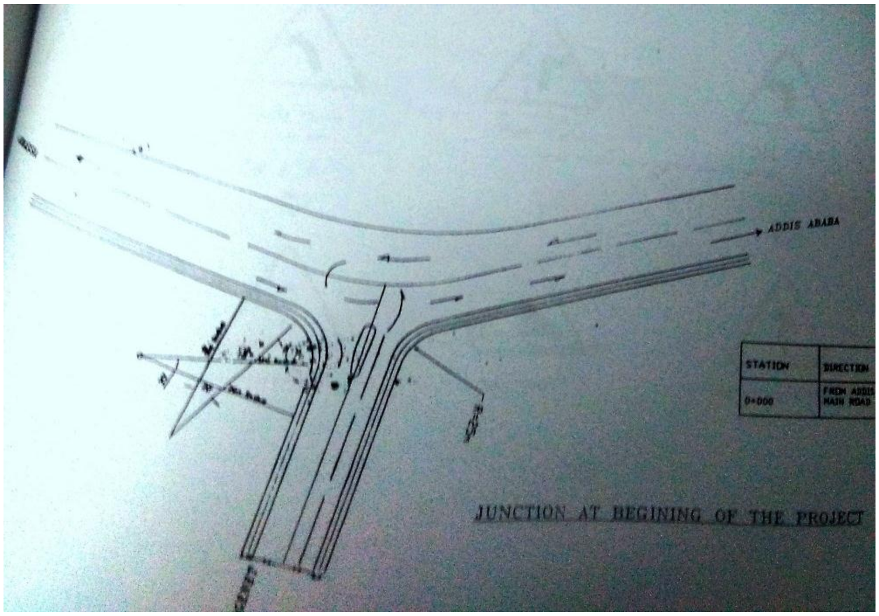
#9	Road Wesha to Kella town		Unpaved shoulder, commercial activities on shoulder, absence or fading out of center line delineation, mixed use of road by motorized and non-motorized vehicles
#10	Roundab out between kella and meribu town		No center and edge line marking of road, dumped construction materials on carriageway, commercial activities near the roundabout edge

#11	**Hailu bridge after Meribu town approaching to Gemeto**		**Bridge on sharp curve , roadside obstruction, no guide post for culvert**

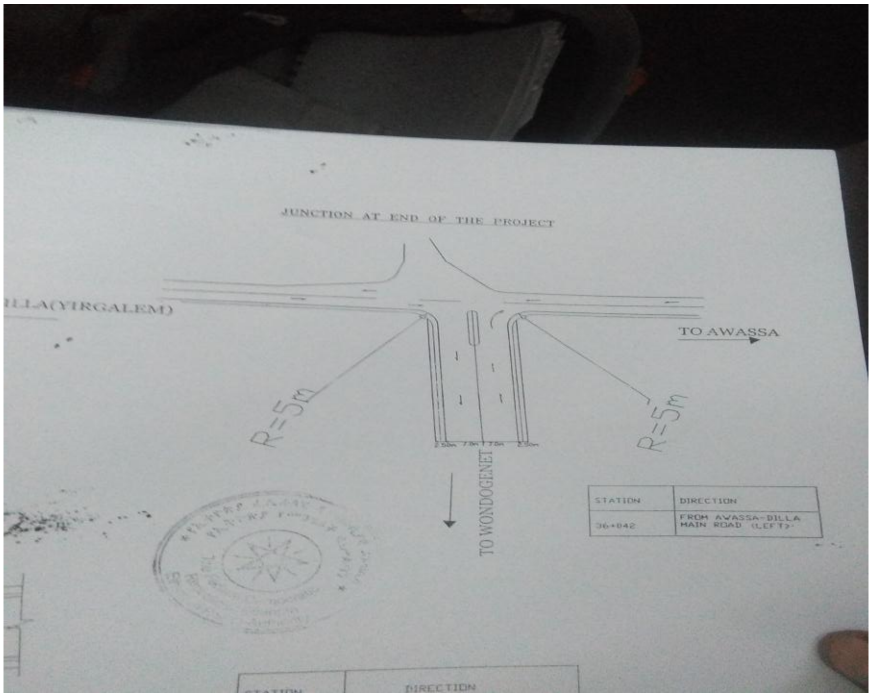
No	Location in kilometers	Problem observed	Recommended countermeasures
1	0+000-5+000	Shoulder drop-off and unpaved shoulder, lack of road markings like center line, edge line and zebra line	Shoulder rehabilitation and marking the road

2	5+000-9+000	Absence of shoulder and road side obstruction near carriageway	Removal of obstruction and provision of shoulder
3	9+000-16+400	Absence of shoulder, obstruction near carriage way, sharp curves with non-recoverable slope and no guardrail, absence of sign for curve approach, bridge with no guardrail	Removal of obstruction,shoulder and barrier for curves with non recoverable slope and bridge guardrails should be provided
4	16+400-20+748	Materials dumped on carriageway, commercial usage of shoulder , inappropriate use of carriage way as Bajaj and taxi station including sharp curves	Banning on dumping materials on carriageway and bajaj and taxi stations
5	20+748-26+200	Roundabout with inadequate delineation and commercial activities near left and right turning ,material dumped on carriage way	Road delineation should be provided and commercial activities should be transferred to far from the edge, banning of dump material
6	26+200-36+042	Bridges on sharp curves, absence of guide posts ,obstruction near carriage way	Provide guide post for bridge approach, remove obstruction

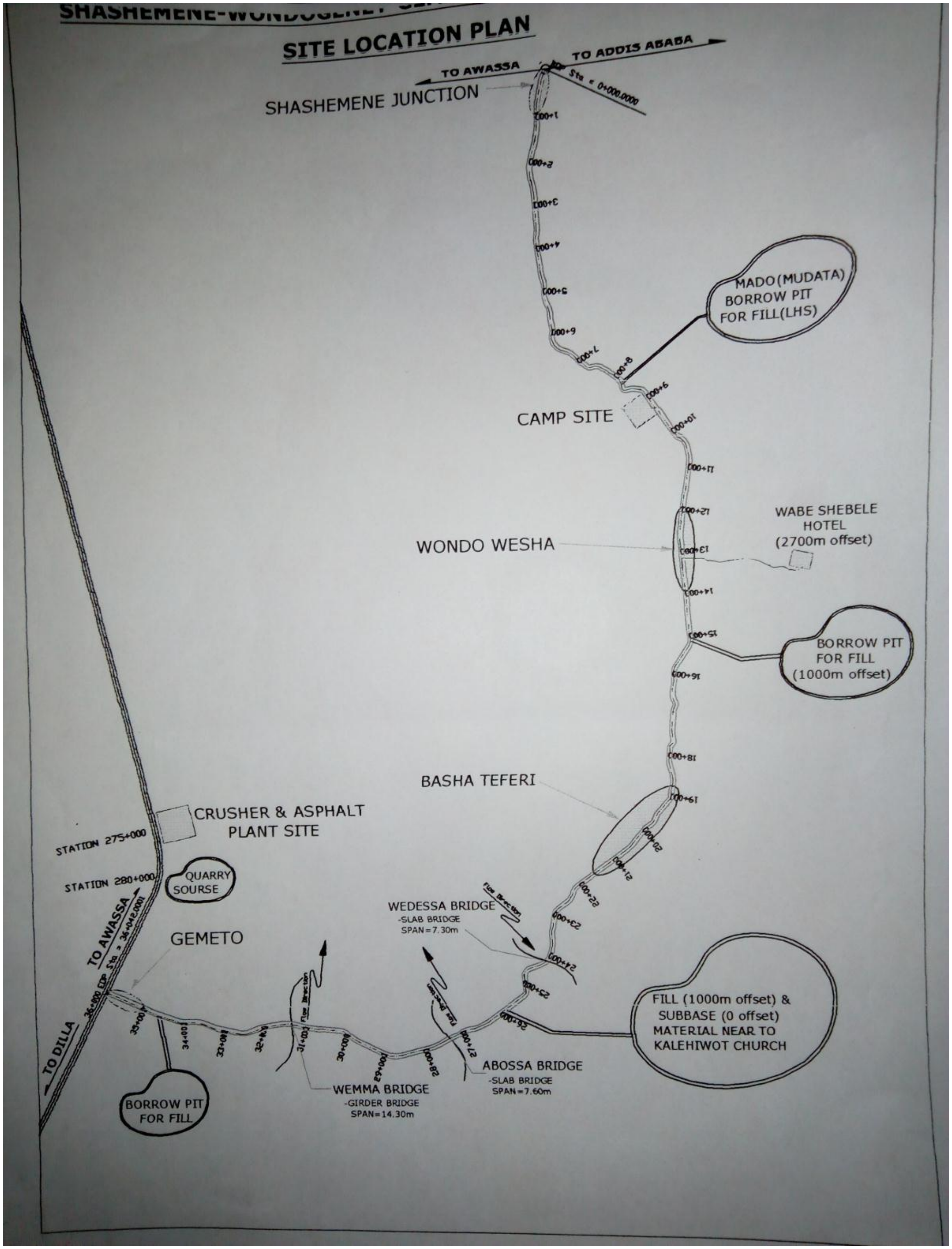
Appendix C: As built drawing



Junction at the beginning of the study area



Junction at the end of the study route



Study rout site location

Horizontal alignment

PI NO	RADIUS	Trin	Trout	X-coord	Y-coord	BC	EC	BTC	ETC
START				454357.331	794369.608				
1	400			454262.47	794207.22	123.443	251.569	123.443	251.569
2	600			454131.69	793588.68	768.946	869.166	768.946	869.166
3	1500	47	47	454106.06	792969.19	1300.841	1575.812	1253.841	1622.812
4	500	47	47	453915.7	792241.88	2117.67	2259.025	2070.67	2306.025
5	1300	47	47	453948.25	791973.58	2427.695	2487.139	2380.695	2534.139
6	1000	47	47	454007.05	791687.33	2706.716	2792.314	2659.716	2839.314
7	600	47	47	454069.79	790792.63	3591.35	3700.345	3544.35	3747.345
8	650	47	47	454024.12	790555.12	3797.23	3974.918	3750.273	4021.918
9	1200	47	47	454147.71	789767.35	4627.539	4736.917	4580.539	4783.917
10	500	47	47	454215.45	789536.92	4854.073	4988.427	4807.073	5035.427
11	500	47	47	454192.01	789232.15	5115.444	5330.086	5068.444	5377.086
12	270	55	55	454327.66	788948.82	5498.505	5566.676	5443.505	5621.676
13	650	47	47	454326.04	788782.24	5668.835	5726.895	5621.835	5773.895
14	450	49	49	454348.34	788636.61	5825.609	5864.197	5776.609	5913.197
15	175	52	52	454398.96	788496.46	5965.575	6018.342	5913.575	6070.342
16	175	52	52	454361.39	788350.56	6133.47	6147.18	6081.47	6199.18
17	200	52	52	454377.36	788221.77	6251.273	6286.31	6199.273	6338.31
18	250	48	48	454453.93	788099.26	6387.605	6435.969	6339.605	6483.969
19	250	48	48	454563.02	788020.26	6534.615	6556.425	6486.615	6604.425
20	250	48	48	454767.75	787946.11	6738.387	6786.273	6690.387	6834.273
21	250	48	48	454894.72	787832.25	6924.067	6939.918	6876.067	6987.918
22	125	48	48	454975.34	787710.35	7065.529	7087.911	7017.629	7135.911
23	175	52	52	455090.39	787658.39	7197.489	7205.458	7145.489	7257.458
24	85			455195.58	787557.03	7299.573	7386.351	7299.573	7386.351
25	180			455336.73	787593.68	7452.75	7515.765	7452.75	7515.765
26	125			455442.68	787583.47	7557.678	7621.629	7557.678	7621.629
27	200			455528.74	787523.62	7674.221	7713.173	7674.221	7713.173
28	190			455614.65	787485.99	7753.318	7820.821	7753.318	7820.821
29	150			455683.08	787419.88	7867.974	7895.659	7867.974	7895.659
30	400	39	39	455768.44	787363.51	7982.727	7985.36	7943.727	8024.36
31	80			455945.54	787218.03	8183.821	8240.16	8183.821	8240.16
32	60			455982.18	787015.41	8357.197	8450.924	8357.197	8450.924
33	175			456199.96	787052.84	8582.234	8642.015	8582.234	8642.015
34	80			456434.15	787012.3	8814.671	8880.365	8814.671	8880.365
35	2000			456844.4	786383.69	9595.837	9596.519	9595.837	9596.519

36	175	52	52	457155.57	785907.24	10141.6	10186.03	10089.6	10238.03
37	175	52	52	457320.61	785829.3	10326.1	10361.57	10274.1	10413.57
38	175	52	52	457402.26	785717.27	10469.78	10491.64	10417.78	10543.64
39	300	44	44	457477.76	785359.12	10810.97	10879.7	10766.97	10923.7
40	3000			457436.91	785118.23	11044.75	11133.13	11044.75	11133.13
41	600			457219.45	783558.58	12582.95	12743.43	12582.95	12743.43
42	3000			457249.25	783328.66	12812.97	12976.1	12812.97	12976.1
43	1300			457284.05	782862.82	13359.07	13364.23	13359.07	13364.23
44	270	55	55	457434.28	781003.44	15162.03	15285.11	15107.03	15340.11
45	270	55	55	457029.24	780380.59	15904.9	16015.46	15849.9	16070.46
46	270	55	55	457039.63	780096.84	16240.97	16241.33	16185.97	16296.33
47	220			456978.51	779737.42	16537.22	16689.8	16537.22	16669.8
48	125			457065.08	779550.76	16750.33	16857.04	16750.33	16857.04
49	200			457001.87	779409.03	16919.56	16990.44	16919.56	16990.44
50	1500			456983.34	779124.64	17231.18	17248.04	17231.18	17248.04
51	300			456965.23	778887.83	17448.09	17505.96	17448.09	17505.96
52	85			456994.08	778641.44	17687.14	17758.39	17687.14	17758.39
53	90			456904.42	778539.54	17828.97	17881.94	17828.97	17881.94
54	270	55	55	456858.77	778198.4	18174.46	18221.83	18119.46	18276.83
55	270	55	55	456972.48	777745.71	18624.98	18700.6	18569.98	18755.6
56	140			456916.2	777516.51	18886.42	18908.32	18886.42	18908.32
57	100			456898.32	777319.89	19060.49	19126.56	19060.49	19126.56
58	120			456572.98	776971.64	19548.86	19588.46	19548.86	19588.46
59	100			456470.93	776743.97	19788.58	19845.76	19788.58	19845.76
60	120			456280.98	776620.1	20022.82	20062.98	20022.82	20062.98

Vertical alignment

SHASHAMENE- WENDOGENET-GEMETO VERTICAL ALIGNMENT DATA

CURVE NUMBER	CHAINAGE	ELEVATION	CURVE LENGTH	LNGTH IN	LENGTH OUT	K-VALUE	BACK GRADE	FRONT GRADE
1	0+000	1934.83						-0.50%
2	0+104	1934.3	85	48.5	48.5		-0.50%	0.50%
3	0+352	1935.56	80	40	40		0.50%	1.00%
4	0+745	1939.58	200	100	100	965.18	1.00%	0.80%
5	1+288	1943.83	120	60	60	196.47	0.80%	1.41%
6	1+522	1947.12	200	100	100	188.61	1.41%	0.35%
7	1+861	1948.3	150	75	75	411.91	0.35%	0.71%
8	2+149	1950.35	150	75	75	123.46	0.71%	-0.50%
9	2+536	1948.4	150	75	75	112.44	-0.50%	0.83%
10	2+909	1951.5	120	60	60	270.87	0.83%	1.27%
11	3+789	1962.7	150	75	75	364.88	1.27%	1.69%
12	4+142	1968.66	120	60	60	205.91	1.69%	2.27%
13	4+473	1976.16	300	150	150	204.65	2.27%	0.80%
14	5+081	1981.03	200	100	100	74.22	0.80%	-1.89%
15	5+535	1972.44	150	75	75	130.73	-1.89%	-0.75%
16	5+937	1969.44	150	75	75	75.37	-0.75%	-2.74%
17	6+564	1952.3	200	100	100	72.37	-2.74%	-5.50%
18	7+287	1912.5	200	100	100	438.02	-5.50%	-5.04%
19	7+849	1884.17	200	100	100	249.67	-5.04%	-5.84%
20	8+688	1835.14	150	75	75	45.88	-5.84%	-2.57%
21	9+121	1824	300	150	150	80.72	-2.57%	-6.29%
22	9+542	1797.5	120	60	60	87.7	-6.29%	-4.92%
23	10+288	1760.8	300	150	150	78.37	-4.92%	-1.09%
24	10+681	1756.5	120	60	60	57.81	-1.09%	-3.17%
25	10+952	1747.9	120	60	60	77.44	-3.17%	-1.62%
26	11+660	1736.42	250	125	125	242.35	-1.62%	-0.59%
27	12+314	1732.57	150	75	75	137.55	-0.59%	0.50%
28	12+665	1734.33	120	60	60	94.85	0.50%	-0.76%
29	13+088	1730.87	100	50	50	36.16	-0.76%	2.00%
30	13+348	1734.72	120	60	60	27.2	2.00%	-2.41%
31	13+489	1732.91	100	50	50	62.82	-2.41%	-0.82%
32	13+803	1730.34	250	125	125	189.34	-0.82%	0.50%
33	14+070	1731.68	150	75	75	82.49	0.50%	-1.32%
34	14+420	1727.07	120	60	60	304.88	-1.32%	-0.92%

35	14+945	1722.22	420	210	210	208.64	-0.92%	1.08%
36	15+315	1726.25	160	80	80	60.53	1.08%	-1.55%
37	15+900	1717.16	240	120	120	70.5	-1.55%	1.85%
38	16+180	1722.34	205	102.5	102.5	66.07	1.85%	-1.25%
39	16+390	1719.71	160	80	80	26.52	-1.25%	4.77%
40	16+530	1726.4	100	50	50	24.16	4.77%	0.64%
41	16+975	1729.25	120	60	60	38.81	0.64%	3.73%
42	17+270	1740.26	160	80	80	49.69	3.73%	0.51%
43	17+920	1743.59	120	60	60	46.65	0.51%	-2.06%
44	18+270	1736.38	150	75	75	62.48	-2.06%	0.34%
45	18+690	1737.81	210	105	105	61.61	0.34%	-3.06%
46	18+905	1731.212	120	60	60	60.91	-3.06%	-1.10%
47	19+060	1729.51	120	60	60	86.55	-1.10%	-2.48%
48	19+805	1711	1000	500	500	324.93	-2.48%	0.59%
49	20+584	1715.618	120	60	60	177.25	0.59%	-0.08%
50	22+100	1715.052	160	80	80	201.43	-0.08%	-0.87
51	22+459	1711.9	150	75	75	299.62	-0.87	-0.38%
52	22+830	1710.5	450	225	225	333.52	-0.38%	0.97%
53	23+150	1713.61	130	65	65	37.74	0.97%	4.41%
54	23+405	1724.87	220	110	110	35.56	4.41%	-1.76%
55	23+765	1718.5	300	150	150	124.98	-1.76%	0.63%
56	24+082	1720.5	120	60	60	20.48	0.63%	-5.22%
57	24+250	1711.72	75	37.5	37.5	14.35	-5.22%	0.00%
58	24+338	1711.72	60	30	30	8.07	0.00%	7.43%
59	24+417	1717.59	80	40	40	12.52	7.43%	1.04%
60	24+630	1719.81	60	30	30	29.9	1.04%	3.04%

Appendix D: Traffic count

Location : wendogenet junction, direction: Hawassa

Date	Car	L/rover	S/ Bus	L/Bus	S/truck	M/truck	H/truck	T/truck	Total
01/02/17 At day time*	313	488	676	130	441	448	265	289	3050
01/02/17 At night*	113	110	167	26	128	161	37	40	782
02/02/17	443	566	668	158	485	464	238	220	3242
03/02/17	315	505	656	148	478	396	431	416	3345
04/02/17	544	620	271	165	632	608	168	101	3609
05/02/17	536	639	769	183	627	552	252	247	3805
06/02/17	446	568	702	171	673	568	342	239	3730
07/02/17 At night**	106	114	135	29	122	154	25	52	737
07/02/17 At day time**	472	637	733	146	611	608	326	308	3841
Total	3309	4247	5277	1156	4197	3959	2084	1912	26141
* Market day ** non market day									

Date	Car	L/rover	S/ Bus	L/Bus	S/truck	M/truck	H/truck	T/truck	Total
01/02/17 At day time*	140	168	225	40	165	148	90	27	1003
01/02/17 At night*	37	28	33	2	41	44	4	6	195
02/02/17	110	161	249	36	139	126	91	26	938
03/02/17	133	275	345	47	201	187	155	5	1348
04/02/17	185	164	277	92	162	182	93	48	1203
05/02/17	154	170	221	44	142	177	91	35	1034
06/02/17	145	172	274	39	156	112	93	13	1006
07/02/17 At night**	43	41	59	7	42	41	17	8	258
07/02/17 At day time**	157	184	249	47	184	176	113	26	1154
Total	1104	1363	1932	354	1732	1193	765	196	8139
* Market day ** non market day									

Date	Car	L/rover	S/ Bus	L/Bus	S/truck	M/truck	H/truck	T/truck	Total
01/02/17 At day time*	422	463	645	139	452	484	264	246	3115
01/02/17 At night*	85	94	123	19	109	122	29	24	605
02/02/17	451	572	747	111	520	491	242	258	3400
03/02/17	410	579	698	133	540	470	440	347	3617
04/02/17	572	696	792	231	659	577	255	127	3910
05/02/17	557	613	763	151	597	530	240	262	3733
06/02/17	513	574	738	127	587	556	311	254	3660
07/02/17 At night**	100	75	132	25	117	111	29	35	624
07/02/17 At day time**	527	623	774	166	665	552	371	305	3983
Total	3643	4289	5432	1102	4246	3896	2181	1858	26647
* Market day ** non market day									

Appendix E:Guide post schedule mentioned on as built drawing

19	7+674	7+713	20	BOTH
20	7+753	7+821	20	BOTH
21	7+868	7+896	16	BOTH
22	7+944	8+024	30	BOTH
23	8+184	8+240	[illegible]	BOTH

GUIDEPOST SCHEDULE FOR CURVE ON ROAD-

SNO.	STATION		DIRECTION	SPACING
	FROM	TO		
1	0+123	0+252	BOTH	30
2	0+068	0+090	BOTH	23
3	0+445	0+514	BOTH	18
4	0+575	0+623	BOTH	18
5	0+831	0+930	BOTH	25
6	1+462	1+516	BOTH	18
7	1+710	1+765	BOTH	20
8	2+026	2+177	BOTH	23
9	2+248	2+390	BOTH	22
10	2+431	2+502	BOTH	20
11	2+628	2+689	BOTH	8

DULE FOR CULVERT

S/No.	STATION		
	FROM		TO
30	14397	14402	BOTH
31	14946	14950	BOTH
32	15304	15308	BOTH
33	15806	15810	BOTH
34	16388	16392	BOTH
35	16498	16502	BOTH
36	16834	16840	BOTH
37	17498	17503	BOTH
38	17740	17744	BOTH
	17918	17922	BOTH

DULE FOR CULVERT

S/No.	STATION		
	FROM		TO
30	14397	14402	BOTH
31	14946	14950	BOTH
32	15304	15308	BOTH
33	15806	15810	BOTH
34	16388	16392	BOTH
35	16498	16502	BOTH
36	16834	16840	BOTH
37	17498	17503	BOTH
38	17740	17744	BOTH
	17918	17922	BOTH