ROAD SAFETY AUDIT AND

A CASE STUDY ON KANO-KADUNA ROAD IN NIGERIA

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Nura Bala:

ABSTRACT

ROAD SAFETY AUDIT AND

A CASE STUDY ON KANO-KADUNA ROAD IN NIGERIA

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The consequence of increasing number of traffic volume, road safety improvement is becoming a major policy for the road authorities. Road accidents create both social and economic cost on the country's economy. When this is taken into consideration, it is therefore important to display different solution alternatives considering the budget limitations of the road authorities.

Road accidents are serious problems throughout the world especially in low and middle income countries considering social, health and economic terms. The number of road accidents in such countries tends to increase every year.

In this thesis, a case study is selected in Nigeria and the studies were performed to summarize actual practices of road safety auditing on existing roads in different countries. By taking account these different opinions and auditing procedures into account a strategy for road safety auditing on existing roads that fits to Nigerian roads conditions is proposed.

For an evaluation, a case study was conducted in order to determine whether the proposed methodology adds a value to the highway network follow up and improvements. Based on this study, the audit report was prepared to summarize findings with possible countermeasures.

Keywords: Road Safety, Road Safety Audit

ÖZ

KARAYOLU GÜVENLİĞİ ETÜDÜ:

KANO- KADUNA KARAYOLUNDA BİR ÖRNEK ÇALIŞMA

Nura Bala

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Mart 2014,102 sayfa

Trafik hacimlerinin artması sonucu, karayolu güvenliği iyileştirmesi karayolu ile ilgili kuruluşların temel politikası olmaktadır. Yol kazaları ülke ekonomisine hem sosyal hem de ekonmomik maliyetler yaratmaktadır. Bu husus dikkate alındığında, karayolu otoritelerinin bütçe kısıtlarını referans alan değişik çözüm alternatiflerinin ortaya konması önemlidir.

Karayolu trafik kazaları bütün dünyada ancak özellikle düşük ve orta gelirli ülkelerde sosyal, sağlık ve ekonomik açıdan çok endişe verici durumdadır. Bu tür ülkelerde yol kazaları ayrıca her yıl artma eğilimindedir.

Bu tezde, değişik ülkelerde trafiğe açık karayollarında uygulanan ‘karayolu güvenlik etütleri’ incelenerek, Nijerya’da bir örnek çalışma gerçekleştirilmiştir. Ayrıca bu analizler ve örnek çalışma dikkate alınarak Nijerya’da trafiğe açık karayollarında uygulanabilecek bir ‘karayolu güvenlik etüdü’ staratejisi önerilmiştir.

Değerlendirmede, önerilen metodolojinin karayolu ağı izlenmesi ve iyileştirmeye bir katkı verip veremeyeceği örnek çalışma kapsamında incelenmiştir. Bu çalışmayı baz alarak, yol güvenliğini tehdit eden bulgular ve uygulanması mümkün iyileştirme önerilerinin yer aldığı bir etüt raporu hazırlanmıştır.

Anahtar kelimeler: Karayolu güvenliği, Karayolu Güvenliği Etüdü

DEDICATION

This thesis is dedicated to all of the mentors that I have had in my life especially Alhaji Rufa'i Buhari (Yaya Ma'aji) for his endless care and support. My mother for her optimistic view of life and never letting me give up. My father for showing me how to always conduct myself honestly and also for guiding me into civil engineering. My lovely wife for her unconditional love and support. My brothers for providing me with a rock solid base from which to go after my dreams. My all friends and teachers I have had in my life, they have always shown me love and encouragement.

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LIST OF ABBREVIATIONS

AADT	- Average Annual Daily Traffic
AASHTO	- American Association of Highway and Transport Officials
ADT	- Average Daily Traffic
AUSTROADS	- Association of Australian and New Zealand Road Transport and Traffic Authorities
ETSC	- European Transport Safety Council
FRSCN	- Federal Road Safety Corps of Nigeria
NHCRF	- National Cooperative Highway Research Program
PIARC	- Permanent International Association of Road Congresses
RSA	- Road Safety Audit
RSIA	- Road Safety Impact Assessment
RSI	- Road Safety Inspection
TERN	- Trans European Road Network
UK	- United Kingdom
WHO	- World Health Organization

CHAPTER ONE

1 INTRODUCTION

1.1 General

Road traffic accidents deaths and injuries occur worldwide. It was estimated that over 1.2 million people died each year on the world roads as a result of road traffic accidents. According to a survey by WHO, more than 3,200 people get killed and over 130 000 injured in traffic every day around the world. Also almost half of all fatal accidents involve pedestrians, cyclists and power two wheelers, collectively called vulnerable road users. (1)

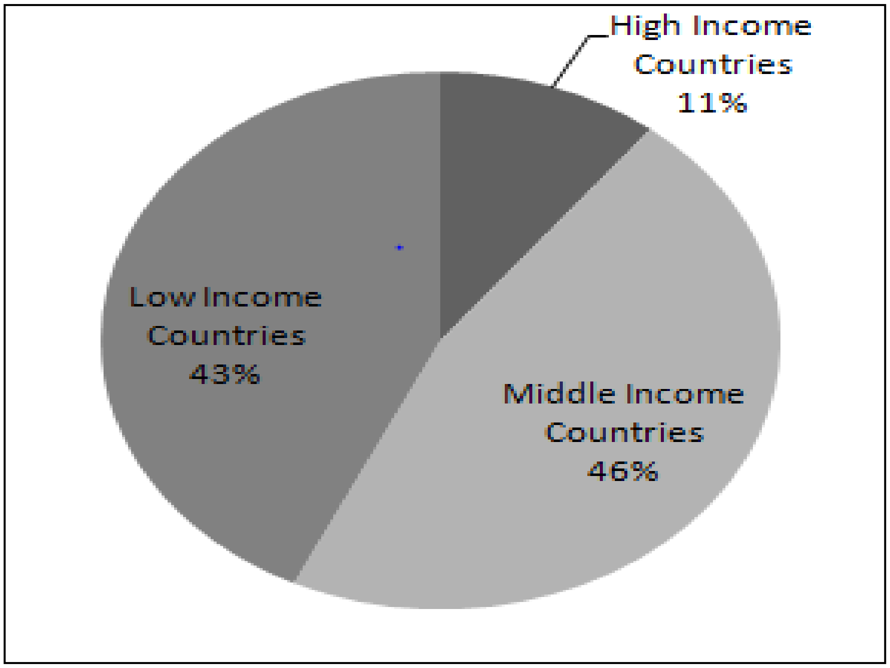

Figure 1.1 Road deaths by level of income. (1)

From figure 1.0 above, it can be observed that more than 85% of accident fatalities occur in low and middle income countries such as Nigeria. Though road fatality rate in high income countries has been decreasing over the last decades, even in these countries road accidents remain one the main causes of death, injury and disability.

Table 1.1 Predicted Road Traffic Fatalities (2)

REGION	% CHANGE 2000-2020
South Asia	144
East Asia & Pacific	80
Sub-Saharan Africa	80
Middle East & North Africa	68
Latin America & Caribbean	48
Europe & Central Asia	18
Sub Total	83
High income countries	-28
Global total	66

From Table 1.1 above, unless there is concerted action, the global road fatalities is expected to increase by more than 65% between year 2000 and 2020, with different trends across the different regions of the world. Fatalities are predicted to be increased by more than 80% in low and middle income countries, but be decreased by nearly 30% in high income countries, thus revealing a widening gap between the road safety in rich and the road safety poor countries.(4)

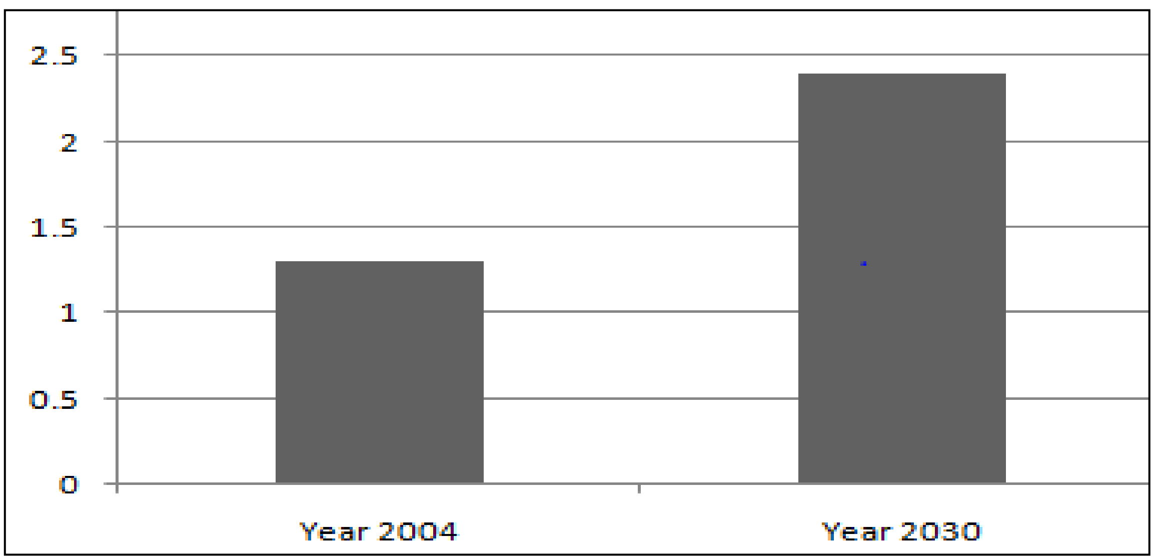

Figure 1.2 Number of road deaths per year (million) without action. (1)

From figure 1.2 above it is observed that while in many high income countries road fatality rate have stabilized or decreased, but on the other hands in the majority regions of the world such as Africa the number of people killed in road traffic accidents is constantly increasing and If the current trends allowed to continue, traffic accident related deaths may take the fifth place in the list of death causing, health disorders and injuries by the year 2030 and results in an estimated 2.4 million fatalities per year. (1)

1.2 Statement of the Problem and Need for the Study in Nigeria

Road traffic accident occurs worldwide, but the incidence is more in developing countries such as Nigeria. The problem of road accidents in Nigeria has reached such an alarming proportion in such a way that our highways have been converted into dead zones, killing citizens daily. According to FRSCN 7,269 peoples died, 20,752 persons sustained various degrees of injuries and 7,517 people are left permanently disabled in the year 2012 as a result of road traffic accidents across highways in Nigeria. (3)

Sudden deaths due to road fatal accidents have continued to be source of grief in a number of homes in Nigeria. There is scarcely a week that passes without an account of a ghastly road traffic accident with many deaths being recorded. Despite the annual road safety campaigns, mobilization of FRSCN, warning against reckless driving and road marshals on our roads, it is unfortunate that the number of traffic accidents is always on increase leading to loss in both human and material resources through road traffic accidents.

Deaths as a result of motor vehicle accidents constitute a great economic loss to our society. Accidents have far reaching effects on families' life, on development and economic life of the country. The strained health services in the country often cannot adequately look after accident victims and there by entire families, relations, friends and collogues were suddenly swept away, which brings grief and economic hardship to the families and survivors.

Besides those that died in road traffic accidents there are many others who survived with residual disabilities of varying degrees of severity, who ends up as burden to the society. The country itself suffers by losing its talented and productive manpower often in the prime of life.

Road traffic accidents have physical, social, emotional and economic implications. The global economic cost of road traffic accidents was estimated at $518 billion per year in 2003 with $100 billion of that occurring in poor developing countries such as Nigeria. (2)

Nigeria loses about 80 billion Naira (4.9 billion US $) annually to road traffic accidents. Of all subjects that are involved in road traffic accidents in Nigeria, 29.1 per cent suffer disability and 13.5 per cent are unable to return to work. (3)

From all search carried out for the preparation of this thesis there was no any relevant report regarding highway safety audit in Nigeria, therefore it can be stated that road safety audit is a new practice in Nigeria, it was never carried out before and in order to save life's it is very important to introduce and carry out a road safety audit on Nigerian highways in order to reduce the number of persons died and severity of injuries on the roads annually.

1.3 Importance of Road Safety Audit

Road safety auditing is a recognized crash prevention road safety tool worldwide that has the following importance:

a) A reduction in the likelihood of crashes on the road network,
b) A reduction in the severity of crashes on the road network,
c) An increased awareness of safe design practices among traffic engineers and road designers,
d) A reduction in the need to modify projects after they are built,
e) A reduction in the life-cycle cost of a road,
f) A more uniform road environment that is more easily understood by road users,
g) A better understanding and documentation of road safety engineering,
h) Eventual safety improvements to standards and procedures,
i) More explicit consideration of the safety needs of vulnerable road users. (4)

1.4 Importance of Road Safety Inspection

The main importance of road safety inspection in general can be summarized as follows:

a) To identify potential road or traffic safety concerns for all road users,
b) To minimize the risk and severity of road accidents that may result from the existing
   situation of a road section,
c) To minimize unsustainable losses to health and economy. (5)

1.5 Costs and benefits of Road Safety Audit

The costs of RSA can vary greatly depending on the size of the project and the phase in which the audit takes place. But the main immediate benefits of road safety audit will be accident savings.

However, there are other longer terms and more broadly based potential benefits, these include not just the immediate accident savings on the schemes subjected to the procedures, but more generally, improvements to the management of design and construction, reduced whole-life cost of road schemes, the development of good safety engineering practice, the explicit recognition of the safety needs of road users, and the improvement of design standards for safety.

The benefits of an RSA are mainly the costs saved on crashes that have been prevented by following the audit's recommendations. In addition, Gadd mentions a series of qualitative benefits after completion a diminished risk of crashes and the repair works resulting from them, a reduction of the total project costs, a greater awareness of road safety and quality in design processes, better facilities for vulnerable road users, and a contribution towards achieving road safety targets, better standards, and design guidelines. (6)

A distinction can be made between direct and indirect costs. The direct costs are the time spent by auditors and the extra time that designers need to include the recommendations in the design. Experiences in Denmark estimate the direct costs to be an average of 1% of the total costs of a project. (6)

A study in Australia by Van Hout and Kemperman reveals that the direct costs vary between € 600 and € 6,000, an average of only 0.2% of the total project costs. Also according to Van Schagen the direct costs during the trial audits in the Netherlands were between € 3,200 and € 4,600; at the present price level this would be between € 4,300 and € 6,600. The earlier in the process an initial RSA is carried out, the lower the relative costs in proportion to the total costs. (6)
The indirect costs are the extra costs of construction and reconstruction activities that result from the auditors' recommendations. Estimates based on international experiences are between 1% and 2% of the total project costs. In smaller projects the direct and indirect costs of an RSA are relatively higher than in large projects. (6)

A study in Denmark focused on 13 projects that had undergone an RSA. The number of crashes if no RSA had taken place was estimated. The savings on crash costs resulted in a cost-benefit ratio of 1:1.46. (7)

Another study in Jordan focused on projects in which no RSA had taken place and where road safety problems occurred a short time after the projects had been completed. The study assumed that the repair works that were necessary after the crashes occurred would have been included in the initial design if an RSA had been carried out. The number of crashes that could have been prevented was estimated, resulting in a cost benefit ratio of 1:1.2. (7)

Also a Surrey County Council in 1994 compared 38 reconstruction plans half of which had been subjected to an RSA and the other half had not. The annual average numbers of casualties saved declined by 1.25, from 2.08 to 0.83 on the reconstructed roads where an RSA had been carried out. On roads where no RSA had been carried out, the annual average number of casualties declined by 0.26, from 2.60 to 2.34. (7)

However, it is by no means clear if the large decline on roads where an RSA was carried out was exclusively attributable to the RSA, the reconstruction activities on roads with an RSA and those on roads without an RSA were not really comparable.

Another study that is being carried out in Great Britain compared before and after crash statistics for a sample of audited schemes and non audited schemes, the study found that audited schemes achieved an average casualty saving per year of 1.25, compared to a saving of 0.26 for non-audited schemes. (6)

From the above studies carried out in different parts of the world by different road safety auditors it can be seen that road safety audit is a very essential tool to be employed in order to reduce the cost and number of traffic accidents globally.

1.6 Actions for Improving Road Safety on Highways

By planning more efforts for increasing highway safety, some transportation agencies have introduced safety programs specifically designed to study and improve some important geometric elements contributing to highway accidents.

At the same time, engineering design has greatly been improved in terms of increasing safety into road structure and environment. In earlier years, engineers designed and built highways, which provides a minor of protection to vehicles colliding with infrastructure or roadside elements outside travel lanes. (8)

In 1960s and 1970s, engineers have started to build more "forgiving highways" which incorporated critical design elements that mitigated the consequence of colliding with elements beyond the travel lanes. More recently, engineers have begun to develop "caring highways" by emphasizing the need to prevent (rather than mitigate) collisions. (8)

Although it is in practiced for nearly two decades, the concept of Road Safety Audits has only recently gained acceptance in North America. Originally developed in the United Kingdom in the 1980s as part of Accident Investigation and Prevention techniques, they have evolved to the point where they are now an integral component of the road safety process. Road safety audits help to ensure that issues associated with road safety are specifically addressed and are given equal importance as the other factors in a design project. (8)

On the other hand, Road Safety Impact Assessment (RSIA) is just come into the Road Authorities Agendas through the proposed applications and obligations that have been set by the European Parliament and The Council of The European Union. The Road Safety Impact Assessment' means a strategic comparative analysis of the impact of a new road or a substantial modification to the existing network on the safety performance of the road network. The Commission expressed the need to carry out safety impact assessments and road safety audits, in order to identify and improve high accident concentration sections within the Community. It also sets the target of halving the number of deaths on the roads within the European Union between 2001 and 2010. (9)

The setting up of appropriate procedures is an essential tool for improving the safety of road infrastructure within the Trans-European Road Network (TERN). Road safety impact assessments should demonstrate, on a strategic level, the implications on road safety of different planning alternatives of an infrastructure project and they should play an important role when routes are being selected. The results of road safety impact assessments may be set out in a number of documents. Moreover, road safety audits should identify, in a detailed way, unsafe features of a road infrastructure project. It therefore makes sense to develop procedures to be followed in those two fields with the aim of increasing safety of road infrastructures on the trans-European road network. (10)

Establishment and implementation of procedures are required by the directive that is relating to road safety impact assessments, road safety audits moreover the management of road network safety and safety inspections by the Member States. Also directive shall apply to roads which are part of the trans-European road network, whether they are at the design stage, under construction or in operation. (10)

1.7 Thesis Scope

The scope of this thesis is to carried out a road safety audit in Nigeria and to evaluate different road safety auditing techniques on the road selected as a case study. Throughout the implementation and reporting at this case study, the present safety situation of Nigerian roads and available techniques will be evaluated.

For the purpose of this thesis a 50 km section of Kano-Kaduna express way which is an existing roadway in Nigeria will be considered as a case study. The road is a dual carriage way which connects two major cities with high population in Nigeria and also many towns were located along the road.

The aim of this thesis is to evaluate different road safety auditing techniques and implement a case study on an existing road section in Nigeria.

1.8 Objectives of Road Safety Audit

The main objective of any road safety audit is to ensure that all new and existing highway schemes operate as safely as is practicable. This means that safety should be considered throughout the whole preparation, construction and after construction of any project but more specific objectives are:

a. To help produce designs and roads that reduce the number and severity of crashes
b. To ensure that road elements with an increased risk potential are removed or that measures are identified to reduce the risk thereof
c. To Reduce likelihoods of accidents
d. To minimize the severity and crash risk of road traffic crashes that may be Influenced by the road facility or adjacent environment;
e. To minimize the need for remedial measures after the opening of a new road Project
f. To identify and report on the crash potential and safety problems of a road Project
g. To avoid the possibility of the scheme giving rise to accidents elsewhere in the road network. (11)

The thesis is divided into five chapters as follows:
Chapter 2 provides an international overview on the historical evolution of road safety audits. This chapter also describes the principles underlying road safety audits. It provides a synthesis of concepts, stages and implementation of road safety audits. It presents also the Turkish road safety audit process of existing roads.
Chapter 3 describes the basic structure and explanations of road safety audit on existing road and it's reporting
Chapter 4 presents road safety audit on existing which were conducted in Nigeria along Kano-Kaduna Highway and Proposal of some specific countermeasures about the safety.
Chapter 5 presents conclusion and recommendations.

CHAPTER TWO

2 ROAD SAFETY ENGINEERING AND WORLD WIDE EXPERIENCES OF ROAD SAFETY AUDIT AND ROAD SAFETY INSPECTION

2.1 Road Safety Engineering

Road safety engineering is a branch of traffic engineering that deals with reducing the frequency and severity of crashes. It uses several aspects such as physics and vehicle dynamics, as well as road user psychology and human factors engineering, to reduce the influence of factors that contribute to accident crashes.

Road safety engineering involves the application of road and traffic engineering principles, based on a sound analysis of all relevant data, with an understanding of road user behavior in order to identify and implement improvements to bring about cost effective reductions in crashes and casualties.

Road safety engineering should be applied at all stages of road/transport development such as in the planning of new developments, in the design of new roads, in safety improvements for existing roads, in remedial treatments of hazardous locations, and in routine maintenance programmes.

The three major components of highway safety are driver behavior, vehicle safety, and roadway safety. Roadway safety refers to that portion of overall highway safety that is determined by the roadway's physical features such as road design, roadway signs, pavement markings, operating conditions, roadside objects (such as utility poles, signs, trees, guardrails) etc.

To reduce the number of traffic accidents on our roads, we need to understand what causes the accidents in general. The highway transportation system can be broken down in to three broad categories:

1- The driver
2- The vehicles
3- The roadway and its environment. (12)

Factors that causes accidents usually falls in to one of those categories above and most accidents have at least one contributing factor and also many accidents have more than one contributing factor.

A human factor includes things like inattention or distraction of driver, fatigue, use of alcohol and vision problems. Vehicle factors may be mechanical failures, bad brakes or tires or any other similar problems and a road related problems can be insufficient sight distance, poor or missing road signs and changes in roadway width or slippery road surfaces.

While concentrating on road safety, road design is one of the most important aspects to be considered regarding highway safety. Roads must be designed to reduce the unexpected situations, thus reduce the failure in the driver decisions. On the other hand, traffic control devices also play an important role on the road safety.

We cannot prevent all accidents on our roads but however, a good road safety improvement plan can be an effective way to reduce the risk of liability. It can reduce the number of accidents, the loss of lives and the economic costs related to them. Reducing the number of accidents reduces the exposure to liability and a good safety planning is a best way to accidents reduction.

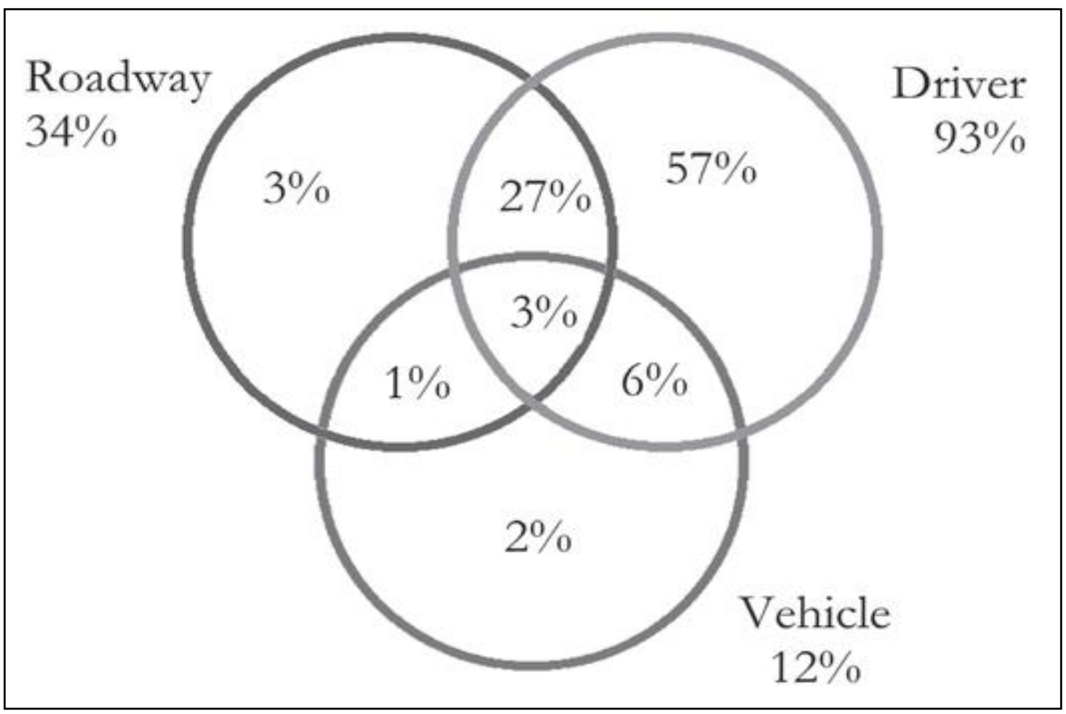

Figure 2.1 Accident contributing factors (12)

Figure 2.1 above shows that driver errors constitutes the highest percentage among the three main factors contributing to accidents followed by road condition with the second and lastly the vehicle defect or malfunction.

Considering road transportation as a system, there are things that we can directly control and things that we cannot. Drivers and environmental events like weather are hard to control and If the parts of the system that can be controlled (roads and vehicles) are designed to allow for those we cannot (road users and weather), the system as a whole will work better.

The road safety is a complex matter to understand and analyze. Because of this reason, a model preparation including all of the three elements; human, vehicle and environment is a very difficult process. These elements can be considered separately or they can be evaluated together with their relations to each other.
Increase in road safety requirements is an unavoidable consequence of rapid economic growth. Unless the road safety is maximized, the resultant economic and social costs could erode a substantial part of the benefits of economic growth. Millions of deaths and injuries, billions of dollars in medical costs, increased strain in welfare services, loss of productivity, and poverty problems are some of the consequences of slack road safety.

Recent analysis in Norway and Sweden (Elvik, 1999; Elvik, 2001; Elvik, 2003; Elvik and Amundsen, 2000) conclude that cost-effective road safety policies could prevent between 50 and 60% of the current number of road accident fatalities in both countries (13).

2.2 Hazardous Roadway Conditions

The following below are considered as the hazardous roadway conditions contributing to accidents regardless of locations on the roadway, these conditions are potentially dangerous to road users.

2.2.1 Roadway Departure Hazards

Roadway departure crashes occur on both straight and curved sections of roadway and often involve either rollover of a vehicle or collisions with fixed objects such as trees and utility poles. Roadside hazards also include steep side slopes, drainage ditches along the roadway, and narrow shoulders not large enough to accommodate a vehicle in trouble. (14)

2.2.2 Road Surface Condition

Some problems in the road surface, such as pavement edge drop-offs, potholes and reductions in surface friction due to age, wear, inadequate drainage during rain storms, and incomplete winter maintenance to remove ice or snow obviously impair vehicle stopping and maneuvering capabilities leading to fatal crashes.

2.2.3 Narrow Roadway and Bridges

A narrow bridge makes it difficult for drivers to safely maneuver in emergency and non emergency situations because there is simply no enough space to maneuver. Narrow bridges are particularly hazardous and collisions with bridge ends are relatively infrequent but they are often severe. Such crashes usually occur when the width of a bridge is less than that of the approaching traveling lanes and shoulders and as a result vehicles strike the end of the bridges, guardrails or curbing. (14)

2.2.4 Rail Road Crossing

Rail road crossings is one of the most dangerous places along the roadway sections because trains cannot stop quickly or steer out of the way and obviously, railroad crossings are of a critical concern, and they can be incredibly hazardous, regardless of how busy they are.

2.2.5 Work zones

A Work zones are areas of construction, maintenance, and utility areas, which creates conditions that can be hazardous to drivers and highway workers. Work zones are a necessary fact of life in our communities and can cause changes in traffic patterns, reduced speed limits, causes congestion; and an influx of construction workers and equipment on the road. Sometimes work zones are poorly marked, and warning signs are hard to see, especially at night. (14)

Warning signs and traffic control devices may not be related to actual work in progress or accurately portray real work zone hazards. Drivers thus disregard these warning signs with potentially tragic consequences.

2.2.6 Intersections

Many intersections are very dangerous intersections, as they are composed with confusing turn lanes, blind spots, or lack of appropriate or inadequate signage or traffic signals. Obstructions, including vegetation, can block a driver's view of signs, signals, and other traffic control devices there by leading to high severity if accident occurs. (14)

2.2.7 Roadway Design Limitations

Many local roads were not built to serve today's high-volume, high-speed traffic. Their safety is limited by hazards such as sharp curves, poor signs and pavement markings, and lack of medians to separate oncoming traffic. These limitations could present an even greater threat to highway safety because of the expected increase in the car ownership over years.

Many of these roads are now high speed commuter corridors, because of these their safety now is compromised by many hazards. Therefore, drivers must therefore be aware of roadway hazards and drive with extra care. (14)

2.2.8 Roadway Access Problems

Roadway access problems are very familiar problem and also one of the most dangerous among the hazards. Constantly growing traffic congestion, concerns over traffic safety, and the ever increasing costs of upgrading our roads have generated a new interest in managing access to our highway systems. Access management is the process that provides access to land development while simultaneously preserving the flow of traffic on surrounding roadways.

Three issues kept in the forefront of access management are safety, capacity, and speed. Fewer direct accesses, greater separation of driveways, and better driveway design and location are the basic elements to be considered for safety.

2.2.9 Pedestrians and Bicycle Traffic

Pedestrian and bicycle traffic must be accommodated and speeds must be controlled for them as they are vulnerable. There were high pedestrian deaths and injuries along the roads in all over the world and these numbers are expected to increase as our population increases. Therefore all highways should be design in such a way to accommodate the safety of pedestrians and bicyclist.

2.3 How to Approach Road Safety Evaluation

Evaluation of completed highway safety projects and programs are essential for safety professionals to identify the improvements that are working, the ones that are producing nominal benefit and the ones not working.

Road safety programs are prepared and are being applied to reduce the number of accidents. These programs generally have similar aim which is to reduce the number of traffic fatalities and injuries.

Once the problem or problems and their sources are identified, then the second step is the selection of the correct and adequate countermeasures to implement as there is no single counter measure that is seldom to provide a total solution to a safety problem.

Before finalizing of the treatment decision, all the cost and accident reduction factors of the different improvement scenarios should be analyzed. The most cost effective countermeasure has to be applied. The word cost effectiveness generally stands for the net resource cost of a measure per year of life saved.

The basic methods for solving safety problems can be categorized in to five stages as follows

1- Identify the type of problem and determine contributing factors

2- Select a countermeasure:

   a- Which improvement offers the best results for the least cost?

   b- Will a possible improvement solve the problem, or just move it down the road?

   c- Will a possible improvement cause problems of its own? If so, are they worse than the problem you are trying to solve?

3- Install the countermeasure

4- Evaluate success

5- Return to Stage 2 if necessary. (15)

The evaluation of effectiveness of safety projects and programs can lead to continuing safety improvements at the same level, increasing resource allocations due to success achieved, or even discontinuing some safety initiatives due to their observed inability to alleviate traffic crash problems. (5)

2.4 Counter Measure Follow-Up

To understand the effects of countermeasures, it is necessary to follow-up the application of the different countermeasures after their respective applications. For this purpose all the data and information that have been recorded before and after (follow-up) stages of the road section improvements should be saved. Again by that way follow-up can give the correct and dependable results for the future improvement applications.
Basically there are two methods for counter measure application follow up for different purposes:

2.4.1 The Short Term Follow-Up

Using this method, Short term effects can easily and shortly show if the road users have taken positive contribution from the improvement and usually takes place immediately after the application of countermeasure.

2.4.2 The Long-Term Follow-Up

Long term follow-up helps to evaluate if the improvement causes a decrease or an increase in the danger of accidents at the inspected road. It is usually carried out after long period of counter measure application.

It is important to start the follow up process just after the implementation of countermeasures. In this way, it can be possible to observe if the applied countermeasure is working as it is planned or if it causes another problem which is not predicted before. It also helps to understand if the countermeasure application totally removes the problem or it reduces the amount and the severity of the problem.

For estimating the exact results of countermeasures it is necessary to make follow-up for minimum three years for the long-term evaluations. On the other hand, all changes in the road and its environment have to be observed, because these changes could affect the road safety and also affect the countermeasure efficiency.

2.5 Planning Highway Network for Safety

Planning of roads can have a profound effect on the level of road safety, planning road networks usually contains a complex interaction of land uses and activities. Each type of land use has its own traffic characteristics and this can lead to safety problems.

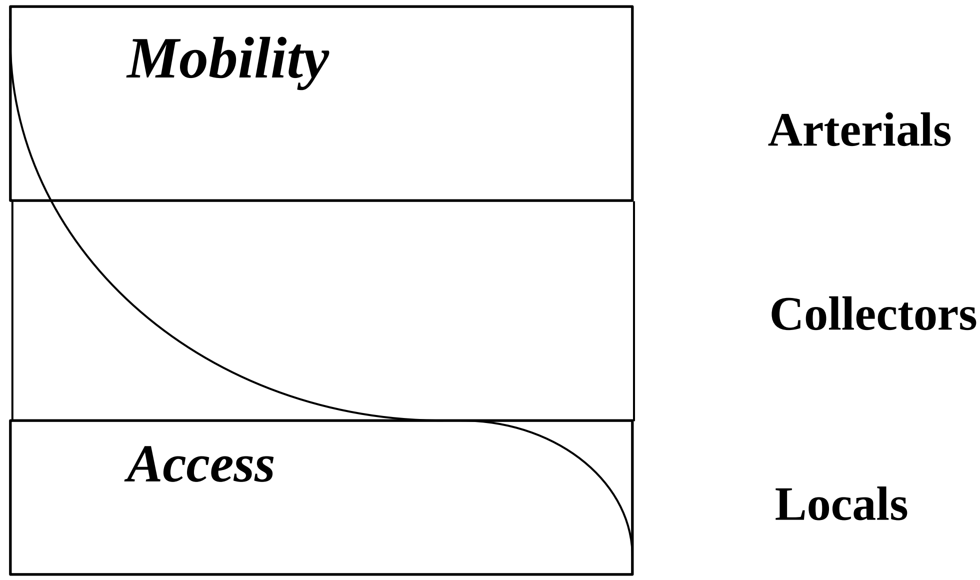

Figure 2.2 Ideal roadway hierarchies. (15)

Road hierarchy in highway planning is to consider the functions of local roads, collectors, and arterials in terms of accessibility and mobility. Local roads mostly provide access to land, whereas arterials mostly provide mobility for through traffic. Collectors fall functionally halfway between local roads and arterials as shown in Figure 2.2 above.

Figure 2.2 above indicates that accident and fatality rates on arterial highways with full control of access are far less than that of collectors and locals with no access control. The increase in roadside development results in an increase in at grade intersections and in business with direct access to the highway, this situation always significantly increases accidents.

Highway network planning for safety should include following three features namely road hierarchy, land use and access control. Each of the three items above is described below.

a) Road Hierarchy

1- Highway networks should be clearly categorized into those which are primarily intended for mobility and those which are originally designed for access.

2- Unmistakable priority should be indicated at each intersection so that the traffic from the more important road is always given preference over that from the less important one. (15)

b) Land Use

1- Critical observations or careful examination on land development proposals should be made on traffic and safety implication before approval.

2- Minimizing road traffic and pedestrian conflicts should be included in land uses

3- Locating shops and schools within the walking distance of homes helps reducing the need of travel. (55)

c) Access Control

1- For a new arterial, a direct access should be permitted only in limited locations.

2- Potentially dangerous locations such as intersection and poor visibility are not allowed to have any access. (15)

2.6 Road Safety Audit History

Road safety audit procedures were developed in 1989 by British traffic engineers and evolved from a tool used by railway engineers to examine safety issues on railways. RSA were soon adopted by Australia, New Zealand, Denmark, and many other developed countries in the early 1990s. The development of the road safety audit procedures was refined before adoption by the American transportation community. (16)

In 1996, the FHWA sponsored a tour of Australia and New Zealand to study their road safety audit programs to learn strategies on how to implement road safety audits in the United States. From the lessons learned, FHWA sponsored a road safety audit workshop in St. Louis to develop procedures to be used in the road safety audit pilot program. The first pilot program included thirteen states and provided a basis for use of road safety audits in the United States. (16)

As road safety audits have gained popularity in the United States they have also gained recognition and acceptance in other parts of the world. The Asian Development Bank, in collaboration with United Nations Economic Commission for Europe and the World Bank, has recently sponsored the use of road safety audits and has published their own toolkit to be used in conducting a road safety audit. Countries around world are starting to realize the low cost tool of saving lives. (16)

There are two different safety auditing processes that can be used. The first one is the Road Safety Audit (RSA) that looks at projects both at design stage and during operational stage. The second safety audit process used is Road Safety Inspection (RSI) that looks at projects only during operation and focusing solely upon safety issues. RSI also focuses more on safety issues associated with the roadway, all road users, operating under all environmental conditions, and to identify the safety issues associated with the existing facility.(16)

Road safety audit on existing road is similar to road safety inspection, for this reason road safety audit and road safety inspection will be used interchangeably for the rest of chapters in this thesis.

2.7 Definition and Principles of RSA and RSI

The national association of road transport and traffic authorities in Australia that is called as Austroads defines a road safety audit as "....a formal examination of an existing or future road or traffic project, or any project which interacts with road users, in which an independent, qualified examiner looks at the project's accident potential and safety performance". (17)

PIARC (Permanent International Association of Road Congresses) also defines a Road Safety Audit as a "formal systematic road safety assessment of the road or road scheme carried out by an independent, qualified auditor or team of auditors who reports on the project's accident potential for all kinds of road users". (18)

Although the given definitions above includes reviews of existing roads, the current international understanding of road safety audits refers to examinations conducted in the planning and the design stages of road projects (which include new projects but also re-design projects) before or shortly after a road is opened to traffic or the measure is completed.

From the definitions above, the purpose of road safety audit is to identify potential safety problems for all road users in all road projects and eliminate those safety problems and also to ensure that countermeasures to eliminate and reduce the problems are fully considered. The scope of safety audit is to minimize number of accidents and severity and to ensure that all new highway schemes operate as safely as applicable. It is clear that consideration is given to enhance the safety of all road users rather than vehicles only.

Road safety audit implies an independent detailed systematic and technical safety check relating to the design characteristics of a road infrastructure project and covering all stages of road safety audit from planning to early operation.

A Road Safety Inspection (RSI) is a systematic field study, conducted by road safety expert(s), of an existing road or section of road to identify any hazards, faults and deficiencies that may lead to serious accidents. (19)

Road safety inspection involves systematic assessment of the safety standard of an existing road, in particular with respect to hazards related to traffic signs, roadside features, environmental risk factors and road surface condition. The main purpose of a road safety inspection is to identify traffic hazards and suggest measures to correct these hazards. (19)

Road safety inspections are, to a large extent, based on similar checklists and procedures as those applied in road safety audits. The only difference among the two is that road safety audits can be applied during the planning of new roads, whereas road safety inspections is only carried out on existing roads.

2.8 Steps of Road Safety Audit

Basically there are eight steps for conducting road safety audit as shown in the figure 3.0 below and there explanations as follows.

Step 1: Identify Project or Existing Road to Be Audited

This is the first step of road safety audit in which the main objective is to identify the existing road to be audited and to set parameters for the RSA as seen from figure 3 below. Some of the reasons that make a road or intersection to be audited are:

1-Roadway sections where there are general safety concerns

2-Roadway sections with high crash levels, high traffic volume, geometric roadway and associated design issues

3-Sections scheduled for overlay projects or school zones that have dangerous aspects associated with them. (20)

Once a roadway or intersection is selected, parameters need to be set that will define for client what work will be accomplished and the parameters should define the scope, scheduled for completion, team requirements, audit tasks, formal audit report contents and formats and the response report expectations.

Step 2: Select RSA Team

At this stage of RSA, the client or project owners should select the RSA team leader and together they should select the remaining individuals that will be on the RSA team. The team should include individuals with expertise in the following fields:

1- Traffic engineering

2- Design

3- Maintenance and safety engineering

4- Expertise in pedestrians and bicyclist, young and older pedestrians, older drivers, local knowledge, human factors, law enforcement and project scoping. (20)

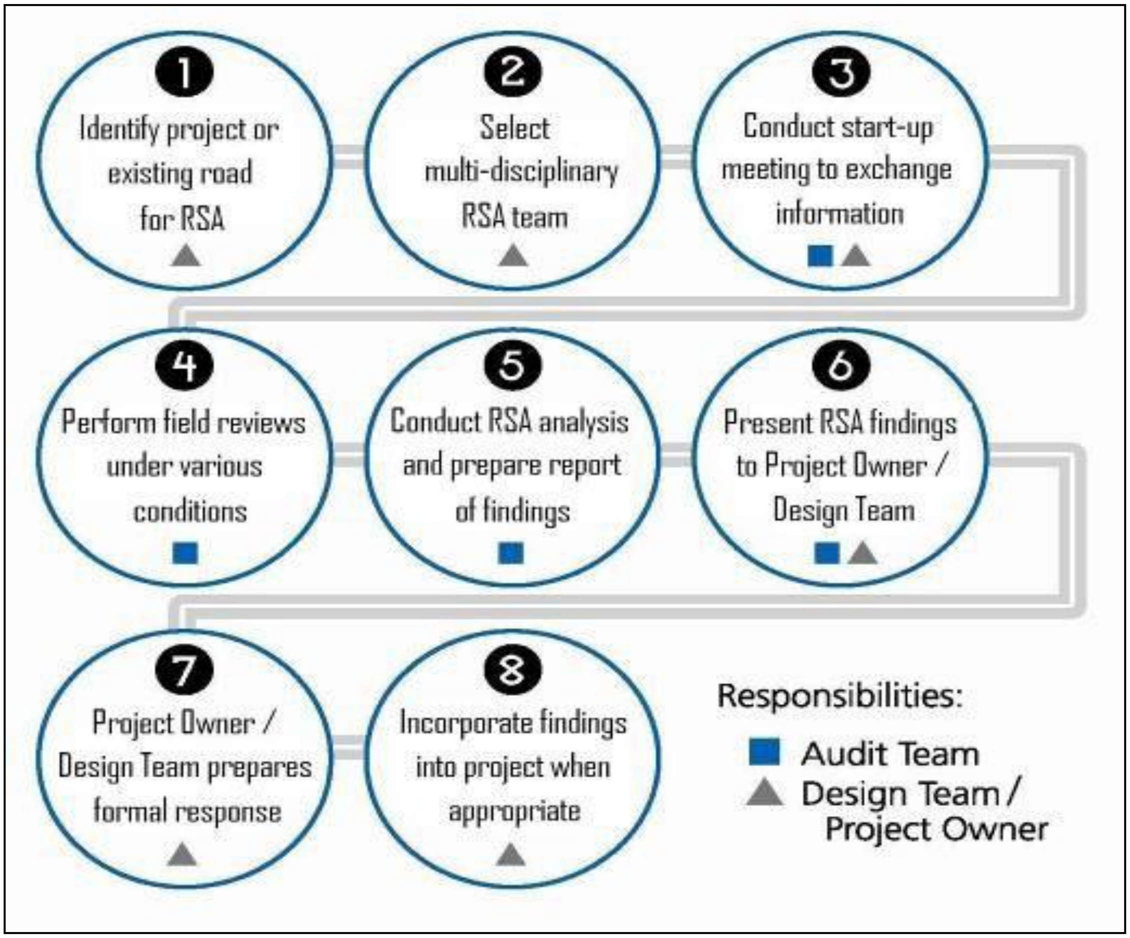

Figure 2.3 Road safety audit process. (21)

This group of experts provides all the necessary knowledge and experience to the process and also the freedom and ability of auditors to comment frankly on potentially controversial safety issue is crucial to the success of RSA.

Step 3: Conduct a Pre-Audit Meeting to Review Project Information and Drawings

At this step of RSA, the pre audit meeting should provide all team members with an overview of the process that the team is undertaking. The client or project owner will then need to provide all relevant information's about the project to be audited, this information's includes road function, classification, environment, traffic and environment characteristics of the road and adjacent road network, crash data detailing the location, and aerial photographs. (20)

Other usual information's if available includes resident complaints, police observations, bicycle and pedestrians use and any school zones on the project.

Step 4: Review of Project Data and Conduct a Field Review

This is the most important step in the RSA process; the field reviews should see the project at least two different times of day. Usually the team will walk through the segment together and note anything that will affect the safety of the road. Standards and policies can be a starting point. Photos and video should be taken of all issues to help in writing the final RSA report. The RSA team should look at physical evidence of past crashes and off road excursions which could include:

1- Damage to curbs, roadside barriers, trees, utility poles, delineator posts, and signs

2- Scuff marks on curbs and concrete barriers

3- Skid marks, broken glass, oil patches on the road

4- Vehicle tracks or rutting in the ground adjacent to a roadway. (20)

Step 5: Conduct Audit Analysis and Prepare Report of Findings

At this step, the RSA team will finalize the RSA findings and develop suggestion in mitigating them. Additionally the audit team should establish how they wish to evaluate risk from certain features and how to prioritize the suggestions given.

Step 6: Present Audit Findings to Project Owner/Design Team

One important aspect of this step is to share with the project owner the key findings and suggestions identified in the RSA report and see if they fit in with the project goals.

At this step the team leader also needs to remind the owner that the intent of the RSA was to identify opportunities to improve safety and it is not a critique of the road. It is also important to gather additional information from the owner about safety recommendations at specific areas. This will allow the RSA team to look back at the project and to modify any recommendations. (20)

Step 7: Prepare Formal Response

This is the stage of RSA that requires the project owner to explain what RSA recommendations are going to be implemented and what are not going to be. Below are some points to be considered at this step:

1- Is the RSA report finding within the scope of the project?

2- Would the suggestion made in the RSA report address the safety issue?

3- Will the suggestion made in the RSA report lead to mobility, environmental, or other non safety related problems?

4- What would be the cost associated with implementing the suggestions?

5- Are there more cost-effective alternatives that would be equally effective? (20)

Step 8: Incorporate Findings in to the Project When Appropriate

This step is to implement the safety recommendations found in the RSA report and to ensure the RSA process was a learning experience. The project owner will need to ensure that the agreements described in the response report are completed as described and in the time frame documented.

2.9 Stages for Conducting a Road Safety Audit

Basically there are six stages at which road safety audit can be conducted, the stages are described below as follows:
1. Feasibility Study (Concept Design);
2. Preliminary Design;
3. Detailed Design
4. Construction
5. Pre-Opening to Traffic; and
6. Existing Road Audit.

Stage 1 - Feasibility Study / Concept Design

At this stage of RSA, some aspects like route options, layout options or treatment options can be examined during feasibility stage audits. They allow an assessment of the relative safety performance of scheme options and identifying specific needs of various road users. By providing a specific safety input at this stage of a scheme, road safety audit can influence fundamental issues such as route choice, standards, impact on and continuity with the existing adjacent network, and intersection or interchange provision. (22)

Stage 2 - Preliminary Design

At this stage of audit, issues to be considered typically include horizontal and vertical alignments, and intersection layouts. Where land acquisition is required, the draft design stage audit should be undertaken before the title boundaries are finalized. It should be noted that once this stage of design is completed, and land acquisition and other associated matters are finalized, subsequent changes in road alignment become much more difficult and costly.

Stage 3 - Detailed Design

This audit stage takes place on the completion of the detailed design but before the preparation of contract documents. Some typical considerations at this stage include geometric layout, line markings, signing, delineation, traffic signals, lighting, intersection details, clearances to roadside objects, landscaping and provision for vulnerable road users.

Stage 4 - Construction

All construction sites are often places of confusion where the traffic route and traffic control devices are changed from their usual state. It is important that good traffic control and guidance be given to motorists to safely guide them through the construction zone and to protect the road workers. Some of the concerns at road works include signing, delineation and roadside objects. Construction projects of substantial size should be safety audited by day and by night. (22)

Stage 5 - Pre-Opening to Traffic

This stage of audit involves a detailed inspection of a newly completed work (new or modified scheme) prior to its opening to traffic. This usually involves inspection by the audit team as motorists and as pedestrians where appropriate.

If cyclists are to use the road, their needs and safety should also be considered. Inspections should be carried out by day and by night as some night time associated problems may not be obvious during the day. (22)

Stage 6 - Existing Road Audit

Road safety audit of an existing road is aim to ensure that the safety features of the road are compatible with the intended purpose of the road and to ensure that these are at an appropriate level of safety.

As the use of a road changes over time, this audit therefore also use to identify any feature which may develop into a safety concern, this stage of audit is independent of the first five as it can be carried out at any time on an existing road. (22)

At any or all stages of the projects RSA can be conducted. In general audits carried out in earlier stages get more potential benefits. That is why it is easier to change a line on a plan than to remove the problem by reconstruction once the road is opened.

2.10 Review of Existing Practices Regarding Road Safety Inspection in Different Countries Including Africa

Countries worldwide using the techniques of road safety audits and road safety inspection increases rapidly especially in most advanced countries since the middle of 1980s.

The degree of implementation of RSI varies across countries. Some countries have already published handbooks and guidelines for RSI, and some other countries have not even started the process of implementation. In this section, the implementation status of each country will be described as well as the different approaches in the countries.

This section presents the existing road safety inspection practices in some countries around the world. The countries are United Kingdom, New Zealand and Australia, Italy, France, Austria, Norway, Kenya, Benin Republic and Tanzania. Worldwide, the RSI concept has proven to be highly effective in identifying and reducing the crash potential of roadway projects.

Moreover in many countries all over the world RSA/RSI application is growing rapidly, since it is considered an important element of a road safety program. In majority of these countries, manuals have been developed and RSA/RSI is being carried out for years. The application concept is not exactly the same for applying countries but the general idea behind is the same.

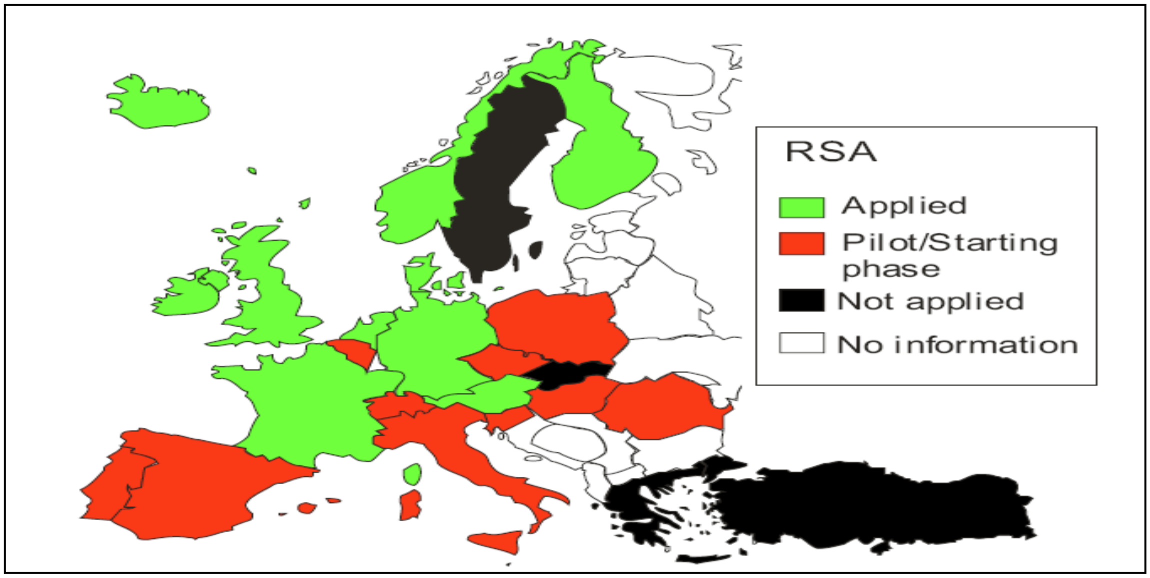

Figure 2.4 Current use of road safety audits in Europe (18)

Figure 2.5 Current use of road safety inspection in Europe (18)

From the figure 2.4 and figure 2.5 above it can be seen that both road safety audit and road safety inspection are being carried out in many European countries as a tool for safety.

Also the figure below shows the application of road safety audit in United State which shows majority of the countries have either adopted road safety audit completely or they are in piloting stage

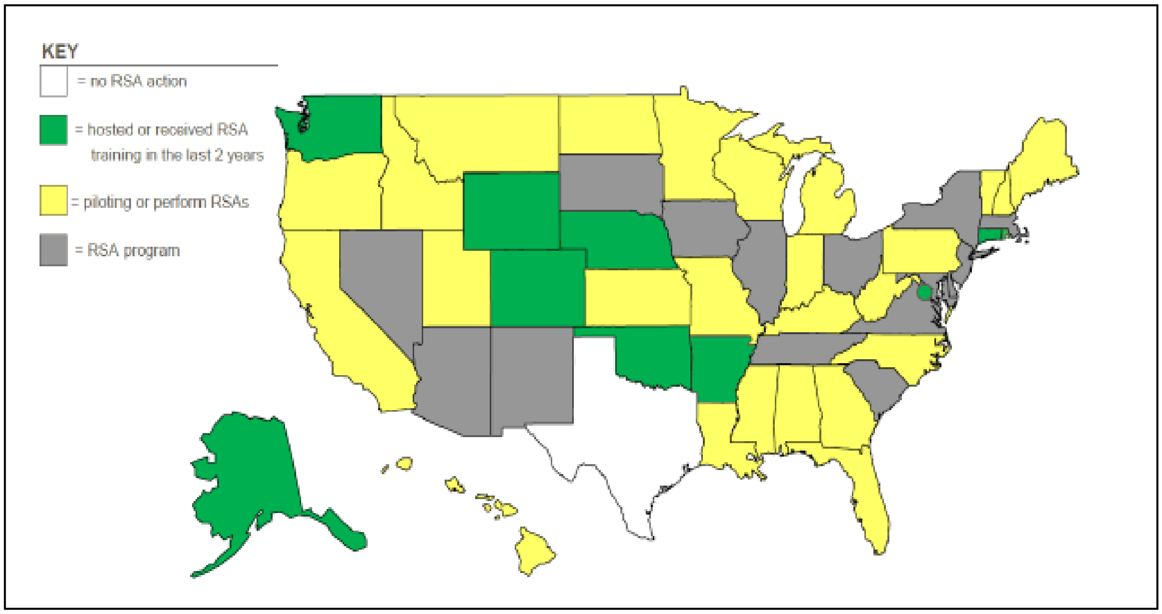

Figure 2.6 Current use of road safety audit in United States. (23)

2.10.1 United Kingdom

RSI in United Kingdom is based on the Road Inspection Manual, issued in 2004. The objectives of the manual were to define hierarchies of carriageways, footways and cycle tracks for inspections, to recommend the procedures and the minimum frequencies for the inspections used to determine routine maintenance tasks, and to encourage consistency in the standards for the inspections. (24)

RSI in UK fall within the remit of Highways Authorities maintenance offices and is therefore part of the routine maintenance, and from that ensures the concentration on short term measures and improvements.
In the UK the inspections are divided into two types as follows:

(1) Safety Inspections (SI): During the Safety Inspections SI all defects likely to create danger or serious inconvenience to users of the network have to be identified. Remedial measures to correct such defects should take place within 24 hours.

SI may be carried out from a slow moving vehicle, or on foot. In order to ensure the safety of the inspection team, the on-foot inspection should be done along the footway, and not along the carriageway. (13)

(2) Detailed Inspections (DI): The Detailed Inspections (DI) is designed according to the Road Inspection Manual (RIM) to record only those types of defects likely to require routine maintenance. These defects do not require urgent repair. Nevertheless, in case of identifying immediate or imminent hazards during the DI, these should also be noted. (24)

2.10.2 Austria

The legal basis for RSI in Austria is the RVS guideline, which was published in 2007. After that a handbook "Handbook for Carrying out Road Safety Inspection" was developed to supplement the guideline and support the systematization and ensure a standardized and structured approach for this instrument in Austria.
In Austria, Road Safety Inspections of motorways and expressways started in July 2003. Between 2003 and 2007 several sections have been inspected by Austrian Road Safety Board. In the following years pilot-inspections on the secondary road network were carried out. In the course of production of the RSI handbook pilot inspections in urban areas and municipalities were conducted. (24)

2.10.3 Italy

In Italy there is a manual called Operative procedures for Safety Inspections on Two-Lane Rural Roads. This manual was developed by the University of Catania, and its use has spread out to all Italian provinces and the Local Agencies in Sicily, Calabria and Campania on a volunteer basis. The manual was published in 2005 and revised in 2008. The manual describes the road safety operative procedures adopted by the IASP research program. (24)
The manual Operative Procedures for Safety Inspections on Two Lane Rural Roads requires several site inspections as follows:

(1) Preliminary inspection
(2) General inspection
(3) Detailed Inspection and
(4) Night time inspection. (24)

The main objectives of the above are as follows: preliminary inspection is trying to understand the general road safety conditions, general inspections is to obtain information about the safety issues and their location, detailed inspection In order to carry out a detailed inspection of the sites which present specific safety issues, and night time inspections is to understand how the road is perceived during the night in which the main focus is on road signs, delineation and visibility.

2.10.4 France

In France Road Safety Inspections are carried out periodically on the entire national road network at a three year interval. These periodical inspections have just started in 2009, after the decision of the Inter-ministerial Committee for Road Safety in February 2008. An extensive "Methodological Guide for Road Safety Inspections" has been published in 2008, which is the basis for this report. (24)

2.10.5 Australia and New Zealand

In Australia and New Zealand the inspection of existing roads is part of the Road Safety Audit (RSA). The guidelines for this instrument were first published in 1993 in New Zealand and in 1994 in Australia. The responsible institution for RSA in these two countries is AUSTROADS, the association of Australian and New Zealand road transport and traffic authorities.

In New Zealand it is required to carry out RSA on the whole road network (both national and local government); in Australia only state road projects must be audited. In Australia local government projects must be audited only if these projects are fully or partly funded by the state. In both countries, Australia and New Zealand, inspectors must be trained and experienced. (24)

2.10.6 Norway

The Norwegian Public Roads Administration published the Handbook Road Safety Audits and Inspections in 2006. According to this handbook RSI in Norway consists of three steps: Preparation, Inspection and Reporting. The handbook suggests the use of the new method for Road Safety Inspection. In this new method more time is dedicated to preparation, while by the traditional method reporting was the most time-consuming step. (24)

These changes were the result of the following developments: In the preparation step the road section is driven through several times, pictures are taken every 20 meters or a video recording is performed, which will be reviewed afterwards in the office. If this documentation is carried out beforehand, the field inspection will then be less time-consuming, when completed forms with pictures and comments are being used.

The inspection team should have an inspection leader, members with road safety knowledge, members with local knowledge of the road network (this is different from other countries where a fresh looks are used) and members with contracting competence.

It can also be appropriate to involve the police, the municipality and specialist with knowledge of tunnels, bridges, signs and markings, operation and maintenance, as well as road users. The number of members can vary depending on complexity, area, type and length of the section. The inspection always starts with an initial meeting, with attendance by all parties.

2.10.7 Kenya

The Kenya road safety program started in 1980 by Ministry of Transport and Communications Kenya, the program were supported by Finland, proposed organizational measures, enforcement, an accident investigation committee, driver training, vehicle inspection, road planning and maintenance, first aid training, information and education, and road safety research. The objective of the project was to improve road safety in Kenya. (25)

The Kenya road safety program came to an end in 1991. As part of the conclusion of this program the National Road safety Council prepared a Cabinet memorandum on measures to enhance safety on Kenyan roads which recommends several countermeasures to be employed.

2.10.8 Benin Republic

A road safety program in Benin begins during the year 1995, a program consisting of three projects were conceived in 1995. These projects make up the road safety part of the Transport Sector Program, which has been initiated with assistance from the World Bank. The projects entail
(a) Creation of a data bank for road accident statistics;
(b) Implementation of an awareness and education program;
(c) Strengthening of the centers for technical control of vehicles.
The main obstacle to realizing the road safety program has been a lack of funds to implement the programmed successfully. (25)

2.10.9 Tanzania

An extensive road safety program started in July 1996 (United Republic of Tanzania, 1996). The program comprises all areas of road safety and, if implemented, should have a great potential for reducing the road accident problem of Tanzania. However, as of February 1997, the government had not yet approved the program. (25)
The main objectives and activities of the program are:

(1) Establish a road safety organization capable of managing a multi-sector integrated approach to the road safety problem with long- and short-term plans.
(2) Increase the quality of life in Tanzania by preventing accident occurrence and by minimizing the consequences of road accidents.
(3) Prolong the life of the road network through effective vehicle and axle load control. (25)

CHAPTER 3

3 METHODOLOGY AND EXPLANATIONS OF ROAD SAFETY AUDIT

3.1 Introduction

The Road Safety Audit can be applied to specific operating and maintenance activities on existing roads as well as for systematic assessment of road safety aspects on existing roads and road networks.

Some of the inputs or information's that are necessary needed for road safety audits on existing road are road function, traffic data, speed data and accident data. These data support auditors for better performing the audit of the road. By the help of these data auditors can clarify the road function, have idea about the typical accident types, volume of traffic, speed levels of different vehicles etc. After getting these data they can immediately determine the potential hazards and focus on them.

3.2 Methodology for Safety Auditing on Existing Roads

Audit on existing roads started after certain information about the road section are obtained. Highway section should be audited for both traffic directions. Nevertheless one site study is never enough to collect auditing information and its evaluation. In many cases two or more auditing studies have to be implemented and at least one survey must be conducted at night.

One of the benefits of the RSA process is the cooperative interaction created by the members of the audit team. The knowledge and experience of the team as a whole are greater than the sum of these attributes as vested in the individual members, so the process benefits from being conducted by a team. While three members in a team may be adequate for some project types, the number may not be sufficient for larger, more complex projects or those requiring specific expertise. (26)

The best practice is to have the smallest team that brings all of the necessary knowledge and experience to the process.

All of the observations achieved during the audit are recorded on the safety audit checklists and forms prepared in a special format as illustrated on the subsequent paragraphs. Below are examples of some features to be observed during the field survey;

a- Locations in which shoulder widths are inadequate
b- Markings that are not in existence or in a complex condition (old and new markings mix each other)
c- Problematic road side zones that include dangerous features which can create specific danger within the clear zone width (Tress, Utility Poles).
d- The existence of various kinds of trees and other vegetation which obstruct the sight distance of the drivers
e- Improper location of the bus stops
f- Non guard-rail sections
g- Concrete structures and dangerous wall endings
h- Improper information signs
i- Improper junction design
j- Improper drainage structures. (26)

All these features above and many others are recorded on the safety audit checklist on existing road during the field survey, also photographs and video records were also made during the site visits which are used to make final discussions and evaluations.

3.3 General Project Data Required for Road Safety Audit on Existing Road

In order to carry out a road safety audit on existing road, there are many important data or information's required about the particular road section selected for auditing/inspection, the basic inputs or data's are described below.

3.3.1 Functional Classification of the Road

Functional classification is a way by which streets and highways are grouped into classes, or systems according to the character of traffic service that they are intended to provide. This classification recognizes that individual highways do not serve travel independently. Rather, most travel involves movement through networks of highways and can be categorized relative to such networks in a logical and efficient manner. Thus, functional classification of highways is consistent with the categorization of travel. (43)

The roads making up the functional systems differ for urban and rural areas. The hierarchy of the functional systems consists of principal arterials (for main movement), minor arterials (distributors), collectors, and local roads and streets. But however, in urban areas there are relatively more arterials with further functional subdivisions of the arterial category whereas in rural areas there are relatively more collectors with further functional subdivisions of the collector category. (27)

Rural roads consist of facilities outside of urban areas. The names provided for the recognizable systems are principal arterials (roads), minor arterials (roads), major and minor collectors (roads), and local roads. (27)

The rural principal arterial highway consists of the following service characteristics:

a. Corridor movement with trip length and density suitable for substantial statewide or interstate travel.
b. Movements between all, or virtually all, urban areas with populations over 50,000 and a large majority of those with populations over 25,000.
c. Integrated movement without stub connections except where unusual geographic or traffic flow conditions dictate otherwise. (27)

The rural minor arterial road system, in conjunction with the rural principal arterial system, forms the following service characteristics:

a. Linkage of cities, larger towns, and other traffic generators those are capable of attracting travel over similarly long distances.
b. Integrated interstate and inter county service.
c. Internal spacing consistent with population density, so that all developed areas of the state are within reasonable distances of arterial highways.
d. Corridor movements consistent with items through with trip lengths and travel densities greater than those predominantly served by rural collector or local systems. (27)

The rural collector routes generally serve travel of primarily between counties and constitute those routes on which predominant travel distances are shorter than on arterial routes. Consequently, more moderate speeds may be typical. (27)

The local road system, in comparison to collectors and arterial systems, primarily provides access to land adjacent to the collector network and serves travel over relatively short distances. The local road system constitutes all rural roads not classified as principal arterials, minor arterials, or collector roads.

Road function is important input for road safety audit. When starting an audit the auditors should have information about the character of the traffic that is based on the road function. All roads should be evaluated in their own function because different types of roads have different types of safety situations.

For example the prevailing risk of having fatal accidents is bigger in rural areas compared to urban areas thus the safety solutions of these areas are also different. The function of a road should be clear to all road users, and a well planned and defined road hierarchy can assist road users in providing a safe road network.

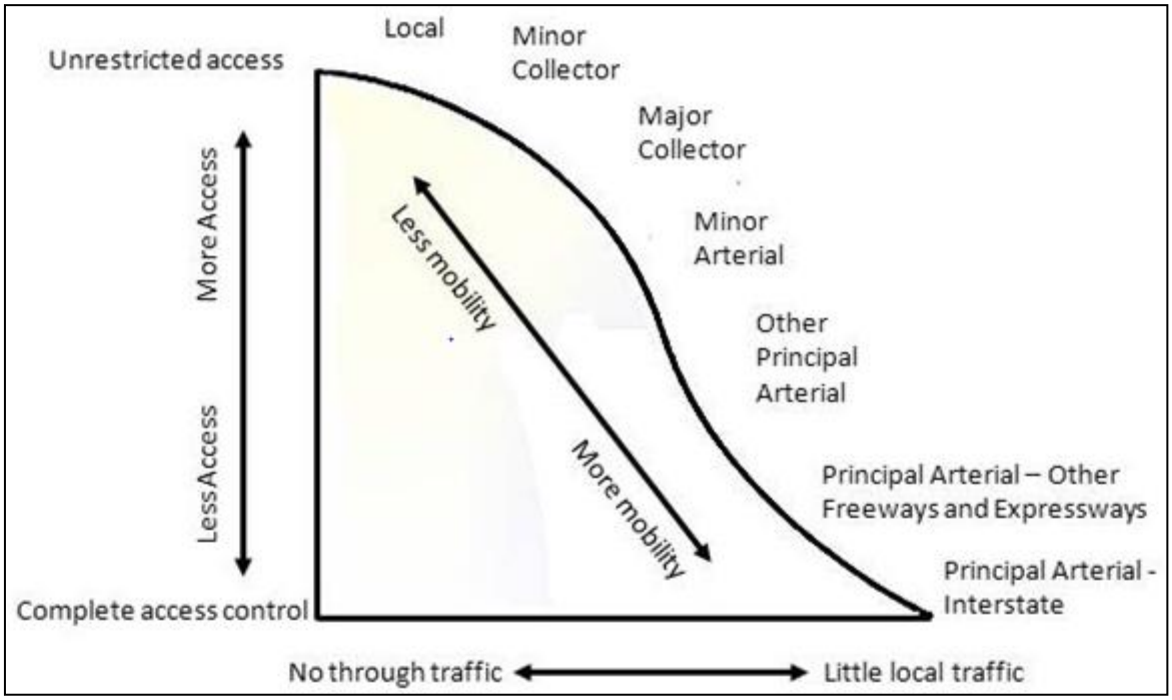

Figure 3.1 Illustration of Access-Mobility Relationship. (28)

Figure 3.0 above shows the relationship between mobility and land access, as well as how Principal Arterials, Collectors and Local Roads proportionally serve their functions**.** Arterials provide mostly mobility, Locals provide mostly land access, and Collectors strike a balance between the two.

Also from the figure 3.0 above, it can be observed that those roadways that provide a high level of mobility are Arterials, those that provide a high level of accessibility are Locals roads and those that provide a more balanced blend of mobility and access are called Collectors. (28)

3.3.2 Traffic Data

Highway Transportation Surveys are performed to establish a basis for transportation planning process and they contribute to the highway design, construction, maintenance and management facilities. Transportation surveys are accomplished according to the Annual Transportation Survey Program carried out by the Planning Departments of Road Authorities. They are achieved in order to determine traffic characteristics of highways by using modern counting devices and techniques.

All pertinent information such as volume, speed and accident data is formed by these surveys. The subsequent paragraphs represent the definitions of these data and explain relationship of the data and the road safety audits on existing road.

3.3.3 Volume Data

In order to carry out safety audit on existing road, traffic volume data is one of the necessary inputs required. Traffic volume studies are conducted to determine the number, movements, and classifications of roadway vehicles at a given location. These data can help to identify critical flow time periods, to determine the influence of large vehicles or pedestrians on vehicular traffic flow and to document traffic volume trends.

The length of the sampling period depends on the type of count being taken and the intended use of the data recorded. For example, an intersection count may be conducted during the peak flow period. If so, manual count with 15-minute intervals could be used to obtain the traffic volume data. (5)

Generally there are two methods available for conducting traffic volume counts 0n existing roadway.

a) Manual Traffic Volume Count

Manual traffic count is conducted without the help of any equipment. Most applications of manual counts require small samples of data at any given location. Manual counts are sometimes used when the effort and expense of automated equipment are not justified. Manual counts are necessary when automatic equipment is not available or the data required is small. (29)

b) Automatic Traffic Volume Count

The automatic count method provides a means for gathering large amounts of traffic data. Automatic counts are usually taken in 1-hour intervals for each 24-hour period. The counts may extend for a week, month, or year. When the counts are recorded for each 24-hour time period, the peak flow period can be identified. (29)

Generally Volume data is an important input for road safety audit on existing road or any other stage of the audit, and the data should always be accurate and reliable. Only reliable and accurate data is needed to correctly identify problems, risk factors and priority areas, and to formulate strategy, set targets and monitor performance. Without this, there will be no significant, sustainable reductions in exposure to crash risk or in the severity of crashes.

3.3.4 Speed Data

Speed data is also an essential data needed for road safety audit on existing road. Design speed is a selected speed used to determine the various design features of the roadway.

Geometric design features should be consistent with a specific design speed selected as appropriate for environmental and terrain conditions. (27)

Low design speeds are generally applicable to roads with winding alignment in rolling or mountainous terrain or where environmental conditions unfavorable and high design speeds are generally applicable to roads in level terrain or where other environmental conditions are favorable. Intermediate design speeds would be appropriate where terrain and other environmental conditions are a combination of those described for low and high speed. (27)

All geometric design elements of the highway are affected in some way by the selected design speed. Some roadway design elements are related directly to and vary appreciably with design speed, such elements include horizontal curvature, super elevations, sight distance, and gradient.

Other elements are less related to design speed, such as pavement and shoulder width and clearances to walls and traffic barriers, the design of these features can however, affect vehicle operating speeds significantly.
The selection of a particular design speed for a particular road is influenced by the following:

a. The functional classification of the highway
b. The character of the terrain
c. The density and character of adjacent land uses
d. The traffic volumes expected to use the highway
e. The economic and environmental considerations. (27)

Typically, the order of speed selection is as follows, an arterial highway warrants a higher design speed than a local road; a highway located in level terrain warrants a higher design speed than one in mountainous terrain; a highway in a rural area warrants a higher design speed than one in an urban area. (27)

When conducting audit on acceleration, deceleration lanes, barrier design, exit and entrance parts of the roadside facilities, desired clear zone width, stopping and passing side distance, all these features are design based on the speed data. On the other hand, prevailing speed surveys may reveal speeding related casualties.

3.3.5 Accident Data

An accident database is needed for accurate assessment of the road safety situation. In order to be useful, the record needs to cover data on deaths and casualties and the circumstances of the accidents. This will help for safety improvements and implement appropriate measures designed to solve specific problems.

The main processes of producing an accident database include an accident reporting and recording system, storage and retrieval system, an analysis system, and an effective dissemination system. (30)

The data collected for all recorded accidents needs to cover the following questions:

a. Where accidents occur;
b. When accidents occur;
c. What type of car involved;
d. What was the result of the collision?
e. What were the environmental conditions?
f. How did the collision occur? (30)

Accident data is very useful for designing appropriate countermeasures, producing plans, monitoring effectiveness, and carrying out research.

3.3.6 Safety Audit Checklist on Existing Road

The recommended structure of safety audit checklist on existing road is illustrated below.

SAFETY AUDIT CHECKLIST ON EXISTING ROAD

Date:

Weather: **Conducted By:**

CONTROL STATION NUMBER(CSN)	KM	DISTANCE M	TYPE OF HAZARD	COMMENT

Table 3.1 Road Safety Audit Checklist

3.3.7 List of Hazards

All the hazards on existing roadway were categorized and classified in to two different groups as road side and road design hazards as shown in the table below:

Table 3.2 Hazard List

A-Road Design Hazards	
Hazard Number	**Hazard Name**
1	Shoulder missing
2	Shoulders too narrow
3	Shoulder unpaved
4	Improper junction design
5	Improper connection to shop, petrol station, commercial activities
6	Improper connection to small access road
7	Improper connection to roadway
8	Improper median opening
9	Limited sight distance
10	Improper or dangerous pedestrian crossing
11	Too small radius of horizontal curve
12	Too small radius length of vertical curve
13	Speed limit too high
14	Speed limit too low
15	Improper vertical sign
16	Improper horizontal sign
17	Potholes
B-Road Side Area Hazards	
18	Dangerous fixed object on the roadway
19	Dangerous fixed object on road side or median
20	Dangerous fixed object on road island
21	Temporary road narrowing (e.g. bridge)
22	Fixed massive poles near road or in the median
23	Road edge deterioration
24	Big trees or trees close to the road
25	Dangerous bridge piers
26	Dangerous hedge
27	Dangerous cut form
28	Dangerous free stones or rocks
29	Dangerous support for signs(advertisement or road information sign)
30	House or other building so close to road

Table 3.2 Hazard List (continuation)

31	Steep edge slope without guardrail
32	Dangerous guardrail start and end
33	Improper culvert design on the road side
34	Improper commercial activities on the roadside
35	Improper bus stop design
36	Missing sign
37	Use of non standard sign

3.4 Roadside Safety

The roadside safety is the prior concept of the road safety audit (RSA) on existing roads. Roadside safety concept includes information about the clear zone area and hazardous obstacles locations for both at project level and for analysis of existing road sections.

Run off road (leaving carriageway / loss of control) results into fatal accident if crash involves dangerous objects on the roadside. The severity of this type of accident may also be influenced by the physical characteristics of the roadside environment (side slopes, etc.). The Highway Project Engineers have to give attention to minimize the number and severity of accidents by designing roads with more gentle side slopes and by arranging safe zones along the road sides. (31)
Flat and traversable, stable slopes can minimize further overturning if vehicle leaves the carriageway. Roadsides, in which obstacles cannot be removed with a reasonable cost, should be controlled by installing guardrails. The guardrail should be given illuminating features so as to be readily visible to motorists. (31)

3.4.1 Safety Zone

Safety zone addresses the area outside the roadway and is an important component of total highway design. There are numerous reasons why a vehicle leaves the roadway, including driver error and behaviors. Regardless of the reason, a roadside design can reduce the seriousness of the error and the subsequent consequences of a roadside encroachment.

From a crash reduction and severity perspective, the ideal highway has roadsides and median areas that are flat and unobstructed by objects. It is also recognized that different facilities have different needs and considerations, and these issues are considered in any final design.

Along both sides of a road, there should be a recovery area (a clear zone) permitting the driver to regain control of a vehicle which for some reason has left the roadway. The recovery area should have a gentle design with flat slopes to prevent the vehicle from rolling over. It should also be clear from hazardous objects which can cause injuries to the driver or passengers. (32)

The typical design of the clear zone is shown in figure below.

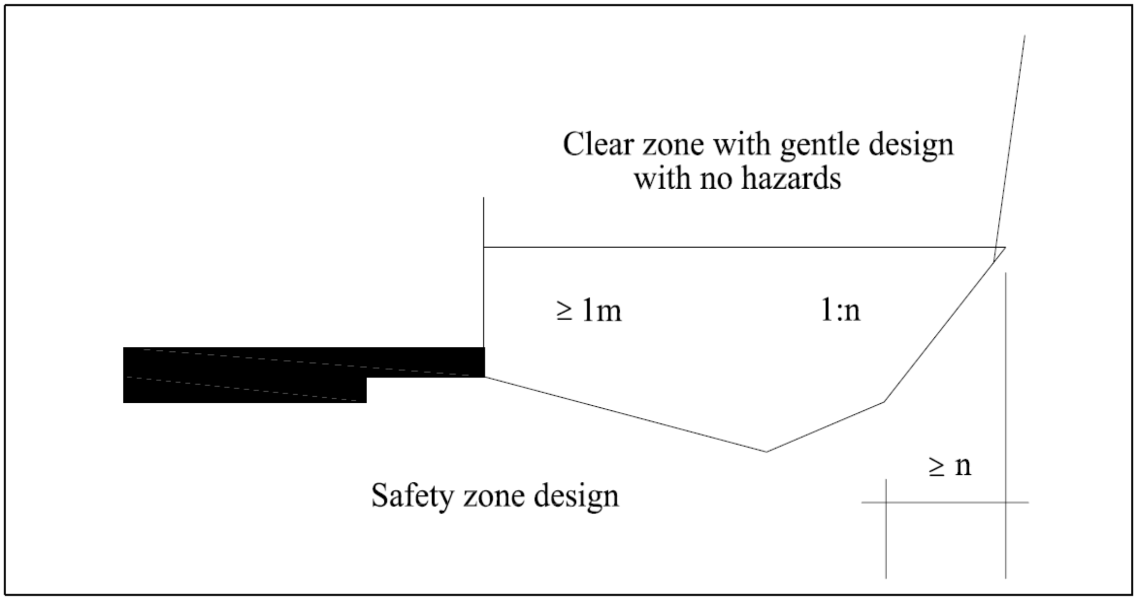

Figure 3.2 Roadside Safety Zone Designs (33)

Some of the hazardous objects associated with roadside are described below;

a. Bridge piers, abutments, railing ends
b. Rocks with diameters > 0.2 m
c. Trees with diameters > 0.1 m
d. Cross (transverse) pipe opening widths larger than (750 mm)
e. Box culverts and cattle passes
f. Approach (parallel) pipe height larger than (600 mm)
g. Cut slopes (rough)
h. Steep in slopes
i. Approach slopes steeper than 6:1
j. Signs/luminaries/traffic signals with non-breakaway supports
k. Utility poles (lighting)
l. Walls (unless crashworthy). (32)

Adequate clear zone distance between the edges of traffic lanes and roadside obstructions has been shown to be a very important safety factor. Out of control vehicles leaving the roadway should have a reasonable opportunity to recover control and return to the roadway without overturning or colliding with roadside obstacles.

To prevent fatal accidents within the clear zone, the hazards that are located in the safety zone should be;

(1) Taken away or removed
(2) Replace it with a non-hazardous equipment
(3) Redesigned or shielded by traffic barriers or crash cushion. (32)

According to AASHTO, the width of clear zone is found out by evaluating the annual average daily traffic (AADT), the design speed and cut or fill slope section of roadside slope. Based on this data, the required widths of safety zone are given table 3.1 below.

Table 3.3 Recommended Clear Zone Width. (33)

Design Speed	Design Year of ADT	Cuts or Fills (Negative Shelf)		Cuts or Fills (Positive Shelf)	
		1:6 or flatter	1:4	1:4	1:6 or flatter
60 km/h or less	Under 750	2.0	2.0	2.0	2.0
	750-1500	3.0	3.5	3.0	3.0
	1500-6000	3.5	4.5	3.5	3.5
	Over 6000	4.5	5.0	4.5	4.5
70-80 km/h	Under 750	3.0	3.5	2.5	3.0
	750-1500	4.5	5.0	3.5	4.5
	1500-6000	5.0	6.0	4.5	5.0
	Over 6000	6.0	7.5	5.5	6.0
90 km/h	Under 750	3.5	4.5	3.0	3.0
	750-1500	5.0	6.0	4.5	5.0
	1500-6000	6.0	7.5	5.0	6.0
	Over 6000	6.5	8.0	6.0	6.5
100 km/h	Under 750	5.0	6.0	3.5	4.5
	750-1500	6.0	8.0	5.0	6.0
	1500-6000	8.0	9.0	5.5	7.5
	Over 6000	9.0	9.0	7.5	8.0
110 km/h	Under 750	5.5	6.0	4.5	4.5
	750-1500	7.5	8.5	5.5	6.0
	1500-6000	8.5	9.0	6.5	8.0
	Over 6000	9.0	9.0	8.0	8.5

3.5 Basic Explanations of Typical Hazards

Some of the typical hazards associated with either roadside or road design are described and explained below.

a) Utility Poles

Utility pole crashes are fixed-object crashes that involve vehicles leaving the travel lane and striking a utility pole.

Utility poles can also contribute to the severity of other crash types. Many crashes are not classified as run of roadway or fixed-object crashes where one or more vehicles strike a utility pole. Crashes are often classified by "first harmful event." In some cases, striking the utility pole is a secondary event that may be as severe as, or more severe than, the first harmful event. Crashes involving utility poles as secondary events easily go unnoticed when examining the total magnitude of the utility pole crash problem. (34)

Utility poles are one of the most substantial objects that are placed on roadsides worldwide. They are substantial both in number and in structural strength. Because of the structural strength of utility poles, these crashes tend to be severe.

b) Trees

Beside the utility pole crashes, another higher crash rates and fatalities are also associated with roadside trees. One of the most common causes of fatal and severe injury accidents on rural roads in particular are fixed objects. Trees are the objects most commonly struck in run off road collisions, and tree impacts are generally quite severe.

A collision between vehicles and trees is one of the major types of traffic fatality. Fatal tree crashes were most prevalent on local rural roads, followed by major rural collectors. The crash effects of nearby trees along high-speed, rural roadways are indisputable. County and township roads that generally have restrictive geometric designs and narrow, off-road recovery areas account for a large percentage of the annual tree-related fatal crashes. Existing trees often pose greater risk than trees that have been placed along new or reconstructed roads. (35)

c) Walls and Concrete Structures

Walls and concrete structures located in critical positions are not consistent with a forgiving roadside. Walls and concrete structures are made by high structural strength of materials. These types of roadside structures cause more serious injury and damage accidents.

d) Improper Signing and Marking

Driving is mainly based on visual information input. There are many types of visual information, but road signs and road markings are important because they can provide relevant information for the driver to execute his or her task safely. Therefore, road signing may constitute an important road safety factor. The characteristics of road signing may have negative effects on traffic safety in the following cases:

a. The driver does not detect the sign/marking;
b. The driver is not able to identify the sign/marking properly;
c. The driver does not understand the sign/marking;
d. The driver does not have enough time to decide and take the action(s) needed;

e. The sign/marking does not meet the driver's expectations;
f. The sign's message is not heeded by the driver;
g. The information on the sign is wrong / inappropriate;
h. The driver does not remember the sign for the necessary time. (36)

e) Intersections

Many accidents on rural highways occur at intersections. Intersections are locations where two or more roads are connected or cross each other. The crossing and turning maneuvers that occur at intersections create risks for vehicle-vehicle, vehicle-pedestrian, and vehicle-bicycle conflicts, which may result in crashes. Thus, intersections are likely points for higher traffic crashes.

f) Improper Access Management

Access regulation along roadway is referred to as access control; it is achieved through the regulation of public access rights to and from properties abutting the highway facilities. These regulations generally are categorized as full control of access, partial control of access, access management, and driveway/entrance regulations. The principal advantages of controlling access are the preservation or improvement of service and safety. (27)

Access control, which is the way of regulating public access to and from properties abutting highway facilities, is one of the most significant factors in the safe, efficient operation of a highway. Full control of access is the most important single safety factor that may be designed into new highways. (27)

The principle of full control of access is invaluable as a means for preserving the capacity of arterial highways and of minimizing accident potential. On the other hand, improper access control may create great potential for the traffic accidents.

g) Improper Bus Stop Design

Improving facilities for public transportation is one of the main concerns of the urban network improvements. In this concept there must be safe areas for busses to stop and take passengers without interrupting the traffic stream. In some cases, bus stop designs are improper thus creating danger for public transportation users and the other drivers. At some other cases there are not any safe areas for bus stops.

h) Improper Drainage Structures Design

Drainage is one of the most critical elements in the design of a highway. Highway drainage facilities carry water across the road and remove storm water from the roadway itself. Drainage structures include bridges, culverts, channels, curbs, gutters, concrete pipes and various types of drains. These elements should be designed, constructed, and maintained considering both hydraulic efficiency and roadside safety.

Ends of large drainage structures, causes safety problems for errant vehicles, therefore culvert openings should be covered with traversable grates, where practical, to prevent trapping a vehicle.

It was stated by National Cooperative Highway Research Program (NHCRP) that:

a. The improper design of roadside (and of wide medians, which is equivalent to roadside) drainage elements can increase accident severity.
b. The improper placement of drainage inlets / outlets may cause improper drainage resulting in a reduced friction hazard and thus contributing to the occurrence of an accident. (37)

i) Improper Medians and Median Openings

A median is the portion of a highway separating opposing directions of the traveled way. Medians are highly desirable on arterials carrying four or more lanes. Median width is expressed as the dimension between the edges of traveled way and includes the left shoulders, if any.

The principal functions of a median regarding safety are to separate opposing traffic, provide a recovery area for out of- control vehicles, provide a stopping area in case of emergencies, allow space for speed changes and storage of left-turning and U-turning vehicles, minimize headlight glare, and provide width for future lanes. (27)

In urban areas there are some additional benefits of median such as it may offer an open green space, also provide a safe area for pedestrians crossing the street, and may control the location of intersection traffic conflicts. For maximum efficiency, a median should be highly visible both night and day and should contrast with the traveled way. Medians may be depressed, raised, or flush with the traveled way surface. (27)

Properly designed median barriers minimize vehicle damage and lessen the accident likelihood of traffic moving in the same direction. A narrow median also does not allow for emergency departure from the lane.

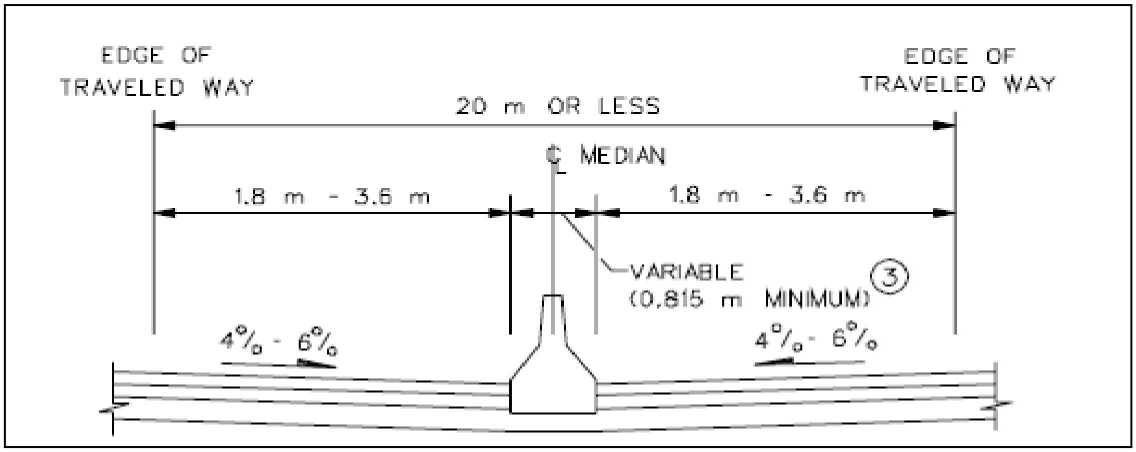

Figure 3.3 Typical Median with Concrete Barrier (21)

j) Improper Selection of Lane and Shoulder Widths

Total roadway width is among the most important cross-section considerations in the safety performance of a highway. Wider lanes and shoulders normally result in fewer crashes.

It can be explained that, although the highway design elements such as lane width, shoulder width, and sight distance restriction are related to accidents, they do not ordinarily serve as good predictors of accidents. Generally speaking, wider lanes, wider shoulders, and unimpaired sight distance result in a safer highway. (27)

The capacity of a highway is affected by the lane width. Narrow lanes force drivers to operate their vehicles closer to each other laterally than they would normally desire. Restricted clearances have much the same effect. In a capacity sense the effective width of traveled way is reduced when adjacent obstructions such as retaining walls, bridge trusses or headwalls, and parked cars restrict the lateral clearance. In addition to the capacity effect, the resultant erratic operation has an undesirable effect on driver comfort and crash rates. (27)

A shoulder is the portion of the roadway platform that accommodates stopped vehicles, emergency use, and lateral support of sub-base, base, and surface courses. In some cases, the shoulder can accommodate bicyclists. Regardless of the width, a shoulder should be continuous. With a continuous shoulder, almost all drivers making emergency stops will leave the traveled way, but with inadequate shoulder, drivers will find it necessary to stop on the traveled way, creating danger to other road users.

k) Improper Selection of Speed Limit

A speed is often a contributing factor in accidents, but it must be related to conditions. It is improper to conclude that any given speed is safer than another for all combinations of different kinds of drivers, vehicles, highways, and local conditions.

For a highway with particularly adverse roadway conditions, a relatively low speed may result in fewer crashes than a high speed, but this does not necessarily means that all potential crashes can be eliminated by low speeds. Likewise, vehicles traveling on good roads at relatively high speed may have lower crash involvement rates than vehicles traveling at lower speeds, but it does not necessarily follow that yet a higher speed would be even safer. (27)

Safest speed for any highway depends on design features, road conditions, traffic volumes, weather conditions, roadside development, spacing of intersecting roads, cross-traffic volumes, and other factors. Crashes are not related as much to speed as to the range in speeds from the highest to the lowest.

l) Improper Fill and Cut Slopes

Fill slopes can present a risk to an errant vehicle with the degree of severity dependent upon the slope and height of the fill. Providing fill slopes that are 4H:1V or flatter can mitigate this condition. According to the critical surface condition the fill slopes can be reduced 3H:1V or more steep but if the fill slope height is high some of the safety conditions should be thought by designer for road users safety. Also 3H:1V or more steep side slopes, the surface stability analysis should be considered. (27)

A cut slope is usually less of a risk than a traffic barrier. The exception is a rock cut with a rough face that might cause vehicle snagging rather than providing relatively smooth redirection. Analyze the potential motorist risk and the benefits of treatment of rough rock cuts located within the Design Clear Zone. Conduct an individual investigation for each rock cut or group of rock cuts. A cost-effectiveness analysis that considers the consequences of doing nothing, removal, smoothing of the cut slope, and other viable options to reduce the severity of the condition can be used to determine the appropriate treatment. (27)

Cut slopes can be changed by the material type and the topographical conditions of the road alignment. In high cut slopes; safety for road users and pedestrians along the cut slope area can be provided by establishing guardrails.

m) Barriers

Roadside barriers are important components in road and bridge project designs when a hazard is perceived alongside the roadway but also at the same time very dangerous by increasing accident severity.

Hazards include fixed objects such as non breakaway light and sign posts, telephone poles, bridge piers and abutments, retaining walls and culverts, trees, rough rock cuts, boulders, embankments, streams and permanent water bodies.

Roadside barriers are also used to separate roadways from pedestrians, bicycle paths and steep grades, to separate opposing traffic lanes, and to define medians. They are typically set in the roadway's “clear zone” or “recovery zone”, the area beyond the travel lane that needs to be kept clear of potential fixed-object hazards. This area’s depth varies with traffic volume and design speed. (38)

Safety barriers include guard fences (traffic barriers on the edge of a carriageway; if used in a median they may be referred to as median barriers) and impact attenuators (devices installed at fixed installations, such as bridge piers; they are also referred to as crash cushions). (38)

Guardrails not only decrease the accident casualty, but also cause increase severity of accidents, with wrong design and loss of functionality.

n) Pavement

The selection of pavement type is determined based on the traffic volume and composition, soil characteristics, weather, performance of pavements in the area, availability of materials, energy conservation, initial cost, and the overall annual maintenance and service-life cost. (39)

Important pavement characteristics that are related to geometric design are the effect on driver behavior and the ability of a surface to retain its shape and dimensions, to drain, and to retain adequate skid resistance.

Nevertheless, when eliminating crashes is not possible, reducing the severity of a crash is an important goal. In this sense, more attention is required to other elements of the roadway system that could be a contributing factor in traffic crashes.

One such contributing factor that has been discussed and evaluated over the years is road surface characteristics, specifically skid resistance (friction) of roadway pavements under various weather and aging conditions. (39)

Skid resistance of pavements is the friction force developed at the tire pavement contact area. In other words, skid resistance is the force that resists sliding on pavement surfaces. This force is an essential component of traffic safety because it provides the grip that a tire needs to maintain vehicle control and for stopping in emergency situations. Skid resistance is critical in preventing excessive skidding and reducing the stopping distance in emergency braking situations. (39)

o) Temporary Work Zones

The driving conditions of work zones differ from normal driving conditions. In addition, the driving conditions of each type of work zone (short-term, long-term, etc.) may differ from those of another type of work zone. These factors can result in violations of road user expectancy, which in turn can lead to congestion, erratic maneuvers, and ultimately crashes.

The factors found to have contributed to crashes at work zones includes:

a. some aspect of the work zone
b. traffic congestion
c. lane changing
d. vehicles entering and leaving the work zone
e. unexpected presence of flag-person.(39)

3.6 Typical Hazards Countermeasure Selection

Having identified the elements of the road and traffic environment or driver behavior, which may have contributed to the crashes, it is now important to consider countermeasures. There are no 'general' road safety solutions; for a solution to be effective, it must be applied to a particular problem, which it is known to affect. It must be an effective countermeasure. Although a large proportion of crashes are deemed to be a result of driver error, but however with engineering measures, it is possible to:

a. modify driver behavior
b. modify the road and environment that led to the error
c. make the environment more accepting of human error

The most important aspect of developing solutions is to link the specific countermeasures to the specific problems identified. The countermeasures could include engineering, enforcement and education. But enforcement and education recommendations need to be forwarded to the appropriate agencies for program development and implementation. (40)

A Crash Reduction Study (CRS) is too focused on low medium cost engineering solutions that will prove to be very effective with an excellent economic return. However, in some cases a significant crash reduction may only be achieved through larger scale, and more substantial improvements. If this is the case, the CRS team would generally recommend a more detailed study to be carried out to investigate these more substantive options rather than to delay the overall study pending more detailed analysis. (40)

The degree to which these more substantive solutions are developed is dependent upon the CRS brief. The Road Controlling Authority (RCA) may widen the study brief to include consideration of medium to high cost options. The expertise of the team members may need to be broadened to accommodate this and other aspects such as traffic flow, environmental impact, mobility, accessibility and sustainability. (40)

There are number of general countermeasures for hazards and problems that can be applied in order to achieve safe traffic operation for the roads which were proposed below.

a) Safety Zone

A clear roadside border area is a primary consideration when analyzing potential roadside and median features. The intent is to provide as much clear, traversable area for a vehicle to recover as practicable given the function of the roadway and the potential tradeoffs.

Roadside safety addresses the area outside the roadway and is an important component of total highway design. There are numerous reasons why a vehicle leaves the roadway, including driver error and behaviors. Regardless of the reason, a roadside design can reduce the seriousness of the error and the subsequent consequences of a roadside encroachment. From a crash reduction and severity perspective, the ideal highway has roadsides and median areas that are flat and unobstructed by objects. It is also recognized that different facilities have different needs and considerations, and these issues are considered in any final design. (40)

It is not possible to provide a clear zone free of objects at all locations and under all circumstances. The engineer faces many tradeoffs in design decision-making, balancing needs of the environment, right of way, and different modes of transportation. (40)

Elements such as side slopes, fixed objects, and water are features that a vehicle might encounter when it leaves the roadway. These features present varying degrees of deceleration to the vehicle and its occupants. The counter measures to be taken depend on the probability of a collision occurring, the likely severity, and the available resources.

According to order of priority, the counter measures according to the Washington State Department of Transportation are:

a. Removal
b. Relocation
c. Reduction of impact severity (using breakaway features or making it traversable) and
d. Shielding with a traffic barrier. (40)

b) Cut Slope
A cut slope is usually less of a risk than a traffic barrier. The exception is a rock cut with a rough face that might cause vehicle snagging rather than providing relatively smooth redirection. Analyze the potential motorist risk and the benefits of treatment of rough rock cuts located within the Design Clear Zone.

Conduct an individual investigation for each rock cut or group of rock cuts. A cost-effectiveness analysis that considers the consequences of doing nothing, removal, smoothing of the cut slope, and other viable options to reduce the severity of the condition can be used to determine the appropriate treatment. Some potential options are:

a. Graded landform along the base of a rock cut.
b. Flexible barrier
c. More rigid barrier
d. Rumble strips. (40)

c) Fill Slope
Fill slopes can present a risk to an errant vehicle with the degree of severity dependent upon the slope and height of the fill. Providing fill slopes that are 4H:1V or flatter can mitigate this condition. If flattening the slope is not feasible or cost-effective, the installation of a barrier might be appropriate.

d) Fixed Objects
Mitigate fixed features that exist within the Design Clear Zone when practicable. Although limited in application, there may be situations where removal of an object outside the right of way is appropriate. The possible mitigative measures are listed as follows in order of preference:

a. Remove
b. Relocate
c. Reduce impact severity (using a breakaway feature)
d. Shield the object by using longitudinal barrier or impact attenuator use engineering judgment when considering the following objects for mitigation:
e. Wooden poles or posts with cross-sectional areas greater than 16 square inches that do not have breakaway features.
f. Signs, illumination, cameras, weather stations, and other items mounted on non breakaway poles, cantilevers, or bridges.
g. Trees with a diameter of 4 inches or more, measured at 6 inches above the ground surface.

h. Fixed objects extending above the ground surface by more than 4 inches; for example, boulders, concrete bridge rails, signal/electrical/ITS cabinets, piers, and retaining walls.
i. Drainage items such as culvert and pipe ends. (40)

e) Trees

When evaluating new plantings or existing trees, consider the maximum allowable diameter of 4 inches, measured at 6 inches above the ground when the tree has matured. When removing trees within the Design Clear Zone, complete removal of stumps is preferred. However, to avoid significant disturbance of the roadside vegetation, larger stumps may be mitigated by grinding or cutting them flush to the ground and grading around them.

Removal of trees may be beneficial to reduce the impacts of driving errors, which result in angle crashes and roadside and clear zone encroachments. It is recognized that different facilities have different needs and considerations, and these issues are considered in any final design. For instance, removal of trees within the Design Clear Zone may not be desirable in contexts such as within a forest, park, or within a scenic and recreational highway. In these corridors, analyze collision reports' contributing factors to determine whether roadside vegetation is contributing to collisions. If large vegetation is removed, replace with shrubs or groundcover or consult guidance contained in established vegetation management plans or corridor plans. (40)

f) Culvert End

Provide a traversable end treatment when the culvert end section or opening is on the roadway side slope and within the Design Clear Zone. This can be accomplished for small culverts by beveling the end to match the side slope, with a maximum of 4 inches extending out of the side slope.

a. Bars might be needed to provide a traversable opening for larger culverts. Place bars in the plane of the culvert opening.
b. Single cross-culvert opening exceeds 40 inches, measured parallel to the direction of travel.
c. Multiple cross-culvert openings that exceed 30 inches each, measured parallel to the direction of travel.
d. Culvert approximately parallel to the roadway that has an opening exceeding 24 inches, measured perpendicular to the direction of travel. (26)

Bars are permitted where they will not significantly affect the stream hydraulics and where debris drift is minor. Other treatments are extending the culvert to move the end outside the Design Clear Zone or installing a traffic barrier.

g) Sign Post

Whenever possible, locate signs behind existing or planned traffic barrier installations to eliminate the need for breakaway posts. Place them at least 25 feet from the end of the barrier terminal and with the sign face behind the barrier. When barrier is not present, use terrain features to reduce the likelihood of an errant vehicle striking the signposts. Whenever possible, minor adjustments to the sign location may be made to take advantage of barrier or terrain features. (40)

Signposts with cross-sectional areas greater than 16 square inches that are within the Design Clear Zone and not located behind a barrier are to have breakaway features. Sign bridges and cantilever sign supports are designed for placement outside the Design Clear Zone or shielded by barrier. (26)

h) Traffic Signal Standards/Posts/Supports

Breakaway signal posts generally are not feasible or desirable. Since these supports are generally located at intersecting roadways, there is a higher potential for a falling support to impact vehicles and/or pedestrians. In addition, signal supports that have overhead masts may be too heavy for a breakaway design to work properly.

Other mitigation, such as installing a traffic barrier, is also very difficult. With vehicles approaching the support from many different angles, a barrier would have to surround the support and would be subject to impacts at high angles. Additionally, barrier can inhibit pedestrian movements. Therefore, barrier is generally not an option. However, since speeds near signals are generally lower, the potential for a severe impact is reduced. For these reasons, locate the support as far from the traveled way as possible. In locations where signals are used for ramp meters, the supports can be made breakaway. (40)

i) Water

Water with a depth of 2 feet or more and located with a likelihood of encroachment by an errant vehicle is to be considered for mitigation on a project by project basis. Consider the length of time traffic is exposed to this feature.

Analyze the potential risk to motorists and the benefits of treating bodies of water located within the Design Clear Zone. A cost effectiveness analysis that considers the consequences of doing nothing versus installing a longitudinal barrier can be used to determine the appropriate treatment. (40)

j) Median

Medians are to be analyzed for the potential of an errant vehicle to cross the median and encounter oncoming traffic. Median barriers are normally used on limited access, multilane, high-speed, high-volume highways. These highways generally have posted speeds of 45 mph or higher. Median barrier is not normally placed on collectors or other state highways that do not have limited access control. Providing access through median barrier results in openings; therefore, end-treatments are needed.

Provide median barrier on full access control multilane highways with median widths of 50 feet or less and posted speeds of 45 mph or higher. Consider median barrier on highways with wider medians or lower posted speeds when there is a history of cross-median collisions.

k) Utility Poles

Since utilities often share the right of way, utility objects such as poles are often located along the roadside. It is undesirable to install barrier for all of these objects, so mitigation is usually in the form of relocation (underground or to the edge of the right of way) or delineation. In some instances where there is a history of impacts with poles and relocation is not possible, a breakaway design might be appropriate. Evaluate roadway geometry and crash history as an aid in determining locations that exhibit the greatest need.

l) Markings and Signs

To reduce the confusions on the route the following improvements should be implemented:

a. Worn signs should be renewed
b. Warning signs should be installed at required sections of the route (e.g. before dangerous horizontal curves, approaching area of intersections, overtaking prohibited sections, work zones, bridge abutments etc.)
c. Existing markings which cause confusion on the route should be removed
d. The markings should be renewed by repainting and widening centerlines and edge lines or re-stripping at nonexistent sections of the route. (40)

m) Barriers

Barriers should be properly installed and placed at required locations. Safety barriers (guardrails) can be effective in reducing the severity of crashes. Also following countermeasures should be considered:

a. Extend guardrails at bridge parapets
b. Guardrails on the bridge should be renewed
c. Install guardrails at all steeper side slope areas
d. Deformity guardrails should be renewed or repaired
e. Missing guardrail sections should be completed. (40)

3.7 Safety auditing reporting

After identifying all potential safety issues, the audit report should be prepared. The outcome of an audit should be a written report, which contains a list of concerns about road safety matters and recommendations on how these identified potential safety problems in the existing road will be addressed.

The report should clearly and succinctly identify the process, issues and recommendations. It is important to note that the recommendations should focus on safety issues, rather than specify the details of a solution. Also the photographs should be included in to the report to help readers visualize the problems. Also while writing a report the video and photographs help to make certain decisions about the safety problems and good level of recommendations. (37)

3.8 Safety Audit Discussions

After safety audit reporting, a meeting is follow-up to provide an opportunity to discuss the findings of road safety audit. Discussion can be made between the auditor(s), a representative from region municipality in which the audit process implemented for and a representative from National Road Service Commission.

At this discussion/meeting the documentation of the safety actions and project scope including programming and scheduling are recommended. If there is uncertainty about the existence of a safety problem exists or about the most appropriate corrective action to improve the situation, it is desirable to consult with qualified highway and safety engineer.

The follow up process is lead by the designer/project manager. The designer/project manager reviews the audit report and prepares a written response to each concern cited. Each remedial measure suggested in the audit report can be accepted or rejected.

For each accepted suggestion, logical remedial measures should be identified and adopted by the designer/project manager. The redesign should then advance to diminish the safety hazard. All project redesigns should be submitted to the audit team for consideration or re-auditing. The designer/project manager must make sure that modifications are made to the project which results from agreed improvements described in the audit report. (20)

3.9 Evaluation of Improvement Projects

Techniques available used by management in evaluating highway projects in terms of project costs and safety impacts can be grouped into two broad categories.

1- Using the first approach, the safety impact is represented by the monetary amount of accident cost savings called Benefit-Cost Analysis,

2- The second approach considers the cost per expected number of accidents reduced as the measure of safety effectiveness called Cost-Effectiveness Analysis. (20)

The basic difference between the two categories is the method of measurement of safety impact.

Benefit = (Accident Cost without Improvement) - (Accident Cost with Improvement)

BCR= Benefits / Cost

Cost effectiveness= Total Cost / Expected Number of Accidents Reduced

CHAPTER 4

4 ANALYSIS AND CASE STUDY PRESENTATIONS

4.1 General

The concept of road safety audits (RSA) is relatively new in Nigeria, it can be stated that (RSA) has never been applied before on Nigerian highways at both the plan stage of the projects and on existing roads yet.

The Case Study of this thesis is an application of a RSA on a 50 kilometer road section of Kano – Kaduna express way in Nigeria starting from Kano state. The case study road is a four lane divided highway with a lane width of 3.3 meters, with a varying shoulder widths from two and half meters to zero meters.

At some places, concrete median barrier height of 1.2 meters has been used. The case study road is one of the three major four lanes divided highways in Nigeria which connects almost all cities of northern Nigeria with Abuja that is the federal capital city of Nigeria with many markets and big towns along the road.

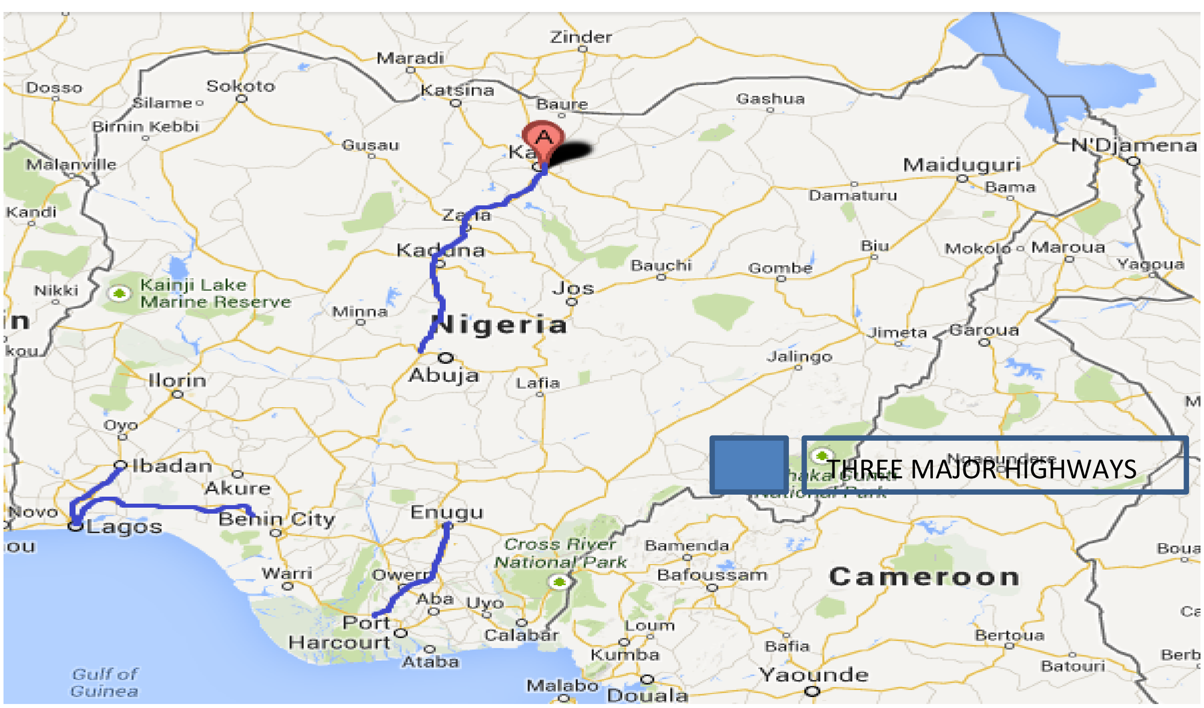

Figure 4.1 Map of Nıgeria Showing Three Major Highways. (44)

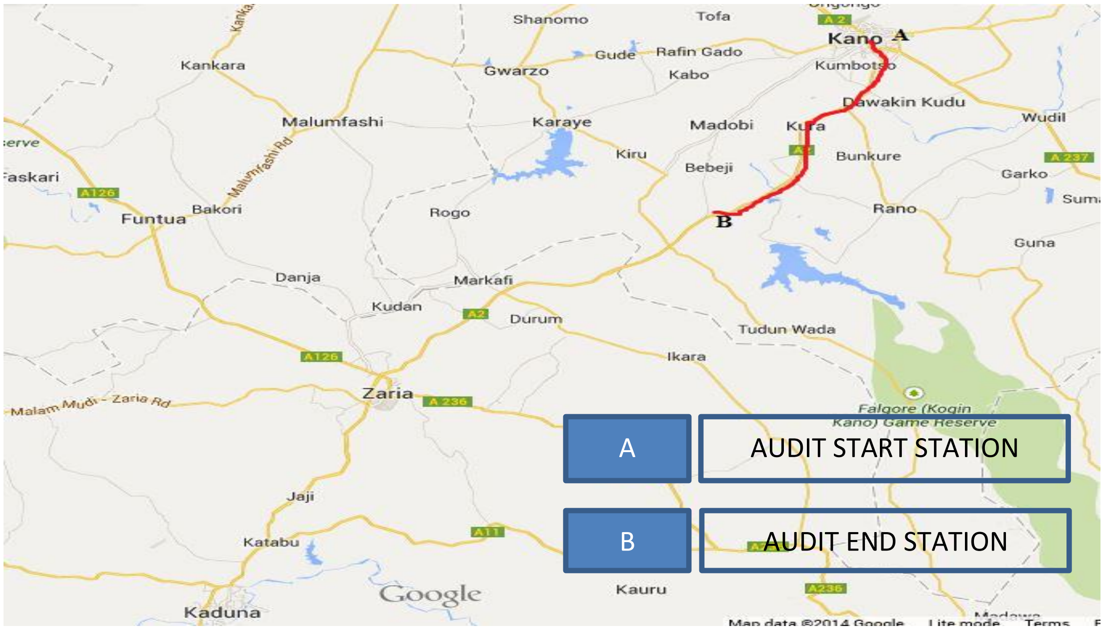

Figure 4.2 Map Showing Kano-Kaduna Highway (44)

The objective of the case study can be explained as follows;

a. Carry out road safety audit along 50 km section of Kano-Kaduna highway.
b. Identify potential safety problems for road users.
c. Carry out RSA along selected section of the highway to identify typical recurring problems.

4.2 Preconditions

4.2.1 General Project Data

a) Function of the Road

The existing paved road was constructed in the year 1986 in order to improve the accessibility of almost all northern cities in Nigeria with newly created federal capital city of Nigeria Abuja.

It also serves as major highway connecting northern Nigeria with its southern counterpart. The route is also an important arterial which connects cities from north-west of Nigeria like Sokoto, Zamfara, Katsina and cities from north-east like Maiduguri, Yobe, Adamawa with those on the north central such as Kaduna and capital city Abuja.

All of these cities are connected by the help of this route. The route is a federal road and the main function is to facilitate regional distribution of traffic (intercity movement).

The audit route has a length of 219 km from Kano to Kaduna in which 50 km section was selected as a case study. The audit section of the road is surrounded by many commercial and agricultural activities along the roads with several markets.

These serve for peoples from northern part of Nigeria who brings their agricultural products and sell to those from the southern part. They used the same route to convey their products to all regions of Nigeria.

b) Traffic Volumes

Hourly traffic volume counts were conducted along the audit case study road at station km 12+000 for two different periods of a day that is in the morning and afternoon sessions for the two different directions of the highway and the result obtained for the hourly volume count were used to compute an Average Annual Daily Traffic (AADT) for the road section using some conversion factors for determining AADT.

The average annual daily traffic of the road was found to be 7465 vehicles/hour (2013).

c) Accident Data

The table below shows the summary of accident data of Nigeria for the period from 1990 to 2001

Table 4.1 Accident Data of Nigeria (41)

Years	Total Cases Reported	Persons Killed	Persons Injured
1990	21721	8154	23687
1991	27498	9525	22686
1992	22909	9620	24508
1993	21412	9454	25759
1994	18218	7420	24416
1995	17000	6647	17938
1996	16793	6364	14554
1997	9034	3616	15290
1998	16046	6538	10786
1999	12424	5429	17341
2000	12705	6521	20677
2001	13801	8012	23249
Total	204561	87300	240621

Traffic accident data which were taken from the Police Commands and Federal Road Safety Corps of Nigeria is shown in table below. There is more specific traffic accidents data information which will be given in appendices part of the thesis.

Table 4.2 Four Years' Accident Data for Kano-Kaduna Highway (2)

Kano-Kaduna Highway			
Years	**Number of Accidents**	**Persons Killed**	**Persons Injured**
2008	426	302	394
2009	309	274	297
2010	332	273	294
2011	288	242	362
Total	1355	1091	1347

d) Road Standards

The audit route can be classified as multilane rural arterial highway (by referring to AASHTO standard) based on the roadway features observed.

It was constructed in the year 1986 and has been served as four lane divided highway road. Existing road platform width is 13.2 m. The existing road pavement surface is surface treatment and generally passing through from flat, rolling and partially mountainous terrain.

The shoulder of road section is completely unpaved with a width of 2.5 meters at few places and majority of the road there is no shoulder completely and even the road lane is deteriorated due to lack of maintenance since initial construction of the road.

e) Speed Limits

The posted legal speed limit of the audit route is 100 km/hr. On the other hand, at some sections of the route the speed decreased to 50 km/hr which may be due to the presence of towns and markets very close to the roadway.

During site visit a spot speed observation was carried out and speed of some vehicles were observed. The observations were around 130 and 160 km/hr respectively which were all above the legal posted speed limit of the road. At some sections of the road, vehicles are subjected to move at a speed of less than 20 km/hr due to the presence of large potholes on the road section.

4.2.2 Surroundings/Land Use

At the beginning of the audit route there are gardens and farm houses where crops and milk are produced. There are also a lot of industrial plants such as sugar and tomatoes processing factories along the road.

There are also many educational institutions along the road like Kano State Sport Institute, Kano State Information Technology Institute and many others. There are also many markets as a result of industries and farming activities along the audit road. There are also many petrol stations along the route which are all connected to both side of the road.

Beginning from 26+450 km section of the road on both sides there are hectares of land for irrigation farming that is the largest irrigation farming in the whole Nigeria controlled by Hadejia Jamaare River Basin Development Authority under federal government of Nigeria.

There are lots of villages and towns along the road their approximate kilometers and directions are given in table 4.3 below.

Table 4.3 Towns Located along the Audit Road

KM	DIRECTION	TOWN NAME
00+300	Kano-Kaduna	Durba
01+700	Kano-Kaduna	Waratallawa
03+800	Kano-Kaduna	Fari
05+600	Kano-Kaduna	Tamburawa
08+600	Kano-Kaduna	Matage village
11+500	Both side of the road	Karfi village
22+900	Both side of the road	Imawa
31+300	Kano-Kaduna	Bauren Tanko village
35+200	Both side of the road	Kura local Government
41+500	Kano-Kaduna	Yadakwari Village
45+700	Kano-Kaduna	Dorawar Sallau Village
48+900	Both side of the road	Ciromawa Town
02+300	Kaduna-Kano	Kadawa Gate Town
13+300	Kaduna-Kano	Dogon Dabino Village
21+500	Kaduna-Kano	Dakasoye Village
32+100	Kaduna-Kano	Samawa Town
38+400	Kaduna-Kano	Tudun Bayero Village
41+700	Kaduna-Kano	Fari Town
45+600	Kaduna-Kano	Dangwuro Village

4.3. Methodology

After the audit route was determined and selected, all necessary information and data about the route were collected. Before going to the site for observations, some information was gathered out and checked such as;

a. Route map
b. Accidents information data for the five years
c. Road geometry inventory (lanes width, surface types, shoulder, median width road
Characteristics)

All of this background information was collected from the relevant authorities. Accident data was obtained from both Nigerian Police Force and Federal Road Safety Corps of Nigeria at their offices in Kano and Kaduna States.

After gathering all those information audit surveys on the case study route were started on the first day from Na'ibawa interchange which selected as a starting point and marked as 00 + 000 km. Photographs and video records were also made during the site visit which are used to make final discussions and evaluations.

Both sides of the audit route were observed and all safety audit aspect of the road was recorded on a safety audit checklist. Photos were taken for subsequent comments and discussions on observed hazards during the field survey.
During the field survey, the following aspects of route were identified;

a. Locations in which shoulder widths are inadequate
b. Markings that are not exist or in a complex condition (old and new markings mix each other)
c. Problematic road side zones that include dangerous features which can create specific danger within the clear zone width. (Trees, Utility Poles, Concrete Structures)
d. The existence of various kinds of trees and other vegetation which obstruct the sight distance of the drivers
e. Improper location of the bus stops
f. Non guarded-rail sections
g. Concrete structures and dangerous wall endings
h. Improper information signs
i. Improper junction designs
(10)Improper drainage structures

During observations, the safety audit checklist was filled. Observations along the route and photos were also illustrated at subsequent paragraphs of the report.

4.5 Observations Performed During Audit

Potential safety problems and hazards were observed along the route during the field survey for further evaluation. All of the problems and deficiencies were recorded in the checklist.

Checklist is categorized under two main headings. One of them is road design another one is the road side area. When conducting the audit, the safety problems were categorized under these main headings and recorded to the respective part of the checklist.

The checklist table consists of five columns. The first and second columns of the checklist define the Kilometer and distance respectively. Kilometer and distance define the location of hazard and potential safety areas. Third column explains the type of the hazards which arise from the road design or road side area, the fourth column of the checklist give the auditor comments and short suggestions to the problems and hazards and the last column gives a reference of an example picture to show the real hazard in the appendices section of the thesis.

4.4 Hazard List

Table 4.4 Hazard Types

A-ROAD DESIGN	
Number	Hazard Name
1	Shoulder missing
2	Shoulders too narrow
3	Shoulder unpaved
4	Improper junction design
5	Improper connection to shop, petrol station or other commercial activities
6	Improper connection to small access road
7	Improper connection to roadway
8	Improper median opening
9	Limited sight distance
10	Improper or dangerous pedestrian crossing
11	Too small radius of horizontal curve
12	Too small radius length of vertical curve
13	Speed limit too high
14	Speed limit too low
15	Improper vertical sign
16	Improper horizontal sign
17	potholes
B-ROAD SIDE AREA	
Number	Hazard Name
18	Dangerous fixed object on the roadway
19	Dangerous fixed object on road side or median
20	Dangerous fixed object on road island
21	Temporary road narrowing (e.g. bridge)
22	Fixed massive poles near road or in the median(lighting, electricity etc)
23	Road edge deterioration
24	Big trees or trees close to the road
25	Dangerous bridge piers
26	Dangerous hedge
27	Dangerous cut form
28	Dangerous free stones or rocks
29	Dangerous support for signs(advertisement or road information sign)
30	House or other building so close to road
31	Steep edge slope without guardrail

Table 4.4 Hazard Types (continuation)

32	Dangerous guardrail start and end
33	Improper culvert design on the road side
34	Improper commercial activities on the roadside
35	Improper bus stop design
36	Missing sign
37	Use of non standard sign

Most of the connection roads observed during the audit were improperly designs. In almost all the 50 km section of the road observed during the audit, road markings were completely worn or missing. All the road signs such as warning signs were also completely worn out and some were improper at some sections of the road.

Moreover, the road pavement was found as not suitable for the design speed. Some sections of the audit route pavement were patched and these were out of date and weathered. A lot of potholes were not even patched which could contribute a lot to the high number of accidents on the road.
It was observed that safety zones were inadequate at some sections and completely missing in some other parts of the road. The concrete structures, big trees, buildings, fixed objects were in the road environment. Free stones and rocks, fixed massive electricity poles were also near to the roadside environment. Drainage structures were observed as hazardous within the safety zone.

The safety checklist of the route was divided into two ways/directions of observations. During the site investigation, the hazardous objects within the safety zone were photographed and reported in detail below.

4.6 Comparison with the Standard

The existing values of cross section elements for the audit road have been measured and compared with AASHTO Highway Design Manual (Multilane Rural Arterial Highway) as shown in table 4.5 below.

Table 4.5 Comparison with Standard (42)

Number	Roadway Element	AASHTO Standard Values	Observed Values
1	Design speed	60-120 km/hr Depending on the terrain	100 km/hr
2	Number of lanes	Four or more	Four lane
3	Travel lane width	3.6 m minimum	3.3 m
4	Right shoulder width	2.4 m	0.0-2.2 m
5	Left shoulder width	1.2-1.8 m	0.0-1.0 m
6	Turn lane width	3.6 m	0.0
7	Median width including left shoulders	Wide median 7.5 m minimum	4.0 m
8	Roadside clear zone	9 m	0.0
9	Fill/Cut slope	4H:1V	5H:9V
10	Minimum bridge vertical clearance	6.248 m	4.5 m
11	Bridge width	At least full approach traveled way width or plus 0.6 m clearance on each side	2/3 of traveled way width
12	Control of access	Partial/by regulation	Uncontrolled access
13	Alignment	Adequate and smooth flowing alignment	Poor alignment
14	Bus turnouts	A well marked widened shoulder or an independent turn out is highly desirable and should be provided at locations where there are known concentration of passengers	No widened shoulder or independent turnout
15	Pedestrians crossing	Controlled	Uncontrolled

4.7 Safety Audit Checklist of Existing Road

Tables 4.6 and 4.7 below shows the safety audit checklist, with all the field observations recorded during the site visits for both sides of 50 km section of Kano-Kaduna multilane rural arterial highway wıth column showing example of the hazard in the appendices sections as P1, P2, P3 up to P24.

SAFETY AUDIT CHECKLIST OF EXISTING ROAD

Date: 17/8/2013 **Conducted by:** Nura Bala

Weather: sunny, partly cloudy **Kano-Kaduna Direction**

KM	DISTANCE (M)	TYPE OF HAZARDS	COMMENTS	APPENDIX REFENCE
0	0		Start station of the audit (Na'ibawa interchange).	P1
1	100-400	1	Dangerous to road users	P9
2	000	1,4,7	Increases accident potential	P9,P24
2	200	29	Increases accident risk	P6
2	400	19	Decrease visibility	P4
2	300-600	23	Decreases roadway capacity	P9
2	500	21	Creates danger to motorist	P16
2	500	7	Causes accidents	P24
2	700	7	Increases accidents potential	P24
2	700-900	19	Increases road side accidents	P13
2	700-800	31	Decreases safety	P10
2	800-900	23	Reduces roadway capacity	P9
2	900	15	Causes confusions leading to accident	P20
3	100	5	Causes an accident	P7
3	200-300	34	Increases accidents	P17
3	400	5	Dangerous to coming vehicles	P7
3	400-900	23	Decreases roadway capacity	P9
3	700-900	19	Increases road side accidents	P4
3	800-900	1	Decreases roadway capacity	P9
5	000	28	Causes accidents	
5	100	15	Causes confusion to drivers	P20
5	200	9	Causes danger to pedestrians	P23
5	200-300	9	Limited sight distance causes accidents	P23
5	200-800	28	Increases roadside accidents	
5	300	5	Causes accidents	P7
6	200-700	23	Decreases road capacity and cause accident	P9

Table 4.6 Safety Audit Checklist for Kano-Kaduna Direction

6	400	28	Causes road side accident	
6	500-600	19	Causes road side accidents	P4
6	600	15	Makes confusion to drivers	P20
6	600	8	Increases accident rates	P18
6	700	16,4,34	Mislead drivers	P24,P17
6	800	35,23	Causes accidents	P14,P9
7	100	9,5	Increases accidents	P23,P7
7	100-300	1	Decreases roadway capacity	P9
7	200-500	23	Decreases capacity of roadway section	P9
7	400	5	Causes accidents	P7
8	200-700	31	Increases accident risks	P10
8	700-900	31	Increases road side accidents	P10
9	000-100	17	Increases accidents on the road	P7
9	200	7	Causes accidents	P24
9	600-700	34	Increases danger to road users	P17
9	700-900	1,7	Reduces roadway capacity	P9,P24
10	000	34	Causes road side accident	P17
10	600-700	34	Causes accident for vehicles leaving the road	P17
10	800	5	Cause accident with coming vehicles	P7
10	900	7	Contribute to high risk of accidents	P24
11	000-200	19	Increases danger of roadside accident	P4
11	300-700	23,17	Increases accident rates	P9
11	400	34	Causes roadside accident	P17
12	500	35	Causes danger to passengers and motorist	P14
12	700	7	Increases confusions to drivers	P24
13	000	37	Mislead drivers	
13	100-300	19	Danger for roadside accident	P4
13	300	37	Increases confusions to drivers	
14	200	10	Causes danger of crossing to pedestrians	P8
14	400-900	17,23	Decreases road capacity and causes accidents	P7
16	300	7	Increases collision accidents	P24
17	200-600	9	forced drivers to reduce speed and cause accident	P23
19	200-300	17	Contribute to accidents	P7
20	300-800	1,23	Decreases roadway capacity	P9
21	500-700	32	Increases severity of accident	P11

Table 4.6 Safety Audit Checklist for Kano-Kaduna Direction

22	700	34	Increases roadside accident	P17
22	800-900	1	Causes accident with errant vehicles	P9
23	000	35	Causes accidents with passengers	P14
24	300	35	Causes accidents with passengers	P14
24	500-680	22	Increases roadside collision severity	P2
24	700	8	Causes accident with turning vehicles	P8
25	100-200,800	17	Causes accidents	P7
28	600	5	Causes collision with coming vehicles	P7
29	700	6	Causes collisions with leaving vehicles	P24
30	900	4	Serves as appoint of accident	P24
32	200-400	34	Increases severity of roadside accidents	P17
34	500-600	1	Allowed errant vehicles to park on the road	P9
34	400	8	Causes accidents	P18
35	700	5	Causes accidents	P7
37	000-200	1,23	Decreases roadway capacity	P9
37	400	35	Increases danger of accidents	P14
38	200	19	Causes roadside accident	P4
38	400-700	24	Increases danger of accidents	P13
39	100-300	17	Causes accidents	P7
40	400-800	31	Increases severity of roadside accidents	P10
40	500-600	1,23	Decreases capacity of the road section	P9
40	900	15	Mislead drivers	P20
41	400	6	Increases danger of accidents	P24
42	100-300	24	Increases roadside accidents severity	P3
42	500	5	Causes accidents	P7
42	800	8	Causes accidents for turning vehicles	P18
43	100	10	Dangerous to pedestrians crossing	P8
43	400	14	Danger for vehicles moving at high speed	P22
44	100-400	1,23	Decreases roadway capacity	P9
44	300	5	Causes accidents	P7
44	600	29	Increases accident potential	P12
44	700-900	22,24	Increases severity of roadside accidents	P2
44	800-900	17	Causes accidents	P7
44	900	6	Serves as accidents location	P24
45	100-200	34	Causes roadside accidents	

Table 4.6 Safety Audit Checklist for Kano-Kaduna Direction (Continuation)

45	200-400	22	Causes accidents when vehicles hit	P2
45	600	5	Causes accidents	P7
45	800	15	Causes confusion to drivers	P20
46	200-300	17	Reduces travelling speed	P7
46	600-700	22	Increases severity of accidents	P2
47	100	8	Causes accidents with turning vehicles	P18
47	200	21	Causes side collision accident	P16
47	500-700	17,31	Causes road side accident	P10
47	800	5	Increases accident risks	P7
48	100-300	34	Causes road side accident	P17
48	500-800	24	Increases severity of roadside accident	P13
48	600-900	17	Causes vehicles to reduce speed	P7
48	700	6	Increases danger of accidents	P24
49	200	4	Increases accidents and delay	P24
49	400	22	Causes roadside accident	P2
49	500-800	1,17	Reduces roadway capacity	P7
49	600	36	Causes confusion to drivers	P24
49	700	4	Causes accidents and delay	P24
49	800-900	22	Causes accident to uncontrolled vehicle	P2

Table 4.7 Safety Audit Checklist (Continuation) For Kano-Kaduna Direction

P1, P2, P3 up to P24 implies picture one, picture 2, picture 3 up to picture 24 which indicates a picture showing an example of the hazard in the appendices section of the thesis.

SAFETY AUDIT CHECKLIST OF EXISTING ROAD

Date: 02/9/2013 **Conducted by: Nura Bala**

Weather: sunny, partly cloudy **Kaduna-Kano direction**

KM	DISTANCE (M)	TYPE OF HAZARDS	COMMENTS	APPENDIX REFENCE
1	100-500	22	Increases danger of roadside accident	P2
2	100	5	Causes accidents	P7
2	200-350	34	Increases danger of accidents along roadside	P17
2	400	10	Causes accidents with pedestrians	P8
2	400-500	23	Reduces roadway capacity	P9
2	700	19	Increases severity of accident	P4
2	800	29	Causes roadside accident	P12
2	800-900	1,23	Reduces roadway capacity	P9
3	100-300	1	Decreases roadway capacity	P9
3	400	19	Causes roadside accidents	P4
3	500-900	23	Reduces roadway capacity	P9
4	200	17	Reduces travel speed	P7
4	300-400	17	Reduces travel speed	P7
4	400-600	31	Causes danger of roadside accidents	P10
4	800	35	Danger of accident with passengers	P14
4	800-900	34	Causes danger of accidents	P17
5	600	5	Increases danger to coming vehicles	P7
5	700-800	31	Increases severity of roadside accident	P10
5	800	11	Danger for motorist	P23
5	800	9	Dangerous to motorist	P23
6	600	15	Causes confusion to drivers	P20
6	900	5	Causes danger of accidents	P7
8	300	14	Increases accidents potential	P22
8	400	5	Causes danger of accidents	P7
9	500	5	Causes accidents	P7
10	700	15	Causes confusion to drivers	P20
11	300	29	Causes accident	P12
12	400	19	Causes roadside accident	P4
13	500	15	Risk of accident	P20
13	600-700	17	Reduces travel speed	P7

Table 4.7 Safety Audit Checklist for Kaduna-Kano Direction

13	900	6	Improper connection to small access road	P24
14	300	36	Causes confusion to drivers	P24
15	800	6	Increases accident risks	P24
16	000	30	Causes roadside accident	P15
16	500-700	24	Increases severity of roadside accidents	P13
18	100	29	Causes accidents	P12
24	600	10	Causes danger of crossing to pedestrians	P8
24	800-900	34	Causes accident with out of controlled vehicle	P17
26	300-400	22	Increases severity of roadside accidents	P2
26	600-700	34	Increases accident risks	P17
26	800-900	31	Causes roadside accident	P10
27	300	15	Causes confusion to drivers	P20
27	800	25	Increases accident risks	P20
29	200-400	31	Increases severity of roadside accident	P10
29	700	32	Dangerous guard rail start	P11
30	100	4	Causes accidents and delay	P24
32	200	14	Lower speed limits increases accident risks	P22
32	500	4	Causes accidents and delay	P24
35	300	29	Causes roadside accident	P12
37	800	21	Causes danger to approaching vehicles	P16
37	900	7	Causes accidents	P24
38	200-600	24	Increases severity of roadside accidents	P13
38	700-900	30	Causes roadside accident	P15
39	400-500	34	Causes accidents with out of controlled vehicles	P17
40	100-600	23,1	Reduces roadway capacity	P9
41	300	10	Dangerous to pedestrians crossing	P8
41	800	5	Causes accidents	P7
43	500-800	22	Causes roadside accident	P2
43	600	8	Causes accidents with turning vehicles	P18
43	900	29	Causes confusion to drivers	P12
44	300	8	Dangerous for turning vehicles	P18
44	500-700	1	Causes errant vehicles to park on the travel lane	P9
44	800	35	Dangerous for pedestrians	P14
44	900	4	Causes accidents and delays	P24
45	100-600	1,23	Reduces roadway capacity	P9
46	100-700	1,23	Reduces roadway capacity	P9
46	500	15	Causes confusions to drivers	P20

Table 4.7 safety audit checklist (continuation) for Kaduna-Kano direction

47	200-700	19	Causes roadside accident	P4
47	300	35	Dangerous to passengers	P14
47	600-900	34	Causes roadside accident	P17
48	100	6	Causes accidents	P24
48	100-600	1	Allowed vehicles to park on the travel lane	P9
48	200	29	Causes confusion to drivers	P12
48	500	4	Causes accidents and delays	P24
48	700	10	Causes danger of crossing to pedestrians	P8
49	200	36	Causes confusions	P24
49	800	8	Danger of accidents to turning vehicles	P18

Table 4.7 safety audit checklist (continuation) for Kaduna-Kano direction

P1, P2, P3 up to P24 implies picture one, picture 2, picture 3 up to picture 24 which indicates a picture showing an example of the hazard in the appendices section of the thesis.

4.8 Typical Hazards

a) Utility Poles in the Safety Zone

Utility pole can cause severe roadside crashes. Along the audit route there have been mostly electricity poles that are made of concrete and telephone poles that are made by wood. They are all located within the safety zone area on both sides of the route. Because of the poles are located in the safety zone area, they create high potential safety risks for road users.

Along the audit route the most noticeable pole type is electricity poles which are made of concrete. The electricity poles have been located within the safety zone at most places. These locations have been assessed as potential dangerous points in which severity of crashes were increased after loss of control accidents. (Figure 1.4)

Figure 4.3 Dangerous Electric Poles Close To the Road (Km 47+200)

b) Trees in the Safety Zone

This section addresses crashes involving trees. Along the audit route trees can be thought as a potential danger for road safety. There are lots of trees with varying size and type along the audit route both on the roadside within the safety zone and also on the road median. Some of the trees have diameter greater than one meter. During the field survey, the trees which involve the high potential safety risk were recorded. Most of the trees that have been on the route can be considered as fixed objects.

Some of the trees have been lined at the beginning section of the route and all of the trees are within the safety zone area. Between km 03+700 and km 05+800 trees have been so close to the road. Between km 11+000 and 17+200, the sight distance have been prevented by trees. At some stations such as station km 46+600; the trees have been located on the road median which creates danger to the drivers. At some sections of the route, the shoulders have been covered by small trees and vegetations.

Figure 4.4 Dangerous Trees within the Safety Zone Area (Km 13+100)

c) Improper Signing and Marking

Most of the information signs have been located at inappropriate locations and are not in accordance with the standard, At km 40+900, the sign has been almost covered by vegetation and it is too short which cannot permit drivers to see it before reaching the sign. It was also observed that all the markings on both sides of the route have been completely worn out to the extent that drivers cannot even see any indication. As a result of that drivers use the road with no marking condition in which might contribute to high number of accidents along the route.

Figure 4.5 Worn Out Sign (Km 5+300)

d) Improper Access Management

There have been many gasoline stations along the audit road located at short intervals and almost all the gasoline stations observed within the 50 km audit section have been improperly connected to the main road.

There has been a gasoline station at station km 46+600. The entrance and exit sections of the petrol station have been too close to the road in which a driver coming out from the gas station cannot clearly see the vehicles coming from the main road travelling at very high speed. In addition to that, concrete wall endings and information signboard of the petrol station create high hazardous risk for road users. There have also been trees on the roadside just near the entrances which limited the sight distance for coming vehicles from the roadway.

Figure 4.6 Improper Connection to Gas Station (Km 3+400)

e) Improper Pedestrian Crossings

A pedestrian crossing or crosswalk is a designated point on a road at which some means are introduced to assist pedestrians wishing to safely cross the road. They are designed to keep pedestrians together where they can be seen by motorist, and where they can cross most safely across the flow of vehicular traffic.

As observed and recorded during the audit survey, there have been many uncontrolled pedestrians crossing on the road. At km5+200 and km24+600 there have been vertical signs indicating the pedestrian crossing, but on the road way there have been no any facility for pedestrians to cross the roadway safely.

Figure 4.7 Improper Pedestrian Crossings (Km 5+200)

f) Improper Shoulder Widths and Danger of Edge Deterioration

The shoulders observed on both sides of the road during the audit survey have been generally all unpaved. There have been some other sections in which shoulders are completely missing. There has been no exact width of the shoulder throughout of the roadway. It varies from 0.00 m to 2.00 m; it was observed that shoulders have only been available in few places of the road that were renovated recently.

Apart from missing and inadequate shoulders on the road; there has also been another serious problem of edge deterioration at majority of the roadway parts. It can cause a serious safety problem along the road as it affects the normal 3.2 m lane width of the road lane. Some parts of the missing shoulder where edge is deteriorated even vegetation covers the edges of road lane.

Figure 4.8 Shoulder Missing (Km 44+100)

g) Improper Fill Slope Designs

At both sides of the audit route there are many sections where the side slopes are steeper than the desirable. Federal Ministry of Works which is responsible for all federal highways in Nigeria uses AASHTO standards. AASHTO considers side slopes of 4H:1V to be the steepest slopes for permitting safe vehicle controls.

As measured during the audit some sections of the route, fill slopes of 5H:9V, 7H:12V, 4H:5V have been used. At station km 02+800 and km 08+700, and also between km 40+400 and 40+700; there have been very high steep side slopes. If an errant vehicle leaves the highway at these locations, the severity of the collision can be increased considerably.

Figure 4.9 Dangerous Fill Slope (Km 2+700)

h) Improper Guardrails

Along the audit route there have been many improper designed or improper positioned guardrails together with their improper starting and terminations which become a great roadside hazard. Between station km 21+500 and km 21+700 there have been many dangerous gaps on the guardrail arrangements. For loss of control accidents, these missing guardrails can create a great danger.

Figure 4.10 Dangerous Guardrail Section (Km 21+500)

i) Pavement Problems/Potholes

Within the area studied, the condition of pavement varies. Generally, road surfaces appear to be roughest in many old sections with cracks, bumps and potholes on them. The pavement conditions have been particularly poor.

There has been considerable rutting those results in pounding of water on the roadway. There is also considerable deterioration at pavement edges. There have been many patches on the road surface. Because of this situation, at some sections road surface has been rugged.

At some sections, the road surface was collapsed because of the probable improper pavement design and construction. It was recorded that the condition of the road surface has been noticed as “poor” throughout the section as observed during the audit.

Figure 4.11 Dangerous Potholes on the Pavement (Km 9+00)

j) Improper Placement of Vertical Signs

Along the route, there have been many improperly placed vertical signs. Almost all the vertical signs along the audit were all located within safety zone area which creates a potential safety hazard to motorist. At many sections of the route observed vertical signs can be one of the greatest hazards causing accidents.

Figure 4.12 Improper Placements of Vertical Sign within the Safety Zone (Km 6+400)

K) Improper Market Location and Commercial Activities

During the audit survey it was noticed that there have been many locations on both side of the road in which small markets and many other commercial activities were located. They can create a great hazard to vehicles using the road some locations observed have been very close to the road side (within the safety zone area) on the other hand, some of the commercial activities have occupied area even on the shoulder of the road.

At km between 3+200 and km 3+300 there have been market and bus stop location for travelling far distance from Kano. As a result the place attracts many peoples and causes all passing vehicles to reduce their speed as lower as 10 km/hr. The location has been recorded as one of the locations in which many accidents were happened.

Figure 4.13 Dangerous Tress, Signboard And Objects Close to the Roadway (Km 3+200)

l) Houses and Concrete Structures in the Safety Zone

Houses and concrete structures located in critical positions or within the safety zone create a great danger for all vehicles using the road. Along the road it was observed that there have been many locations in which house and structures made of concrete were located very close to the roadway.

One of the most hazardous sections of the audit route has been mentioned between km 16+000 and km 16+100. There have been houses located very close to the road within the safety zone as shown in the figure below. There are also many concrete foundations for vertical signs within the safety zone.

Figure 4.14 Dangerous Concrete for Support Close To the Road (43+200)

m) Road Narrowing

Road narrowing is also one of the hazards recorded on the road during the safety audit survey. At station km 00+100 the road narrows and changes from three lanes to two lanes as a result of bridge a head; these can increase accident risk to vehicles approaching the bridge.

A narrow bridge makes it difficult for drivers to safely maneuver in emergency and non-emergency situations because there is simply no enough space to maneuver. Narrow bridges are particularly hazardous and collisions with bridge ends are relatively infrequent but they are often severe.

Figure 4.15 Dangerous Road Narrowing (Km 0+300)

n) Missing Safety Zone

A Clear Zone is an unobstructed, traversable roadside area that allows a driver to stop safely, or regain for control of a vehicle that has left the roadway. By creating clear zones, roadway agencies can increase the likelihood that a roadway departure results in a safe recovery rather than a crash, and mitigate the severity of crashes that do occur.

At the case study road, the width of the safety zone is zero at majority of the roadway and maximum of five meters at few places which is not sufficient and not in accordance with the standards.

Figure 4.16 Missing Safety Zone (Km 5+900)

4.9 Proposal of Countermeasures

After all the above data were collected and analyses, some counter measures for some typical hazards were proposed as follows;

a) Utility Poles

At km 24+500 and km 47+200 and many other sections on the route surveyed, there are electric poles within the safety zone area, which are made of concrete. There are some applicable countermeasures to be applied to such situations to minimize accidents severity as follows.

1- The first one is to install reflector on the poles, which can be seen by drivers from far distance. This solution has low cost and short term implementation.

2- The second is to install guard rail or crash cushion for hazardous utility poles near curve locations, which has low/mid cost of implementation.

3- Another one is, removing or relocating utility poles from safety zone area, and it has the long term and mid/high cost implementation. In addition to this the poles cable can be buried underground this is also long term and mid/high cost implementation.

b) Trees

At km 16+500 and km 38+700 trees were located within both the safety zone and median area which creates a great hazard to vehicles. To mitigate the effect of trees along the route, it may be considered appropriate to remove a tree which clearly presents an unacceptable hazard to vehicles or to erect a longitudinal barrier, to reduce the risk of a vehicle striking the tree.

To prevent the stopping sight distance problem, the trees must be removed from safety zone. However, the potential benefits of removing such obstacles should be weighed against the adverse environmental and aesthetic effects of their removal. Therefore, trees should be removed only when considered essential for safety and alternatively, trees which cannot be removed should be protected by guardrails.

Removal of trees within the Design Clear Zone may not be desirable in places such as within a forest, park, or within a scenic and recreational highway. In such cases, collision contributing factors report is analyzed to determine whether roadside vegetation is contributing to collisions. If large vegetation is removed, replace with shrubs or groundcover or consult guidance contained in established vegetation management plans or corridor plans.

c) Safety Zone Area

At almost all the road section inspected, there is no clear road side zone which is a serious hazard to vehicles. The importance of a clear zone is to provide as much clear, traversable area for a vehicle to recover as practicable given the function of the roadway and the potential tradeoffs.

Elements such as side slopes, fixed objects, and water are features that a vehicle might encounter within the safety zone when it leaves the roadway. These features present varying degrees of deceleration to the vehicle and its occupants. The measures to mitigate these depend on the probability of a collision occurring, the likely severity, and the available resources.

The measures for mitigation of these hazards are listed below in order of priority as follows:

(1) Removal
(2) Relocation
(3) Reduction of impact severity (using breakaway features or making it raversable)
(4) Shielding with a traffic barrier.

d) Markings and Signs

At many locations on the road inspected, there are many signs confusing drivers on what decision to be taken and in some locations, the signs were either worn-out or completely missing. To reduce the confusions on the route the following improvements or countermeasures should be considered:

a. Worn signs should be renewed
b. Warning signs should be installed at required sections of the route (e.g. before dangerous horizontal curves, approaching area of intersections, overtaking prohibited sections, work zones, bridge abutments etc.)
c. Existing markings which cause confusion on the route should be removed
d. The markings should be renewed by repainting and widening centerlines and edge lines or re-stripping at nonexistent sections of the route
e. Markings/signs should be placed where missing.

e) Shoulders

At majority sections of the roadway inspected, the shoulders are either inadequate or completely missing. A shoulder provides space for emergency stop or for errant vehicles to park, without shoulders vehicles should be parked on the roadway which increases chances for accidents. In such situations the countermeasures to be employed are as follows:

a. Shoulders should be constructed where missing
b. Shoulders should be paved
c. Shoulders should be wide/adequate
d. Upgrading and re-surfacing of shoulders should also be considered.

f) Houses and Concrete Structures

At km 38+700 and km 43+ 200 there is house and concrete structure within the safety zone, the appropriate possible counter measures to be applied to that locations are either removing or relocating from the safety zone. Also installing the guardrails or barriers along the building section can be a possible solution for reducing the accident risk.

g) Bus Stops

Along the audit route all of the bus stops should be relocated. Also bus stops should be visible for all road users. Beside this bus stop signs should be installed properly. Moreover the construction of the bus bays should be considered as another possible solution.

h) Barriers

Barriers should be properly installed and placed at required locations such as Km 21+500. Safety barriers (guardrails) can be effective in reducing the severity of crashes. Also following countermeasures should be considered:

a. Extend guardrails at bridge parapets
b. Guardrails on the bridge should be renewed
c. Install guardrails at all steeper side slope areas
d. Deformity guardrails should be renewed or repaired
e. Missing guardrail sections should be completed

h) Entrance to the Road Side Facilities

Almost all the entrances of the Gas Station along the road section surveyed should be re-designed in a way not to include any hazard risks. Widening the shoulders and traffic lanes can be a solution.

At Km 3+400 and Km 21+500 along the road section, entrance and exit parts can be considered highly potentially accident area. Construction of turning lanes at entrance and exit parts for the vehicles that are coming from both directions can be an alternative to minimize accident risks. In addition to this there should be warning signs both sides of the route.

i) Fill Slope

At the fill sides along the roadway surveyed, generally the side slope are steeper than 4H:1V. Slopes steeper than 4H:1V are critical because the possibility of the vehicle to rollover increases substantially. Fill slopes steeper than 3H:1V should be used with appropriate safety barriers.

4.10 Case Study Conclusıons

a) After audit survey and analysis it is recognized that the most common hazards observed are fixed massive objects within the safety zone area, deficient guardrails, pavement damages, missing shoulders, non-gentle slope and improper bus stop locations

b) Also after comparison of the existing roadway cross section elements with that in AASHTO standard it is observed that majority of the roadway elements were not in accordance with AASHTO which is used as Nigerian standard for highway design.

c) Among all the most common hazards recorded during the survey it is observed that the most dangerous hazards are pavement damages like potholes on the roadway and pavement edge deterioration, fixed massive objects associated with road side area such as fixed massive poles and sign post that were improperly placed within the safety zone area and missing or narrow shoulder along the whole section of the roadway. All these hazards listed above contributes to the increasing number and severity of accidents along the road as some accidents were seen physically during the field survey involvıng fixed massive objects on the road side and some accidents associated with pavement damages.

d) Lack of adequate and proper record of accident data that covers some aspects like accident location, time of occurrence, type of vehicles involved, reasons or accident contributing factors, result of collision and many others by relevant authorities in Nigeria hinders or limits the possibility of this research to analyses the accident data and understand that either this hazards are among the accident contributing factors on this road section or not and also to know the level of contribution by each hazard on the accidents.

e) As observed during the site visit missing and narrow shoulders forces errant and vehicles that stop for emergency to park along the road section which also has ınsufficient lane width. Considering the supportive characteristic of the shoulders and their usability in emergency situations, it can be concluded that most of the present shoulders might have adverse effect to road safety.

f) Another problem which is not as dangerous as the ones listed above is improper connection of gas stations and other roadways to the main road which creates additional danger to the overall safety of the road and its environment.

g) Another significant safety problem is recorded as steep fill slopes. It is considered that slopes were not designed regarding safety standards on the fill cross sections. Guardrail application can be considered as a solution for this problem.

h) As discussed above most of the dangerous problems observed on the road section were associated with road side area, therefore it can be concluded that providing a cleared and unobstructed road side area will solve larger portion of the accident problems.

The tables below shows the most common and most dangerous hazards observed during the site visits for both directions of the road.

Table 4.8 most common and dangerous hazards observed

KANO-KADUNA DIRECTION	
KILOMETER	**MOST COMMON AND DANGEROUS HAZARDS OBSERVED**
00-05	Dangerous fixed object on road side, missing shoulder and improper junction design
05-10	Missing shoulder, potholes, improper commercial activities and improper bus stop location
10-15	Potholes and dangerous fixed objects
15-20	Limited sight distance improper trees on road sıde
20-25	Missing shoulder and improper bus stop location
25-30	Potholes and improper connection to petrol station
30-35	Missing shoulder, improper median opening and improper commercial activities
35-40	Potholes and bıg trees close to the roadway
40-45	Missing shoulder and improper commercial activities
45-50	Potholes and edge deterioration
KADUNA-KANO DIRECTION	
KILOMETER	**MOST COMMON AND DANGEROUS HAZARDS OBSERVED**
00-05	Dangerous fill slope and fixed massive poles close to the roadway
05-10	Missing signs, pavement damages and improper connectıon to petrol stations
10-15	Potholes and dangerous supports for advertisement signs
15-20	Dangerous trees on the median and missing shoulder
20-25	Fixed massive poles and ımproper commercial activities
25-30	Dangerous fill slope and fixed massive poles close to the roadway
30-35	Improper junctıon design and pavement damages
35-40	Improper median opening and junction design
40-45	Missing shoulder and improper connectıon to petrol statıon
45-50	Dangerous trees and fixed massıve objects very close to the roadway

CHAPTER FIVE

5 CONCLUSIONS AND RECOMENDATIONS

5.1 Conclusions

A roadway safety is one of the items that are being brought to the forefront of the transportation industry. Road Safety Audit (RSA) is becoming a major tool for assessing the risk on existing roadways. RSA is proactive in nature and look to find safety risk before crashes occur. It has been used to improve the ability of decision makers' to assess risk on the roadways. On the other hand, transportation professionals need such a tool that can look at the complexity of the roadways.

In this thesis the real practices of road safety audit on existing roads in different countries were summarized. By taking account these different opinions and auditing procedures into account a case study has been performed for road safety auditing on existing road on Nigerian highway. The conclusions that are drawn from the thesis study can be summarized as follows:

a. Some safety defects observed during the audit study that can be considered as typical for Nigerian rural highway network can be mentioned as follows:
   - Guardrails are deficient or not in appropriate positions,
   - Slopes are steep and cannot be considered as gentle regarding road safety,
   - Pavement damages such as potholes and pavement edge deterioration are considerably remarkable,
   - Shoulders are insufficient, narrow and are not paved at most locations

b. The realization of safety audits on existing roads bring great support and guidance for building road safety and improving existing or potential accident prone locations. With the performed case study and the evaluated results, it is hoped that it will contribute to the development of 'safety audit concept' in Nigeria.

c. Lack of long term and dependable local accident and countermeasure data limited the process of this study and these limitations forced the study to make reasonable acceptations.

d. Lack of adequate and proper record of accident data that covers some aspects like accident location, time of occurrence, type of vehicles involved, reasons or accident contributing factors, result of collision and many others by relevant authorities in Nigeria hinders or limits the possibility of this research to analyses the accident data and understand that either this hazards are among the accident contributing factors on this road section or not and also to know the level of contribution by each hazard on the accidents.

5.2 Recommendations

The following recommendations can be drawn from the case study:

a. The case study methodology as a safety audit should be followed and implemented on all present rural highway networks in Nigeria and all other roadways for evaluating the overall safety of the country roads.
b. Road safety audit surveys should be done for short intervals to observe changes in the road structure and equipment as well as the road environment.
c. Road Safety Audits are being considered as more and more important and widely used tools/applications to increase the road and the road environment safety.
   It is necessary to introduce course programs to teach young highway engineers in all parts of Nigeria and world in general, about these techniques as quickly as possible. The different teaching techniques such as distant learning and distant workshop facilities should be applied.
d. Problems with the lack of dependable traffic and accident common database in Nigeria have adversely influenced the road safety activities. Thus, implementing reliable and well-designed traffic safety database including road and traffic statistics and records should be accepted as the first priority action in the recent future. This common database should be open to researchers with no restrictions.
e. Nigeria should start to invest in the researches of accident reduction factors for different road safety countermeasures that are currently not available but adapted from international studies. These researches require long-term studies and should be implemented as soon as possible.

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APPENDIX

Safety Audit Checklist

The Hazards of the route which observed and recorded during the field survey is given with their appropriate locations on the road.

Picture one (P1) Start station of the audit

Picture 2 (P2) Dangerous electric poles close to the roadway km 47+200

Picture 3 (P3) Dangerous trees within the safety zone area km 16+500

Picture 4 (P4) Dangerous trees on the road median km 38+700

Picture 5 (P5) Warn out vertical sign km 10+700

Picture 6 (P6) Improper placements of vertical sign km 23+200

Picture 7 (P7) Improper connection to petrol station km 21+500

Picture 8 (P8) Improper pedestrian crossing km 41+300

Picture 9 (P9) Missing shoulder and edge deterioration km 40+100

Picture 10 (P10) Dangerous fill slope km 4+400

Picture 11 (P11) Dangerous guardrail section km 21+500

Picture 12 (P12) Dangerous support for advertisement km 32+700

Picture 13 (P13) Dangerous tree and objects close to the road km 17+600

Picture 14 (P14) Improper bus stop location close to the road km 6+800

Picture 15 (P15) Dangerous house within the safety zone km 38+700

Picture 16 (P16) Dangerous road narrowing km 0+300

Picture 17 (P17) Missing safety zone km 15+600

Picture 18 (P18) Improper median opening km 23+300

Picture 19 (P19) Dangerous guardrail start km 49+100

Picture 20 (P20) Improper placement vertical sign km 30+500

Picture 21 (P21) Confused warning sign km 41+700

Picture 22 (P22) Speed limit too low km 28+600

Picture 23 (P23) Limited sight distance km 16+200

Picture 24 (P24) Improper junction design km 24+900