SAFETY AUDITING ON URBAN ROADS WITH SPECIAL EMPHASIS TO INTERSECTIONS

IN A CASE STUDY IN KANO, NIGERIA.

A MASTER'S THESIS

in

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by

ABUBAKAR SANI HABIBU

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ABUBAKAR SANI HABIBU

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Approval of the Graduate School of Natural and Applied Sciences, Atılım University

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I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

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This is to certify that we have read the thesis " Safety Auditing on Urban Roads with Special Emphasis to Intersections in a Case Study in Kano, Nigeria" submitted by "Abubakar Sani Habibu" and that in our opinion, it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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I declare and guarantee that all data, knowledge and information in this document has been obtained, processed and presented in accordance with academic rules and ethical conduct. Based on these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

SAFETY AUDITING ON URBAN ROADS WITH SPECIAL EMPHASIS TO INTERSECTIONS

IN A CASE STUDY IN KANO, NIGERIA

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The current international reviews and action plan strategies regarding rapid increase in road traffic volumes and present status of huge number of traffic accidents have made road safety audits/inspection procedures necessary major policy for implementation in any country worldwide.

Road traffic accidents affect social and economic aspects of any country which need serious and urgent action to be taken in order to provide effective improvements, solutions, suitable and desired counter measures so as to avert the present situations.

In this aspect, urban road safety audits have been analyzed in the study. A case study of an urban Katsina Road section in Kano, Nigeria was selected and evaluated using actual practices, strategies, and procedures of road safety audits in developed countries in relation to deficiencies, hazards and intersection capacity and level of service measures.

Based on the evaluated case study conditions through proposed methodology, different number of safety defects were detected and related counter measures were proposed for the present case study accident potentials, capacity and level of service for accident severity reduction and elimination.

Keywords: Road Safety Audits, Capacity, Level of Service

ÖZ

KAVŞAKLAR INCELEMESINI IÇEREN ŞEHIRIÇI ARTERLERDE YOL GÜVENLIK KONTROLÜ KANO NIJERYA'DA BIR ÖRNEK ÇALIŞMA

Habibu, Abubakar Sani

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Tez Yöneticisi: Y. Doç.Dr. Cumhur Aydın

Haziran 2014, 108 sayfa

Trafik hacimlerindeki hızlı yükselme ve büyük trafik kaza sayılarına yönelik mevcut uluslararası değerlendirmeler ve uygulama plan stratejileri; yol güvenlik kontrolleri /inceleme yöntemlerini dünya çapında her ülkede gerekli uygulama politikalarından birisi haline getirmiştir.

Karayolu trafik kazaları her ülkeyi sosyal ve ekonomik olarak etkilemekte, bu durumu değiştirmeye yönelik etkin iyileştirmelerin, çözümlerin; uygun ve istenen önlemlerin sağlanmasına yönelik birçok acil eylemi gerekli kılmaktadır.

Bu çerçevede şehiriçi arterlere yönelik yol güvenliği etütleri bu çalışmada analiz edilmiştir. Kano, Nijerya'da bulunan Katsina Yol Kesimi bir örnek çalışma için seçilmiş ve kavşak kapasitesi, hizmet seviyesi ile özellikle gelişmekte olan ülkelerde gözlenen bazı güvenliği eksiklikleri gibi yol güvenliği etüt parametreleri kullanılarak değerlendirilmiştir.

Önerilen yöntem ve elde edilen örnek çalışma yolu özellikleri temel alınarak birçok yol güvenliği eksikliği saptanmış ve bunlara yönelik değişik iyileştirme önerileri ortaya konmuştur. Bu öneriler belirlenirken, kaza şiddetinin azaltılması ve ortadan kaldırılmasına yönelik mevcut kaza potansiyelleri, kapasite ve hizmet seviyesi gibi unsurlar değerlendirilmiştir.

Anahtar Kelimeler: Karayolu Güvenlik Etütleri, Kapasite, Hizmet Seviyesi.

To My Parents

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May Allah bless them all and reward them abundantly.

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LIST OF ABBREVIATIONS

GNP	Gross National Products
FRSC	Federal Road Safety Commission
UK	United Kingdom
FHWA	Federal Highway Administration
USA	United State of America
RSA	Road Safety Audits
RSI	Road Safety Inspection
RSA/I	Road Safety Audits/Inspection
IHT	Institute of Highway Transportation
SI	Safety Inspection
DI	Detailed Inspection
NSW	New South Wales
RTA	Road and Traffic Authority
ITE	Institute of Transportation Engineers
RSAIU	Road Safety Audits and Inspection Unit
CBMOT	Controlling Body in the Ministry of Transport
LOS	Level of Service
V/C	Volume/Capacity
NHCRP	National Co-operative Highway Research Program
AASHTO	American Association of States Highway Transport Officials
TH	Through
L	Left
R	Right

CHAPTER 1

INTRODUCTION

Urban road transportation system provides benefits to the nations and individuals by facilitating the movement of goods and people. However, the rapid increase in road transportation has also placed considerable burdens on people's safety in the form of road traffic accidents. [1] Road traffic accidents are a routine occurrence phenomenon which happens by chance, unexpectedly and un-designed as a result of the use of or operations of vehicles and pedestrians on roads throughout the world. Thousands of people lose their lives on the roads every day, many millions more were left with disabilities or emotional feelings that they carry for the rest of their lives. Although, the phenomenon is not completely inevitable, but its leading cause of deaths and injuries makes it has more concerns and attracts attention. It is one of the major public health problem epidemics that costs countries millions of US dollars but neglected globally, which requires concerted efforts for effective and sustainable prevention. It could either be fatal, resulting in death of road users (drivers, passengers, motorcyclists, cyclists and pedestrians), injury or damage only. [1]

Moreover, driving near and through intersections is one of the most complex conditions drivers encountered. It is a critical section of a highway that has a higher concentration of traffic accidents, traffic accidents often occur because it is a location where two or more highways join or cross each other on the same level and handles a variety of activities such as turning left, turning right, cross over which create conflicts among vehicles, pedestrians and bicycles. Vehicles and pedestrian in every direction must pass through an intersection, get across it and come about, then combine into an established traffic flow. Because of the mutual disturbances, this leads to the traffic jam, speed reduction and make accidents more often. [1]

Improving intersection safety and capacity can be achieved through safety audits and inspection procedures in order to avoid and eliminate the high number of approach legs, conflict points and providing proper geometric design, layout elements and facilities, which could effectively improve traffic safety through minimizing the number and severity of potential accidents, while facilitating the movement of people traversing intersection. Though, it constitutes only a small proportion of an entire roadway system, but significant proportion of accidents occur at intersections, which its design standards are based on a compromise between safety, capacity and cost. [1]

1.1 General Road Accidents Data

1.1.1 World Road Traffic Accidents Data and Casualty Figures

Approximately, over 1.2 million people die every year on the world's road, and between 20 and 50 million suffer non-fatal injuries. In most of world's region this epidemic of road traffic accident is still increasing, almost half of those who died in road traffic accidents are vulnerable road users and this proportion is higher in low income and middle income countries. These countries have higher road traffic fatality rates of 21.5 and 19.5 per 100,000 populations, respectively, than high income countries of 10.3 per 100,000. Over 90% of the world fatalities on the roads occur in low income and middle income countries that have only 48% of the total world's registered vehicles. [2]

Table 1.1 World road traffic deaths per 100,000 populations [2]

WHO REGION	HIGH-INCOME	MIDDLE-INCOME	LOW-INCOME	TOTAL
AFRICAN REGION[b]	—	32.2	32.3	32.2
REGION OF THE AMERICAS[c]	13.4	17.3	—	15.8
SOUTH-EAST ASIA REGION[b]	—	16.7	16.5	16.6
EASTERN MEDITERRANEAN REGION	28.5	35.8	27.5	32.2
EUROPEAN REGION	7.9	19.3	12.2	13.4
WESTERN PACIFIC REGION	7.2	16.9	15.6	15.6
GLOBAL	10.3	19.5	21.5	18.8

Road traffic injuries are estimated to be the ninth leading cause of death globally, with an impact similar to that caused by many communicable diseases. It is the leading cause of death of young people aged around 15-29 years, and as a result takes a heavy percentage toll on those in their most productive years which drastically reduces social and economic activities. It has been estimated that, unless immediate action is taken, road death will rise to the fifth leading cause of death by 2030, resulting in an estimated 2.4 million fatalities per year. [2]

Almost, 16,000 people die every day from all types of injury, which represents 12% of the total global burden of diseases. And within the category of injury, it is dominated by those incurred in road traffic accidents by 22.8%. [3]

1.1.2 Trends of Road Traffic Accidents in Africa

About 10 percent of the global road deaths in 1999 took place in Sub-Sahara Africa, where only 4 percent of the global vehicles were registered. While, in the entire developed nations with 60 percent of the global registered vehicles, only 14 percent of road deaths occurred. Africa and Asian countries, with a relatively low vehicle density are experiencing a substantially higher fatality rate per 100,000 vehicles than the industrialized European and North American states. [4]

Nigeria and South Africa have the highest fatality rates (33.7 and 31.9 deaths per 100 000 population per year, respectively) in the region. More than one in four deaths in the African region occur on Nigeria’s roads. Traffic crashes also make a significant impact on the African country's economy at an estimated cost of 1-2% of a country’s gross national product (GNP) per annum, as a result of injury, mortality and property-related costs. [5]

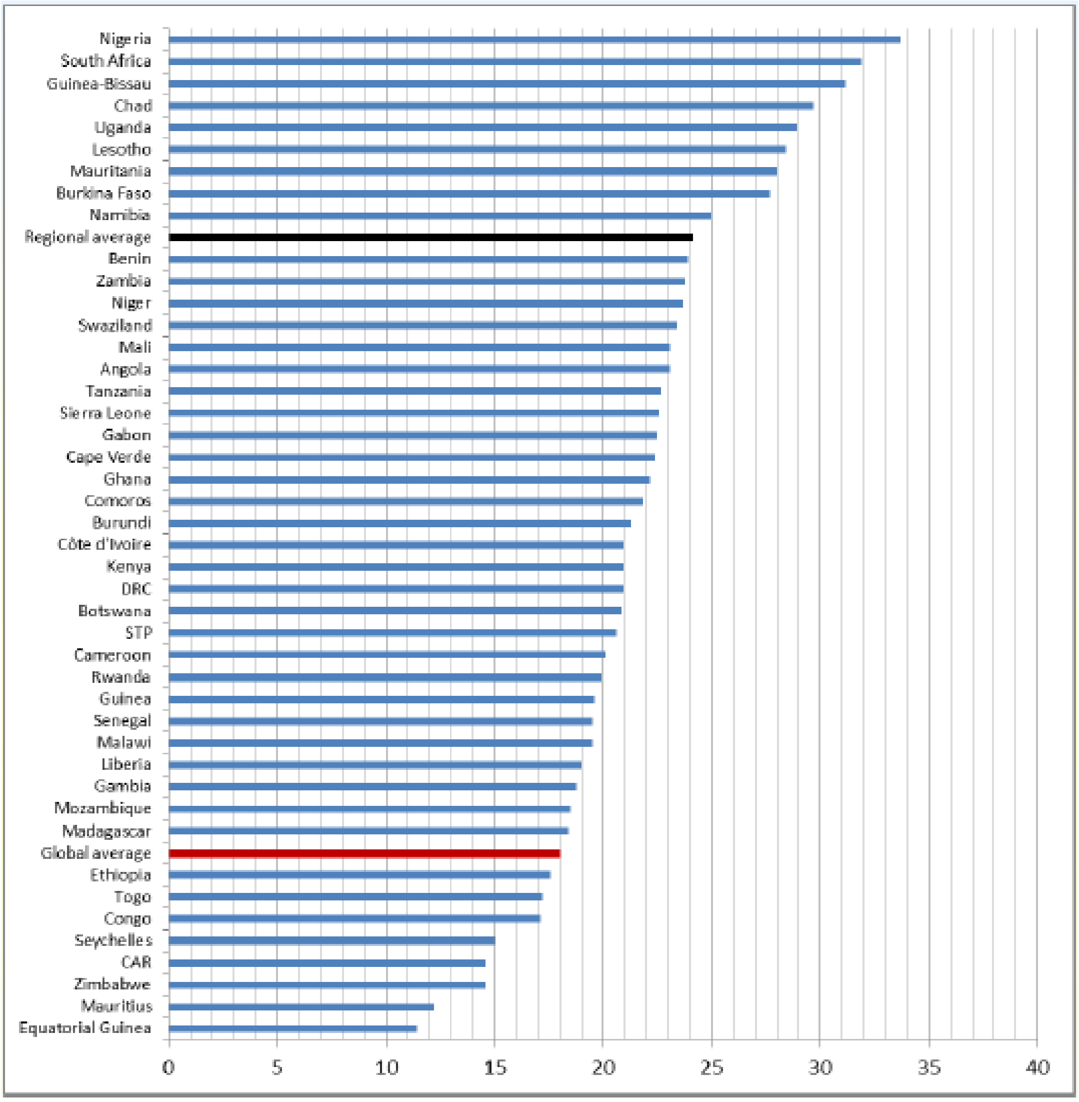

Figure 1.1 African road fatality rates per 100,000 populations per year [4]

1.1.3 Current Trends of Vehicular Accidents in Nigeria

Nigeria has a total land mass area of 910,771 square kilometers and about 167 million human populations; it is the most populous country in Africa and the seventh most populous nation in the world. It has number of vehicular traffic figure estimated to be over 7.6 million with a total road network of about 194,000km that comprises of 34,120km federal, 30,500km state and 129,580km local roads. Nigeria was ranked the second largest country having road network in Africa in 2011, with density varies in rural and urban areas approximately 51.7% and 48.3%, respectively, which translates to a population-road ratio of 860 people per kilometer, indicating intense traffic pressures on the available road network which lead to higher traffic accidents in the country. [6]

Figure 1.2 Map of Nigeria showing a case study area [6]

Road traffic accident statistic in Nigeria reveals a serious and growing problem with absolute fatality rates and casualty figure rising rapidly when compared with the road traffic accidents in developed countries of the world. In 2002, the road traffic accidents were as high as 23.16 per thousands in Nigeria, which equivalents to 0.3 and 0.45 per thousands in North America and Western Europe respectively. [7] It has the highest road accident rate as well as the largest number of deaths per 10,000 populations in Africa. [8]

Table 1.2 Road traffic accidents figure in Nigeria. [9]

	REPORTED CASES				PERSONS INVOLVED		
YEAR	FATAL	SERIOUS	MINOR	TOTAL	KILLED	INJURED	TOTAL
2005	6,132	7,849	4,678	18,659	8,980	16,888	25,868
2006	5,806	8,052	4,804	18,662	9,131	19,200	28,331
2007	5,678	6,958	4,799	17,797	9,114	18,013	27,127
2008	6,345	7,257	4,252	17,854	9,572	19,495	29,067
2009	4,683	5,450	3,570	13,703	5,661	11,055	16,716
2010	6,853	9,092	4,965	20,910	10,793	34,713	45,506

In an effort to check-make this alarming road traffic accidents trends, the Nigerian Federal Government inaugurated the Federal Road Safety Commission (FRSC) in 1988 in-order to inspect highway against reckless driving, safety deficiencies, law enforcement, collecting and storing accidents statistics, revising traffic regulations, promotion of road safety education, ensuring adequate provision of medical facilities for traffic injury victims and undertaking research in road traffic safety. But, unfortunately this trend persists because the authority concerned practically relegated the background of road safety audit and inspection operations, which are one of the inevitable aspect of modern methods of road administration and management, which determines the number of traffic accident potentials concerning highways, protection of errant vehicles from electric poles, trees, ditches and replacement of damaged and missing signs. [10]

1.2 Road Safety Inspection on Urban Roads

Road safety inspection is one of the safety management tools that could be implemented by any road authority in any country of the world, with the view intention of accidents eliminating or reducing the number and severity of accidents. It is generally incorporated as part of the overall safety process “It is defined as a systematic on site review, conducted by independent road safety experts on an existing road or a section of a road to identify hazardous conditions, faults and deficiencies that might lead to serious accidents”. [11]

It is a procedure that checks all elements of a roadway, including intersection, which has the highest number of potential conflicts and create more accidents than other sections of the road due to the multiple decision makings so as to ascertain the magnitude of safety operational performance of the drivers, pedestrians and cyclists. Balance should be checked to make sure that, all categories of road users are provided with adequate facilities that would enhance their safety and conveniences. Road safety inspection of urban roads can be carried out on all categories of roads within a city or municipal whether having a high accident figure or not, but priority may be emphasized on roads having the highest number of accident types and casualty figure, if there is budget constraint or lack of available safety experts. [11]

1.3 Contributions of Road Safety Audits

Road safety audit is one of the simplest and easiest way tends to simplify the existing safety problems and reduce the number of potentials on the road section, in which level of safety and safety performance can be easily seen and recognized. It is a simple, systematic process that contributes a lot to safety aspects of view when considering cost-benefits analysis, the benefits overweight the cost in such a way that, simple inspection can reduce fatalities per day and year and be carried out within some days without costing much to the authority concern. Developed countries have already understood that, investment in road safety audits saves lives and money and also contributes a lot in providing feedbacks to highway designers in order to be applied in other projects for ensuring high safety, quality is maintained throughout a project's life cycle, improve learning experience for audit team and create consistency among all projects. It has been estimated that, standard road safety audit cost about €2,000 which is meager when compared with a cost per accident. [12]

Table 1.3 Accident severity and estimated value cost [12]

Accident Types	Values at Market Prices		Values at Factor Costs	
	Per Casualty €	Per Accident €	Per Casualty €	Per Accident €
Fatal	2,018,126	15,882	1,694,480	13,335
Serious Injury	226,757	6,769	190,392	5,683
Slight injury	17,486	3,896	14,682	3,271
Damage only	Not applicable	2,403	Not applicable	2,017

1.4 Key Requirements of Road Safety Audits

The following aspects are key requirements for successful Road Safety Audits:

a. Adequate time and information to conduct the road safety audit

b. Commitment from management

c. A recognized and agreed Road Safety Audit process

d. An independent road safety audit team or auditor

e. Prompt lists for the various stages of a road project

f. The development of expertise

g. Evaluation and monitoring of the Road Safety Audit Process

1.5 Evaluation of Road Safety Audits

The road authorities should introduce and implement an evaluation program for road safety audits. The evaluation of road safety audits should be done for the improvement of the road safety audit process and the utilization of the road safety audit results to revise and update planning and design applications. [12]

The evaluation of road safety audit findings is to identify and publicize common problem areas and the main reasons for increased risk would therefore provide an opportunity to review existing design practices and improve these for future application. [12]

The evaluation of the administrative process for road safety audits should also address the following aspects:

I. Procedures, problems encountered and effectiveness of the system

II. Critical appraisal of the prompt lists and their use

III. Evaluation of costs and resources by scheme types and stages

1.6 Aim of the Research

The aim of this thesis study is to evaluate road safety inspection procedures on an urban road section in Kano, Nigeria. And also, to determine the capacity and the quality of service conditions for addressing existing and potential road safety issues.

1.7 Objectives of the Research

I. To identify conflicting road messages from users' point of view

II. To identify existing or potential road safety hazards and deficiencies that could adversely affect road users

III. Improve awareness of safety and maintenance practices

IV. Reduce the need of safety modification

V. To ensure that, road safety audits scheme operates to the highest safety standard.

VI. Analyze the safety issues and operational performance of signalized intersection within the road section.

CHAPTER 2

WORLDWIDE DIFFERENT URBAN SAFETY AUDITING EXPERIENCES

2.1 General History of Road Safety Audits

Road safety audit procedures were developed in 1989 in United Kingdom (UK) by traffic engineers from a tool used by railway engineers to examine safety issues on railways. In the early 1990s, it was adopted by Australia, New Zealand, Denmark, and many other developed countries. The acceptance and recognition of road safety audits in Australia and New Zealand followed interactions among road safety engineers between these two countries and the United Kingdom in the early 1990s, where the first road safety audit guidelines were developed in 1993 and 1994 in New Zealand and Australia respectively. [13]

In 1996, the Federal Highway Administration (FHWA) of the USA sponsored a tour, visit to Australia and New Zealand to study their road safety audit programs and to learn strategies on how to implement road safety audits in the United States. It also 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 which includes thirteen states provided a basis for road safety audits use in the United States. Gradually, road safety audits gained popularity, recognition and acceptance in the United States and other parts of the world. The Asian Development Bank, in collaboration with the United Nations Economic Commission for Europe and the World Bank, had recently sponsored the use of road safety audits and published tools that are to be used in conducting a road safety audit. Different countries around the global world have started realizing significant benefits and importance of road safety audits and inspections as low cost tools of saving lives. [13]

2.2 Road Safety Audits and Road Safety Inspection on Urban Roads

One of the newest tools today use by traffic engineers in the urban transportation system, regarding addressing road deficiencies are Road Safety Audit (RSA) and Road Safety Inspection (RSI). As a result of having number of practical importance that has remarkable benefits to local authorities in systematically addressing safety deficiencies on their road network. [14]

"A road safety audit (RSA) is a formal safety performance examination of an existing or future road or intersection by an independent audit team with the intention of accident severity prevention and crash protection". Another definition by AUSTROADS "is a formal examination of an existing or future roads or traffic projects or any project which has an interaction with road users, in which an independent, qualified examiner reports on the projects accident's potentials and safety performance". According to RIPCOST-ISERET "is a preventive tool for detecting safety issues, consisting of a regular, systematic, on-site inspection of existing roads, covering the whole road network, carried out by trained safety expert teams". [14]

Road hazards and safety issues detected with this activity are described in a written report, for which a formal response by the relevant road authority is required; it can also be applied to both small as well as large projects, regardless of whether the project concerns new construction or the re-construction of an existing project. It will often be advantageous to carry out an audit several times during the course of a project, depending on its size, complexity and character. Road Safety Audit (RSA) is carried out to ensure that a new road scheme operate as safely as possible for all road user groups. RSA consist of an examination of road schemes at the different stages of project development (starting with the preliminary design), before or shortly after a road is opened to traffic. [14]

It is considered as a preventive tool because its application to an itinerary or road section is not dependent on knowledge concerning its specific safety level. In fact, neither the decision for the initiation of an RSI nor the procedures for its execution require knowledge on the registered safety record of the relevant itinerary. To carry out a road safety audits only general knowledge on road hazards, safety issues which are related to road environment and effective infrastructure interventions are needed.

It is an activity that is performed on-site, though experience has shown that some inspection tasks can be carried out at office, provided that adequate inventory and reporting techniques are used. Some of the selected safety interventions will be proposed for implementation, which involves the possible investment of an important amount of funds. [14]

The elements to be addressed in road safety audits should be known as risk factors for accidents or injuries, inspections should be standardized and designed to ensure that all elements included are assessed in an objective manner. The RSI report should be standardized and its contents should include a description of detecting safety issues and of proposed corrective measures and follow-up activities should be carried out to check if the proposed measures are implemented. Checklists for RSI should include the following core important elements: the quality of traffic signs, road markings and road surface characteristics, the adequacy of sight distances, the presence of roadside traffic hazards and consistency between road function and key aspects of traffic operation.

It is not a means of rating or ranking of projects, checking against compliance to the standard, accident investigation, re-design of the project but rather a means of safety improvement and accident severity reduction. There are common considerations in many countries regarding road safety management as a whole which Road Safety Audits/Inspection are integral components that are used as part of the safety management system. [14]

2.3 Current Review Regarding Road Safety Audits Approaches in Different Countries

Road Safety Audit/Inspection process has been developed internationally as a result of different number of guidelines, safety audit checklists and safety audit procedures being executed and tested in different countries. In most countries where safety audit is applied, the safety guidelines form the milestone for assessing the potential road safety performance of a new, reconstructed or existing road. Road safety audits can be conducted throughout each stage of the road infrastructure life cycle (feasibility stage, draft design stage, detailed design stage, pre-opening stage, post opening and/or existing road stage). The safety audits are mostly conducted by an independent, qualified team who are mostly multi-disciplinary road safety specialists. In most situations, the audit is a formal process where the audit findings and recommendations are documented and presented to the client. Potential road safety deficiencies are pointed out to the client. [15]

The magnitude of applying and implementing (RSA/I) varies across Europe. Some countries have already published handbooks and guidelines, while others have not yet started the process of implementation. The implementation status of each country will be described in order to give information about whether a legal basis for RSI exists, which steps have been taken to execute RSI, who is responsible for conducting RSI, information about the contents of the report and checklists being used, as well as different approaches and methodologies of the countries. [16]

2.3.1 United Kingdom

In the early 1980s, the concept regarding road safety audit was originated in the United Kingdom and in 1987 the department of transportation developed strategies to reduce road casualties by one-third by the year 2000. In 1988, the responsibilities were placed on road controlling authorities by the legislative arm of government in order to take action to reduce crashes. In connection to this, the institution of highways and transportation (IHT) prepared guidelines for the safety audit of highways which was published in 1990. Road safety audits were made mandatory for all national roads and freeways in the United Kingdom in April 1991. [17]

Road inspection manual was developed and issued in 2004 with the aim of defining hierarchies of carriageways, footways and cycle tracks for inspections, and 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. The maintenance tasks should include operations or works necessary for maintaining and restoring the road network to serviceable and safe conditions. When filing report, forms and checklists should be used and completed as much as possible at the time of the inspection. The inspectors should receive adequate training and have to be familiar with the inspection procedures. [16]

The inspection is divided into two categories, namely, safety inspection and detail inspection. When conducting safety inspections (SI) all defects that are likely to create a danger or serious discomfort to users of the network have to be identified and appropriate remedial measures to correct such defects has to be taken. The defects recognized during the inspection should be put down in a report form during the inspection. The inspectors can be able to add items to the forms when it is necessary, portable data collection devices can also be used as well as details of follow-up inspections. The detailed inspections (DI) are designed in order to record only such types of defects likely to require constant maintenance which do not require urgent repair. [16]

2.3.2 Australia

Australia is among the first countries that regard formulation and the implementation of road safety audit processes, the national association of road and traffic agencies (AUSTROADS) has set up a working party to develop road safety audit guidelines in order to provide a national focus. The states of New South Wales (NSW), Victoria and Queensland have published road safety audit guidelines. The development of road safety audit manual for NSW began in 1990, and was published in July 1991. [17]

The road safety audit was carried out first in 1990 on the Pacific highway by roads and traffic authority (RTA) in NSW. The RTA requires in each year a concrete number of road safety audits within each of the RTA’s regions together with road safety inspection of a certain percentage of the existing road system. In Victoria State, the safety audits are an integral component of a quality management process used by Vic Roads (the state’s road agency), all major projects must have at least one safety audit, and there is also a scope for safety reviews, according to Vic Roads procedures for investigating hazardous locations. In 1994, they published the first guidelines that become an international guiding principle in the road safety audit process. The International Road Safety Forum held in Melbourne in May 1998 where its guidelines were amended and second edition of the Austroads guidelines was published in 2002. This improved version reflects the knowledge and experience gained around the world in the last years and it has been seen as an essential tool in the road safety audit practice. [17]

2.3.3 New Zealand

In New Zealand, it is required to carry out road safety audits on a whole road network (both national and local government). The safety audit process began with a series of post-construction safety audits in 1990 with the help of experienced safety auditors from the United Kingdom and Australia, where also some pilot safety audit projects were conducted in 1992 and 1993. A safety audit policies and procedures were set up with representatives from all sectors in-order to developed safety working party. [17]

Transit New Zealand (Transit NZ) has introduced safety auditing procedures of projects in 1993 and is continuing to be used to ensure safety aspects of projects are addressed in the best possible ways. Procedures were developed for feasibility (stage one) through Pre-opening (stage four) of road improvement projects. Australian methods for the safety auditing of existing roads were undertaken as trial in February, 1995 where 13 audits were conducted. The trial procedures used in the initial period were later modified as a result of the experiences obtained. In February 1996, draft procedures for safety auditing of existing roads were issued and have been used for closely two years. The final draft of the revised procedures was the results of experiences gained by all personnel involved in undertaking the audits up to date. Many workshops series had been held during November 1997 to review the draft procedures prior to the preparation of Transfund New Zealand, which has been developed by an organization. [18]

2.3.4 United States

In 1994, the federal highway authority (FHWA) sponsored an international technology scanning review focused on Japan, Australia, and New Zealand with the purpose of reviewing safety management systems. One of the review findings was that, safety audits were an effective tool in improving highway safety. The FHWA has recommended that, a follow-up scanning review on road safety audits has to be undertaken from October 21 to 31, 1996. While recognizing the value of this proactive safety strategy, the FHWA started piloting road safety audits in the United States, and agencies such as the Institute of Transportation Engineers (ITE) further started exploring the concept and expanding the knowledge base on transportation profession. A workshop for pilot States and other interested agencies was conducted in May 1998. In March 1999, the ITE carried out a very successful conference entitled “Enhancing Transportation Safety in the 21st Century, New Tools for Transportation Professionals”. In connection with this conference, a one-day seminar entitled, “An Introduction to Road Safety Audits” was conducted by ITE with financial support from the FHWA. A web site was developed which provides an easy, centralized way to access a variety of resources related to safety audits including references, full text documents, information about courses and conferences, contact information for experts in the field, links to other safety audit web sites and a convenient way to discuss issues with safety experts. [17]

2.3.5 Belgium

In Belgium, the concept of road safety audits has not been intensifying like other parts of Europe, but there is an idea and procedure similar to RSI, which also uses checklists, but applied only on areas where there is a higher percentage of road accidents or complaints received by the local authority. There was no different methodical approach regarding road safety audits in relation to different road categories, legal basis for carrying out the process and the implementation is not compulsory. The road administration authority is the one responsible for checking, ordering, financing and carrying out safety inspections. It has made a recommendation that, the RSI should be carried out by someone who had not been involved in the original road project, so the inspector should be an independent. [16] The qualification criteria for inspectors were not specified, but the qualification should be as broad as possible and should take into consideration of all aspects of mobility. [16]

2.3.6 Norway

The Public Roads Administration responsible for roads in Norway published "Handbook Road Safety Audits and Inspections" in 2006.In relation to this handbook RSI in Norway comprises of three steps which are namely preparation, inspection and reporting. The handbook also suggested the use of the new method for Road Safety Inspection in which more time is allocated to preparation, while considering the traditional method reporting was the one having the most time-consuming step. During preparation step, an inspection is carried out by driving through the road section several times where pictures are taken every 20 meters or a video recording is performed, which will be reviewed afterwards in the office. An agreement must be reached between road safety inspector and project owners on where inspection should describe, what shall be included in the inspection (for example, traffic safety deficiencies must be pointed out) a deadline for delivering an inspection report as well as other things must be specified. [16]

The inspection team must have an inspection leader, who has broader road safety knowledge, knowledge of the local road-network and high level of competence. It is reasonable to involve police, specialist as well as road users. The inspection always starts with an initial meeting, with attendance by all parties concern and the number of team members can vary depending on the area of the road section, type and complexity. [16]

2.3.7 Italy

In Italy, there is a manual called "Operative Procedures for Safety Inspections on Two-Lane Rural Roads" which was developed by the University of Catania and its contents and use has spread out to all Italian provinces and the local agencies in Sicily, Calabria and Campania on a volunteer basis. It was published in 2005 and revised in 2008 which describes the road safety operational procedures, the inspection team should have qualified and independent members from design, maintenance and operation of the inspected road so that fresh eyes will be applied to the project. The active participation between the inspection team and the client help in building a better relationship, gets in-depth information and procedure concerning technical reasons relating to the identification of problems and understanding each other between members of the team and the client. The inspection team must consist of at least three or more people, because different backgrounds, approaches, exchange of ideas can be beneficial. [16]

The manual "Operative procedures for Safety Inspections on Two-Lane Rural Roads" requires several site inspections which include:

I. Preliminary inspection
II. General inspection
III. Detailed Inspection and
IV. Night time inspection

Preliminary inspection has to do with understanding the general road safety conditions, interaction between road and the road users. In this type of inspection at least three inspectors are needed: the driver, the front seat inspector and the back-seat inspector and the road have to be driven at normal speed. The general inspections are used in order to obtain information about the safety issues and their location and not more than 30km should be covered at low speed in order to allow inspectors to fill in the checklists. The checklist should contain a safety problem that is usually present on local rural roads. Front-seat and back-seat inspectors, who have different views of the road, fill in different checklists. The checklist consists of two parts, part A and B. Where part A must be filled during the inspection, part B can be completed during video examination in the office. Safety issues are ranked as high level problems and low level problems. In case of a high level problem the reviewer fills out the grey box, if a low level problem occurs, the reviewer fills out the blank and has to be done in a section of 20m. [16]

2.4 Road Safety Inspection Partners and their Roles

The first decision to be taken in the road safety inspection is to determine the extent of the inspection by defining the start and end points. Generally, this could be a road from a starting point to final destination (i.e. between well-defined major intersections, but it could be a section of a road of reasonable length). It could be outlined in an agreement between the parties involved in the inspection, the road authority (Client), road safety audit and inspection unit (RSAIU) and the inspector or inspection team. The written agreement will describe what to inspect, who is paying who, for what certain amount, timelines and deadlines. [19]

The Client (usually the road authority or private road operating company) and the inspector or (team of inspectors) participates in the audit process. The process is supported and monitored by the RSAIU. The Client is the institution (i.e. Road Administration) which is responsible for the road safety in the network. It is the client's full responsibility to ensure that inspection demands will be obeyed and implemented as soon as possible to the proposed improvements. It is also the task of the client to organize all the necessary investments for the implementation of the results of the RSI. The second component in the system is a special road safety audit and inspection unit. This could be organized as part of the road administration – RSAIU and a controlling body at the level of the ministry of transport (CBMOT). Another solution is to delegate this task to a national road safety agency or the Institute. However, this component will assist in the RSA /RSI procedures. [19]

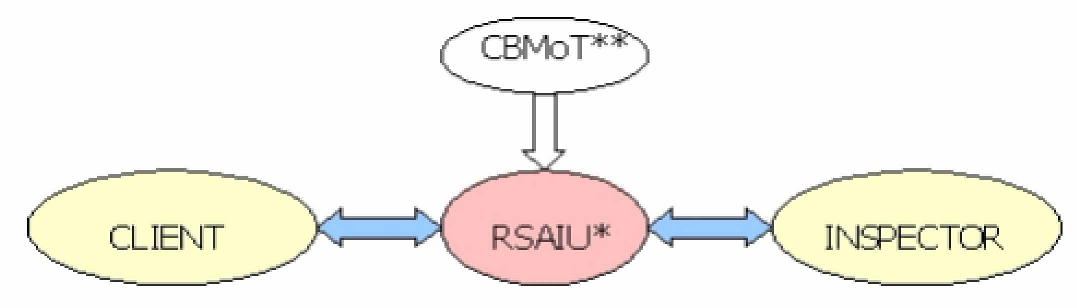

Figure 2.1 Partners in the road safety inspection process [19]

An inspector is an independent road safety expert, a team or organization that will conduct the road safety inspection. The expert is responsible to conduct the RSI carefully with the focus to the viewpoint of the road safety; through a formal written report the inspector shall present the findings, the deficiencies and references. An inspector will use his expert knowledge regarding the best practice in the evaluation of the existing situation, It is crucial that the inspector should have profound experience in road design and construction as well as road safety engineering and accident analysis. To ensure the quality of the road safety inspection, the inspectors should undergo an initial training in the award of a certificate of competence and should take part in periodic further training courses. [19]

2.5 Reasons for Performing Road Safety Audits

Technical standards and design guidelines are used in most countries when designing the traffic scheme, these standards and guidelines specifically considered road safety issues, but accidents still occur on new roads, which are built according to the relevant standards and guidelines but caused by certain reasons and factors. Design standards, mostly contain minimum requirements regarding road safety and such combinations of design elements with minimum standards can lead to dangerous road layout. When constructing, it is not always possible to comply with the standards (e.g. in built-up areas or in difficult terrain). Furthermore, the final content of technical standards is mainly the results of compromise between professionals with different opinions not all safety issues were involved. Human factors play the most important role in more than 90% of all road accidents, road designs do not only have to comply with standards, but they must also consider human behavior and the latest road safety research. [14]

2.6 Road Safety Audits and Accident Data

Road safety audit does not require an accident data, it can be performs in cases that have no reliable accident data. It is a systematic review process of a selected road or relatively long section of a road, regardless of the number of accidents. The traditional road engineering approach to safety has very often been some kind of "wait and see" approach, i.e. safety countermeasures are not considered until the accident situation becomes unacceptable. After the identification of the high risk road section and the analysis of the accident situation, then countermeasures would be designed and implemented. But, the RSI process does not only focus on a particular high risk road section which had been identified with high accident data or by incidents information from local police or local residents. It is a process that uses experienced experts during the field study and supported by detailed checklists, and its output contents contain detailed analysis of problems and the proposal for sufficient countermeasures in order to identify any risks that might lead to accidents in the future, so that our remedial measures may be implemented before the accident's occurrence. [20]

2.7 Cost and Benefits of Road safety Audits/Inspection

The main target of a road safety audit is to address the operational safety performance of a roadway and to provide a high level of safety for all user groups.

Road safety audits promote safety through the proper elimination or mitigation of safety hazards and encouraging incorporating suitable crash-reducing features (like guard rail, traffic control and delineations). Proper and acceptable road safety audit should comprise two complementary approaches, crash reduction and crash prevention. The RSA process must develop corrective measures for sites where crashes occur frequently, but also modify existing roads or designs in order to suit new ones and prevent frequent crashes. [17]

It also targeted at, minimizing the risks and severity of road crashes, eliminating the need for remedial works after construction, and reducing the whole life costs of the project. In addition, this practice can ultimately enhance the awareness of safe design practices by everyone involved in the planning, design, construction, and maintenance of roads. The costs related to road safety audit can be divided into two distinct components. Firstly, the cost of the audit itself, which related to time spent to carry out the process rather than the cost of the scheme itself.

It takes less time to audit a scheme involving a new link road with a simple junction at each end than it does to audit a complex traffic signal junction in an urban area.
The second component of cost is related to implementation of the recommendations contained in the audit report. In general, these costs are not significantly high, and items identified in feasibility Stage may not have cost implications at all (although they may require some re-design time). It is difficult to identify the benefits of carrying out a road safety audit on a scheme in a quantitative way, when an audit has been carried out, the scenarios are that either the recommendations are implemented or they are not. It is not possible to judge how an individual scheme that has been audited would have performed when the audit had not been carried out. It is difficult to attribute saving lives to any audit recommendations or actions, monitoring audited projects and the actions taken should help to reinforce the value of an audit and further qualitative benefit is the extent to which design engineers receive improved safety awareness through the road safety audit process. [17]

2.8 Process of Road Safety Audits

There are eight processes related to road safety audits/inspection of an existing road and are as follows;

I. Identify project or road in-service to be audited.

II. Select the road safety team that can carry out the task.

III. Conduct a pre-audit meeting to review project information.

IV. Perform field observations under various conditions.

V. Conduct audit analysis and prepare reports of findings.

VI. Present audit findings to Project Owner/Design Team.

VII. Project Owner/Design Team prepares formal response.

VIII. Corporate findings into the project when appropriate

When identifying and selecting a project for an RSA, the public agency should adhere to a pre-determined policy. This approach will eliminate questions and concerns as to why or how projects should be audited; once a project is identified the project owner should help establish clear parameters for the RSA. The parameters should define the following: scope, schedule for completion, team requirements, audit tasks, formal audit report contents and format and response report expectations. The project owner is responsible for selecting the RSA team leader, the project owner and the RSA team leader need to select a set of qualified individuals from within the agency, from another public agency, or from outside sources regardless of where they find the team members. [21]

The objective of the pre-audit meeting is to set the context of the RSA by bringing together the project owner, the design team, and the audit team to discuss its scope and review all information available which is one of the most efficient and effective way to acquaint the road safety team with project details. The review of the project will help to have insight knowledge into the project or existing road, to prepare for the field visit, and to identify preliminary areas of safety concern. The field visit is used to gain further insight into the project or existing road, and to further verify/identify safety concerns. Conducting audit analysis and preparing reports of findings is to succinctly report the findings of the audit team through identification and prioritization of safety issues.

The formal response is for the project owner and the design team to review the audit report and jointly prepare a written response to its findings, the response should outline what actions the project owner or design team will take related to each safety concern listed in the audit report. Once the response report is sent to the RSA team, the project owner and design team will need to ensure that the agreements described in the response report are completed as described and in the time-frame documented. [21]

Figure 2.2 Road Safety Audits/Inspections Process [21]

2.9 Stages of Road Safety Audits

Road safety audits are conducted at one of the following stages in the project, so as to ascertain and improve safety deficiencies.

I. Feasibility (planning stage)

II. Preliminary Design Stage

III. Detailed Design Stage

IV. Pre-opening Stage

V. Existing Road Audits

Feasibility stage of road safety audits is done when the project is under development, means that when an idea or conception of a particular project is under consideration. This audit procedure evaluates the options available and feasibility of the project base on the available options such as route locations, layouts, treatments, interchange location, type and number of access control and impact of the planned project on the existing road network and other features.

In preliminary design stage, general design standards are evaluated such as horizontal and vertical alignment, intersection and interchange types and layout, sight distances, lane and shoulder widths, super elevation and provision of pedestrian and cyclists. [22]

Detailed design stage deals with the review of the final geometric design features, traffic signs and marking plans, lighting plans, landscaping, intersection and interchange details, provision for special users such as elderly pedestrians, handicapped, cyclists, drainage, guardrails and other roadside objects.[22]

Pre-opening stage concerns about the final check prior to opening of the project to ensure that, all the safety concerns of all categories of road users have been addressed and all hazardous conditions have been eliminated which includes both day and night. [22]

For existing road safety audits, these are perform on existing facilities to see if the safety needs of road users are currently being served and introduce modification to the current status-quo of the existing situation so as to properly address the challenges regarding safety, it can perform on a road section just open to the traffic to evaluate its performance or be used to identify safety deficiencies on long time existing roads. [22]

2.10 Traffic Safety Management

Traffic safety management gets great attention of almost all governments around the world due to the current urbanization process constantly accelerating, which causes a lot of traffic safety problems. It facilitates traffic accident's rule, adopts the traffic legislate, makes regulation of the traffic safety management and implements the controls of the traffic by studying road traffic accidents, in order to prevent accidents, reduce the number of deaths and property loss. It is one of the complicated system engineering, which harmonizes the relationship between road, traffic flow and the administrators in controlling the emergence of traffic road accident and switching the safety management of urban road traffic to be digital and informational. The consummate and scientific traffic safety management will improve the environments of traffic and reduce the number of traffic accidents. [19]

2.10.1 Relationship between Traffic Safety Management and (RSA/I)

Road safety inspection is a part of traffic safety management tools that can be implemented by road authorities as part of an overall road safety management. The main aim is to find out potential problems and propose sufficient countermeasures to reduce the number of accidents or minimize the accident severity. This in turn will lead to reduced costs associated with accidents, to individuals, families and society. [19]

Traffic safety management and traffic safety inspection/audits are integral components of the road transportation system, which, if not implemented appropriately can influences road traffic accidents. Traffic safety inspection reflects the current situation of traffic safety management, by which people find existing road problems and improve its deficiencies. It includes traffic safety administration management which involves road mechanism, traffic safety policy, personnel duty, traffic safe practice (driver's physiology and psychology), vehicle safe practice, traffic crash analysis, counter measures and road traffic safety facilities. The compatible traffic safety management is pre-requisite of ensuring un-obstructed road and people's safety and promoting economic development. [19]

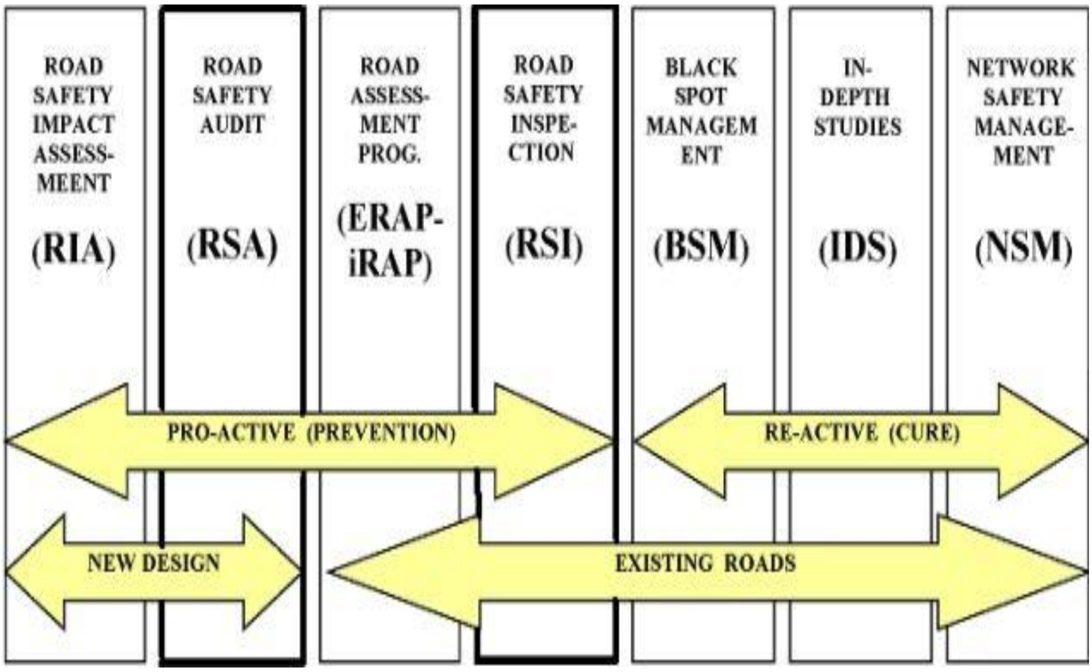

Figure 2.3 Road safety inspections as part of the road safety management [19]

2.11 Intersection Safety

Urban intersections have different number of traffic conflict potentials and wherever there are conflicts potentials there is a probability of accident risk occurrences, denying or closure of a particular movement can increase safety at one site of the intersection, but may affect other factors like local access, which may cause accidents being shifted to other sites and resulted in no more improvements at all to the overall road network safety system. The objective of the safety programs is to obtain an appropriate balance between risks and other network performance parameters. [23]

2.12 Intersection Capacity

Interrupted traffic flow is predominates on most of the urban roads and some major rural roads. Generally, it is the major signalized intersection or un-signalized that determines the overall capacity and performance of the road network. Significant volumes of crossing or turning traffic on minor roads cause interruption and capacity reduction, which can be lessened by channelization and intersection control. To determine capacity, an analysis of one of these is required.

I. Mid-block or route capacity
II. Un-signalized intersection capacity
III. Signalized intersection capacity

The capacity of a route or an intersection can be significantly affected by lane width, gradient and presence of transit bus and trucks in the traffic stream. While, the capacity of traffic moving at signalized intersection depends on saturation flow and proportion of cycle that is effective green time for that particular movement. The saturation flow that use to compute capacity depends on the number of factors which comprises. [24]

I. Type of the road environment
II. Type of lane (through, turning and combined)
III. Lane width
IV. Gradient on approach intersecting leg
V. Traffic compositions

The capacity of a particular roadway segment will be greatest when all of the roadway intersection segments and traffic conditions meet or exceed their base conditions. Empirical analysis has determined the value of these roadway base conditions for which the capacity of road can be maximized. Values in excess of base conditions will not increase the capacity of the roadway, but values in restrictive to base conditions lower capacity. It should be noted that, for the purpose of level of service analysis and determination, capacity should be considered not absolute maximum flow rates ever observed, but rather as the maximum flow rates that can be reasonably expected on a recurring basis. [24]

2.13 Intersection Level of service

In general, the level of service terminology represents a qualitative ranking of traffic operational condition experienced by users of such facility under specified roadway, traffic and traffic control conditions. Several highway operational performance measures such as speed, flow, and density can be measured for any transportation facility, and in--order to determine the correct level of service. It is mandatory to select performance measures that can represent the quality of service perceive by drivers on that facility. Drivers use to describe and evaluate their quality of service in terms of measures such as speed, travel time, traffic interruptions, freedom of maneuvers, comfort and convenience. Therefore, it is important to select an operational measure comprises of some or all of these measures which can be represented as a service measure of such transportation facility. Level of service can be determined for the entire intersection, each intersection approach, and each lane group, the service measure use for the interrupted facility such as signalized intersection is control delay. [25]

Level of service is an indication of the overall acceptable delay to drivers and must be interpreted with cautions, because what might be acceptable in a large city is not necessarily acceptable in a smaller city or rural area. The analyst should always verify that each lane group is providing acceptable operation and consider reporting the level of service for the poorest-performing lane group as a means of providing context for the interpretation of the intersection level of service. Before implementation of any developed signal phasing plan of an intersection, the level of service of such facility should be determined to assess whether such intersection can operate at an acceptable level under this plan, control delay alone can be used to characterize the level of service of a signalized intersection which quantifies the increase in travel time due to traffic signal control and measure the motorists discomfort and fuel consumption. [25]

Table 2.1 Signalized level of service threshold for an automobile mode [26]

Control Delay (s/veh)	Level-of-Service by Volume-to-Capacity Ratio	
	<=1.0	>1.0
<10	A	F
>10-20	B	F
>20-35	C	F
>35-55	D	F
>55-80	E	F
>80	F	F

I. LOS A represents operation with a control delay of 10 s/veh or less and having a volume to capacity ratio no greater than one. This circumstance typically indicates when the volume-to-capacity ratio is low and either progression is exceptionally favorable or the cycle length is very short.

II. LOS B represents an operation with control delay between 10 and 20 s/veh and a volume-to-capacity ratio no greater than 1.0. This level is typically assigned when the volume-to-capacity ratio is low and either progression is highly favorable or the cycle length is short.

III. LOS C represents operations with control delay between 20 and 35 s/veh and a volume-to-capacity ratio no greater than 1.0. This level is typically assigned when progression is favorable or the cycle length is moderate

IV. LOS D represents operations with control delay between 35 and 55 s/veh and a volume-to-capacity ratio no greater than 1.0. This level is typically assigned when the volume-to-capacity ratio is high and either progression is ineffective or the cycle length is long.

V. LOS E represents an operation with control delay between 55 and 80 s/veh and a volume-to-capacity ratio no greater than 1.0. This level is typically assigned when the volume-to capacity ratio is high, progression is unfavorable, and the cycle length is long.

VI. LOS F represents an operation with control delay exceeding 80 s/veh or a volume-to-capacity ratio greater than 1.0. This level is typically assigned when the volume-to-capacity ratio is very high, the progression is very poor, and the cycle length is long. [26]

CHAPTER 3

METHODOLOGY OF URBAN ROAD AND INTERSECTION SAFETY AUDITS AND LEVEL OF SERVICE DETERMINATION

3.1 Introduction

Road Safety Audit (RSA) is a formal procedure for assessing safety performance examination of an existing or future road or intersection by an independent audit team. Since, our roads are designed and constructed by striking socio-economic balance between safety, accessibility, environment, economy and locally available material and skill; it might have some determined shortfall in safety, but might not be able to correct the deficiencies in pavement design, drainage, and appropriate space standard etc. It leads to identification of accident prone situation on existing or already constructed roads for potential accident elimination or reduction and analysis of an intersection operation under current traffic and geometric conditions on the basis of road user's knowledge, attributes and skills, day/night, wet/dry road conditions. [27]

Safety Audits and countermeasures should be considered as a necessary cost within the project and not as additional expenses. The necessary inputs and information that are needed for road safety audits on existing road includes road function, traffic data, speed data and accident data. These information help auditors performing better in carrying out auditing of the road and clarifying the road function, having an idea about the typical accident types, volume of traffic, different vehicle speed limit. [27]

3.2 Procedures for Urban Road Safety Inspection on Existing Roads

Background information concerning the existing road to be inspected should be obtained. The urban road section should be inspected for both traffic directions. Furthermore, single inspection could not be enough to collect audit information and its evaluation results. 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 is 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 might not be sufficient for larger, more complex projects or those requiring specific expertise.

The proper practice is to have a competent team that brings all of the necessary knowledge and experience to the process. All observations achieved during the audit are to be recorded on the checklists which serve as tool in carrying out the inspection and forms in special format have been prepared so as to guide inspectors. Below are examples of some features to be observed during the field survey;

I. Road surface condition
II. Road marking
III. Problematic road side zones that include dangerous features which can create specific danger within the clear zone width (Tress, Utility Poles).
IV. The existence of various kinds of trees and other vegetation which obstructs the sight distance of the drivers
V. Improper location of the bus stops
VI. Absence of guardrail sections
VII. Improper information/directional signs
VIII. Improper junction layout
IX. Improper drainage system/structure

All above listed deficiencies and hazards and many others are going to be recorded on the safety audit checklists for an existing road during the field survey, photographs and video records are also going to be obtained during the site visits which are used to make final discussions and evaluations. [28]

3.3 General Project Data

Conducting an effective road safety audit on existing road requires many important data or information to be obtained which are related to the particular road section selected for auditing/inspection, the basic inputs or data are described below.

3.3.1 Functional Classification of the Road

Functional classification is a process by which streets or highways can be grouped into the national, state or local road within a road network system based on the character of traffic services intended to provide. This classification indicates that individual highway does not serve travel independently alone, but rather involves movement through networks of road, categorized in relation to such networks in a logical and efficient manner. Thus, functional classification of highways is consistent with the categorization of travel. The functional system classifications differ from urban and rural areas, the hierarchy of the functional systems consists of principal arterial (for main movement), minor arterial (distributors), collectors, and local roads and streets. But however, in urban areas there are relatively more arteries 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. [24]

Road function is one of the important inputs of the road safety audit, because during the process of conducting road safety audit/inspection, the auditors should have information about whether it is a school bus route, does the road pass through any town or village, what kind of traffic uses the road, is it short distance or long distance, do vulnerable road users use the road, if the road passes through agricultural or industrial areas are there slow moving vehicles using the road, are speed limits appropriate, is there any impact from adjacent land development, are there any problem to accesses of the private properties. All types of roads should be evaluated based on their own function, because different types of roads have different types of safety situations, the function of the road should be clear to all road users. [24]

3.3.2 Traffic Data

Highway Transportation Surveys are performed to establish bases in the transportation planning process which 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. [29]

3.3.3 Volume Data

In order to carry out a safety audit on existing roads, 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. Generally, there are two methods available for conducting traffic volume counts on existing roadway. [29]

a) Manual Traffic Volume Count

A 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. Its count is necessary when automatic equipment is not available or the data required is small. [29]

b) Automatic Traffic Volume Count

The automatic traffic count method provides a means for gathering large amounts of traffic data; it is usually taken in 1-hour intervals for the 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.

Generally, volume data is an important input for road safety audit on existing road or any other stage of the audit, the data should always be accurate and reliable. Only reliable and accurate data are needed to correctly identify problems, risk factors, 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. [29]

3.3.4 Speed Data

Speed can be considered as an essential data needed for road safety audit on existing road, it 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. Low design speeds are generally acceptable to roads with winding alignment in rolling or mountainous terrain or where environmental conditions are unfavorable. While, 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 the terrain and other environmental conditions are a combination of those described for low and high speed. [24]

All geometric design elements of the highway are affected in one way or the other 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, wall clearance 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:

I. The functional classification of the highway
II. The character of the terrain
III. The density and character of adjacent land use
IV. The traffic volumes expected to use the highway
V. The economic and environmental considerations.

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. When conducting audits on acceleration, deceleration lanes, barrier design, exit and entrance parts of the roadside facilities, desired clear zone width and stopping and passing sight distance, all these features are design based on the speed data. [24]

3.3.5 Accident Data

Accident data are needed for an accurate road safety situation assessment. In order to be more useful, the record needs to cover data concerning deaths and casualties and the accident circumstances. This will help for appropriate safety measures to be taken and improvement designed to solve specific problems to be implemented. The best ways of gathering accident data includes an accident reporting and recording system, storage and retrieval system, an analysis system, and an effective dissemination system. The data collected for all recorded accidents needs to cover the following questions:

I. At where does accident occurs?
II. When the accident happened?
III. What type of cars involved?
IV. What were the results of the collision?
V. What were the environmental conditions?
VI. How did the collision occur?

Accident data are very useful for designing appropriate countermeasures, producing plans, monitoring effectiveness, and carrying out research. [30]

3.3.6 Safety Audit Checklist for an Existing Urban Road

One of the key parts of an audit process is the evaluation of the route section using relevant checklists, which can either be in a paper form or in a computerized form. It helps the auditors to consider almost all the necessary factors and provide a reminder of potentially overlooked safety issues. They are not just to be used by running through the lists and marking off items, they should focus on the evaluation of the specific issues that can be included in the audit. [31]

Table 3.1 Safety audit checklist for an existing road [31]

SAFETY AUDITS CHECKLIST FOR AN EXISTING URBAN ROAD

Road Controlling Authority………… Road Name/Description……… Classification…….

Weather………… Completed By…………… Date………….

Features	Standards (Observation)	Comments
1. Road Marking	**Condition**	
	Lane markings	
	Edge lines	
	Transverse markings	
	Flush median	
2. Road Surface Condition	**Maintenance**	
	Drainage/ Channels	
3. Signs	**Regulatory Signs**	
	Warning Signs	
	Street Names	
	Directional/Info Signs	
	Advertising	
4. Vegetation Control	**Intersections**	
	Signs and Signals	
5. Pedestrian Facilities	**Crossing**	
	Refuges	
	Footpaths	
	Mobility challenged	
6. Cyclists	**General**	
	Cyclist Facilities	
7. Parking	**Maneuvering**	

	Control	
8. Property Accesses	**Adequacy of Design**	
	Visibility (entry and exit)	
	Turning Traffic Issues	
9. Speed Control	**Appropriateness**	
10. Lighting	**Adequate**	
	Placement	
	Intersections	
	Pedestrian Facilities	
11. Hazards	**Poles**	
	Bus Stop Shelter	
	Pedestrian crossing Pillars	
	Transformer	
	Signboards	

Table 3.1 (continued).

3.4 Intersection Safety Audits and Level of Service Procedures

Intersection locations, particularly in urban areas can expose to potential hazards due to the higher number of traffic and traffic exposure to conflict points. The crossing and turning maneuvers that occur at an intersection creates risks of vehicle-vehicle, vehicle-pedestrian, and vehicle-bicycle conflicts which might result in crashes. Although, intersections physically represent only a small percentage of an urban highway system, crashes at these locations have significant values compared to the other section of the highway. The intersection features that can be studied when carrying out road safety audits are: [32]

3.4.1 Intersection Study Location/Surroundings

The intersection location should be analyzed and study critically in order to know the type of land use adjacent and businesses surrounding the intersection study, the location where it is situated and the type of roads that form the approaches at that particular intersection. Speed limits, nature of pavement at intersection area should be observed and stated. [32]

3.4.2 Intersection Road Users

Intersection travel modes category that uses the intersection regularly and during the study periods should be stated, the type of vehicles uses, and the nature of travelling weather reflecting the use of the resident of the area or by through traffic. [32]

3.4.3 Intersection Traffic Control

Traffic control at an intersection provides guidance and navigational information that often not regularly noticeable and available. Such control includes regulatory, warning, guide signs, and other route guidance information. Other traffic controls such as markings and delineation, display additional information that augments particular roadway or environmental features. These devices help drivers perceive information that might otherwise be overlooked or difficult to recognize when approaching an intersection. The intersection traffic control should be stated and even mode of operation of the traffic using the intersection. [32]

3.4.4 Intersection Accident Data and Analysis

Accident data related to subject intersection is needed for accurate road safety inspection, the record needs to cover data concerning fatal, injury and the property damage only with the figure representing the category of each accident type and circumstances. This will help for appropriate safety measures implementation and improvement designed to solve specific problems and analysis of accident collision type should also be presented. [32]

3.4.5 Intersection Traffic Counts

Traffic volume counts studies are conducted to determine the number, movements, and classifications of roadway vehicles at a given location. These data can help in identifying critical flow time periods, determine the influence of large vehicles or pedestrians on vehicular traffic flow, or 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, 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. Intersection counts are used for timing traffic signals, designing channelization, planning turn prohibitions, computing capacity, analyzing high crash intersection, and evaluating congestion. The manual count method is usually used to conduct an intersection count, a single observer can complete an intersection count only in very light traffic conditions and the count period should avoid special event or compromising weather conditions. The intersection count classification scheme must be understood by all observers before the count begins. The intersection movements are through, left turn, and right turn and the observer should record intersection movement for each vehicle that enters the intersection. [24]

3.4.6 Intersection capacity and level of service

Capacity at an intersection is defined for individual lane group, approach legs and for the intersection as a whole. A lane group may be a single movement, a group of movements, or an entire approach and is defined by the geometry of the intersection and the distribution of movements over the various lanes. The capacity of a lane group is calculated as the maximum rate of flow that may pass through the intersection under prevailing traffic, roadway, and signalization conditions. The rate of flow is generally measured or projected for a 15-minute period and capacity is stated in vehicles per hour. Capacity analysis of an intersection involves the computation of volume-to-capacity (v/c) ratios for each lane group, from which an overall intersection v/c ratio may be derived. [25]

Generally, when two opposing flows are moving during a single phase, one of the lane groups may require more green time than another to process all of its volume. This would be defined as the "critical" lane group for the subject signal phase. The concept of a critical v/c ratio is used to evaluate the intersection as a whole, considering only the critical lane groups or those with the greatest demand for green time within each signal phase. This procedure assumes that green time has been appropriately allocated. Thus, it is possible to have an overall intersection v/c of less than 1.00 (under capacity), but still have individual movements be over saturated within the signal cycle if the green time has not been appropriately allocated to the various approaches. The other major concept in signalized intersection analysis is level of service, which is an index used to grade intersection operations. Level of service is defined in terms of delay and ranges from LOS A (free-flow conditions) to LOS F (long delays). Delay represents a measure of driver discomfort, frustration, fuel consumption, and lost time. Specifically, level-of-service delay criteria are stated in terms of average stopped delay per vehicle for a 15-minute analysis period.

Delay is a complex measure that depends upon a number of variables such as quality of signal progression, cycle length, allocation of green time, and v/c ratio. Considering all the factors cited, v/c ratios have the least effect on delay. Thus, for any given v/c ratio, a range of delay values (and therefore, level of service) may result. Conversely, for a given level of service the v/c ratio may lie anywhere within a broad range. The base saturation flow rate used in the analysis model is 1,900 passenger cars per hour of green per lane (pc/hr/ln), this value is adjusted for prevailing traffic conditions such as lane width, left turns, right turns, heavy vehicles, grades, parking, area type, bus blockage, and left turn blockage. [26]

Table 3.2 Intersection checklist [33]

ROAD SAFETY AUDITS CHECKLIST FOR AN INTERSECTION

Date:

Intersection Aspects/Features	Observation	Recommendation
1. Location		
2. Visibility, sight distance		
3. Signs and markings		
4. Layout		
5. Lighting		
6. Lane/shoulder width		
7.Acceleration/Deceleration (speed change length)		
8. Tapers		
9. Turning radii		
10. Triangle sight distance		
11.Channelization		
12.Pedestrian/bicycles consideration		
13. Traffic signal operation		
14. Signal head visibility		
15. Bus stop location		

Table 3.3 Intersection summary sheet [25]

INTERSECTION SIGNAL ANALYSIS AND LEVEL OF SERVICE SUMMARY SHEET

APPROACH	EAST BOND	WEST BOND	NORTH BOND	SOUTH BOND
Lane group				
A. flow rate (v)				
S. flow rate(s)				
Flow ratio (v/s)				
C. lane group				
Y_c				
Lost time/phase				
Total lost time				
C. length(C)				
X_c				
Eff. G. time (g)				
g/C				
L.G capacity(c)				
v/c (X)				
d_1				
PF				
K				
I				
T				
d_2				
Lane group delay (d)				
Lane group LOS				
Approach LOS				
Intersection delay				
Intersection LOS				

3.5 Roadside Safety

Roadside safety addresses the area outside the roadway, and is one of the important components of total highway design. There are various reasons why a vehicle leaves the roadway, which includes 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. [34]

It is not possible to provide a clear zone free of objects at all locations and under all circumstances. The engineer needs many trades in design decision-making, balancing needs of the environment, right of way, and different modes of transportation. 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. Unfortunately, geography and economics do not always allow ideal highway conditions. The preventive measures to be taken depend on the probability of a collision occurring, the likely severity, and the available resources. The roadside safety is the prior concept of the road safety audit (RSA) on existing roads which includes information about the clear zone area and hazardous obstacle locations for both at the project level and for analysis of an existing road section. [34]

3.5.1 Safety Zone

It is expected that no hazards should be found within the safety zone, such as hazardous obstacles or hazardous slopes and areas adjacent to the road should be given a safe design within the safety zone. The width of the safety zone is measured from the edge of the lane and is determined based on the road’s safety separation, with additions for steep slope and reduction for a deep and steep cut. 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 reasons 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 of hazardous objects which can cause injuries to the driver or passengers.

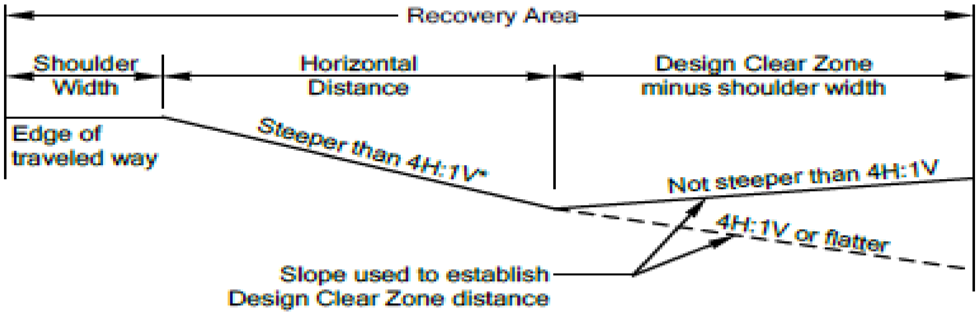

Figure 3.1 Roadside safety zone designs [34]

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

I. Bridge piers, abutments, railing ends
II. Rocks with diameters > 0.2 m
III. Trees with diameters > 0.1 m
IV. Cross (transverse) pipe opening widths larger than (750 mm)
V. Box culverts and cattle pass
VI. Approach (parallel) pipe height larger than (600 mm)
VII. Cut slopes (rough)
VIII. Steep slopes
IX. Approach slopes steeper than 6:1
X. Signs/luminaries/traffic signals with non-breakaway supports
XI. Utility poles (lighting)
XII. Walls (unless crashworthy).

The adequate clear zone distance between the edges of traffic lanes and roadside obstructions has been shown to be a very important safety factor. Run off 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;

I. Taken away or removed
II. Replace it with a non-hazardous equipment
III. Redesigned or shielded by traffic barriers or crash cushion.

The width of clear zone is found out by evaluating the annual average daily traffic (AADT), the design speed and cut or fill slope sections of roadside slope. Based on this data, the required widths of the safety zone are given. [24]

Table 3.4 Recommended clear zone width. [24]

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

3.6 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 poles can also contribute to the severity of other accident crash types. Many crashes are not classified as run off the roadway or fixed-object crashes where one or more vehicle strikes 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. Utility poles are one of the most substantial objects that are placed on roadsides worldwide, which are substantial both in number and in structural strength. Because of the structural strength of utility poles, these crashes tend to be severe. [35]

b) Trees

Tree crashes are other types of higher crash and fatality rate accident, which also associated with roadside. One of the most common causes of fatal and severe injury accidents on urban roads in particular are fixed objects. Trees are mostly and commonly the objects struck during run off the road collisions, and its impacts are generally quite severe. A collision between vehicles and trees is one of the major types of traffic fatality. Existing trees often pose greater risk than trees that have been placed along new or reconstructed roads. [36]

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 input information, while there are many types of visual information, but road signs and markings are one of the important because they provide relevant information for the driver to execute his/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: [37]

I. Drivers do not detect the sign/marking
II. Drivers are not able to identify the sign/marking properly
III. Drivers do not understand the sign/marking
IV. Drivers do not have enough time to decide and take the action(s) needed
V. The sign/markings do not meet the driver's expectations
VI. The signs' messages are not heeded by the driver
VII. The information on the signs are wrong / misleading

e) Intersections

Most of the urban accidents occur at intersections, because it is a location where two or more roads connected or crossed each other. The crossing and turning maneuvers that occur at intersections create risks of vehicle-vehicle, vehicle-pedestrian, and vehicle-bicycle conflicts, which may result in crashes. Thus, intersections are likely points of higher traffic crashes. [37]

f) Improper Access Management

Access management is achieved through the regulation of public access rights to and from abutting properties of 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. Access control, which is the way of regulating public access to and from property 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.

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 greater potential hazards for the traffic accidents. [24]

g) Improper Bus Stop Design/Location

Improving facilities for public transportation is one of the main concerns of the urban network system development. Regarding this concept, there must be safe areas for busses to stop and take passengers without interrupting the traffic stream. In some cases, when bus stop designs are improper thus creates danger for public transportation users and the other drivers. [24]

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 by 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. [38]

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

(1) The improper design of roadside (and of wide medians, which is equivalent to roadside) drainage elements can increase the accident severity.

(2) 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. [38]

i) Improper Medians and Median Openings

A median is the portion of a highway separating opposing directions of the traveled way, which are highly desirable on arteries 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 loans.

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. 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 an emergency departure from the travelled lane. [24]

j) Improper Selection of Lane and Shoulder Widths

Total roadway width is one of the most important cross-sectional 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. [24]

The capacity of a highway is affected by the lane width, narrow lanes force drivers operate their vehicles closer to each other laterally than they would normally desire and also restricted clearances have much the same effect. In capacity perspective, 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.

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 and 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 which creates dangers to other road users. [24]

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. Safest speed for any highway depends on design features, roadway conditions, traffic volumes, weather conditions, roadside development, spacing of intersecting roads, cross-traffic volumes, and other factors. [24]

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 steeper, but if the fill slope height is high some of the safety conditions should be thought by designer for road users' safety. 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. 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. [24]

m) Barriers

Roadside barriers are important components in road and bridge project designs, when hazards are perceived alongside the roadway, but also at the same time very dangerous by increasing accident severity. Hazards include, fixed objects such as no 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, steep grades, opposing traffic lanes, and to define medians which are typically set in the roadway's "clear zone" or "recovery zone". This area's depth varies with traffic volume and design speed, 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 are also referred to as crash cushions). [24]

n) Pavement

The selection of pavement type is determined based on the traffic volume, 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.

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. [24]

Skid resistance of pavements is the friction force developed at the tire pavement contact area; it is an essential force 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. [24]

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:

I. Some aspect of the work zone
II. Traffic congestion
III. Lane changing
IV. Vehicles entering and leaving the work zone
V. Unexpected presence of flag-person.

3.7 Safety Auditing Reporting

After identifying all potential safety issues, the audit report should be prepared and outcomes of an audit should be documented in written report format, which contains a list of potentials safety observations and recommendations on how these identified potential safety problems in the existing road and intersection will be addressed. The report should clearly identify the process being followed, issues being observed and recommendations being proposed. It is important to note that the recommendations should focus on safety issues, rather than specifying the details of a solution. Also, the photographs should be included in 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. [39]

3.8 Safety Audit Discussions

After safety audit reporting has been documented in a reporting format, the meeting is follow-up to provide an opportunity to discuss the findings of road safety audit. Discussion will hold between the auditor(s), representatives from region municipality in which the audit process implemented for and representatives from National Road Service Commission. In this discussion/meeting the documentation of the safety actions and project scope which includes programming and scheduling will be recommended. If there is uncertainty about the existence of safety problems, the most appropriate corrective action in order to improve the situation is desirable to consult qualified highway and safety engineers. 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. [39]

CHAPTER 4

CASE STUDY ANALYSIS AND PRESENTATION OF DATA

4.1 General

The idea of an urban road safety audit is not widely accepted and executed in Nigeria, but recently the concept has started becoming known and familiar due to the awareness programs and policy making by international organizations and developed countries. The concept had never before been applied on Nigerian roads, particularly existing urban roads due to the authorities' less concern and commitments to safety related issues which cause a high number of accidents and injury severity in Nigeria.

This thesis study is considered as an application of an existing urban road safety audit concept and signalized intersection level of service analysis on Nigerian road, a case study of an urban section of the Katsina Road in Kano metropolitan. The case study route is a four lane divided highway that has a 7m width of carriage way in one direction with each lane approximately 3.5m width, having central reservation of 4.55m width and 0.1m height and guardrail of 0.9m height been mounted throughout the urban road section on both sides of the central reservation at 0.2m from its edges. Many junctions have been observed along the audited route, but this signalized intersection has been selected for the analysis because it is the most congested and only signalized one.

It is also been regarded, as one of the most congested roads within Kano metropolitan especially during peak hour periods because it serves through and short distance traffic in relation to the areas surrounding the road network. The inspection started at the Aminu Kano International Airport roundabout that connected Katsina Road and Airport Road and terminated at Bachirawa Junction, 7.8 km from the initial starting point.

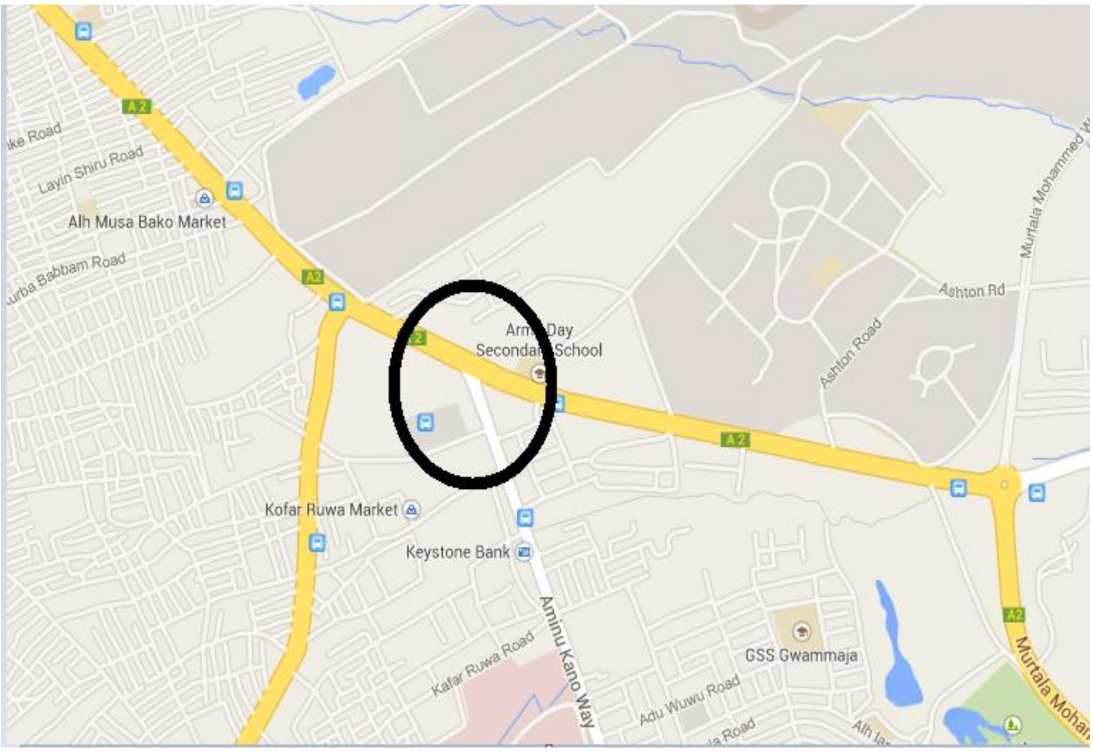

Figure 4.1 Katsina Road urban section map with the intersection location

4.2 Preconditions

4.2.1 General Project Data

a) Function of the Road

The existing paved route is an urban multilane highway (main collector and distributor) which its section extended to villages, towns and other state within Nigeria. It was made up of surface dressing which initially been constructed to serve long distance and short distance traffic in providing access to the abutting or adjacent properties; it was constructed initially by the federal government under trunk A category of road classification in Nigeria but currently it is urban section. It has been controlled, maintained and serviced by state government under trunk B category.

The urban section of the road is surrounded by many residential, commercial, administrative settlements, school and market areas with a significant number of heavy vehicles using the road especially during early in the morning and late in the evening. It consists of a considerable number of vulnerable road users such as pedestrian, motorcyclist or scooter riders and cyclists.

b) Traffic Volume

The traffic hourly volume count has been conducted along the audit route at Kurna Asabe Main Line about 2 km from the starting point of the inspection and 100m from the first pedestrian crossing bridge for two different periods of the day, that is morning and afternoon sessions at both directions of the audit route. The AADT value was estimated to be 21,350 vehicles per day.

c) Road Accident Data

Road traffic accident data related to the route under investigation were obtained from the Federal Road Safety Commission of Nigeria at Fagge Unit Command. The type, number and year of the accidents are tabulated and presented below, where detail explanations related to the location and day of accidents and other information can be obtained in appendices attached to this thesis study.

Table 4.1 Five Year Traffic Accident Data for Katsina Road Urban Section

Katsina Road Accident Record					
Years	2009	2010	2011	2012	2013
No. of Accident	6	7	12	5	7
No. of People killed	3	3	6	2	3
No. of People Injured	21	18	26	10	15
Total Casualty	24	21	32	12	18

d) Road standard

The road under investigation or audit was constructed by the federal government of Nigeria, it is a four lane divided urban multilane highway (main collector and distributor) which has paved surface and almost completely smooth unless at some particular locations and having straight horizontal and vertical alignment in most of the road section. It is generally considered in a relatively good condition and passing through flat terrain, it has the highest number of traffic volumes with a considerable number of different junctions comprising of U-turn, un-signalized, signalized and roundabout. The speed limit of the road is obtained to be equal to 50km/hr and also comprises all categories of vulnerable road users due to the residential and commercial areas along the urban section of the route. Different types of guard rails have been installed and mounted on the central reservation or median that forced pedestrians not to cross the road at any locations but to use pedestrian crossing bridges built at some strategic locations.

e) Speed Limits

The posted legal speed limit of the route was observed to be 50km/hr within the urban section of the road. However, the audit route has little geometric standard in relation to all road user categories at relatively almost all sections of the route. It was observed that most of the vehicles were moving below the legal speed limit due to the nature of the road congestion especially during peak hour period. The absence of vulnerable road user facilities forced them to use the right side traffic lane which reduced the operational performance of the vehicles.

4.2.2 Surroundings / Land Use

The audit route is surrounded by urban linear settlements that comprises of residential, commercial, market, schools and government buildings; the initial point of the audit is a roundabout that linked to Aminu Kano International Airport, Air Force Base and Hajj Camp. Several built up areas existed which comprised of a considerable number of petrol stations, schools and local markets that serves residents of the area, the complete audited 7.8 km urban road section is within built up areas and surrounded by many business and government activities.

4.3 Methodology

All necessary information and data related to the audit route were collected after route selection and determination before proceeding to the site for observation, some required items and information which were gathered and obtained includes.

I. Route map
II. 2 hours traffic counts for all road users type
III. Accident information data for the past five years

IV. Road geometry

All above listed items were obtained from the relevant authorities; the route map was obtained from the Ministry of Land and Physical Planning while the accident information data has been collected from the Federal Road Safety Corps of Nigeria at Fagge Unit Command, Kano State while road geometry was obtained by critical road inventory and road features measurement.

After all the above mentioned information has been collected, the audit investigation and auditing started at the roundabout of the Aminu Kano International Airport, which served as the starting point of 00 + 00 km and ended at Bachirawa Junction that was 7.8 km from the initial position. Pictures have been snapped during the route visit that would be used to make final discussions and evaluation of the route deficiencies. Both directions of the route under inspection were observed and safety related issues were recorded on a designed road audit checklist. During the auditing process, the safety audit checklist was filled.

4.4 Inspection Performed During Road Safety Audits

Potential safety related issues and road side hazards were observed and identified along the route during the field study trip. All recognized and identified problems and deficiencies were recorded on the checklist that has been prepared.

However, the road pavement has been considered to be considerably satisfactory at some locations, but there were absence of proper drainage and channel system which could adversely affect the pavement. There were few or unidentified road signs, some directional/ information signs have totally been worn out, no street name signs were present and there were many advertising signboards. Almost all the connected roads related to the route observed during the audit process were inappropriately being designed, road markings which include lane markings, edge marking and transverse marking were totally missing or worn off completely.

There were completely absent of footpaths, refuge at some intersections and only two pedestrian crossing bridges were located at Kurna Asabe Main Line 1.9 km and Gobirawa Special Primary School 2.9 km respectively from the starting point, guard rails have been mounted in the median in order to protect pedestrian crossing. There were completely absence of parking maneuver and proper control, presence of improper bus stop locations which could force vehicles to park on the travelled lane along the whole route section. Considerable numbers of roadside hazards have been observed along the route section which includes electric poles, bus stop shelter, pedestrian crossing pillars, transformers and signboards that could contribute to the high number of road accidents.

4.5 Urban Safety Audits Hazards List and Inspected Road Safety Checklists

All necessary potential defects and hazards were classified into eleven (11) different main categories which area; a) Road marking b) Road surface condition c) Signs d) Vegetation control e) Pedestrian facilities f) Cyclists g) Parking h) Property accesses i) Speed control j) Lighting and k) Roadside Hazards. Each defects/ hazards were given a number used for identification in the checklist. The checklist used for the inspection is divided into two different types; one of them was used to inspect the existing road features and its deficiencies while the other one was used to inspect the intersection problems and its deficiencies. The first checklist consists of three columns in which the first column described the road features to be audited or inspected; the second column consists of standard observations related to the features of the road while the third column is for comments.

Table 4.2 Hazards and features lists

Hazard (Features) Category	Hazard (Features) Name	Hazard ID
A. Road Marking	Condition	1
	Lane Markings	2
	Edge Lane markings	3
	Transverse Markings	4
	Flush Median	5
B. Road Surface Condition	Maintenance	6
	Drainage / Channels	7
C. Signs	Regulatory Signs	8
	Warning Signs	9
	Street Names	10
	Directional/ Informational sign	11
	Advertising	12
D. Vegetation Control	Intersections	13
	Signs and Signals	14
E. Pedestrian Facilities	Crossing	15
	Refuges	16
	Footpaths	17
	Mobility challenged	18
F. Cyclist	General	19
	Cyclist Facilities	20
G. Parking	Maneuvering	21
	Control	22
H. Property Accesses	Adequacy of Design	23
	Visibility (Entry and Exit)	24
	Turning Traffic Issue	25
I. Speed Control	Appropriateness	26
J. Lighting	Adequate	27
	Placement	28
	Intersections	29
	Pedestrian Facilities	30
K. Hazards	Poles	31
	Bus Stop Shelter	32
	Pedestrian Crossing Pillar	33
	Transformer	34
	Signboards	35

Table 4.3 Road safety checklists for Airport Roundabout-Bachirawa Junction

SAFETY AUDITS CHECKLIST FOR AN EXISTING URBAN ROAD

Road Name/Description: Katsina Road**. Classification:** Trunk B **Weather:** Sunny **Completed By:** Abubakar Sani Habibu **Date:** 15/04/20.

Airport Roundabout- Bachirawa

KM	DISTANCE (m)	HAZARD ID	COMMENTS
0	0		Audit starting point (Airport Roundabout)
Throughout the route		2	Unspecified travelled lane
Throughout the route		3	Unrecognized travelled lane edge
Throughout the route		4	Lack of guidance at junctions and on travelled lane
Throughout the route		16	Blocked and exposed pedestrians in danger
Throughout the route		17	Absence and create vehicle-pedestrian conflicts
0	40	30	Cause serious accident injury when hit by a car
0	60	30	Cause serious accident injury when hit by a car
0	80	7	Increase roadside accident potentials
0	250	30	Cause serious accident injury when hit by a car
0	550	12	Expose driver to danger when hit
0	700	7	Increase roadside accident potentials
1	600	15	Improper pedestrian crossing
1	700	8	Improper bus stop sign and location
2	800	34	Causes accident when loss control
2	900	32	Increase severity of the accident when struck
3		31	Increase roadside accident and reduce sight distance

3	200	34	Causes accidents when loss control
3	550	7	Increase roadside accident potentials
3	900	32	Increase accident severity when struck
4	7	8	Improper bus stop sign and location
4	200	33	Improper location of transformer shelter
5	300	7	Increase roadside accident potentials
5	800	7	Increase roadside accident potentials
7	700	33	Improper location of transformer shelter
7	800	7	Increase roadside accident potentials

Table 4.4 Road safety audit checklists for Bachirawa-Airport Roundabout

SAFETY AUDITS CHECKLIST FOR AN EXISTING URBAN ROAD

Road Name/Description: Katsina Road**. Classification:** Trunk B **Weather:** Sunny
Completed By: Abubakar Sani Habibu **Date:** 15/04/20.

Bachirawa **-**Airport Roundabout

KM	DISTANCE (m)	HAZARD ID	COMMENTS
0	0		Returning point (Bachirawa Junction)
Throughout route section		2	Unspecified travelled lane
Throughout route section		3	Unrecognized travelled lane edge
Throughout route section		4	Lack of guidance at junctions and on travelled lane
Throughout the route		16	Blocked and exposed pedestrians to danger
Throughout the route		17	Absence and create vehicle-pedestrian conflicts
0	5	7	Increase roadside accident potentials
0	20	8	Improper no parking sign
2	500	6	Poor routine maintenance
3	500	8	Improper no parking sign
3	600	7	Increase roadside accident
3	900	32	Increase accident severity when struck
4	250	7	Increase roadside accident potentials
4	900	32	Increase accident severity when struck
4	900	6	Poor routine maintenance
5	700	11	Worn out and difficult to understand

5	720	30	Cause serious accident injury when hit by a car
6		8	Improper bus stop location
6	10	8	Worn out speed limit sign
6	550	9	Improper pedestrian crossing sign
7	200	34	Causes accident when loss control
7	700	7	Increase roadside accident potentials
7	790	11	Worn out and difficult to understand

4.6 Observed Route Problematic Hazards and Features

a) Road Marking

I. Condition

The road marking condition was very poor at almost all sections of the audit route, particularly at the travelled way where there was no road marking completely. Some portions of the signalized intersection that have been positioned along the audited route have faded markings, especially at the pedestrian crossing location, but the overall condition of road marking along the route was terrible.

II. Lane Markings

Absence of lane marking caused vehicle drivers to leave a particular travelled lane that creates confusion among motorists and cause a serious accident. Throughout the route section been observed, there was a complete absence of lane marking.

Figure 4.2 Absence of lane markings (Throughout the road section)

III. Edge Markings

Absence of edge markings might create serious misunderstanding issues with the drivers of the vehicles using the inner and outer lanes. Drivers using inner lane might mistakenly hit the median edge due to the edge line missing and create accidents. There were completely absences of route edge line markings throughout the observed route section.

Figure 4.3 Absence of edge line markings (Throughout the road section)

IV. Transverse Markings

There was complete absence of transverse markings of the route, especially at the junction areas that help in alerting drivers to stop or yield. This circumstance could lead to serious intersection accidents, especially at un-signalized junctions.

Figure 4.4 Absence of transverse marking (throughout the road section)

b) Road Surface Condition

I. Maintenance

Absence of proper routine maintenance has been observed along the overall road section particularly at outer travelled lane edges, some sections of the route had been routed and deformed, which caused vehicles to have sudden break or parked on the outer travelled lane which could lead to serious accidents.

Figure 4.5 Lack of maintenance (Km 04+900) Bachirawa Junction-Airport Roundabout

Figure 4.6 Lack of maintenance (Km 02+500) Bachirawa Junction-Airport Roundabout

II Drainage/Channels

Poor drainage systems and open channels culverts have been observed along the entire route section, These situations could contribute a lot in destroying the surface pavement and create high potential safety problems to vehicle drivers and vulnerable road users.

Figure 4.7 Improper drainages (km 04+250) Bachirawa Junction-Airport Roundabout

Figure 4.8 Improper drainages (Km 05+300) Airport Roundabout-Bachirawa Junction

Figure 4.9 Improper drainages (Km 00+5) Bachirawa Junction-Airport Roundabout

Figure 4.10 Improper channels (Km 07+700) Bachirawa Junction-Airport Roundabout

c) Signs

I Regulatory Signs

Several improper and worn out regulatory signs have been observed along the audited route section, some observed signs were not clear enough at some relative distance while others were inappropriately being placed close to an outer travelled lane which can create potential problems to the road users.

Figure 4.11 Worn out speed limit sign (Km 06+10) Bachirawa Junction-Airport Roundabout

Figure 4.12 Improper parking control sign (Km 0+20) Bachirawa Junction-Airport Roundabout

II Warning Signs

Many inappropriate pedestrian crossing signs have been observed along the audited route section in which guardrails have been mounted completely on the median in order to block pedestrians from crossing the road, There were completely absence of warning ahead sign on the overall route section.

Figure 4.13 Improper pedestrian crossings (Km 06+550) Bachirawa Junction-Airport Roundabout

III Directional/ Information Signs

Several numbers of worn out directional and informational signs have been observed along the audited route section that helped in guiding and informing drivers about intended destination. Such circumstances could contribute a lot in creating accident as drivers would be busy trying to read and identify the intended direction.

Figure 4.14 Worn out directional sign (Km 05+700) Bachirawa Junction-Airport Roundabout

Figure 4.15 Worn out directional sign (Km 07+790) Bachirawa Junction-Airport Roundabout

e) Pedestrian Facilities

I Crossing

Throughout the audited route section only two pedestrian crossing bridges were observed which were located at Kurna Asabe Main Line and Gobirawa Special primary School 2.9 km and 3.9 km respectively along the route section. Moreover, guardrails have been mounted in almost all the urban route section being audited. This situation exposed pedestrians to great dangers while crossing.

Figure 4.16 Lack of pedestrian crossing (almost throughout the road section)

Figure 4.17 Lack of pedestrian crossing (almost throughout the road section)

II Footpaths

As observed along the audited route section, there was a complete absence of proper pedestrian footpaths whereby pedestrians were walking on an outer travelled lane which exposed them to serious potential accident risks.

Figure 4.18 Lack of pedestrian footpath (throughout the road section)

f) Cyclists

I Cyclist Facilities

Along the inspected section of the urban route being audited on both directions, there were completely lacking of cyclists' facilities which forced them to travel on an outer travelled lane that has 3.5m width which exposed them to high potential accidents and according to AASTHO the outer travelled lane should be 4.2m if no shoulder exists.

Figure 4.19 Lack of cyclist facilities (throughout the road section)

g) Parking

I Maneuvering

Parking maneuvers were totally missing along the audited route section, where stopped vehicles could safely park outside the travelled lane without disturbing continues traffic movement which creates serious problems for drivers and vulnerable road users.

Figure 4.20 Lack of parking maneuver (Km 06+00) Bachirawa Junction-Airport Roundabout

II Control

Along the audited route section, there have been many improperly placed parking control signs which were not designed based on standard and might not even exact serious warning impacts to vehicle drivers using the route.

Figure 4.21 Improper parking controls (Km 03+500) Bachirawa Junction-Airport Roundabout

k) Hazards

I Utility Poles

Utility poles can cause severe roadside crashes. Along the inspected route section there have been many concrete and wooden electric poles, which were located close to the outer travelled lanes on both sides of the road that could create higher potential safety problems to the road users.

Figure 4.22 Improper poles location (Km 05+750) Bachirawa Junction-Airport Roundabout

Figure 4.23 Improper pole locations (Km 07+200) Bachirawa Junction-Airport Roundabout Junction

Figure 4.24 Improper pole locations (Km 00+40) Airport Roundabout-Bachirawa Junction

II Bus Stop Shelter

Improperly designed and located bus stop shelter can contribute a lot in creating severe risk of potential accident to the road users, along the audited section observed, there has been improperly located bus stop shelter closed to the outer travelled lane.

Figure 4.25 Improper bus stop shelter (Km 03+00) Airport Roundabout-Bachirawa Junction

III Pedestrian Crossing Pillars

Along the audited route section on both sides of the road, there have been two pedestrian crossing bridges which their pillars were located close to the outer travelled lanes at Kurna Asabe main line and Gobirawa Special Primary School 2.9km and 3.9km respectively that can create a serious potential accident situation.

Figure 4.26 Improper pillar location (Km 04+900) Bachirawa Junction-Airport Roundabout

Figure 4.27 Improper pillar location (Km 03+900) Airport Roundabout-Bachirawa Junction

IV Transformer

Along the route section been observed, there was transformer shelter positioned close to the outer travelled lane that can cause serious safety problems to the road users.

Figure 4.28 Improper transformer location (Km 07+700) Airport Roundabout-Bachirawa Junction

V Signboards

Inappropriate positioning of signboards at the road side contribute massively to serious accidents causation, along the audited route section there have been many located signboards and advertising boards mounted close to the outer travelled lane that can contribute a lot to accident occurrences.

Figure 4.29 Improper signboard locations (Km 2+800) Airport Roundabout-Bachirawa Junction

Figure 4.30 Improper location of advertising board (Km 00+550) Airport-Bachirawa Junction

4.7 Intersection Safety Auditing

4.7.1 Intersection Location/surroundings and Layout

The subject inspected signalized intersection is located at Kofar Ruwa, 1.92km from the audit starting point (Airport Roundabout) and has 7.0m width of carriageway on west bound approach, 7.4m on the eastbound approach with right turning lane having 3.6m and 3.4m width for left and right turning travelled lane on northbound approach. It has been located close to Kofar Ruwa market, Bukavu Military Barrack and many schools. It was an at grade signalized intersection that has three signalized approaches connected to Katsina Road and Aminu Kano Way and has a Y-junction layout. The subject signalized intersection has high number of traffic personnel that also oversee its operational conditions despite the installed signal controls due to the complexity and congestion. In relation to that, adequate and proper intersection control and management system could adversely increase safety and better operational performance of the junction.

Figure 4.31 Intersection surroundings and layout

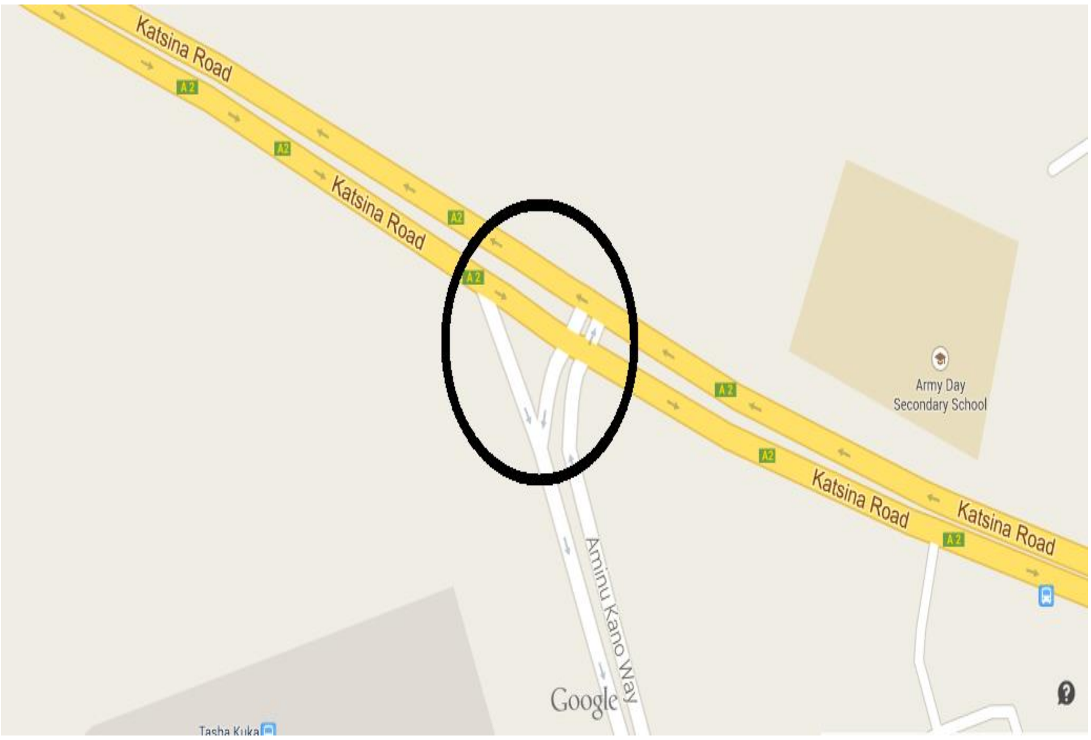

Figure 4.32 Intersection map

4.7.2 Intersection Road Users

A variety of travel modes were observed using the subject intersection, which includes vehicles, pedestrian, motorcycles and even cyclists by residents of Kofar Ruwa, Gwammaja and other locations along Aminu Kano Way on northbound approach. While on the westbound approach were Kurna Asabe, Rijiyar Lemo, Bachirawa, Miltara, Dawanau and long distance traffics that passed through many villages, towns, cities and even other states. The morning travel patterns were greatest in the east bond direction while evening travel patterns were greatest in the westbound direction; many pedestrians used the subject intersection in order to access local busses to their various destinations within Kano metropolitan

4.7.3 Intersection Traffic Control

The inspected intersection used signal mode as control device that directs vehicles for a particular movement, it has three phasing system one each for east bound, west bound and north bound approach. It has faded marking, the absence of central channelization**,** no posted speed limit sign and lack of intersection ahead warning sign to notify drivers. There were considerable absence of regulation, warning and guide signs at the overall intersection approaches.

4.7.4 Intersection Traffic Count

The observed and recorded signalized intersection traffic counts along the inspected route section during morning peak hour and afternoon off peak hour period between (09:00-10:00 am) and (02:00-03:00) pm have been tabulated below.

Table 4.5 Intersection traffic count for morning peak hour period

Approaches	East Bound		West Bound		North Bound	
Lane Group	Through	Right	Left	Through	Left	Right
09:00-09:15	744	305	156	288	240	150
09:15-09:30	739	325	185	303	243	140
09:30-09:45	720	320	170	284	254	144
09:45-10:00	725	315	165	310	220	146

Table 4.6 Intersection traffic count for off peak hour period

Approaches	East Bound		West Bound		North Bound	
Lane Group	Through	Right	Left	Through	Left	Right
02:00-02:15	402	165	104	197	143	94
02:15-02:30	382	160	96	188	152	84
02:30-02:45	378	158	86	182	139	86
02:45-03:00	394	150	105	154	141	101

4.7.5 Observed Intersection Features and Deficiencies

Table 4.7 Intersection safety audit checklists

ROAD SAFETY AUDITS CHECKLIST FOR AN INTERSECTION

Date: 15/04/2014

Intersection Aspects/Features	Observation	Recommendation
1. Location		
2. Visibility, sight distance	There was limited visibility and horizontal sight distance at the intersection north bond approach (Aminu Kano Way)	Re- alignment of the north bond approach should be considered (Aminu Kano Way)
3. Signs and markings	Inadequate and worn out lane and pedestrian crossing markings	Proper lane and pedestrian crossing markings should be provided at all three approaches
4. Layout	Poor layout at northbound approach	Should be corrected if possible
5. Lighting	The lighting system was adequate	Should be maintained
6. Lane width	The lane width observed was 3.4m at northbound and 3.5m at westbound approaches.	The lane width should be increased to 3.6m if possible.
7. Acceleration/Deceleration (speed change length)	Absence of speed change length at some approaches	The speed change lane should be considered at east bound and north bound approaches
8. Tapers	Adequate taper at west	

	bound approach	
9. Turning radii	Inadequate turning radii at north bound approach	The turning radii should be increased by removing some portion of the adjacent curbs been constructed.
10. Triangle sight distance	Adequate triangle sight distance	
11.channelization	Absence of channelization especially at the center	Channelization should be constructed to provide definite vehicles' paths
12.Pedestrian/bicycles consideration	Absence of pedestrians' and cyclists' facilities	Pedestrians' and bicycle facilities should be provided
13. Traffic signal operation	Some signal heads have worn out and not showing fully.	Replacement and proper routine maintenance should be adopted
14. Signal head visibility	Signal head visibility was not adequate at north bound	The re-positioning of signal head and making yellow background should be applied
15. Bus stop location	Presence of bus stop location	Bus stop should be re-located to a proper location

a) Visibility/ Sight Distance

As observed during inspection, the horizontal curvature of Aminu Kano Way has limited visibility to the drivers using the subject intersection, vehicles that joined a queue often extended beyond clear visibility of the signal head indications which might contribute to rear-end crash and long trucks obscured the view of head indication.

Figure 4.33 Limited sight distance at the northbound approach

1. Signing and Markings

There were the absences of designated lanes at the subject intersection in all three approaches. Absence of pavement markings might create difficulty to drivers and increases sideswipe collisions.

Figure 4.34 Lack of pavement markings at the intersection

2. Turning Radii

It has been observed that, there was an inadequate turning radius at northbound approach for vehicles trying to make U turn and left turn movement from the westbound approach. The turning radius could not even be enough to comfortably accommodate smaller vehicles rather than the large ones which can cause loss of control and accident causation.

Figure 4.35 Inadequate turning radius at northbound approach

Figure 4.36 Inadequate turning radius at northbound approach

3. **Channelization**

It has been observed that, vehicles that approached and passed through the intersection did not have definite and specific paths to be followed due to the large area of the intersection without channelization, this situation might create confusion among drivers on deciding a particular path to be followed and lead to the accident causation.

Figure 4.37 Lack of channelization

4. **Pedestrian Consideration**

There have been completely less consideration given regarding pedestrian facilities at the subject intersection, pedestrian crossing lines have faded out almost completely at all approaches, absence of pedestrian countdown signal head that give the right of way for them to cross. In the median also, guardrails have been mounted directly facing the pedestrian crossing location which could create potential safety problems while crossing.

Figure 4.38 Faded and blocked pedestrian crossing

5. Bicycles deliberation

There were absence of proper considerations given to the cyclists at the subject intersection; they shared and interacted together with other road users like motorists and motorcyclists. This subject intersection was a crossing location of nearby residents and students of the Kofar Ruwa Secondary School and Army Day Secondary School, Bukavu. This current situation could lead to serious safety problems to the bike riders as they were exposed to dangers.

Figure 4.39 Absence of cyclists' facilities

6. Signal Head Visibility

It has been observed that, there was an absence of routine maintenance of damaged traffic signals which limits visibility of the traffic heads at the subject intersection. Vehicles that had long queues often extended beyond clear visibility of the signal head indications could only understand green indication by proceeding forward of the front vehicles which might contribute to rear-end crash accident type.

Figure 4.40 Lack of signal routine maintenance

Figure 4.41 Damage and poor traffic signal head visibility

7. Bus Stop Locations

Bus stop location has been observed at10m just ahead of the subject intersection through eastbound approach, whereby most of stopped vehicles parked on the outer travelled lane which decreased the rate of traffic flow and contributes to potential safety problems.

Figure 4.42 Improper bus stop locations

4.7.6 Observed Signal Phasing at the Subject Intersection

The subject intersection has three signal phasing systems, one each for east bound, west bound and north bound. Moreover, it has been observed that some right turning vehicles crossed during the red time period at east bound and north bound, but the numbers have been recorded and subtracted from the total traffic volume. Below are the observed green, yellow and red time allocated to each phase during observation.

Table 4.8 Signal timing at the subject intersection

Signal Phasing	Lane Group	Green Time	Yellow Time	Cycle Time
East Bound	EB/T EB/R	38	5	
West Bound	WB/T WB/L	36	5	129
North Bound	NB/T NB/R	40	5	

4.7.7 Adjusted Value of the Intersection Saturation Flow Rate and Level of service

The adjusted value of the saturation flow rate for each lane group was obtained through multiplying the base saturation flow rate of 1900 (pc/hr/ln) with each lane group correction factors and the final results have been tabulated below.

Table 4.9 Adjusted value of saturation flow rate for peak hour period (09:00-10:00)

Lane Group	S_o (pc/hr/ln)	N (Lane)	S (veh/hr)	V (veh/hr)
EB. Through	1900	2	3015	2976
EB. Right	1900	1	1372	1300
WB. Left	1900	1	1366	740
WB. Through	1900	2	2947	1240
NB. Left	1900	1	1483	1016
NB. Right	1900	1	1406	600

Table 4.10 Adjusted value of saturation flow rate for off-peak hour period (02:00-03:00)

Lane Group	S_o (pc/hr/ln)	N (Lane)	S (veh/h)	V (veh/hr)
EB. Through	1900	2	3171	1608
EB. Right	1900	1	1419	660
WB. Left	1900	1	1514	420
WB. Through	1900	2	3044	788
NB. Left	1900	1	1521	608
NB. Right	1900	1	1406	404

Since, there is no reliable and enough accident information for the junction, the thesis safety audit study has been extended with capacity and level of service.

Table 4.11 Lane groups and intersection level of service for peak hour (09:00-10:00)

APPROACH	EAST BOND		WEST BOND		NORTH BOND	
Lane group	TH	R	L	TH	L	R
Analysis flow rate (v)	2976	1300	740	1240	1016	600
Saturation flow rate(s)	3015	1372	1366	2947	1483	1406
Flow ratio (v/s)	0.987	0.948	0.542	0.421	0.685	0.427
Critical lane group	*		*		*	
Y_c	2.214					
Since the calculated value of Y_c is greater than one, it indicated that the intersection is too congested. Thus, there is no need to continue with the detail analysis but for demonstration purposes, further analysis steps were carried out.						
Lost time/phase	5					
Total lost time	15					
Cycle length (C)	129					
X_c	2.51					
Eff. g. time (g)	50.7	50.7	27.9	27.9	35.2	35.2
g/C	0.393	0.393	0.216	0.216	0.273	0.273
L. g. capacity (c)	1185	539	295	637	405	384
v/c (X)	2.51	2.41	2.51	1.95	2.51	1.56
d_1	39.2	39.2	50.6	50.6	46.9	46.9
PF	1.0					
K	0.5					
I	1.0					
T	0.25					
d_2	26	38.8	52.4	35.7	44.7	45.9
L. g. delay (d)	65.2	78	103	86.3	91.6	92.8
Lane group LOS	E	E	F	F	F	F
Approach delay	69.1		92.5		92	
Approach LOS	E		F		F	
Intersection delay	80					
Intersection LOS	F					

Table 4.12 Lane groups and intersection level of service for off-peak hour (02:00-03:00)

APPROACH	EAST BOND		WEST BOND		NORTH BOND	
Lane group	TH	R	L	TH	L	R
Analysis flow rate(v)	1608	660	420	788	608	404
Saturation flow rate(s)	3171	1411	1514	3044	1521	1406
Flow ratio (v/s)	0.507	0.468	0.277	0.259	0.399	0.287
Critical lane group	*		*		*	
Y_c	1.183					
Since the calculated value of Y_c is greater than one, it indicated that the intersection is too congested. Thus, there is no need to continue with the detail analysis but for demonstration purposes, further analysis steps were carried out.						
Lost time/phase	5					
Total lost time	15					
Cycle length (C)	129					
X_c	1.34					
Eff. g. time (g)	48.8	48.8	26.7	26.7	38.4	38.4
g/C	0.378	0.378	0.207	0.207	0.298	0.298
L. g. capacity (c)	1199	533	313	630	453	418
v/c (X)	1.34	1.24	1.34	1.25	1.34	0.966
d_1	40.1	40.1	51.1	51.1	45.3	45.3
PF	1.0					
K	0.5					
I	1.0					
T	0.25					
d_2	26	39	50.9	35	42.3	44
L. G delay (d)	66.1	79.7	102	86.1	87.6	89.3
Lane group LOS	E	E	F	F	F	F
Approach delay	70.1		91.6		88.3	
Approach LOS	E		F		F	
Intersection delay	80					
Intersection LOS	F					

4.7.8 Short Term Intersection Improvements base on the Current Conditions

I. The junction geometry and operating conditions can be improved. Thus, it yields high saturation flow values and low Y_c values

II. In addition to this, one of the intersection approaches or particular movement have be eliminated for operating condition to be improved

III. The grade separated junction alternative could not be avoided in a recent future base on the prevailing conditions

4.7.9 Proposed Counter Measure for the Case Study Deficiencies and Hazards

After the overall inspection of the route section and signalized intersection, some selected counter measures have been proposed for the identified deficiencies and typical route and intersection hazards been encountered. These proposed countermeasures would help in accidents elimination or severity reduction when properly implemented.

4.7.9.1 Proposed Counter Measures for the Route Hazards and Deficiencies

a) Road Marking

In the overall section of the route being audited and inspected, there were completely absence of lane marking, edge lane marking and transverse marking that help in directing and notifying the vehicle drivers and vulnerable road users. The road marking principles should be followed and implemented, proper lane demarcation and transverse markings have to be provided especially at the junction areas connected to the route section.

b) Road Surface Condition

Proper routine maintenance should be provided in the route section, especially at Km (4+900) Bachirawa-Airport Roundabout and Km (2+500) Bachirawa-Airport Roundabout and other sections of the route, Good routine practice would reduce sudden break on a travel lane due to rutting, potholes and depression and outer travelled lane parking due to lane edge deteriorations which might contribute massively to accident reduction. Drainage channels should be covered completely or guide rails should be mounted at particular route locations such as Km (04+250), Km (05+300), Km (07+700) Bachirawa-Airport Roundabout and Km (05+300) Airport Roundabout-Bachirawa directions.

c) Road signs

There were many confusing, inappropriate and worn out signs along the audited route section, that put the driver in dilemma in determining which direction to follow or decision to carry out. To eliminate or reduce the above mentioned scenario, the following countermeasures have to be considered:

I. Worn out speed limit signs have to be replaced with new ones, especially at Km (6+10) Bachirawa- Airport direction

II. Warning ahead signs have to be mounted on all sections of the route close to the un-signalized and signalized junction on the route section and roundabout

III. Existing worn out and confusing directional signs have to be replaced with proper ones, especially at Km (5+700) and Km (7+790) Bachirawa-Airport Roundabout direction

IV. Pedestrian crossing signs should be removed at all route sections where guardrails blocked the passage and proper ones should be placed where crossing is allowed, especially at Km (1+25) Airport-Bachirawa and Km (6+550) Bachirawa-Airport directions

V. Inappropriate no parking signs should be replaced with standard ones in all route sections, particularly at Km (0+20) and Km (3+500) Bachirawa-Airport Roundabout direction

e) Pedestrian Facilities

Available crossing facilities should be provided at designated locations, which could help in crossing the road as a result of guardrails been mounted on the overall route section. Walkway facilities should be provided on the overall route section in order to protect and separate pedestrian from moving vehicles

f) Cyclists

Considerable numbers of cyclists have been observed, cyclists' facilities or travelled lane should be provided on the overall route section in order to be separated from the moving vehicles or the outer travelled lane should be increased from 3.5m to 4.2m width as recommended by AASHTO

g) Parking

Parking maneuvers and proper parking control signs have to be provided along the overall route section

h) Hazards

1. Utility poles

At some route locations being audited, there were considerable numbers of electric poles at Km (0+40) Airport-Bachirawa and Km (5+750), Km (7+200) Bachirawa-Airport direction, some proposed counter measures have been suggested in reducing accident severities

I. The reflector should be installed on the observed poles that can be identified by drivers
II. Guardrail has to be mounted in order to reduce accident magnitude
III. Relocation of electric poles far from the travelled lane

2. Bus Stop Shelter

Along the route section being audited, bus stop shelter has been observed at Km (3+0) Bachirawa- Airport Roundabout direction which has to be relocated to the nearby distance away from the outer travelled lane.

3. Pedestrian Crossing Pillars

Barriers or crash cushions have to be installed on the pillars, which were located at Km (3+900) and Km (4+900) along Airport-Bachirawa direction and Km (2+900), Km (3+900) Bachirawa-Airport direction. Another one is to relocate the pedestrian pillars to a far distance away from the outer travelled lane.

4. Transformer

Transformer and shelter have to be removed and re-located far away from outer travelled lanes, which were located at Km (4+300) and km (7+700) Airport Roundabout-Bachirawa direction.

5. Signboards

Along the route section, there were numerous number of signboards situated close to the travelled lane at Km (0+550), Km (2+800) Airport Roundabout-Bachirawa direction and Km (6+0), Km (7+200) Bachirawa-Airport Roundabout direction which has to be removed completely and relocated to safer locations.

4.7.8.2 Proposed Counter Measures for the Intersection Deficiencies

I. The horizontal curvature of the northbound approach should be adjusted to suit all categories of vehicle drivers in order to be able to see the signal head indication when the queue has been observed or encountered

II. Proper and designated lane markings together with stop bar line marking has to be provided at the intersection approaches, intersection ahead warning sign and proper pedestrian crossing signs and marking have to be installed

III. Intersection layout has to be re-consider in order to provide adequate balance at north bound approach

IV. The width of the lane on the northbound approach has to be increased to 3.6m if possible

V. Speed change lanes have to be provided at east bound and north bound approaches if possible

VI. The radius of turning at the northbound approach has to be increased by removing the constructed portion of curbs island

VII. Proper channelization has to be provided at the intersection physical area in order to facilitate movement of vehicles and pedestrians

VIII. Pedestrian and cyclists' considerations have to be considered at the intersection, which includes pedestrian countdown signal and cyclists' lane

IX. Worn out traffic signal heads have to be replaced at east bound and north bound approach, proper routine maintenance culture has to be adopted and yellow background signal head compartment is needed to increase visibility

X. The bus stop station located at the intersection downstream on the eastbound approach should be relocated to a better location or position in order to facilitate vehicle movements.

CHAPTER 5

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The following conclusions can be derived from the thesis study:

- **a.** A different number of deficiencies and hazards have been observed on the route section during the performed inspection, which are dangerous to the motorists and vulnerable road users.
- **b.** The realization of an urban road safety audits and process of identifying such deficiencies and roadside hazards could contribute in providing safe road environment and help in eliminating prone potential hazards on or along the route section.
- **c.** Absence of reliable and dependable accident record data in Nigeria, limits detail evaluation and explanation of the intersection and route section safety audits studies.
- **d.** The proposed counter measures are short term improvement proposals, which need meager amount of funds that can also serve as guidance for evaluating road safety audit procedures and its results.
- **e.** Lack of routine maintenance culture has great effect to the signal timing indication and effective performance of the analyzed signalized intersection.
- **f.** It is clear that, the available accident data is quite limited and undependable. Because of this reason, several accident and safety analysis could not be made.
- **g.** Since the value of Y_c is greater than one, this indicated that the signalized intersection is too congested and other alternatives such as geometry improvements and grade separated junction should be considered.

5.2 Recommendations

The following recommendations were proposed for the study:

- **a.** This thesis study methodological approach and other available approaches should be used on all urban road sections in Nigeria in order to evaluate the overall safety conditions of the road network.
- **b.** There should be a dependable and an available database system of traffic accidents for research, statistical record and future intended measures.
- **c.** The proposed countermeasures should be implemented as soon as possible in order to tackle the road section deficiencies and hazards.
- **d.** There should be a teaching program regarding Road Safety Audits importance at all levels of government directorates (Local, State and Federal) so as to formulate proper road safety procedures and be implemented regularly in Nigeria.
- **e.** Nigeria should start to consider Road Safety Audits as one of the accident reduction tools by investing in researches and adopting current international approach counter measure techniques.
- **f.** Regular maintenance of the installed devices should be adopted at the intersection.
- **g.** More detail and dependable accident data have to be generated in order to start implementing more detail accident analysis.

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APPENDIX A

FEDERAL ROAD SAFETY CORPS
FAGGE UNIT COMMAND, KANO ZONAL COMMAND
FEDERAL REPUBLIC OF NIGERIA
ACCIDENT RECORDS FOR KATSINA ROAD URBAN SECTION

S/N	DATE OF RTC	TYPE	LOCATION	ROUTE	NO INJURED	NO KILLED	SEX	
							M	F
1	11-08-08	M/C M/C	KOFAR RUWA	DALA/ KATSINA ROAD	3	NIL	3	NIL
2	12-10-08	TRL M/C	BY BABAN LAYI	DALA/KATSINA RD	7	NIL	7	NIL
3	14-10-08	CAR M/C	BY KURNA MARKET	DALA/KATSINA RD	4	NIL	3	1
4	12-12-08	BUS M/C	BY BUKAVU BARRACKS	DALA/ KATSINA RD	3	NIL	3	NIL
5	17-12-08	M/C M/C	BY HAJJ CAMP	DALA/ KATSINA RD	4	NIL	4	NIL
6	02-01-09	M/C M/C	KOFAR RUWA	DALA/ KATSINA RD	3	NIL	2	1
7	09-04-09	TRL	TRL PARK @ KWANAR UNGOGGO	DALA/KATSINA RD	4	1	5	NIL
8	17-04-09	M/C M/C	BY HAJJ CAMP	DALA/HAJJ CAMP	2	NIL	2	NIL
9	19-06-09	LOR	KOFAR RUWA	DALA/KATSINA RD	5	2	6	1
10	03-08-09	M/C M/C	AIRPORT AROUND ABOUT	DALA/KATSINA RD	3	NIL	2	1
11	04-10-09	M/C M/C	BY AKEJA HOTEL	DALA/KATSINA RD	4	NIL	4	NIL
12	11-02-10	CAR CAR	BY BUKAVU BARRACKS	DALA/ KATSINA RD	3	1	4	NIL
13	05-03-10	M/C M/C	@ NNPC FILLING STATION BACERAWA	DALA/KATSINA RD	3	NIL	3	NIL
14	09-03-10	CAR	BY FEDERAL SECTRY	DALA/KATSINA RD	2	1	3	NIL
15	09-05-10	CAR M/C	KOFAR RUWA	DALA/KATSINA RD	1	1	1	1
16	14-05-10	BUS CAR	9MILE R/ABOUT	DALA/KATSINA RD	5	NIL	3	2
17	26-05-10	M/C CAR	BY KANDAHAR MOSQUE KURNA	DALA/KATSINA RD	2	NIL	2	NIL

18	22-07-10	CAR M/C	HAJJ CAMP	DALA/HAJJ CAMP	2	NIL	2	NIL
19	24-03-11	BUS PICK-UP	KUFAR RUWA	DALA/KATSINA RD	3	1	3	1
20	10-04-11	CAR CAR	BY BUKAVU BARRACKS	DALA/KATSINA RD	9	NIL	9	NIL
21	02-06-11	BUS	KOFAR RUWA	DALA/KATSINA RD	NIL	1	1	NIL
22	16-06-11	M/C M/C	KOFAR RUWA	DALA/KATSINA RD	NIL	1	1	NIL
23	27-06-11	M/C M/C	AZMAN FILNG STATION BACERAWA	DALA/ KATSINA RD	2	1	3	NIL
24	29-07-11	M/C M/C	NNPC @ KOFAR RUWA	DALA/KATSINA RD	2	NIL	1	1
25	05-08-11	CAR M/C	PADESTRAIN CROSSING @ K/RUWA	DALA/KATSINA RD	2	NIL	2	NIL
26	06-08-11	BUS M/C	BY BUKAVU BARRACKS	AIRPORT RD BY BUKAVO BRKS	2	NIL	2	NIL
27	07-09-11	M/C M/C	KOFAR RUWA	DALA/KATSINA RD	1	2	3	NIL
28	06-11-11	M/C	KOFAR RUWA	DALA/KATSINA RD	2	NIL	1	1
29	08-11-11	M/C M/C	@ AIRPORT R/ABOUT	DALA/KATSINA RD	1	NIL	1	NIL
30	14-11-11	BUS M/C	BY BABBAN LAYI KURNA	DALA/KATSINA RD	2	NIL	2	NIL
31	26-08-12	M/C	BY BABBAN LAYI KURNA	DALA/R/LEMU	2	NIL	2	NIL
32	28-08-12	M/C M/C	HAJJ CAMP	FAGGE/HAJJ CAMP	2	NIL	2	NIL
33	13-09-12	CAR CAR M/C	BY BUKAVU BARRACKS	DALA/KATSINA RD	5	1	6	NIL
34	8-11-12	M/C	KOFAR RUWA	DALA/KATSINA RD	1	NIL	1	NIL
35	27-12-12	CAR T/CL	@ KURAN MARKET	DALA/KATSINA RD	2	1	3	NIL
36	17-04-13	TRL T/C	9MILE R/ABOUT	KANO KATSINA RD	3	2	4	1
37	21-07-13	M/C	@ NNPC FLLNG STN KOFAR RUWA	KATSINA RD	1	NIL	1	NIL
38	26-07-13	TRL M/C	KOFAR RUWA	AIRPORT RD	4	1	3	NIL
39	07-08-13	M/C	HAJJ CAMP	DALA/KATSINA RD	1	NIL	1	NIL
40	08-08-13	M/C PED	HAJJ CAMP	DALA/KATSINA RD	1	NIL	1	NIL
41	27-10-13	BUS M/C	HAJJ CAMP	HAJJ CAMP/KTN RD	3	NIL	3	NIL
42	08-12-13	CAR PED	BY BUKAVU BARRACKS	OPP BUKAVU BARACKS/KTN RD	2	NIL	1	1

43	01-01-14	CAR T/C	9MILE R/ABOUT	9MILE/KTN	2	NIL	2	NIL

APPENDIX B

ADJUSTED VALUE OF SATURATION FLOW RATE FACTORS

Adjusted saturation flow rate factors for peak hour period (09:00-1000) am

L. Group	f_w	f_{Hv}	fg	f_p	f_{bb}	f_a	f_{Lu}	f_{LT}	f_{RT}	f_{Lpb}	f_{Rpb}
EB/T	1.000	0.928	1.00	1.00	1.00	0.90	0.95	1.00	1.00	1.00	1.00
EB/R	1.000	0.944	1.00	1.00	1.00	0.90	1.00	1.00	0.85	1.00	1.00
WB/L	1.000	0.934	1.00	1.00	0.90	0.90	1.00	0.95	1.00	1.00	1.00
WB/T	0.967	0.938	1.00	1.00	1.00	0.90	0.95	1.00	1.00	1.00	1.00
NB/L	0.967	0.944	1.00	1.00	1.00	0.90	1.00	0.95	1.00	1.00	1.00
NB/R	0.967	1.000	1.00	1.00	1.00	0.90	1.00	1.00	0.85	1.00	1.00

Adjusted saturation flow rate factors for off-peak hour period (02:00-03:00) pm

L. Group	f_w	f_{Hv}	fg	f_p	f_{bb}	f_a	f_{Lu}	f_{LT}	f_{RT}	f_{Lpb}	f_{Rpb}
EB/T	1.000	0.976	1.00	1.00	1.00	0.90	0.95	1.00	1.00	1.00	1.00
EB/R	1.000	0.976	1.00	1.00	1.00	0.90	1.00	1.00	0.85	1.00	1.00
WB/L	1.000	0.981	1.00	1.00	0.95	0.90	1.00	0.95	1.00	1.00	1.00
WB/T	0.967	0.969	1.00	1.00	1.00	0.90	0.95	1.00	1.00	1.00	1.00
NB/L	0.967	0.968	1.00	1.00	1.00	0.90	1.00	0.95	1.00	1.00	1.00
NB/R	0.967	1.000	1.00	1.00	1.00	0.90	1.00	1.00	0.85	1.00	1.00