WORK ZONE SAFETY AUDIT

AND CASE STUDY IN KANO, NIGERIA

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

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This is to certify that we have read the thesis "Work Zone Safety Audit and Case Study in Kano, Nigeria" submitted by "Ibrahim Khalil Umar" 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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Umar Ibrahim Khalil:

ABSTRACT

WORK ZONE SAFETY AUDIT

AND CASE STUDY IN KANO, NIGERIA

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The continuing increase in vehicles demand resulted in the construction of new roads as well as improvement of the existing ones, hence creating more work zones. These work zones poses more dangers to the life and safety of road users and the workers performing various tasks.

This thesis research reviews the concept of work zone safety audit at construction stage. The various safety measures for efficiently and safely guiding traffic through the work zone, improving the safety of workers, equipment, and the road users traversing through the work zone were also reviewed.

A case study on a Nigerian highway was conducted where lack of regular maintenance of the installed temporary traffic control devices, non-compliance with standards, human behaviors like over speeding, disregard to traffic rules in the work zone were identified to be the major causes of all hazards within the work zone.

Keywords: Work zone, Work zone safety audit

ÖZ

KARAYOLU ÇALIŞMASI ALANI GÜVENLİK KONTROLÜ VE KANO, NİJERYA'DA BIR ÖRNEK ÇALIŞMA

Umar, Ibrahim Khalil

İnşaat Mühendisliğinde Yüksek Lisans

Tez Yönetcisi: Yrd. Doç. Dr. Cumhur Aydın

Mart 2014, 94 Sayfa

Motorlu taşıt kullanımındaki artan talepler, yeni karayolu gereksinmeleri ortaya çıkardığı gibi mevcut karayollarının iyileştirilmesi ve buna bağlı olarak daha fazla yol çalışması alanı yaratılması sonucunu doğurmaktadır. Bu tür çalışma alanları yol kullanıcıların yaşam ve güvenliklerine daha fazla tehlike yaratıkları gibi alanda çalışanların da güvenliklerini olumsuz etkilemektedir.

Bu tez araştırması, inşaat aşamasında yol çalışması alanı güvenlik etütleri konusunu değerlendirmektedir. Yol çalışması alanı içindeki trafiğin etkin ve güvenli bir biçimde yönlendirilmesine ilişkin, bu alan içerisinden hareket eden yol kullanıcıları, alan içinde çalışan görevliler ile ekipmanın güvenliğini geliştirecek değişik yol güvenliği uygulamaları, bu araştırma içinde gözden geçirilmiştir.

Nijerya içindeki bir karayolu üzerinde yer alan çalışma alanı içinde bir örnek araştırma gerçekleştirilerek; yerleştirilmiş geçici trafik kontrol cihazlarının düzenli bakım eksiklikleri ve yol kullanıcılarının trafik yönetim ve hız kurallarına uymamaları gibi hususlar, çalışma alanlarında ortaya çıkan temel tehlike yaratan unsurlar olarak saptanmıştır.

Anahtar sözcükler: Yol Çalışması alanı, yol çalışma alanı güvenlik etüdü.

To My Parents

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CHAPTER 1

1 INTRODUCTION

1.1 General

A road traffic accident is a global phenomenon posing a serious social problem. Road traffic accident results to death of over 1.2 million people each year [1]. Figures are on the increase in many countries. If proper measures were not taken, by the year 2030, road traffic accidents will be listed as the fifth cause of death in the world, resulting in a death of about 2.4 million people every year [1]. In low and middle income countries vulnerable road users**,** cyclist and pedestrians were at higher risk of injury accidents than the vehicle occupants. Studies show that vulnerable road user in middle and low income countries covers 70% of road mortality while in countries like America, 65% of the fatality were vehicle occupants. Speed was identified as the key factor resulting in injury to vulnerable road users, but only 29% of world countries met the criteria for speed reduction with only 10% reported effectiveness[1]. Studies revealed that persons from low income setting are more vulnerable to road accidents by far than those from affluent families regardless of the country's economic status. In İndia mortality rate from a traffic accident in poor economic setting was found to be 13.1 and 48.1 per 100,000 in urban and rural areas respectively, compared to their affluent urban and rural counterpart having a death rate of 2.8 and 26.1 respectively, another research conducted in Australia shows a disproportionate number of children from low economic background been involved in road injuries than those from well to do family [1].

Many studies reveal that the roads of African region are the worst in the world. The region has the least number of motor vehicles in the world approximately 2% of the world. Despite this low number of motor vehicles on the road, it contributes 16% of world's road deaths having a higher death rate than any other region of the world. Motor vehicles in the region stand a chance of being involved in fatal accident more than 100 times a car in the United States or United Kingdom. The region has an average death rate of 24.1 per 100,000 populations as compared to the world average of 18.0 per 100,000 populations. Youth between the ages of 15-44 are the most vulnerable road users covering 62%. Vulnerable road users (pedestrians and 2-3 wheel riders) account for almost 52% of the overall fatalities [2].

Nigeria has recorded the highest number of fatal accidents in the region with an average death rate of 33.7 per 100,000 populations. Studies also revealed that, out of every 4 fatal accidents in the region one- occurred on Nigeria's highway [2].

The causes of accidents are related to road, vehicle and human factors. The main problem with road safety in Africa is lack of implementation of countermeasures which were in existence for decades [3]. Politics have great influence on the implementation of these countermeasures. This is because of the scarcity of resources available for road safety. The most effective countermeasures are costly and limit the road user's freedom to choose traveling speed. Politicians in the region are reluctant to overcome these side effects [3].

Table 1-1 Percentage of regıonal population, road facilities and registered vehicles [2]

Region	Population, %	Vehicles %	Fatality %
African region	12	2	16
American region	14	27	12
Eastern Mediterranean region	9	4	10
European region	13	26	8
South East Asian region	26	15	27
Western Pacific region	26	26	27
*World population (2009)	2.5 billion		
*Number of world registered vehicle (2010)	1.015 billion		
*Annual fatality (2009)	1.2 Million		

1.2 Road Safety Management

Road safety management is aimed at integrating the direct and indirect road safety activities that influence the safety of roads. Road safety management consists of 3-main elements; safety measures; safety and other related objectives for policies; authorities and organizations involved. The effectiveness of road safety management depends on the co-ordination and integration of these elements. The following five reasons were identified to be the major reasons why road safety management is necessary regardless of country level of development.

a. Large number of safety problems to be dealt with
b. Safety measures are more effective if they form part of a comprehensive policy
c. Traffic safety is not a priority for local policy makers, but when they become part of some major policy they will not be neglected.
d. Accidents are distributed throughout cities; it will not be desirable to design safety measures for each individual accident site.
e. Integrated safety programs help authorities have an overall understanding of the problem and make prioritization for improvements [4].

There are two approaches in traffic safety management reactive approach and proactive approach.

a. Reactive approach: is applied to existing road open to public. It involves identification and diagnosis of problematic locations as well as recommending and implementation of appropriate countermeasures. Lack of adequate data which will help for better diagnosis, high cost of countermeasures implementations because it involves improvements on a road that is in use, large number of casualties before any given location is considered for improvement were the major limitations of this approach. Road safety inspection of existing roads is an example of this approach.

b. Proactive approach: This approach is for planned projects, which were not yet built or open to traffic. It is concerned with prevention of problems before they occur. The advantage of these approaches is that; it does not require any accident data before proposing a counter measure. Another advantage is that implementation of counter measure requires less cost because the road is not yet constructed or open to traffic. Road safety audit for planned project is an example of this approach.

For an effective road safety management, there should be a balance between the reactive and the proactive approach. In both approaches, it is necessary to identify the safety deficiencies and then recommend countermeasures to be implemented. Figure 1-1 below shows the deficiency determination process.

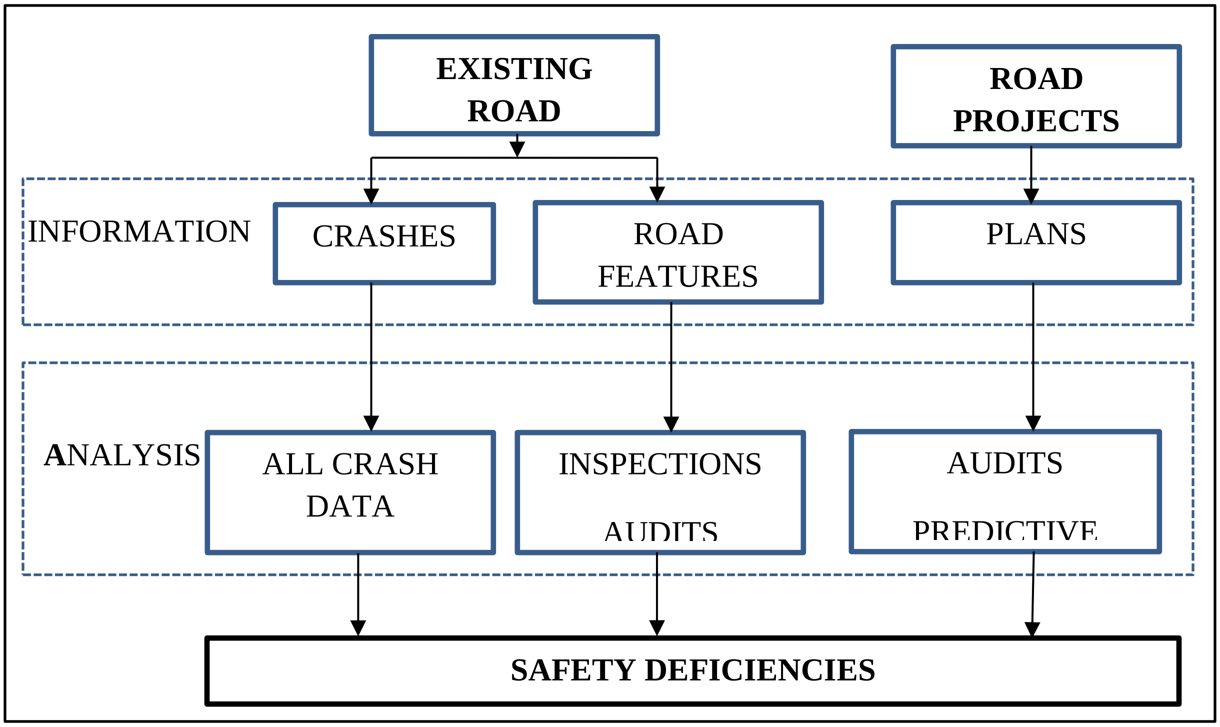

Figure 1-1 Safety Deficiency Determination Process [4]

1.3 Statement of the Problem

Highway conditions are getting worst and worst each day and at the same time number of registered vehicles are increasing worldwide. Research shows that, there is a 15% increase of registered vehicle from 2007 to 2010 [5]. This result in an increasing number of work zones (maintenance and improvement sites) putting life of motorist, road workers and other vulnerable road users at risk. The international review of accident studies revealed that work zone areas have, typically, higher accident rates in comparison with equivalent non-works sections. Studies on road user behavior in work zones reveal that speeding, abrupt deceleration and inadequate distances of preceding vehicles occur frequently in road work zones. Such behavior is reasonably characterized as high-risk behavior and assumed to influence traffic safety negatively [6].

1.4 Justification of the Research

The project involves improvements and reconstruction of 591km of road that is open to the public. So far only 26% of the project has been completed. The contractors are improving the road section by section. This section under study covers only 30km of the overall project. Therefore, this research will serve for both reactive and proactive approach for safety improvement by:

a. Identifying the high risk level hazards and propose short term mitigation measures for the section under study.
b. Identifying dangerous operations applied and avoid future occurrence of same danger.
c. Taking preventive measures for road users' behavior that were identified to be hazardous for the work zones.
d. Maintaining best practices and applying them to other work zones.
e. Better instalment of temporary traffic control devices.

1.5 Aims

The aim of this research is to review the concept of work zone safety audit and conduct a case study on Nigerian Highway to explore major hazards that surround the local work zones by taking Kano-Maiduguri road as a case study. The research will also provide recommendations that can help enhance safety in the work zones by eliminating the most apparent hazards on Nigerian work zones.

1.6 Research Objectives

The above aim of the research can only be achieved through the following objectives;

a. Identify various safety hazards in work zones and determine their risk level.
b. Assess compliance of installed temporary control devices and operations with the Manual of Uniform Traffic Control Devices (MUTCD) minimum requirements and evaluating their condition.

c. Identify best practices in work zones and those that are ineffective and make recommendations for other work zones.
d. Determine overall safety condition of the work zone.

1.7 Scope and Limitations

The scope of this research is limited to achieving the above objectives on Nigerian highway. The data were mainly from:

a. Federal Road Safety Commission (FRSC)
b. Dantata and Sawoe Construction Company.
c. Field inspection

CHAPTER 2

2 WORK ZONE AND WORK ZONE SAFETY AUDIT

2.1 History of Road Safety Audit

The Australian Transportation Authority (Austroads) in 1994 published a comprehensive handbook titled "Road Safety Audit," which combined road safety auditing practices from Australia and other countries that practices road safety audit to create guidelines for performing Road Safety Audit [7].

The Austroads handbook acknowledged that the Road Safety Audit (RSA) originated "in the United Kingdom in the 1980s," with the aims of helping "highway authorities to take steps to reduce the possibility of accidents on their roads" [8]. According to the U.S. Federal Highway Administration ("FHWA"), the concept of using an independent auditor was introduced during the Victorian Period to preview new rail lines [9]. By April of 1991, the Scottish Development Department and its U.K. counterpart mandated safety audits for roads above specified costs [9]. New Zealand also adopted the safety audit concept, conducted its pilot audits in 1992 and developed policies and procedures related to road safety audits by 1993 [9]. It was also acknowledged that Road safety audit was pioneered 20 years ago in the United Kingdom and was in use for the past 16 years in New Zealand. [10].

The United Nations Economic Commission for Africa (UNECA) has long been active in road safety. In 1984 UNECA co-organized the First African Road Safety Congress to draw attention to the problem. Two more Congresses were held respectively in 1989 in Addis Ababa, Ethiopia and in 1997 in Pretoria, South Africa. The Third African Road Safety Congress, leads to the creation of," an African Road Safety Initiative. The objective was to improve the road safety situation in Africa. Such an initiative can use the competence and capacity for road safety work that already exists in several African countries, improving and expanding this capacity in cooperation with international experts [11].

2.2 Road Safety Audit Experience in Nigeria

There were limited literatures regarding the existence of RSA application in Nigeria. The Federal Road Safety Commission (FRSC) was the government body responsible for providing safer roads for drivers and pedestrians. The commission was established in 1988 and functions of the Commission generally relates to: Making the highway safe for motorists and other road users, recommending works and devices designed to eliminate or minimize accidents on the highways and advising the relevant governmental agencies on the localities where such works and devices are required [12]. The commission also makes some public enlightenment campaigns in schools and public places to increase road user's awareness of road safety. A formal road safety inspection carried out by independent consultants as explained in the definition is not in practice in Nigeria.

2.3 Road and Work Zone Safety Audit

Road Safety Audit (RSA) is a formal, independent, and comprehensive road safety performance review conducted by an experienced team of safety specialists to maximize safety of the roadway environment for all highway users. It has been adopted by many state and local transportation agencies in the United State and abroad in the last several decades. It is conducted at various stages of a project, ranging from planning, programming, design and contracting, construction, to post-construction [10].

Austroads defined road safety audit as "A formal examination of an existing or future road or traffic project or any project which interacts with road users, in which an independent, qualified examiner reports on the project's accident potential and safety performance" [7].

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

The success of RSA motivated stakeholders to introduce work zone safety audit (WZSA). WZSA is intended to assist work zone stakeholders in identifying potential safety and mobility hazards and to recommend practical measures for improving mobility and safety in work zones. Similar to RSA, a WZSA can be conducted at different stages from planning to final construction stage [13].

A work zone is a segment of roadway where activity takes place, including maintenance of existing roadways, construction of new elements, or other non-roadway work (e.g., utility installations) [14].

Work zone safety audit has been defined as "a formal safety performance evaluation, which can be performed at any stage of a planned or existing work zone (project planning and design, or in active work zones) by an independent, multidisciplinary team, and considers methods of improving safety in a work zone" [14]. A WZSA assesses the temporary elements of a project that will eventually be removed upon successful completion of the project. [13]

WZSA recommendations must be provided to the road owner within short period due to limited construction period [13].

The difference between RSA and a WZSA is that, RSA mainly focused on the review of highway safety engineering issues concerning geometric design standards, consistency of geometric design, and pavement and bridge conditions, safety hardware, and roadside conditions while WZSA aims at mitigating work zone's safety and mobility impacts on highway users and workers when a highway project is under construction [13].

The European Transport Safety Council (ETSC) identifies limited information regarding change in collision risk and costs associated with road works as one of the major limitations currently encountered while assessing safety in road work zones. Many countries routinely collect information on the number of collisions of works, but these do not allow general estimation of the increased risk. It also outlined that "Research to date is limited, but demonstrates firstly that the presence of work zones increases risk on the roads, secondly, that working on the roads is one of the most dangerous occupations and thirdly, that improved safety practices can reverse these scenarios" [16].

2.3.1 Stages of Work Zone Safety Auditing

a. Planning: For long term works, planning is very essential. Work zones are planned by experts of different disciplines. At this stage, work zones are just conceptual and exist only in discussions. During this stage someone who is familiar with the proposed road and the surrounding, or someone who has conducted work zone safety auditing within the vicinity should be included in the team. The project significance was determined, the historical data (traffic volume and crash data), road geometry of the work zone location, road users to be affected by the project are the matters that are discussed and evaluated to come up with safety measures that enhance the safety of the proposed work zone. This helps in assigning costs and duration of the work zone [15].
b. Design: The audit at the design stage involves the review of the drawings to ensure that all appropriate traffic controls are included. The review should put into consideration safety of road users, workers and provide measures that enhance their safety. A field investigation should also be made to help give the team understanding of the impact that the transition of the existing road might cause with regard to safety and mobility. The team should include someone with expertise in road geometry and road maintenance [15].

   During the planning and design stage special regard should be given, but not limited to; ensuring that balance was achieved between safety and mobility; geometry of the road; construction techniques; environmental condition where the work zone is sited; appropriate selection and installation of temporary control facilities; construction duration; work zone impact on its surrounding; communication channel during active work zone phase [15].

c. Active work zone: At this stage, the temporary traffic control devices were installed, traffic management strategies were already deployed, workers and equipment were all there and road users traverse through. Here emphasis should be given to the effectiveness of the installed traffic control devices, safety and mobility performance [15].

2.3.2 Benefits of Work Zone Safety Audit

The benefits of work zone safety auditing are not quantitative rather qualitative. These benefits are substantial. They include [15];

a. Improving the safety of the worker and the road users.
b. Maximizing mobility in the work zone.
c. Reduce risk claims, a component of both agency and societal costs
d. Lessen the societal costs of collisions with safer roads and fewer, less-severe crashes
e. Avoid or substantially reduce the cost of reconfiguration of the work zone safety.
f. Ensuring compliance with applicable plans, policies, and standards.

2.3.3 Factors Contributing to Work Zone Crashes

Queuing and congestions are the two major mobility factors that adversely affect safety on roadways. The following 8 factors were itemized to be major factors contributing to work zone crashes [15]. The factors are explained in the paragraphs below:

a. Driver expectation – Accidents may occur in a work zone when a road user is not expecting any change in roadway normal operation. This may be due to insufficient or improper signing in advance of the work zone.
b. Roadside hazards – Roadside hazards refers to dangerous object close to the road travel lane. These hazards can be workers themselves, improper parking of construction equipment. They pose a danger to the moving traffic, hence resulting in accidents.
c. Driver behavior – Aggressive driving, impaired driving, over speeding, non-familiarity of the work zone can all lead to accidents within the work zone.
d. Unsuccessful mitigation strategies – These refers to the failure of the accident prevention measures that were in place.
e. Roadway characteristics – Temporary road geometry, poor pavement condition, insufficient clear zone, eroded roadway edge, may have great impacts on roadway crashes.
f. Environmental conditions – Environmental conditions such as snow, rain, fog, have effects on driver’s control of the vehicle. Environmental conditions might cause poor visibility as in the case of fog, skid surface by rain or snow which might result in accidents.

g. Secondary congestion caused by roadway incident – Generally work zones are characterized by a reduction in the number of lanes or lane width. When accident occurs and the vehicles involved were not taken away immediately. Congestions will start to accumulate at the upstream of the work zone, hence more accidents.
h. Combined effect – Due to the continuous change in the work zone, deployed temporary traffic control devices which once help guide the road user through the work zone safely, will become a hazard as the work zone condition changes.

2.3.4 Road Safety Audit Management

Road safety audit management has a variety of methods that have provided satisfactory results. The successful management of a Road Safety Audit can be guaranteed by these factors; [17].

a. Scope and organization of the audit should be clearly specified in the terms of reference. The safety team should be independent of the design team.
b. The safety team must have specialist up-to-date knowledge of safety engineering.
c. The findings of the audit should be formally documented and reported.
d. The roles and responsibilities of owner, design team and audit team should be clearly understood by all parties.
e. The reasons for various actions resulting from the audit recommendations should be formally documented.

2.4 Steps For Conducting Work Zone Safety Auditing In an Active Work Zone

There were no proper guidelines for conducting work zone safety auditing in a construction stage [13]. In the same research eight steps for conducting work zone safety auditing in construction stages were presented. In another publication, an American organization also presented eight steps for conducting work zone safety auditing at any stage [15]. The steps are are a) Identifying Candidate Project for Work Zone Safety Audit b) Selection of Audit Team and Team Leader c) Pre-Audit Reviews d) Organizing Audit Meetings with the Key Project Parties e) Audit Inspections f) Audit Analysis g) Present Audit Findings to the Project Owner h) Report on Audit Findings and Recommendations.

2.5 Temporary Traffic Control

Temporary traffic control involves directing vehicular and pedestrian traffic in a work zone, where the normal function of the road is disrupted. It ensures the safety of road users, road workers, and hep emergency response team through the work zone without difficulty. This is achieved by using traffic control plans, devices and operation [18].

2.5.1 Functions of Temporary Traffic Control

The function of a Temporary Traffic Control (TTC) is to provide reasonably safe and effective movements of road users through or around the TTC zone, and at the same time, ensuring the safety of road users, workers, responders to traffic incidents and equipment [19]. Other functions of TTC include

a. Providing safety of workers performing the various types of work within the work zone.
b. TTC provides efficient completion of whatever activity interrupting the normal use of the roadway.
c. Efficient resolution of traffic incidents wıthin the work zone.
d. Protecting construction equipment.
e. Provides efficient construction and maintenance [20].

The type of highway, duration of work, physical conditions and movement management activity of road users determines the type of TTC devices and operations that can be used in any particular work zone [19].

2.5.2 Considerations in TTC

The major considerations of every TTC, from planning through completion are ensuring the safety of road users, workers and efficient movement of road users through the work zone. Because every work zone situation is different, so several items must be considered in determining the traffic control needed [19]. These items are:

a. Time duration of the work
b. Location of the work zone
c. Type of road involved
d. Imposed speed limits on the road
e. Traffic volume
f. Impact of the work on the roadway
g. İnvolvement of law enforcement agencies
h. Type of signing required
i. Flagger requirement
j. Need for channelization

2.5.3 Fundamental Principles of TTC

Providing safe access for road users through a TTC zone and ensuring safety of road users and workers must be an integral part of the TTC. Safety should be given highest concern in every TTC from planning through design and construction [17]. FHWA reported the following fundamental principles that must be considered in order to achieve the above mentioned:

a. Road user and worker safety in temporary traffic control zones should be an integral and a high priority element of every project from planning through design and construction.

b. General plans or guidelines should be developed to provide safety for drivers, bicyclists, pedestrians, workers, enforcement/emergency officials, and equipment.

c. Road user movement should be inhibited as little as practical.

d. Drivers, bicyclists, and pedestrians should be guided in a clear and positive manner while approaching and traversing temporary traffic control zones and incident sites.

e. Routine day and night inspections of temporary traffic control elements should be performed.

f. Attention should be given to the maintenance of roadside safety during the life of the temporary traffic control zone.

g. Each person whose actions affects temporary traffic control zone safety should receive training appropriate to the job decisions each individual is required to make.

h. Good public relations should be maintained.

i. All temporary traffic control devices shall be removed as soon as practical when they are no longer needed [19].

2.6 Work Zone Terminologies

a. Work duration: MUTCD defined work duration as the" length of time work operation occupies a spot location". It is the major factor determining the number and type of devices to be used in a work zone [18].

b. Long term stationary: is a work that occupies a place for more than 3 consecutive days. It has an ample time to install the full range of TTC devices and procedures. It involves the use of larger channelizing devices, traffic barriers, and temporary roadway.

c. Intermediate stationary unlike the long term stationary work, there is no ample time to install some TTC procedures and devices, because that can lengthen the work duration. It is a work that is between 1-3 days.

d. Short term stationary a daytime work that occupies a location for more than one hour.

e. Short duration a work operation that is up to one hour

f. Mobile a work operation that moves intermittently or continuously

2.7 Internal Traffic Control

The purpose of an internal traffic control plan is to develop strategies to control the flow of construction workers, vehicles and equipment in the work zone [22]. Backing of vehicles had been reported as the leading cause of fatal accidents involving workers in a work zone. The included safety measures, such as back-up alarms are not always effective in preventing accidents with workers within the work area. This can be as a result of confused loud sounds in the work site that has alarms on several pieces of equipment, so that workers cannot identify when vehicles are within their vicinity, because of the multiple sound sources or sometimes due to the failure the alarm systems [23].

To reduce the hazard associated with backing construction vehicles and equipment, an internal traffic control plan (ITCP) is developed to minimize the backing of all construction vehicles and equipment on site. This is accomplished by taking into consideration the tasks to be performed and how the vehicles can safely navigate through the construction site to complete these tasks while backing as little as possible. The ITCP should also address workers on foot by creating walkways for these workers that are clear of backing construction vehicles and equipment. In addition, some areas within a construction work zone might have to be defined as areas that are prohibited for workers on foot [22].

2.8 Work Zone Components

Work zone has been defined as" A segment of roadway where activity takes place, including maintenance to existing roadways, construction of new elements, or other non-roadway work (e.g., utility installations)" [18]. Another definition says work zone is the section of roadway occupied by work which affect traffic flow and road users as those areas of carriage way in advance of the working area for the advance warning signs, channelizing devices for transition of traffic movement, the activity area where actual work is taking place and the termination zone where drivers are informed to return to their normal operations [20]. A work zone is classified into four components; advance warning zone, transition zone, working area and termination area [18] as shown in Figure 2.2. In a research conducted by Pigman and Agent, they declared the advance warning area as the most critical area regarding safety [22]. In a different research activity area was declared the most dangerous area in the work zone with a high frequency of severe crashes. Earlier, before the two researches in determining the most dangerous component of work zone by Nemeth and Migletz, declared the transition area as the most dangerous [22]. This indicates that all components of work zone are characterized by a high frequency of accidents. This is because there is no agreed result in declaring the most dangerous area in work zone.

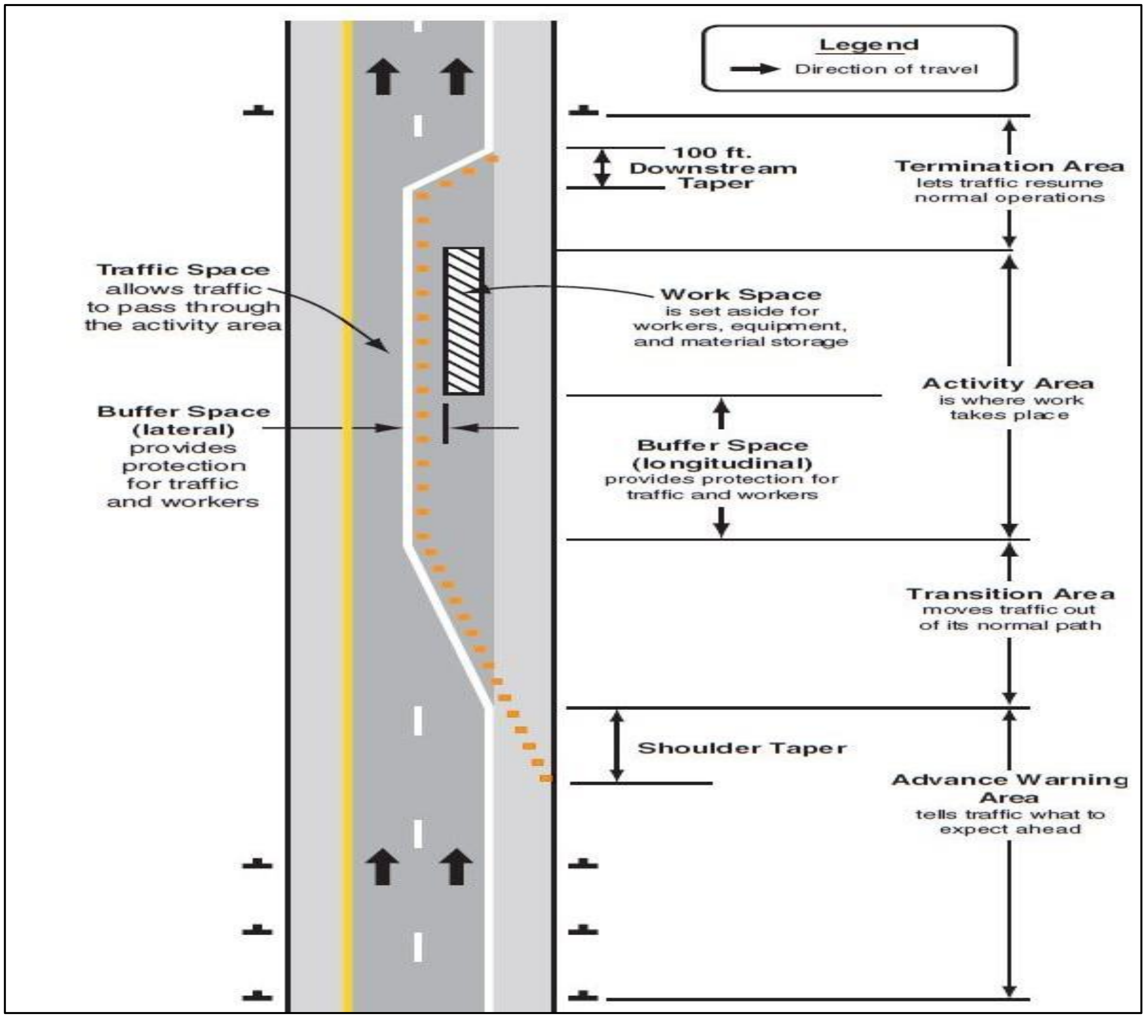

Figure 2-1 Component Parts of Temporary Control Zone

2.8.1 Advance Warning Zone

This is the area of the work zone that informs the road users about upcoming changes on the road normal function. It prepares the driver to change their driving conditions. The information is conveyed using series of traffic signs. The advance warning area must provide the road user with the following [20]:

a. The presence of the Hazard and distance of the hazard using a “Road work ahead” sign.
b. Any change with regard to traffic arrangement (example reduction in the number of lanes, speed reduction etc.)
c. Type of the Hazard.
d. Extent of the Hazard

The recommended minimum spacing between successive warning signs for different type of roadways is presented in table 2.1 below.

Table 2-1 Recommended Advance Warning Minimum Spacing

Road Type	Distance Between signs		
	A	B	C
Urban(low speed)	100ft	100ft	100ft
Urban(high speed)	350ft	350ft	350ft
Rural	500ft	500ft	500ft
Express/Freeway	1,000	1,500ft	2640ft

A=distance from the transition or point of restriction to first sign.

B=distance between the first and second sign.

C= distance between the second and the third sign.

2.8.2 Transition Zone

This is the area where road users are redirected out of the normal travel path and guided into an altered traffic flow pattern through the TTC zone. This is achieved by use of various temporary traffic devices. As far as safety is concerned, this is the most critical zone due to merging and turning movements involved [18]. Each transition zone should have the following:

a. Sufficient turning radius to be able to accommodate the longest vehicle using the roadway.
b. Adequate visibility by reducing the dust.
c. Should have proper drainage to avoid any ponding of water on the surface.

In mobile operations, it is impractical to redirect the road user's normal path with stationary channelization. More dominant vehicle-mounted traffic control devices, such as arrow boards, portable changeable message signs, and high-intensity rotating, flashing, oscillating, or strobe lights, may be used instead of channelizing devices to establish a transition area [18].

2.8.3 Termination Zone

This is the area where road users are informed to return back to their normal/original path by "End of Work sign". Speed limits can be used to inform the drivers that, they return back to their normal operation.

2.8.4 Working Zone

This is the area where actual work is taking place, it comprises of four different zones. Figure 2.3 below shows a working area.

a. Work area: The area that is physically occupied by the actual work.
b. Workspace: Part of the road closed for road users and set aside for workers, equipment and materials. The method of construction determines the space

needed. Since there should be many workspaces in a project, the area should be well signed and delineated, to reduce confusion.

c. **Traffic space:** This is part of working area where traffics are routed through the work area. It must be delineated to safely guide the traffic through. Traffic demand and road capacity are the ruling factor in deciding the width of traffic space.

d. **Safety buffer:** These are the longitudinal and lateral areas that separate the road user flow from the work space. No materials or equipment should be kept in this area, workers are not allowed in this area except for maintenance purposes. It allows the vehicle to stop before hitting the workspace which increases the safety of workers.

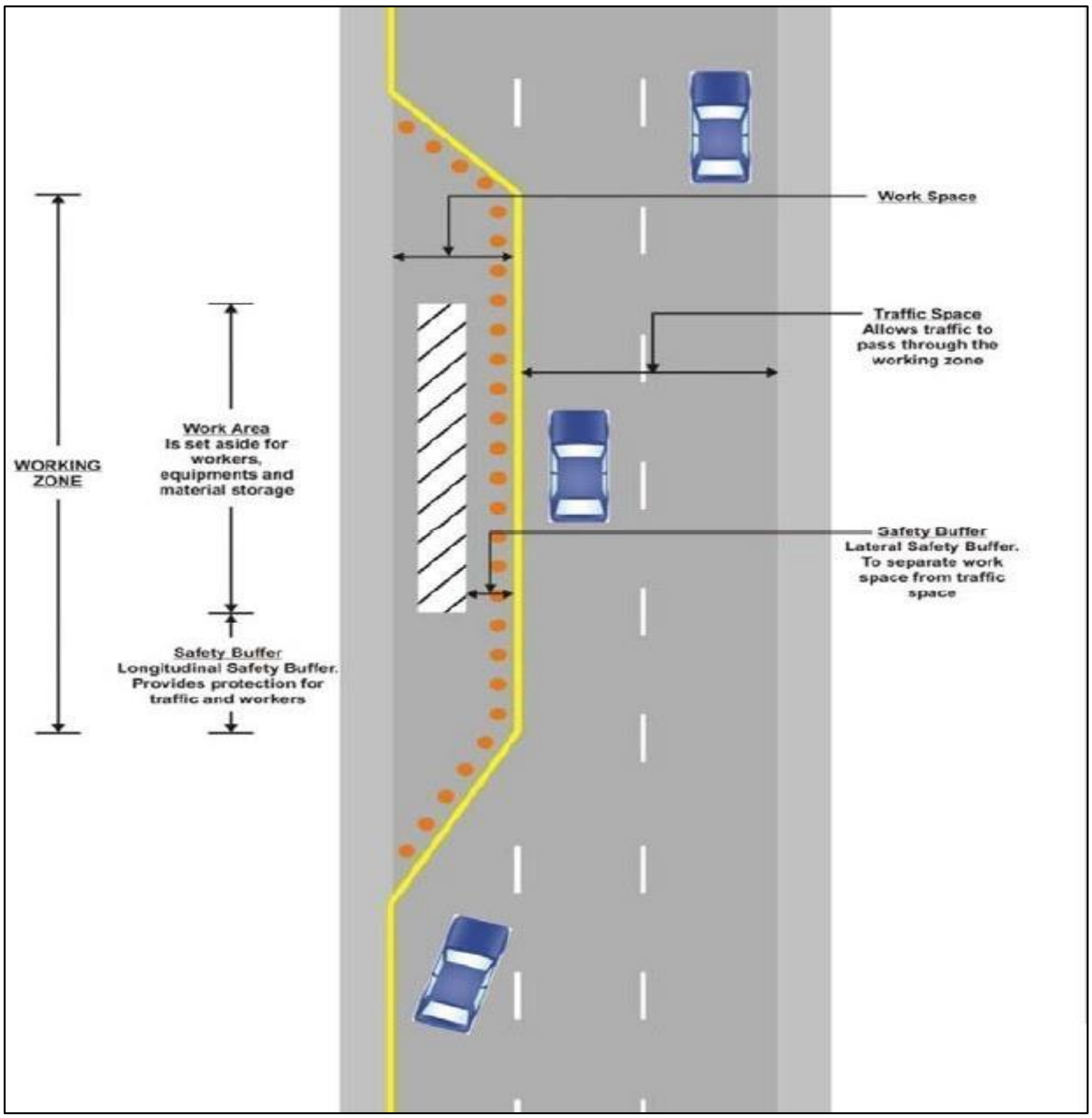

Figure 2-2 Components of Working Area [16]

2.9 Tapers

Tapers are series of channelizing devices and or pavement markings formed to divert traffic out of its normal path. Tapers are used both in transition and termination area. There are five different types of tapers. Table 2.2 and table 2.3 give the minimum length for each taper length and formulas for determining the length [18].

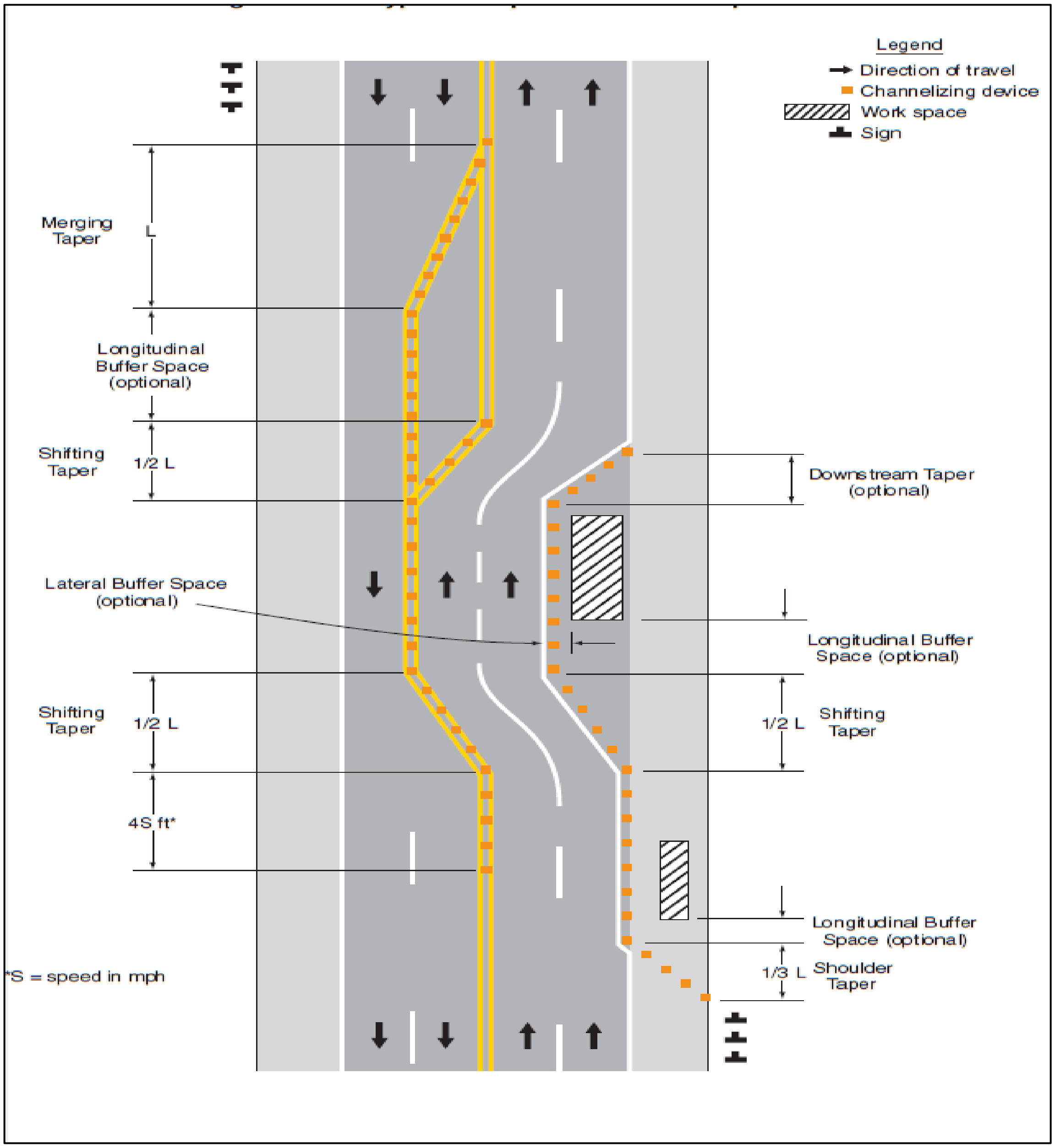

Figure 2-3 Types of Tapers and Buffer Spaces [10]

a. Merging taper is the type of taper that helps to merge drivers into a common road path. It has to be long enough to enable the drivers adjust their speed as they merge into the adjacent lane before the end of the downstream [18].

b. Shifting taper is used when the lateral shift is needed. A length of 0.5L is required when the posted limit is less than 50mph or an above [18].
c. Shoulder taper is beneficial on a high speed roadway where shoulders are part of the activity area and are closed. It is also provided when improved shoulders might be mistaken as driving lanes [18].
d. Downstream taper are used in the termination area to help drivers with a visual sign that they can return to their original travel path.
e. One lane-two lane taper is used when the activity area is part of a two way roadway in which part of the roadway is used alternatively by the opposing directions [18].

Table 2-2 Formulas for Determining Taper Length [18]

Speed [S]	Taper Length [L] in feet
40mph or less	$L=\frac{WS^2}{60}$
45mph or more	L= ws

Source: MUTCD

Table 2-3 Taper Length Criteria for Temporary Traffic Control Devices [18]

Type of Taper	Taper Length
Merging taper	At least L
Shifting taper	At least 0.5L
Shoulder Taper	At least 0.33L
One-lane, Two-way traffic Taper	50ft minimum, 100ft maximum
Downstream Taper	50ft minimum, 100ft maximum

Source: MUTCD

2.10 Traffic Control Devices

Temporary Traffic control devices (TTCD) are primarily all the signs, signals, markings, and other equipment mounted on or adjacent to road open to public travel that are removed when the work is completed [18]. TTCD perform the following functions:

a. Warning the road user.
b. Informing the road user.
c. Guiding the road user.
d. Modifying road user's behavior.
e. Protecting road users and vehicles.
f. Ensuring safe movement of the road user.
g. Providing safe area for the workers [20].

The traffic control devices must satisfy the following conditions before serving the above functions [20].

a. Convey the message in a simple and clear manner.
b. Command attention and respect of the road users.
c. Allow adequate time for proper response from road users.
d. Have adequate conspicuity both in day and night.
e. The ability to fulfil the intended need.
f. Should have proper stability.

2.10.1 Signs

Signs refer to any traffic control device that is meant to pass specific information to road users through a word or symbol legend. Signs do not include traffic control signals, pavement markings, delineators, or channelization devices [19]. Their function is to provide regulations, warning and guidance information to the road users. Static traffic signs could effectively reduce crashes in work zones on urban two-lane highways when used together with flaggers [24]. Regardless of the type of the sign, consideration must be given to a) sign placement b) sign maintenance c) sign support d) sign placement and e) size of the sign. Table 2.4 and Table 2.5 summarize the requirements of each temporary traffic sign.

a. Regulatory signs are the type of signs used to inform road users of traffic laws or regulations and indicate the applicability of legal requirements that would not otherwise be apparent. Example, fines for violating any traffic regulation. Regulatory signs are authorized by the public agency or official having jurisdiction. They are generally rectangular with a black legend and border on a white background. Exceptions include the STOP, YIELD, DO NOT ENTER, WRONG WAY, and ONE WAY signs [19].
b. Warning signs are used notify road users of specific situations or conditions on or next to a roadway that road users might not prepare for unless they are informed on its occurrence. Temporary traffic control warning signs have a diamond-shape with a black symbol or message and border on an orange. The exception is only for the Highway- Rail Grade Crossing, Advance Warning signs, and other signs that are permitted in Part 2 of the MUTCD to have yellow or fluorescent yellow-green backgrounds [19].
c. Guide signs provide road users with information to help them along their way through the temporary traffic control zone. The following guide signs should be used in temporary traffic control zones as needed: standard route markings, directional signs, street name signs, and special guide signs relating to the condition of the work being done. If additional guide signs are used in temporary traffic control zones, they shall have a black legend on an orange background [19].

Table 2-4 Summary of Temporary Traffic Sign Properties

S/N	Characteristics	Regulatory	Warning	Guide
1	Color	Black legend and border on white background (section 2A-4)	Black legend on orange background (section	Black legend on orange background
2	Size			
3	Night visibility			
4	Material			

Table 2-5 Sign Placement [19]

S/N	Characteristics	Requirements
1	Location	All signs should be located on the right hand side of the roadway.
2	Mounting height	Minimum height from the bottom of the sign on the road side is 5ft for rural road and 7ft for urban road.
3	Lateral offset	6-12ft from the edge of the pavements to the edge of the sign
4	Supports	All supports should be crashworthy and should not be placed on road walks, pedestrian walkways.

2.10.2 Sign Maintenance

Some significant properties of signs are lost with time and some due to accidents. A regular maintenance is required to ensure that all signs are serving their purposes effectively. The following maintenance is needed regularly for effective performance [18].

a. All signs should be maintained for cleanliness, visibility and correct positioning.

b. Signs that lost significant legibility should be promptly replaced.

c. Also signs that lost their retro reflectivity should be replaced.

2.10.3 Channelizing Devices

Channelizing devices are devices used to divert vehicles into predetermined paths in a safe and orderly manner [20]. The function of channelizing devices is to warn road users of conditions created by work activities. The work activities might be near or on the roadway. They also guide road users through the work zone. All channelizing devices used should be detectable to users and to persons having low visions. All devices should be properly maintained. All devices should be crashworthy and spacing used should not exceed 1.0 times the speed limit in meter when used in taper channelization and a distance of 2.0 times speed limit when used for tangent channelization [18]. Results of some research showed that channelizing devices were effective in alerting and guiding drivers when properly deployed in an orderly manner, [25]. Channelizing devices include drums, cones, barricades, tubular markers, and vertical panel and will be discussed below.

- **a. Cones** are rubber or plastic made cones with a height of 500mm, 750mm, or 1000mm and a square base. They are used to channelize traffic, divide opposing traffic lanes, divided traffic lanes when two or more lanes are kept open to traffic and to delineate short duration maintenance [20]. Traffic cones have the advantages of causing minor impediments to traffic flow and capacity; well organized and understood; are not dangerous to vehicle when struck; can be fastened to the pavement and self-restrain when hit. The disadvantages of using cones are: they can easily be blown and displaced by air unless used with ballast; have less respect by drivers [20].
- **b. Drums** Are 800mm to 1000mm high and 600mm diameter devices. They can be used either as channelizing devices or warning devices. One of the sides should be flat to preclude rolling [20]. They should be retro-reflective for use at night and should never be used without an advance warning sign. They have visibility and formidable commanding respect of drivers. Plastic drums have the advantage of posing fewer hazards to drivers and workers.
- c. **Barricades** are intended to provide containment without significant deflection or deformation under impact, and to direct errant vehicle along the barrier [9]. Barricades are designed to serve the following functions a) prevent traffic from entering work area b) provide protection for workers c) separates two way traffic d) protect constructions such as false work for culverts and other exposed works. However, it was found that the use of barricades in any combination of traffic control devices on urban multilane highways seemed to reduce the effectiveness of other traffic control devices. [24]
- **d. Tubular markers** they should be made of a material that will not cause damage when struck, they should not be less than 18” high and 2” wide. They should be predominantly orange. Where used at night time, they should be retro reflectors, Because of their lesser visibility to the road user. They should only be used where space restrictions do not allow the use of more visible devices. They should be attached to the pavement to display the minimum 2 inch width of the approaching road users [18].

  Figure 2.5 below shows examples of some temporary traffic control devices

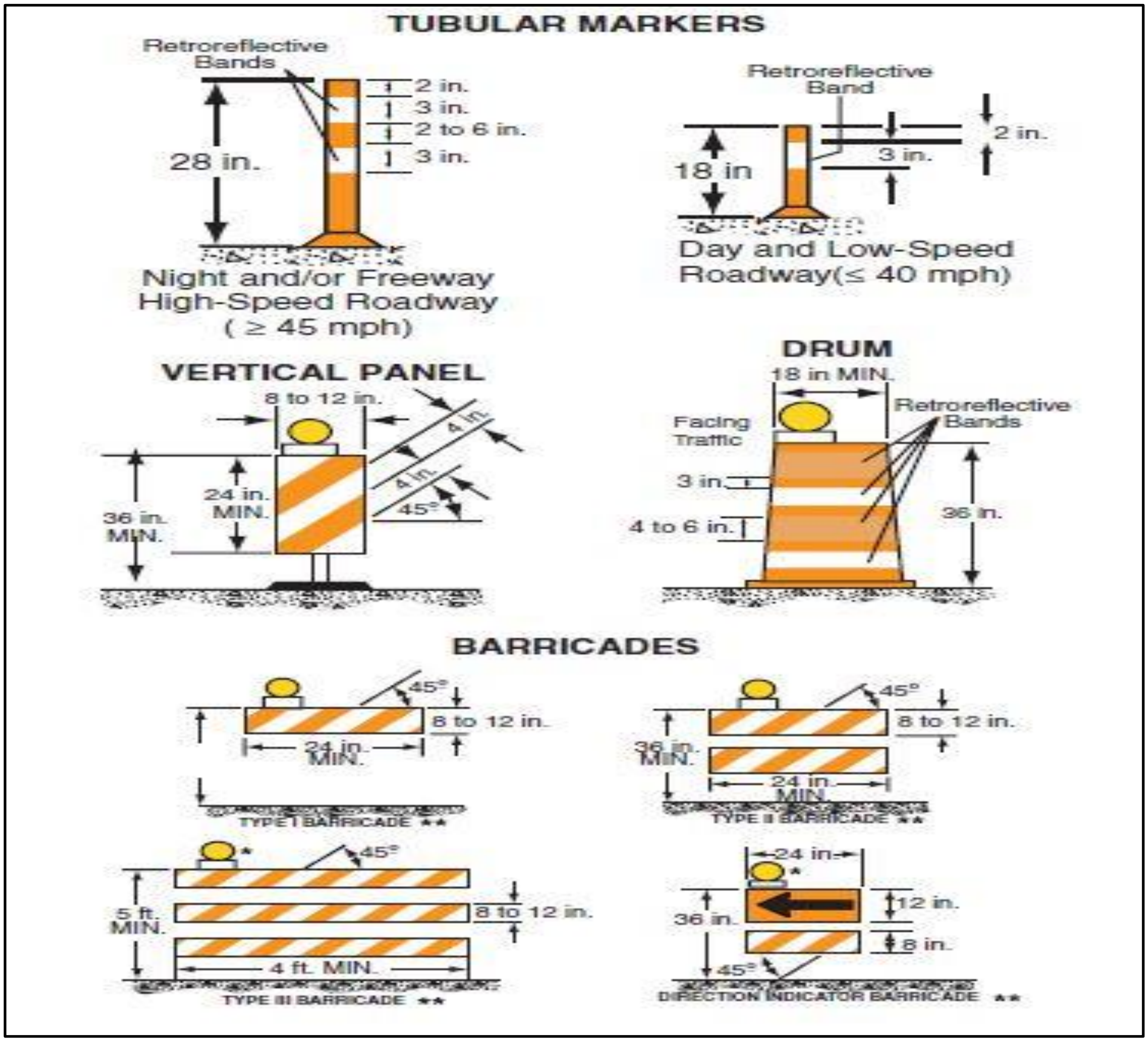

Figure 2-4 Temporary Channelizing Devices [19]

2.11 Flagger

Flaggers are qualified personnel wearing high-visibility safety apparel and equipped with handheld devices such as STOP/SLOW paddles, lights, and red flags to direct vehicles through work zones. Flaggers are located in the work zones in order to allow incoming vehicles a sufficient distance to stop at an intended stopping point [19]. Flaggers should be preceded by an advance warning sign. The signs should also be illuminated for flagging at night time. For a short one-lane, two-way work zone that allows a flagger to see from one end of the work zone to the other, a single flagger may be used to control traffic, while for relatively long work zones, a flagger at each end of the work zone is necessary. These flaggers should be able to communicate with each other orally, electronically, or with manual signals. In addition, flaggers should coordinate traffic so that vehicles from one end of the work zone do not proceed until vehicles from the opposite direction have travelled through the work zone [24]. Studies revealed that flaggers are most efficient on two-lane, two-way rural highways and urban arterials where they are able to attract the majority of drivers' attention. Flaggers are also well-suited for short-duration applications (less than one day) and for intermittent use of long-duration work zones. It was concluded that the most effective combinations of traffic control devices for work zones on multilane highways are cones, flashing arrows, and flaggers [24]. It was also found that the most effective combinations of traffic control devices for work zones on urban two-lane highways are cones and flaggers, and static signs and flaggers. Flaggers were effective in reducing fatal work zone crashes. However, some studies indicated a need for improving flagging for heavy truck traffic. Survey showed that one third of truck drivers believed the flaggers were hard to see; half of them thought the directions of the flaggers were confusing. Recently, researchers believe that, the presence of flaggers in work zones could lower the odds of fatalities caused by severe crashes by 56% [21].

2.12 Road Users, Worker And Equipment Safety

2.12.1 Road Users Safety

Road users refer to both drivers and pedestrians. Many studies showed that road users are exposed to higher risk in work zones than in non-work zone areas. In Finland and Slovenia it was found that motorists are up to five times more likely to get hurt when travelling through a work zone than non-work zone area [27]. In Germany, approximately one quarter of collisions occurring on national highways occur in work zones. In order to improve safety of pedestrians in work zones, as most temporary traffic control devices, including signs, channelizing devices are used to guide the drivers safely through the work zone, the following considerations are necessary at planning stage for pedestrians' safety [19]:

a. Pedestrians should not be led into direct conflicts with work site vehicles, equipment, or operations.
b. Pedestrians should not be led into direct conflicts with mainline traffic moving through or around the work site.
c. Pedestrians should be provided with a convenient and accessible path that replicates as nearly as possible the most desirable characteristics of the existing sidewalk(s) or footpath(s).

2.12.2 Workers Safety

The safety of workers performing various works in construction is equally important as the safety of road users. The continuous change in the conditions and the nature of the work zones creates confusion to the road users. Workers are exposed to risks of collisions with vehicles. The collision could be inside or outside the work zone. The accident could be with passing or work vehicle. It can also be at the entrance or exit of the work zone. The worker can be a pedestrian or driving a vehicle [11].

The Labourers Health and Safety Fund of North America (LHSFNA) reported that "highway construction had high rates of fatal injuries in highway construction compared to other construction activities and to all other industries zones". This same report also found that backing of equipment, particularly dump trucks, accounted for half of the fatalities of pedestrian workers in work zones [22].

In the United Kingdom, about 20% of road workers had suffered some injury caused by passing vehicles in the course of their careers and 54% had experienced a near miss with a vehicle [27]. The following five (5) principles help increase worker safety in work zones.

a. Avoid exposure of workers to traffic.
b. Make workers visible to road users, workers exposed to traffic should be attired in bright, highly visible clothing similar to that of flaggers. For night time work, lighting the work area and approaches may allow the driver better comprehension of the requirements being imposed. Care should be taken to ensure that the lighting does not cause blinding.
c. Provide physical protection of workers from traffic, barriers should be placed along the work space depending on such factors as lateral clearance of workers from adjacent traffic, speed of traffic, duration of operations, time of day, and volume of traffic
d. Protect workers from collisions involving works vehicles.
e. Avoid excessive work hours.

Apart from the above five principles given, the MUTCD added that all workers should be trained in how to work next to traffic in a way that minimizes their vulnerability. In addition, workers with specific traffic control responsibilities should be trained in traffic control techniques, device usage, and placement.

2.12.3 Safety of Vehicles

Research shows that, the majority of fatalities that occur in road construction work zones in the United States involve a worker being struck by a piece of construction equipment or other vehicle. A worker in this industry is likely to be struck by a piece of construction equipment inside the work zone than by passing traffic [22]. To ensure the safety of the workers, road users, and the vehicle, the MUTCD provides the following safety guides for vehicle safety

a. All equipment left unattended at night must have appropriate lights or reflectors, or barricades equipped with appropriate lights or reflectors, to identify the location of the equipment.
b. All vehicles with cabs must have windshield wipers and operable defogging or defrosting devices.
c. All vehicles must have headlights and brake lights in operable condition.

d. All vehicles must have audible horns.
e. All vehicles with an obstructed rear view must be equipped with back-up alarms or the vehicle is backed up only when an observer signals that it is safe to do so.
f. All cab glass must be safety glass, or equivalent, that introduces no visible distortion affecting the safe operation of any machine.
g. Vehicles used to transport employees must have as many seats as there are people and vehicle occupants must wear seat belts.
h. Operators of excavators and backhoes must wear their seat belt when seated in the normal seating arrangement for tractor operation.

CHAPTER 3

3 METHODOLOGY AND DATA COLLECTION

3.1 Introduction

Many researches indicated that, there were no standard guidelines for conducting Work zone safety audit at construction stage. Some researches target is hazard identification and determination of their risk level [13]. Some targeted assessment of the work zone as a whole by determining the average score for the Temporary Traffic Control Devices, safety measures, various operations and work zone configuration [14]. In this thesis both determinations of the hazards Risk level and the safety level of the work zone were targeted as it can be seen in Figure 3.1.

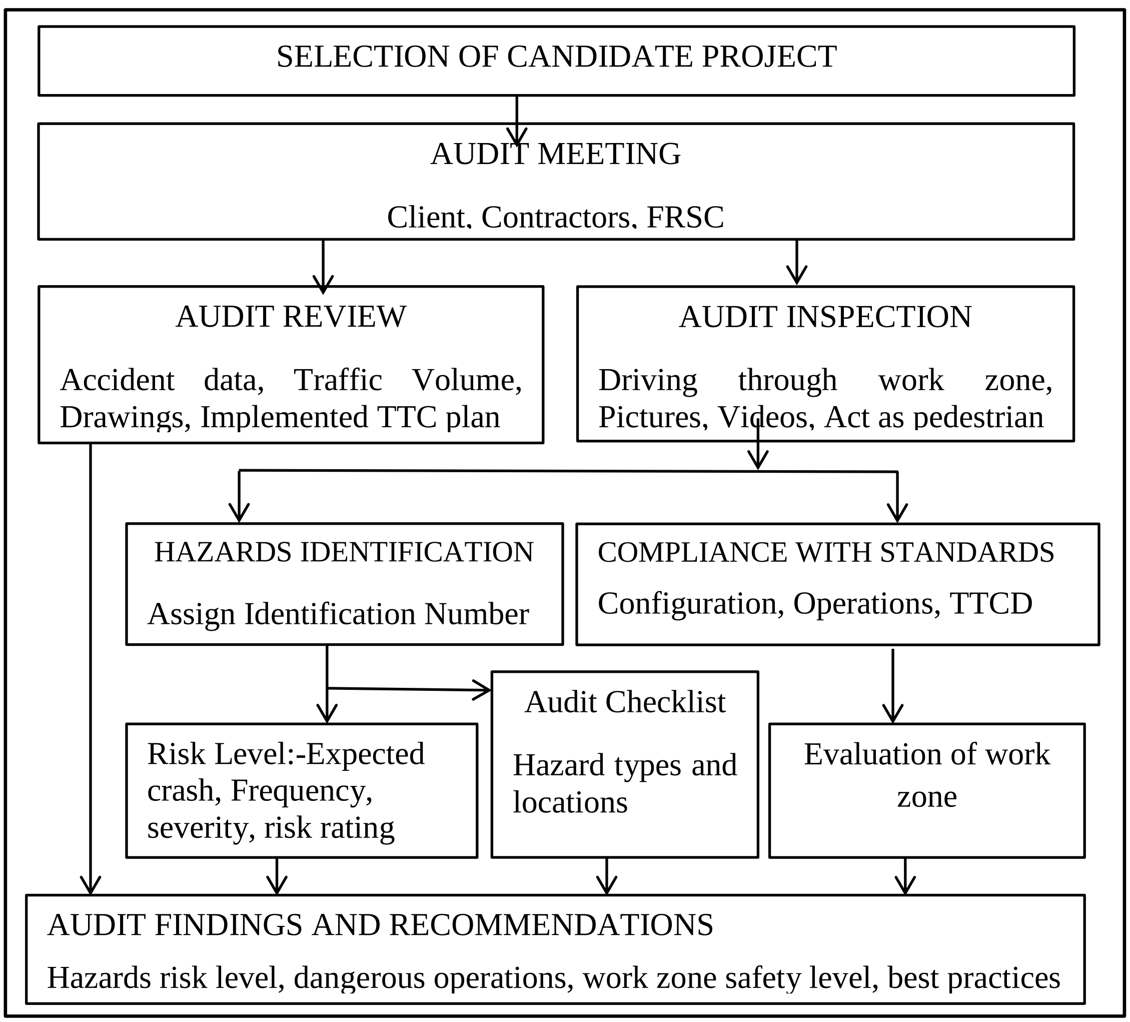

Figure 3-1 Process of Conducting Work Zone Safety Audit at Construction Stage

The steps listed in figure 3.1 above will explained in the paragraphs below as performed during the study.

3.2 Identification of Candidate Project

A significant project was selected for conducting the work zone safety audit. A significant project is a project that requires the use all three safety mitigation requirements. They are temporary traffic control devices, transport operation strategies, and public information strategies. [29] In work zone safety auditing, it was these three strategies that are audited as they affect the traffic flow workers safety and safety of road users during the construction. A chart in Figure 3.2 below gives the criteria for determining significant project. The project under study was on an interstate road, having duration of over a year making it a significant project.

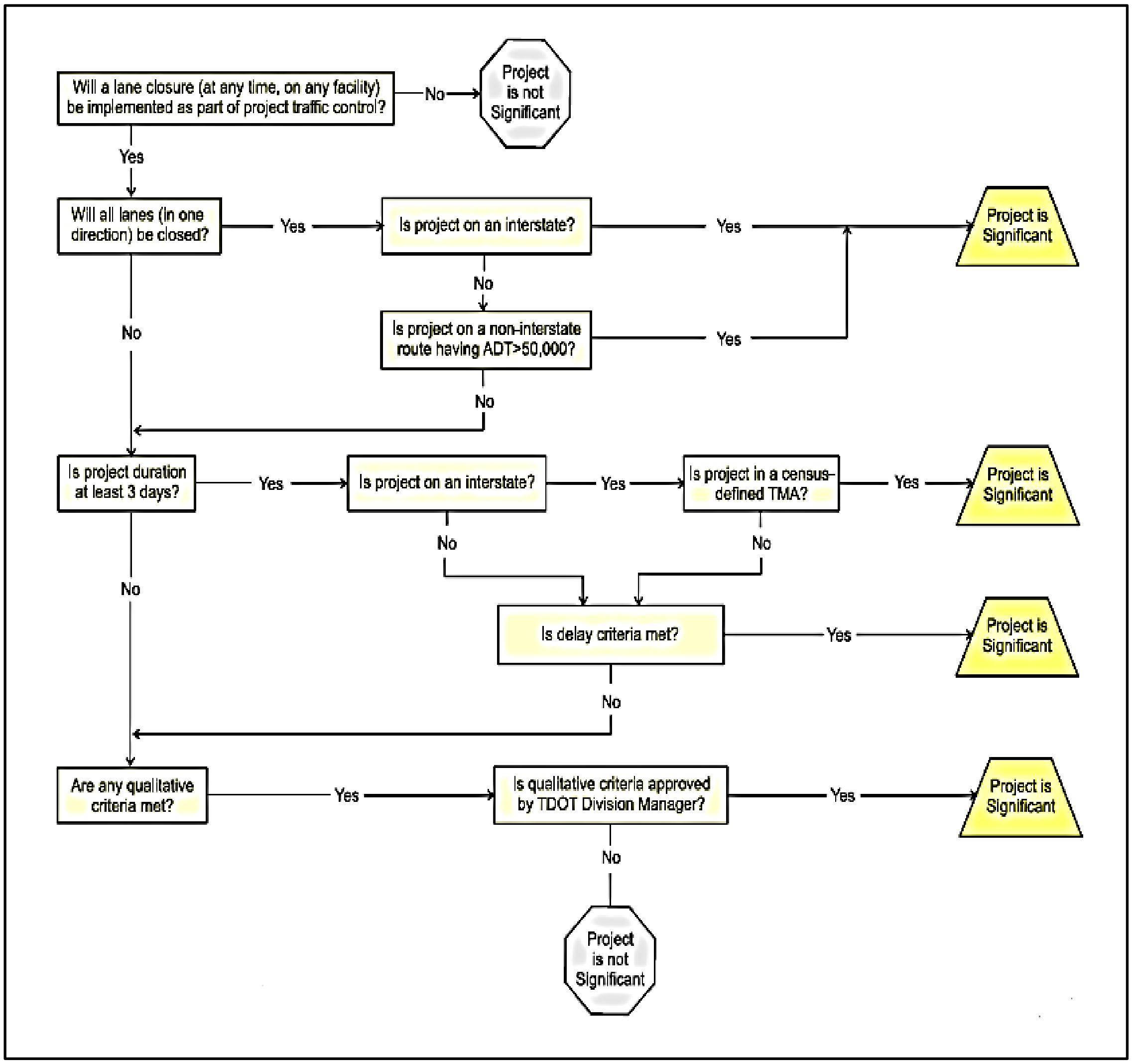

Figure 3-2 Significance Determination Charts [29]

3.3 Meeting With Key Project Parties

After the research candidate project has been selected, a meeting was organized with the project key parties. The meeting was attended by the project manager, owner's representatives and the resident engineer from the designer's team. The Matters discussed includes, but not limited to, project scope and duration, traffic demand, work restriction policies, lane closure policies, traffic and construction management plans, worker safety training, compliance of posted speed limits by drivers, records incident records. Worker injury records, site operation plans, best practices regarding safety of the work zone were discussed. Also, some of the basic challenges regarding safety were discussed. The drawings for the existing and planned road were also supplied by the contractor. The information obtained during the meeting form the basis for the pre-audit review.

3.4 Pre-Audit Reviews

Pre audit was the first steps that help in understanding the safety situation and the impact of the candidate project. Here all relevant documents regarding project design, construction and transportation management strategies and drawings supplied by the contractors were reviewed. Other items reviewed were, traffic demand, accident records, project scope and duration, work restrictions policies, delays as well as the operating and imposed speed limits. The implemented traffic control strategies were also reviewed.

3.4.1 Accident Data

Accident records for 5years were obtained from the Federal Road Safety Commission (FRSC). The records give total number of accidents, fatalities, injuries, number of vehicles involved, accident cause, number of people involved. The accidents were reviewed by their causes, fatalities and injuries per year. A major accident was then identified from the analysis. Also a location having the highest number was then identified from the records. Major accidents that occurred during the construction stage were not documented by the contractors, but pictures of the accidents involving both the construction equipment and other road users were supplied by contractors. Records from the FRSC include accidents that were not part of the road section under study. Only relevant accidents were extracted from the record.

3.4.2 Traffic data

Traffic record for the selected route was not available from relevant agencies. A manual traffic volume count was taken and recorded at an interval of 15min for three days (27th-30th July, 2013) between the hours of 8 and 17 to estimate average daily traffic. Robertson hinted that "typical count periods are 15 minutes or 2 hours for peak periods, 4 hours for morning and afternoon peaks, 6 hours for morning, midday, and afternoon peaks, and 12 hours for daytime periods"[30]. The traffic count also helps obtain the percentage of heavy vehicles in the traffic stream. The data were recorded using tally on a prepared data recording sheet as in table 3.1. A stopwatch was used to measure the time interval.

Two observers were located each on one direction. The observers record each vehicle that passes the observation point with a tally in the appropriate column of the recording sheet. At the end, the total value and the percentage of each category was computed. The vehicles were grouped into two cars and trucks. The cars include passenger cars, station wagons, pickup trucks, while the trucks comprises of all other truck types.

.

Table 3-1 Manual Traffic Volume Count Form

MANUAL TRAFFIC COUNT SHEET				
Road section				
Date				
Weather				
Observer				
Direction				
Time	Vehicle	Tally	Total	Percentages
	Cars			
	Trucks			
	Total			
	Cars			
	Trucks			
	Total			
	Cars			
	Trucks			
	Total			
	Cars			
	Trucks			
	Total			
	Cars			
	Trucks			
	Total			
	Cars			
	Trucks			
	Total			

Cars = passenger cars, station wagons, pick-up trucks
Trucks = other trucks and buses

3.5 Audit Inspection

During the audit inspection, the team experienced and visualizes the actual condition of the work zone. Driving was experienced four times through the work zone during the peak hour, off-peak hour, day and night in both directions. Traffic condition, work zone configuration, behaviors of drivers and pedestrians, queue length, delay time, actual travel speed, feasibility of enforcement, effectiveness of signs, lighting, marking, and delineations, guard rails and crash cushions were all observed. Adequacy of the temporary traffic control devices was also noticed. Photographs were taken during the inspection for later referencing.

During the inspection, all the potential safety risk hazards within the work zone area were identified and recorded. A three (3) columns record form was used for hazard identification. The first column for the hazard category, the hazards was classified into five (5) categories. The categories are hazards related to traffic control devices, construction activity area, roadside hazard, road design, and hazards related to the road user’s behavior. The second column was for the observed hazards and the third columns for the hazard identification number. A checklist was also used by the team in conjunction with the hazard identification form to identify the exact location of each particular hazard that will help during the upgrade and application of a countermeasure. The checklist has 5 columns; the first column is for the control station, the second and third columns for the KM post and the distance respectively given the exact location of the hazard. The fourth column was for the hazard identification number, and lastly the fifth column for technical comments. Table 3.2 and 3.3 shows the hazard identification form and the work zone safety audit checklist respectively.

Table 3-2 Hazards Identification Form

HAZARD CATEGORY	**HAZARD TYPE**	**NUMBER ID**
A. Temporary traffic control devices.		
B. Construction activity area hazards.		
C. Roadside hazards		
D. Road design		
E. Road users' behavior		

Table 3-3 Safety Audit Checklist

CONTROL STATION	KM	DISTANCE	HAZARD	COMMENT

The condition and adequacy of the installed temporary traffic control devices were inspected. The temporary traffic controls include temporary markings, barricades, drums, cones, tubular markers and vertical panels. Temporary traffic control devices conformity with the MUTCD requirement was assessed. The device's properties including height, shape, size, color, retro-reflectivity, night visibility, lateral offset, legend size as in the case of warning signs were inspected against the MUTCD requirements. A three column table was used for the device inspection. The first column was for the device properties, the second and the last for minimum requirement and observed conditions respectively. Table 3.4 gives an example of an advance warning sign. A similar was prepared for channelizing devices.

Workers delineation from traffic, safety garments for workers, and entrance and exit points of the work area, buffer space requirements, flagger operations and other safety issues regarding worker safety were inspected.

Table 3-4 Advance Warning Signs Requirements and Observation Form

PROPERTIES	REQUIREMENTS BY MUTCD	OBSERVATIONS
Shape	Diamond	
Size	1.2m X1.2m	
Height	≤ 2.1m	
Color	Black on orange background	
Illumination and retro-reflectorizing	All signs used during hours of darkness shall be made of retro-reflective material or illuminated	
Night Visibility	Excellent	
Distance from hazard	450m	
Spacing between signs	150m	
Number	3	
Lateral offset	1.8-3.6m	
Sign placement	All Signs should be placed at the right of the road except stated otherwise	
Legends height (H)	15cm	
Legends Width	-	
Spacing between words(cm)	1.5times H	

3.6 Audit Analysis

In the audit analysis, emphasis was given to evaluation and rating of the identified safety risk hazards, rating the adequacy and compliance of the temporary traffic control devices, also best practices were identified from the safety inspection and pre-audit review. Some short term countermeasures were recommended for each hazard.

Development of Risk Matrix for Safety Hazard Risk Ratings: Risk is defined by the degree of frequency and severity of expected crashes for each safety issue and given an overall rating level as presented in the following:

R = f (P, C) Where: ……………………………………………………………….. (1)

R = Risk level, P = Crash probability, the likelihood of a crash occurring.

C = Crash consequence, the severity of a crash once it happens.

Due to limited and lack of comprehensive crash data, a qualitative method was used for assigning the severity and frequency level of each of the expected crash to be caused by a hazard. The frequency and severity levels were assigned by a four team committee with vast experience on Nigerian work zones and highways. The team includes a road safety marshal from FRSC, Project Manager of Dantata and Sawoe Construction Company, an experienced site engineer from Federal Ministry of works and me.

The risk assessment matrix of potential work zone safety hazards was adopted from Campbell as Table 3.6.

Table 3-5 Risk Level and Countermeasures Form of Identified Hazards

Safety Hazards		Expected crash				Recommended counter measures
		Type	Frequency	Severity	Risk level	

Modified from shı et al [13]

Table 3-6 Risk Level Matrix [32]

Risk Rating		**Severity**				
		5	**4**	**3**	**2**	**1**
Frequency	**5**	25	20	15	10	5
	4	20	16	12	8	4
	3	15	12	9	6	3
	2	10	8	6	4	2
	1	5	4	3	2	1

Table 3-7 Frequency Index

Frequency	**Tittle**	**Description**
1	Remote	Less than once in five years
2	Possible	Once within 1-5 years
3	Occasional	Once within 2-12 month
4	Regular	Once in a period between 1-4 weeks
5	Common	Once within a period of 1-7 days

Table 3-8 Severity Index

Severity	Description
1	Trivial, minor, or no injury
2	Injury requiring first treatment.
3	Major injury requiring hospitalization
4	A serious injury that may result in permanent disability
5	Any fatality

Table 3-9 Risk Level Index and Action

Risk rating	Risk Level	Action
20-25	Very High Risk Unacceptable	Stop the activity immediately. Implement control measures to reduce risk to ALARP. Ensure that controls are documented and staffs are briefed on their importance.
10-16	High Risk Requires Action	A safe system of work must be implemented and briefed prior to the work commencing. Consider stopping the activity if control measures are not suitable. Seek an alternative solution where possible
05-09	Medium Risk	Control measures should be reviewed to ensure they continue to be effective. Acceptable to work with care. Consider additional safety controls to reduce risk further before implement a change.
01-04	Low or Minimal Risk	No action required. If control measure were in place, ensure that they are reviewed in order to remain effective.

Evaluation of traffic control devices and operation: each of the temporary control devices installed were evaluated and scored with a value ranging from 1-10, one being the worst condition 6 as average and 10 being the excellent rank. The score was based on device compliance with the minimum requirement of the MUTCD. Flagger operations, pedestrians and bicyclist safety requirements, workers safety garments and equipment were also rated in the same way. After each item has been scored, the overall score is computed by summing all the values and dividing with the number of scoring items. The average value scores the work zone. Table 3.10 below which was modified from Oregon DOT State-wide Work Zone audit scoring sheet gives example of the work zone safety evaluation form.

Table 3-10 Work Zone Evaluation Form [14]

<table>
<tr><td colspan="8">Project :</td><td colspan="3">Date :</td></tr>
<tr><td colspan="6">Highway:</td><td colspan="3">Region:</td><td colspan="2">State:</td></tr>
<tr><td colspan="9">Contractor:</td><td colspan="2"></td></tr>
<tr><td colspan="11">Reviewed by:</td></tr>
<tr><td colspan="11">SCORING</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td colspan="2">9</td><td>10</td></tr>
<tr><td colspan="4">Notify project manager</td><td>Below average</td><td>Aver age</td><td>Above Average</td><td>Good</td><td colspan="2">Very good</td><td>Excelle nt</td></tr>
<tr><td colspan="2">CATEGORIES</td><td colspan="2"></td><td>Score</td><td colspan="6">NOTES</td></tr>
<tr><td colspan="2" rowspan="3">Temporary signs</td><td colspan="2">Quality</td><td></td><td colspan="6" rowspan="3"></td></tr>
<tr><td colspan="2">Placement</td><td></td></tr>
<tr><td colspan="2">Spacing</td><td></td></tr>
<tr><td colspan="2" rowspan="3">Channelizing devices</td><td colspan="2">Drums</td><td></td><td colspan="6" rowspan="3"></td></tr>
<tr><td colspan="2">Barricades</td><td></td></tr>
<tr><td colspan="2">Cones</td><td></td></tr>
<tr><td colspan="2" rowspan="2">Pavement markings.</td><td colspan="2">Condition</td><td></td><td colspan="6" rowspan="2"></td></tr>
<tr><td colspan="2">Placement</td><td></td></tr>
<tr><td colspan="2" rowspan="3">Pedestrians and bicyclist</td><td colspan="2">Signing</td><td></td><td colspan="6" rowspan="3"></td></tr>
<tr><td colspan="2">Continues route</td><td></td></tr>
<tr><td colspan="2">Disabled</td><td></td></tr>
<tr><td colspan="2" rowspan="3">Flaggers</td><td colspan="2">Visibility</td><td></td><td colspan="6" rowspan="3"></td></tr>
<tr><td colspan="2">Performance</td><td></td></tr>
<tr><td colspan="2">Paddle</td><td></td></tr>
<tr><td colspan="2" rowspan="2">Worker garments and equipment</td><td colspan="2">Garments</td><td></td><td colspan="6" rowspan="2"></td></tr>
<tr><td colspan="2">Equipment</td><td></td></tr>
<tr><td colspan="2" rowspan="2">Tapers</td><td colspan="2">Placements</td><td></td><td colspan="6" rowspan="2"></td></tr>
<tr><td colspan="2">Quality</td><td></td></tr>
</table>

3.7 Findings and Recommendations

Based on the analysis results, major safety challenges, the most dangerous risk hazard, operations and temporary traffic devices that need attention were identified. Also, proper mitigation measures were suggested. The counter measures could be long term, short term or intermediate depending on the risk level. Best practices observed that need to be maintained were recommended, likewise safety measures that need to be eliminated due to their inefficiency within the work zone were identified and recommend their removal.

CHAPTER 4

4 ANALYSIS AND PRESENTATION OF CASE STUDY

4.1 General

The Kano Maiduguri road was selected as thesis case study. The road section is a rural highway connecting the Kano city with many states in the North Eastern and North Western part of Nigeria. The road is undergoing reconstruction in which it is been changed from the 2-lane single carriage way to a 4-lane divided highway. The first part of the contract has been given to Dantata & Sawoe construction company (Nigeria) Limited, which covers 101.365km out of the total distance of 591km, that is from Kano to Shuarin. For the purpose of this thesis only the first 38km of the road was considered, (Kano – Wudil) which is known as a dangerous road section from the traffic safety point of view. In this particular road section, a 15 km of a new road was constructed adjacent to the existing roadway. Traffic was diverted to this newly constructed carriageway giving the contractor room to reconstruct the existing road which will become one carriage way of the road.

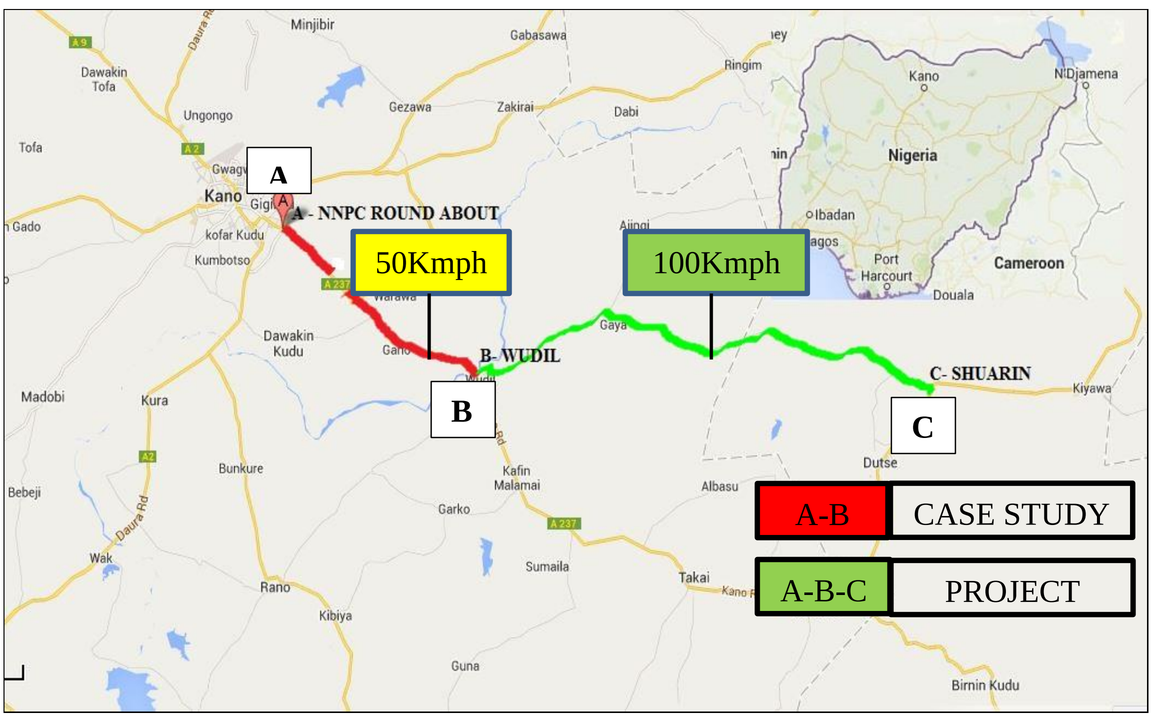

Figure 4-1 Map of Nigeria Showing Case Study

The project information was summarized in Table 4.1 below:

Table 4-1 Summary of Project Information

Project	Dualling and reconstruction of Kano Maiduguri road
Contractor	Dantata & Sawoe Construction Company (Nigeria) Limited
Project Length	101.365 X 2 = 202.73Km
Commencement Date	12th October 2006
Initial completion date	11th February, 2010
Second extension date	31st December, 2015
Contract period	111 months
Overall progress	25.87%
Lapse of contract period	68.12%

Source: Dantata & Sawoe Construction Company Limited

4.1.1 Scope of the Project

The scope of the work includes site clearance, earthworks to execute the construction of additional 2- lane carriageway and upgrading the existing road. The two carriageways were separated by a median. A by-pass was also constructed to remove congestion in Wudil Township, with adjoining interchanges at its entrance and exit. Each carriageway should be designed in accordance with standard requirements for rural highways. The roadway was designed to satisfy all the minimum requirements for all the roadway elements such as; pavements, shoulders, culverts, line drains, channels, lighting, bridges, flyovers and all other miscellaneous works.

There were no any work restriction policies applied to the project, and lane closures were as the contractors work program.

4.1.2 Accident Records

The section of the road under study was classified as a dangerous road section by the Federal Road Safety Commission (FRSC) due to its several numbers of black spots. Most drivers have also agreed with that classification. Accident records were available from the Federal Road Safety Commission. The records did not classify the work zone accidents separately, though some pictures were available. Table 4.2 below gives summary of the accidents obtained from the commission from the year 2009 to 2013.

Table 4-2 Accident Record

Year	No. accidents	No. Injured	No. killed	Total causalities
2009	79	313	54	367
2010	104	352	50	402
2011	78	327	33	360
2012	93	581	28	609
2013*	45	234	30	264

Source: Federal Road Safety Corps (FRSC)

* The accident data is from January-August 2013.

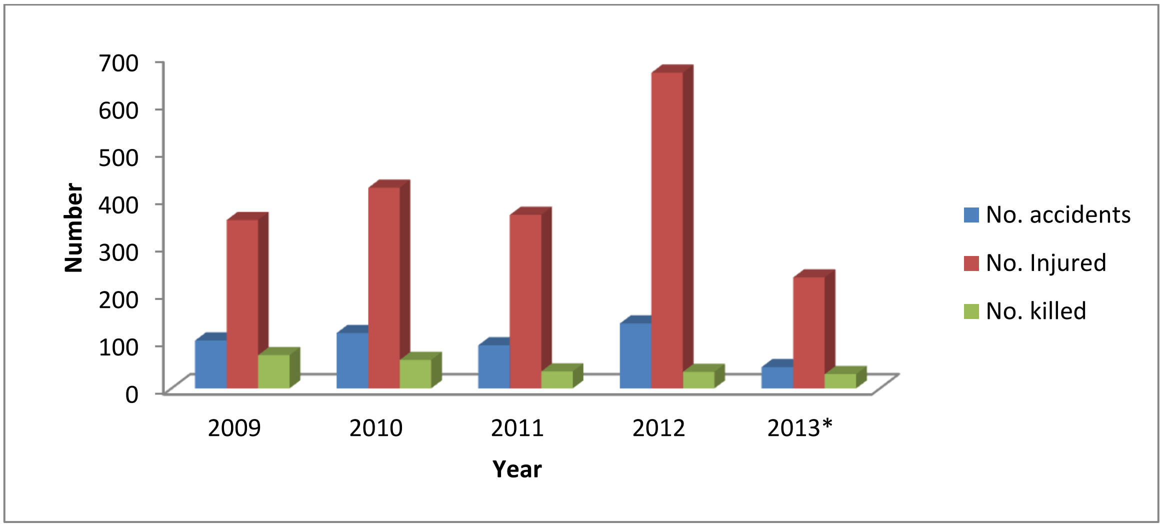

Figure 4-2 Accident Data for Road Section

The average fatality on the road section is 42 deaths in an 89 accidents annually translating to approximately 1- fatality in every 2 accidents, and leaving over 393 people with various degrees of injuries.

4.1.3 Traffic Volume

There were no records of traffic volume along this road. For that reason, traffic volume counts were conducted between 8 am in the morning and 5 pm in the evening at an interval of 15min throughout a selected day. The Average Annual Daily Traffic (AADT) was estimated using hourly expansion factors (HEF), monthly expansion factor, (MEF) and daily expansion factors (DEF) of a road showing similar traffic hourly distribution. Table 4.3 and table 4.4 gives the hourly traffic distribution and traffic HEF, MEF and DEF factors used to come up with the estimated AADT. Trucks make 11% of the overall traffic.

Table 4-3 Hourly Traffic Volume on 27th June, 2013

Duration	Volume (Veh/hr.)
08:00-09:00	1252
09:00-10:00	1329
10:00-11:00	1597
11:00-12:00	1337
12:00-13:00	1288
13:00-14:00	1431
14:00-15:00	1205
15:00-16:00	1508
16:00-17:00	1757

Table 4-4 DEF and MEF values

S/No.	Factor	Time	Value
1	DEF	Thursday	7.012
2	MEF	June	0.948

Source: Traffic and Highway Engineering, Garber and Hoel [7]

The AADT was estimated to be 23,045 vehicles per day.

4.1.4 Speed Data

Speed data are very essential in every roadway; this is because speed is the governing factor for all geometric designs. In order to enhance safety through the work zone, speeds are reduced through the zone using many temporary traffic control devices, including, speed bumps, advance warning signs, etc. The speed data for the roadway under study was summarized in table 4.5 below. Drivers were observed not to be complying with imposed speed limit which was as a result of limited enforcement.

Table 4-5 Speed Data

Design speed	100Km/hr
Imposed speed through the work zone	50km/hr

Source: Federal Ministry of work and Transport.

4.1.5 Road Geometric Data

The roadway section is on a flat terrain and upgraded to meet the requirements for rural divided highway. The road satisfied AASHTO minimum requirements for the lane widths, shoulder width, median width and height, radius of horizontal and vertical curves, side slopes etc. the geometric data were summarized in table 4.6 below.

Table 4-6 Road Geometric Data

Number of lanes	4
Lane width	3.65m
Shoulder width	2.75m
Median width	4m
Median height	0.25m
Radius of Horizontal curves	≥550m

Source: Dantata & Sawoe Construction Company.

4.1.6 Surrounding

The road, routed through many settlements, especially the section under study. There are many secondary and minor roads connected to the road. There are 18 gas stations along the road section under study. Farawa and Danladi Nasidi housing estate attracts heavy traffic during the rush hour.

Some weekly markets, for example Makole on Sundays and also Laraba on Wednesdays were located on the road making the road more dangerous in these days due to increased traffic volume and increased entry and exit through the villages at uncontrolled intersections. Some farming activities also took place. On the other hand, some secondary schools and primary schools were located on the route. The Nigerian Police Academy was also located along the same road section. Being the only route that connects Kano city with the North Eastern part of Nigeria, a military checkpoint was located at Jido (KM 5+800 from the NNPC roundabout) forcing all vehicles to encounter delays at this point. Table 4.7 below gives KM of all the villages located on the road.

Commercial activities along road were seriously affected especially the gas stations. Gas stations on the existing carriageway were forced to completely shut the stations for weeks due to the ongoing upgrade.

Table 4-7 Villages along the Road with Their Direction

KM	Direction	Village Name
1+200	Right	Farawa
3+100	Left and right	Mariri
5+050	Left	Dorawar na Abba
6+150	Right	Jido
8+300	Right	Rijiyar gwangwan
10+633	Left	Yar Gaya
13+000	Right	Zogarawa
16+100	Left	Makole
21+000	Left	Gano
24+800	left	Jigawar Gano
29+100	Left	Police Academy
32+100	Right	Garin Dau
38+000	Left	Wudil

Right: Kano- Maiduguri direction Left: Maiduguri- Kano direction

4.2 Audit Inspection

During the audit inspection, potential traffic hazards within the work zone were identified. Checklist was used to note the exact location of each hazard with reference to the audit starting point. Also traffic control devices were examined and later their compliance with the standards was determined. The subsections below give the detail of the audit inspection.

4.2.1 Hazards Identification

During the work zone safety inspection, all the potential risk and hazards were observed and recorded on the work zone safety hazards list form. The hazards were classified into 5 main categories, those related to; a) Temporary traffic control devices b) Construction activity area c) Road design d) Road side hazards e) Road user associated hazards. Each hazard is given an identification number, which has been used in the checklist. All the hazards were recorded and presented in Table 4.8 below.

Table 4-8 Work Zone Safety Hazards List

Hazard category	Hazard type	Number ID
A. Temporary traffic control devices.	Use of a dangerous object for road closure.	1
	Non retro-reflective temporary traffic control device (TTCD)	2
	Placement of wrong traffic sign	3
	Missing buffer	4
	Wrong placement of TTCD	5
	Use of inadequate taper length	6
	Missing TTCD	7
	Damaged TTCD	8
	Missing / dangerous flagger	9
	Sign not visible to road users	10
	Poor Access design	11
	Missing taper	12
	Confusing signs	13
B. Construction activity area hazards.	Improper access of road users into working area	14
	Unprotected working area	15
	Use of a dangerous device for pedestrian paths	16
	Construction activity left on unsafe stage and not guarded.	17
	Steep slopes due to construction activity	18
	Construction materials/equipment along the road user's path.	19
	Exposure of worker to traffic	20
C. Roadside hazards	Dangerous object on the road side	21
	On street parking	22
	Dangerous road edge	23
	Improper culvert design on road side	24
	Big trees close to the road	25
D. Road design	Improper connection to gas station, and other commercial activities	26
	Improper trailer park design	27
	Missing traffic design	28
	Uncontrolled entry	29
	Improper pedestrian crossing	30
	Missing traffic marking	31
E. Road users' behavior	Noncompliance with road signs	32
	Noncompliance with the posted speed limits	33
	Reckless and aggressive driving	34
	Misuse of traffic control device	35

Hazards linked with the temporary control devices outnumbered all other categories of the hazards. It was observed that, lack of proper maintenance is the major cause of this high number of temporary traffic control devices related hazards. The hazards due to road user's behaviour were due to lack of proper enforcement.

Hazards identification goes simultaneously with recording the exact location of each hazard in a work zone safety audit checklist. Each hazard is represented by the identification number assigned to it in the hazard identification form.

The checklist has five columns; the first column gives the control station, the second, third and fourth columns are reserved for the kilometre (chainage), distance, the hazard and the hazard type respectively. The fifth column has been designed for technical comments. The kilometre and the distance columns give the exact position of the hazard, which helps during the maintenance stage.

Because this study deals with a work zone safety audit, more concern has been given to the safety of road users, workers and the construction equipment in and around the temporary control zone.

During the inspection, several photographs of the observed hazards were taken and attached to the report to provide a clear picture of the actual situation.

Table 4-9 Audit Checklist

WORK ZONE SAFETY AUDITING CHECKLIST				
Date:	16-07-2013	Weather:	Partly cloudy	
Conducted by:	Ibrahim Khalil Umar			
CONTROL STATION	KM	DISTANCE (m)	HAZARD	COMMENT
	0	0	1	Cause serious injury when struck by a car
	0	360	3	Given wrong message to the drivers
	0	566	4	Taper not provide
	0	800	5	Not visible to the road users
	0	810	6	Workers exposed to risk
	0	566	14	Road user entering the working area
	0	566	15	Road users expose to high risk
	0	600	16	Risk of falling into excavated trench
	0	0	26	Conflict between traffic
	0	200	27	On street trailer parking
	0	300	28	Dangerous to drivers
	0	760	29	Uncontrolled intersection
	0	760	30	Traffic sign missing
	0	0	21	Reducing road capacity
	0	800	21	Limiting sight distance
	1	800	7	Serious danger to pedestrians
	1	160	17	Culvert edge
	1	280	17	Environmental hazard
	1	800	18	Deep drainage without protection or sign
	2	600	47	School for children
	2	600	31	Missing pavement marking and sign
	3	180	19	Cover slab
	3	0	31	
	3	280	29	
	3	700	29	
	3	100	22	Concrete structure on the road side
	3	280	21	
	5	100	8	Falling sign becomes a dangerous object on the road side

Table 4.9 Work Zone Safety Checklist (continuation)

	5	500	9	
	5	550	10	
	5	500	27	Workers exposed to traffic flow
	7	850	1	
	7	850	11	Dangerous turning point
	8	280	13	Confusing drivers
	8	400	7	No road sign in Kano- Maiduguri direction
	8	840	12	
	10	300	7	Tapper missing
	10	60	24	Earth work
	10	300	24	Culverts
	11	100	22	Unattended car involved in a road accident
	14	960	5	Not visible by drivers
	16	60	22	
	17	0	7	Workers at risk
	17	580	8	
	17	160	22	Manhole at road edge
	18	10	3	
	18	230	8	
	18	480	7	
	18	20	24	Excavated trench
	18	480	22	Workers are at risk
	19	200	24	Environmental effect
	20	980	8	
	21	340	5	
	24	980	13	
	24	980	25	
	26	300	8	
	26	820	8	
	27	300	8	
	27	750	8	
	28	0	22	Man hole
	30	972	24	Damaging the work

4.3 Identified Hazards

The paragraphs below explain the most frequent and major hazards identified in the work zone during the audit inspection. Pictures and location of each of the hazards were provided.

a) **Improper sign placements:** The work zone area starts at the roundabout and traffic merged into one way movements after the roundabout. Some of the advance warning signs to inform the drivers about the change in the travel path were placed in opposing direction. This poses a danger to drivers who are not familiar with the road condition. They do not serve the function of informing drivers about the danger or change in the traffic condition.

Figure 4-Error! Bookmark not defined. **Wrong Sign Placement (100m before Work Zone)**

b) **Damaged signs:** Lack of regular maintenance of the temporary control traffic devices, poses a great danger to the road user traversing through the work zone. This because a damaged device can be a hazard on its own or lack the ability to serve its purpose. Inability to inform the drivers about upcoming danger in case of warning signs, miss guiding the traffic, etc.

Figure 4-3 Damaged Warning Signs Km 5+100

c) **Confusing signs:** At some places through the work zone, especially in transition zones, devices were placed in a way that confuses the road user contrary to the standard requirement. At KM 7+800 two guide signs were placed, each guiding the driver to move the opposite direction. Once a wrong decision was taken by the driver, so many lives will be at risk. This is because the traffic coming from the opposing direction will have a head on collision with vehicle toward Maiduguri. The MUTCD recommends that all sign must be clear and precise in guiding traffic through the work zone.

Figure 4-4 Confusing Traffic Signs Km 7+800

d) Use of non-retro-reflective signs: The work is long stationary work, meaning the work extends to night time. All traffic control to be used should be retro-reflective for long term works [1]. At some locations in the work zone, the channelizing devices are either non retro-reflective or have lost this property. Therefore, they become a serious hazard to drivers at night and causing serious injury when struck.

Figure 4-5 Non Reflective Drums Km 0+000

e) Missing buffer area: Buffers provide both lateral and longitudinal safety space between road users, and the working area, thus enhancing safety of both workers and road users. At some locations within the working area, these buffers were missing, exposing the workers to the moving vehicles. At KM 0+566 longitudinal buffer was missing, which create conflict between the working equipment and company vehicle traversing the working area.

Figure 4-6 Missing Buffer Space Km 0+566

f) Missing taper: The use of one way two lane taper helped separate traffic from opposing directions. At some locations during the inspection it was observed these tapers were missing, this has created a condition leading to increased potentiality in a head on conflicts between vehicles in opposing directions.

Figure 4-7 Missing Taper Km 9+500

g) Dangerous flagging: During the inspection, it was discovered that, flagging in the work zone was a dangerous act. It was noted that the flaggers were not using the right equipment (stop paddle or flag) for flagging. At 8+890 a flagger was observed using tree leaves to slow down traffic instead of the slowdown paddle. The flagger was not wearing the safety apparel, hard hat or any boat. The act was really dangerous as drivers might not notice his presence from a far distance.

Figure 4-8 Dangerous Flagging Km 8+890

h) **Exposure of construction workers to traffic:** The construction workers were not always safe in the work zone. At some locations the workers have been so much exposed to the traffic. The work zone safety targeted enhancing safety of both the road users and the worker safety. This exposure of the workers has an adverse effect on the worker’s safety and at the same time reduces his efficiency.

Figure 4-9 Worker Exposure to Moving Traffic Km 18+480

i) **Unprotected working area:** Where the work area was not cordoned, the pedestrians and road workers have been exposed to serious hazards. At KM 1+560 an excavating machine was used to excavate trenches for the drainage. Although it has some distance to the passing traffic, pedestrians and other workers have been endangered with this rotating machine because the area was not cordoned from any passer-by and other workers.

Figure 4-10 Unprotected Working Area Km 1+560

j) Unsafe storage of construction equipment: At some locations on the work zone, it was observed that some construction equipment were not safely stored, some construction materials were even on the pedestrian path. This poses serious harm to road users. The standard requires that all construction equipment and supplies that are not in use have to be stored off travel way, clear zone and buffer space.

Figure 4-11 Equipment on Road Users Path

k) **Non consideration for disabled:** MUTCD requires that all pedestrian facilities should be capable of accommodating people with disabilities. It was observed at KM 3+000 a dangerous facility was used to help pedestrians cross drainage. Three wooden materials with irregular shapes were used for this purpose; it was hazardous to pedestrians with no disability talk less f those with disabilities. It lacks stability; every user who has to use the facility hesitates before doing so, due to the fear of potential danger. At some points, similar hazards were present, but they were reinforcement bars from the slab used that poses danger to the user.

Figure 4-12 Dangerous Facility for Pedestrians 3+000

l) **Noncompliance of traffic rules by road users:** All traffic signs are meant to guide road users safely through the work zone. Disregard of this information by one road users might endanger many road users. It was observed at some locations that some drivers pay little respect to this device. Figure 4.12 below shows a picture of tanker driver disregarding the informatory guide through a transition zone.

Figure 4-13 Noncompliance to Signs by Road User Km 8+870

m) **Misuse of traffic control devices:** During the inspection, it was observed that pedestrians who were waiting for the bus, sometime use some of the devices present around the work zone to sit while awaiting the bus. This action by the road users risk their lives as they were very close to roadsides, and since the drivers were not expecting pedestrians at that distance from the roadway, the pedestrians were in danger.

Figure 4-14 Misuse Of Traffic Control Device Km 3+450

n) **On street parking:** At KM 0+100 which was very close to the audit starting point, lots of on street parking poses serious hazard to both pedestrians ad drivers. Some of the parked vehicles were also heavy vehicles. It was observed that a mechanic garage for trailers and tankers at this point has been the influencing factor for increased on street parking. During rush hour, the parked vehicles significantly reduce the capacity of the road. This leads to increased delay, queuing and aggressive behavior by the driver's hence speeding and increased rear end collisions.

Figure 4-15 On-Street Parking Km 0+900

o) **Uncontrolled access through the work zone:** The work zone does not have full access control at some points, this creates a serious hazard. It was observed this uncontrolled access led to two way traffic moving in both directions. Only a video coverage can show the real picture of the situation. Pedestrians find it very difficult while crossing the road.

4.3.1 Temporary traffic control devices and operations

Inspection of the temporary traffic control devices was made to examine the adequacy, effectiveness and compliance with the requirements given by the Manual of Uniform Traffic Devices. The properties of the devices were tabulated in form with three columns. The first column is for the safety and requirement elements, second column is for the requirement from the manual and lastly third for the observations. The temporary devices examined were signs, and channelizing devices (drums, barricades, cones).

The flagging operation was also examined and noticed to be the worst operation within the work zone. It was observed that the flagging was done for short duration works within the work zone. The flaggers were not using safety apparel and appropriate equipment for flagging. The observation as well as the standard requirements by MUTCD was tabulated in table 4.12.

In table 4.10 below, it can be seen that the advance warning signs in the work zone conform to the MUTCD standards with regards to size, retro-reflective properties, and required number of signs, lateral offset, sign placement and legends. The shape, colour, night visibilities were not as specified by the standard. Lack of regular maintenance of these signs as observed at some locations makes them lose some of their major properties including retro-reflectiveness, height, lateral offset.

Table 4-10 Advance Warning Sign Requirement and Observation

ELEMENTS	**REQUIREMENTS BY MUTCD**	**OBSERVATIONS**
Shape	Diamond	Square
Size	1.2m X1.2m	1.2m X 1.2m
Height	≤ 2.1m	2.85m
Color	Black on orange background	Red on white background
Illumination and retro-reflectorizing	All signs used during hours of darkness shall be made of retro-reflective material or illuminated	No illumination except at some few locations
Night Visibility	Excellent	Poor
Distance from hazard	450m	300m
Spacing between signs	150m	50m
Number	3	6
Lateral offset	1.8-3.6m	0.6m to 2m
Sign placement	All Signs should be placed at the right of the road except stated otherwise	80% placed on the right side
Legends height (H)	15cm	25cm
Legends Width	-	15cm
Spacing between words (cm)	1.5times H	30cm

As it can be seen in table 4.11 below, traffic cones, barricades comply with the minimum requirements. Drums on the other hand are the only exception among the channelizing devices in which their shape and colour do not match the standard requirement.

Table 4-11 Channelization Requirements and Observations

Device	Property	Requirement By MUTCD	Observations
Traffic cone	Color	Orange	Orange and white
	Height	700mm	750mm
	Material	Should be made of material that does not cause damage to the impacting vehicles.	As required by specification
	Stability	Steps should be taken to make sure they are not blown by air or displaced by moving traffic.	At some locations
Barricades	Diagonal stripes	Slant down word to the direction where the traffic is intended to travel.	The diagonal stripes slants downward as required by the standard, but some of the barricades are wrongly positioned
		The minimum for or type I and II barricades is 600mm and 1200 for type III.	The length of each barricade is 3000mm
	Spacing between rails	Between 200 – 300mm	300mm
	Stability	Placed is such a way that they cannot be displaced or blown.	They are well stable
	Upper rail	Ballast should not be placed on the upper rails	No ballasts were placed.
	Stripes	Must be retro-reflective.	Were retro-reflective.
	Visibility by road users.	They should be supported in a way that they are seen by road users at all time.	They are visible to road users day and night.
Drums	Height	≥ 900mm	1400mm
	Width	≥450mm	760mm
	Material	Metal drums should not be used.	Drums are made of concrete.
	Top	The top should be closed to prevent debris from collecting in them	The top is closed
	Markings	Horizontal, circumferential, alternating orange and white retro-reflective stripes 100 to 150mm wide.	Drums are colored completely white with one face and orange on the other face, alternately, and are placed with alternating faces.
	Ballast	No ballast to be placed on top of a drum.	Nothing was placed.

Table 4-12 Flagging Operation Requirements and Observations

Basic requirement for flaggers		
Elements	Standards	Observations
Safety Apparel	1. Clearly identifies the wearer as a person 2. Retro-reflective material is orange, yellow, white, silver, yellow-green or a fluorescent version of these colors.	1. Flagger does not use the safety apparel, although at some points the flagger do wear the safety apparel. 2. Yellow green is used where available.
Proper devices.	1. Flaggers should have STOP/SLOW paddle made out of type III or IV retro-reflective material. 2. STOP/SLOW paddles have a minimum width of 450mm with a minimum 150mm height of letters. 3. STOP/SLOW paddles used at night should be retro-reflective.	1. The flaggers use non-standard device as they sometimes use green leaves or hand. 2. No flagging is done at night.
Procedure	1. Flags are not used except in emergencies. 2. For a highway with a speed of 100km/hr as in the case of this road, a distance of 185m is required in advance 185m.	1. Flagging is used only for short time works within the work zone. 2. The flagging is within the work zone, and the flaggers take chance to start when the traffic flow fall down such that the drivers that will come later will them in advance.

Flagging as seen in table 4.12 above did not comply with the minimum requirement for safe flagging. The flaggers are not using the appropriate devices for flagging, are not wearing safety apparel that can identify them from far.

4.4 Audit Analysis

The data obtained from the audit inspection and the audit review were analysed to obtain the risk level of the hazards, temporary traffic control devices compliance with the MUTCD requirements and finally the overall safety level of the work zone.

4.4.1 Risk Rating and Countermeasure of the Identified Hazards

After the hazards were identified during the inspection, the expected crash to be caused by each hazard was also clarified. Thus its risk and severity were also estimated. The risk and severity level were estimated by qualitative method (experience and engineering judgements). The resulting risk level was then identified using risk matrix. Base on the risk level a countermeasure was proposed to mitigate the perceived risk. Table 4.13 gives the list of the hazards, expected crashes, frequency, severity risk level, and the resulting countermeasure for the potential hazard. The risk matrix table, table for the severity and frequency was given in chapter 3.

The analysis of the identified risk shows; dangerous flagging, confusing signs, use of non-retro-reflective devices, missing buffers and aggressive driving by the drivers were the hazards with high risk value. It was also discovered that all the hazards were serious because none has a risk value less than average, apart from the slippery road edge, lack of safety training by the works and wrong sign placement that have a medium risk level all others have high risk value. Therefore the work zone has been associated with high risk. The use of the safety audit checklist in table 4.9 can help in applying the proposed countermeasures given in Table 4.13 below.

Table 4-13 Risk Level Assessments

Safety Hazards		Expected crash				Recommended counter measures
		Type	Frequency	Severity	Risk level	
Temporary traffic control devices	Improper sign placement.	Sideswipe, head-on collision	3	3	Medium	Maintenance to ensure all signs was placed in accordance with standards.
	Improper maintenance of signs.	Swipe	4	4	High	Regular maintenance
	Confusing signs.	All types of swipe	4	5	Very high	Make signs legible and clear
	Missing buffer	All types	4	5	Very high	Provide buffer spaces
	Missing taper.	Sideswipe, head on collisions	5	4	Very high	Provide and ensure minimum taper length is provided.
	Use of non-retro-reflective signs	Collision with dangerous object	4	5	Very high	Change all devices that lost their retro-reflective property.
	Signs close to the travel lane.	Sideswipe	4	4	High	Provide required minimum lateral length
Construction activity area	Workers' exposure to traffic	Sideswipe and same direction	3	5	High	Provide both lateral and longitudinal buffer spaces.
	Unprotected work area	Sideswipe, rear end	4	5	Very high	Provide buffers
	Improper work zone design	All types of swipe	3	5	High	Refer to the MUTCD for proper configuration.
	Dangerous flagging	Sideswipe same direction	4	5	Very high	Flaggers should be trained and provided with proper flagging equipment.
	Lack of safety training to the workers	Struck by plants while operating	1	5	Medium	Train all workers on safety in working close to equipment and traffic.
pedestrians	Non-compliance with signs	Sideswipe opposite direction	2	5	High	Provide enforcements.

Table 4.11 Risk Level and Countermeasures of the Identified Hazards (continuation)

pedestrians	Misuse of traffic devices	Sideswipe same direction	3	5	High	Provide enforcements.
	Speeding and aggressive driving.	All	5	5	Very high	Employ the use of speed calming measures like use of speed bumps.
	On street parking	All types of swipe	3	4	High	Enforcement and provide an alternative parking area for visitors.
Roadside area	Dangerous object within clear zone	Sideswipe	4	3	High	Provide minimum clear zone width.
	Slippery road edge	Sideswipe	3	3	Medium	Provide lateral protection.

4.4.2 Temporary traffic control devices and operation compliance with MUTCD standards

a. Warning signs: The warning signs compliance with the MUTCD standard in the work zone is good for newly installed signs. Due to lack of regular maintenance, observation shows that some of the signs become a mess with time.
b. Channelizing devices: The channelizing devices comply with the MUTCD requirements except for drums where the shape is more of pyramid than a cylindrical shape
c. Flagging: Flagging is not as described in any standard. It is one of the most hazardous acts in the work zone.

4.4.3 Evaluation of Work Zone

After all of the temporary traffic control devices and operations were examined for their effectiveness, compliance with the standards in the manual of uniform control devices, an assessment to determine the overall effectiveness of the work zone was made. Each device property was assigned a score ranging from 1-10, with one being the worst score and 10 having the highest score. At the end the overall score for the work zone was obtained using a weighted average. The items evaluated were temporary signs, channelizing devices, pavement markings, flagger operations, worker safety equipment, internal traffic control and the site housekeeping operation. The overall devices and operations had a score of 5.54 showing that it has an average effectiveness and so much has to be done to improve the condition of the work zone. The work zone evaluation was summarized in table 4.14 below.

Table 4-14 Work Zone Safety Audit Evaluation

Project: Reconstruction and Dualling of Maiduguri Road	Date: 26/07/2013
Highway: Kano-Maiduguri Road; Region: North west	State: Kano state
Contractor: Dantata & Sawoe construction Company Limited	
Reviewed by: Ibrahim Khalil Umar	
General Notes: Only Devices witnessed on the Project were scored	

SCORING

1	2	3	4	5	6	7	8	9	10
Notify project manager				Below Average	Average	Above Average	Good	Very good	Excellent

CATEGORIES		Score	NOTES
Temporary signs	Quality	8	Some signs were placed in close proximity to the roadside. The shape does not comply with MUTCD requirement.
	Placement	7	
	Spacing	8	
Channelizing devices	Drums	6	The devices comply with the standards, but their number is not sufficient.
	Barricades	7	
	Cones	9	
Pavement markings.	Condition	7	Tapes were used to mark working area.
	Placement	6	
Pedestrians and bicyclist	Signing	2	The pedestrian facilities were poor and no provision for pedestrians crossing,
	Continues route	5	
	Disabled	1	
Flaggers	Visibility	3	They do not use the appropriate paddles and safety attires.
	Performance	6	
	Paddle	1	
Worker garments and equipment	Garments	5	50% of the workers do not have safety jackets.

Table 4.14 Work Zone Safety Audit Evaluation (continuation)

	Equipment	8	
Tapers	Placements	6	Shoulder tapers were not provided
	Quality	8	
Site house keeping	Clean	5	The yard is far from the work site.
	Orderly	6	
Internal traffic control	Access control	5	No proper access control, workers have to shout while communicating.
	Communication between workers	2	
Driver friendly work zone.	Navigation	7	Driving through the work zone was not challenging
	Consistency	6	

Grand total =	134	N*=	24	Final score=	5.58
N*= the number of scored categories					

4.4.4 Best Practices

Several best practices that enhance the safety of the work zone were discovered during the safety audit. First, due to the behavior of over speeding and disregard for traffic signs, the contractors employed the use of physical speed calming measures that force the drivers to reduce their speed. These physical measures were the use of speed bumps in advance of the transition area. This really helped to avoid the risk of vehicle collision with channelizing devices.

Another safety measure in use that really helps improved safety in the work zone was the lighting provided in the transition areas. The lighting provides clear visibility of all the transition zone to the drivers, hence avoided collision with the devices at night.

The third practice which was considered among the best practices that reduced rate of accidents was the use of roadblocks on the shoulder at 20m intervals throughout the work zone. These helped prevent vehicles from sliding into the excavated drainage structure which is under construction. Because the roadblocks are retro-reflective, it helps drivers at night not to take the shoulder as part of the travel lane.

4.5 Conclusions of Case Study

The following conclusions can be derived from the case study:

a. The section under study has an average of 1-fatal accidents in every 2-accident on the road. The average annual fatality and injuries were 42 and 394 respectively in 89 accidents. Work zone accidents were not recorded separately, thus making it difficult to analyse work zone accidents separately.
b. 35 different hazards have been identified. Hazards related to the temporary traffic devices were the majority, recording 14. Hazards linked to construction activities and road designs recorded 6 each. 5 hazards associated with roadside hazards were identified and 4 others related to road user's behavior.
c. None of the hazards analysed has a risk level less than average, which shows that there is a great threat to the life and health of the workers and the road users traversing the work zone. The hazards with highest risk level were dangerous flagging, use of confusing signs, use of non-retro-reflective signs and other hazards that lead to the workers' exposure to traffic. Proper and regular maintenance of the installed temporary traffic control devices will help reduce the risk level by reducing its frequency. The maintenance will also help avoid some of the hazards present within the work zone. All the hazards related to road users' behavior had a significant severity level when occurred. Effective enforcements can help reduce these hazards.
d. The observations of temporary control devices (signs, drums, cones, barricades, and pavement markings) reveal that they were not adequate. Most of the signs properties conform to MUTCD specifications except for their color, shape ad retro-reflective property of the signs. Traffic cones and barricade satisfy the minimum requirements. Drums on the other hand did not satisfy the color requirement likewise the shape. Although a newly installed device did satisfy the MUTCD requirements, poor installations and lack of proper maintenance makes them lose lots of their properties with time, thus reducing their effectiveness
e. Four best practices that help improve safety of work zones were identified. The use of bumps in advance of the transition zones to calm down drivers speed is an essential safety measure. Provisions of lighting at all the transition zones at night also help avoid collision with channelizing devices at night. Another practice that helps was the use of roadblocks on the shoulders at 20m interval to prevent vehicles from sliding to the excavated trenches made for drainage. Lastly safe keeping of construction activities after work is among the best practices observed in the case area
f. Flagging was the most dangerous operation in the work zone; the flaggers were not using the right attires, devices and procedure.
g. The work zone was evaluated and was scored a value slightly (5.54/10) less than the average (6/10). This shows that, a lot has to be done to improve safety of the work zone.

CHAPTER 5

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The following conclusions can be derived from the thesis study;

- **a.** Road safety audit is an old safety tool originated in the United Kingdom in 1980s with the aim of reducing accident rates on highways carried out by an independent auditor. It was later accepted by New Zealand, Australia, and the United States in early 1990s. Now it is in use widely all over the world on planned projects and existing roads.
- **b.** The success of RSA motivated the stakeholders in road safety to apply the same principles in work zones, with the aim of identifying potential safety and mobility hazards within the work zone and also to recommend practical measures for improving mobility and safety in work zones. But unlike the RSA, WZSA assess temporary traffic control elements that will be removed upon successful completion of the project.
- **c.** Work zone safety audit is an eight step process starting with selection of candidate project to the final stage, which is presentation of findings and recommendation to the road owner. WZSA can be done also during planning, design and construction stage.
- **d.** Accidents occur more often in work zones than on non-work zone sections of road. Also, their severity is higher. This is because of the change in the normal traffic operation and exposure of workers to the moving traffic. There is no specifically agreed component of the work zone that is characterized with higher and severe accident rate.
- **e.** Accidents in work zones are not documented separately as work zone accidents; this makes it difficult in analysing work zone accidents separately. This hinders identifying specifically the section of work zone associated with higher risk and the resulting causes of the accidents.
- **f.** Because of the nature of work zones, traffic control devices are used to guide and direct roads safely through the work zone. The type of highway, the work duration, traffic volume determines the type of devices and traffic operation plan required.
- **g.** Noncompliance with standards, lack of worker training, poor work zone configuration and lack of proper maintenance of traffic control devices are major causes of safety hazards in work zones.
- **h.** Use of non-retro-reflective devices, confusing signs, workers' exposure to traffic, dangerous flagging, negligence to warning signs, speeding and

aggressive driving are the major and most dangerous hazards surrounding construction sites.

i. The risk level of all work zone potential hazards is determined by the use of safety matrix base on the hazard's frequency of occurrence and possible severity level when occurred. Appropriate measures are provided depending on the risk level. For very high and high level risk hazards, such hazards are given immediate action to improve safety.

j. The best practice in work zones includes the use of speed calming measures in advance of every transition area of the work zone. This prevents an over speeding or aggressive driver from striking the channelizing devices which results into a serious injury. Other practices include; safekeeping of equipment while not in use; removal of temporary devices that are not in use anymore; lighting most sensitive parts of work zone at night to provide vision from far.

k. The overall rate of the work zone safety can be obtained as the average of the number of safety elements scored during the work zone evaluation.

5.2 Recommendations

The following recommendations were made from the study:

a. Work zone crashes should be documented separately to help analyse work zone accidents separately. This helps identify fatal, injury and damage only accidents within the work zone and their resulting causes.

b. Work zone safety audit should be made at both design stage and at the early stage of construction (active work zone) to improve work zone safety. This will help reduce the cost of modifying the work zone to improve safety during construction and accidents caused by work zone activities.

c. The contractors should always refer to appropriate specifications for proper configuration of the work zone, likewise use of appropriate and proper installation of all temporary traffic control devices.

d. Worker training, regular maintenance of the installed devices and increased enforcements are required for enhanced safety in work zones.

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APPENDICES

APPENDIX A

Accident Information for the Case Study Route

Causes of accidents (speed limit violation, mechanical defective vehicle, etc.) are given code for easy use

Table A 1 Causes of Accidents

Causes of Accidents	Code
Wrong overtaking	WOV
Over speeding	SLV
Tire burst	TBT
Dangerous driving	DGD
Mechanically defective vehicle	MDV
On-street parking	SVO
Fatigue	RTV
Run-off	LOC

Table A 2 Number of Accidents by Causes

YEAR	ACCIDENT CAUSES								
	WOV	SLV	TBT	DGD	MDV	SVO	RTV	LOC	TOTAL
2012	12	38	7	32	1	0	1	2	93
2011	17	20	3	37	0	0	1	0	78
2010	20	53	8	22	1	0	0	0	104
2009	12	41	8	16	1	0	0	0	78
TOTAL	**61**	**152**	**26**	**107**	**3**	**0**	**2**	**2**	**353**

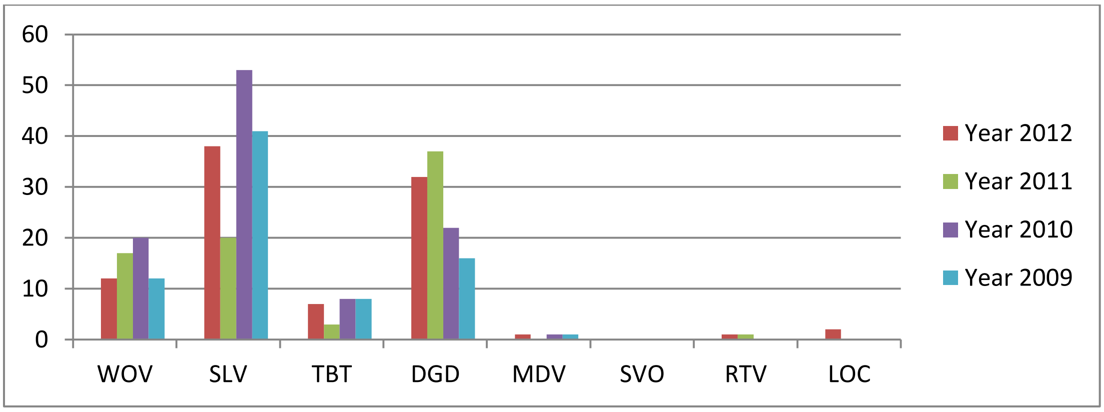

Figure A 1 Cause Number of each Accidents

Table A 3 Number of Fatalities by Causes

YEAR	ACCIDENT CAUSES								
	WOV	SLV	TBT	DGD	MDV	SVO	RTV	LOC	TOTAL
2012	7	6	2	10	0	1	0	2	28
2011	12	11	2	7					33
2010	3	33	2	13	0	0	0	0	51
2009	10	17	12	15	0	0	0	0	54
TOTAL	**32**	**67**	**18**	**45**	**0**	**1**	**0**	**2**	**166**

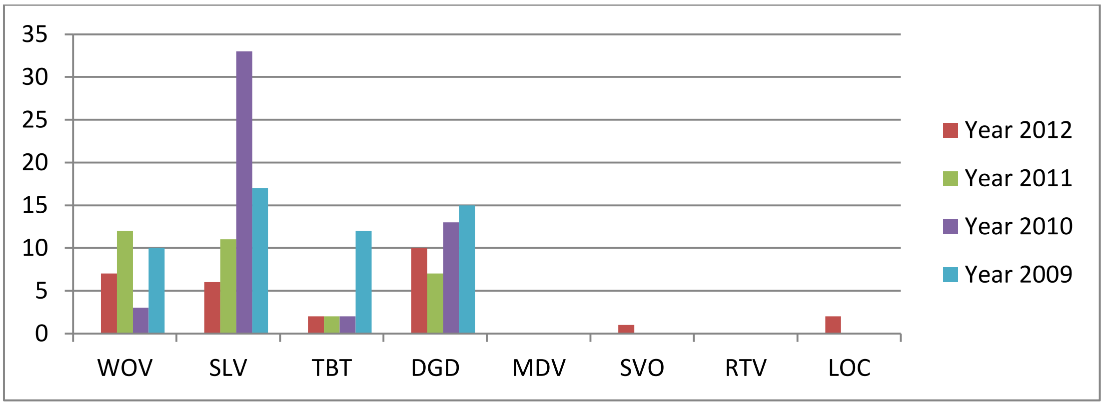

Figure A 2 Number of fatalities for each Group

Table A 4 Summary for Number of Injuries

YEAR	ACCIDENT CAUSES								
	WOV	SLV	TBT	DGD	MDV	SVO	RTV	LOC	TOTAL
2012	95	207	62	185	15	6	0	11	581
2011	101	70	23	128	0	0	3	0	327
2010	89	172	24	67	0	0	0	0	352
2009	54	144	24	70	21	0	0	0	313
TOTAL	**339**	**593**	**433**	**450**	**36**	**6**	**3**	**11**	**1573**

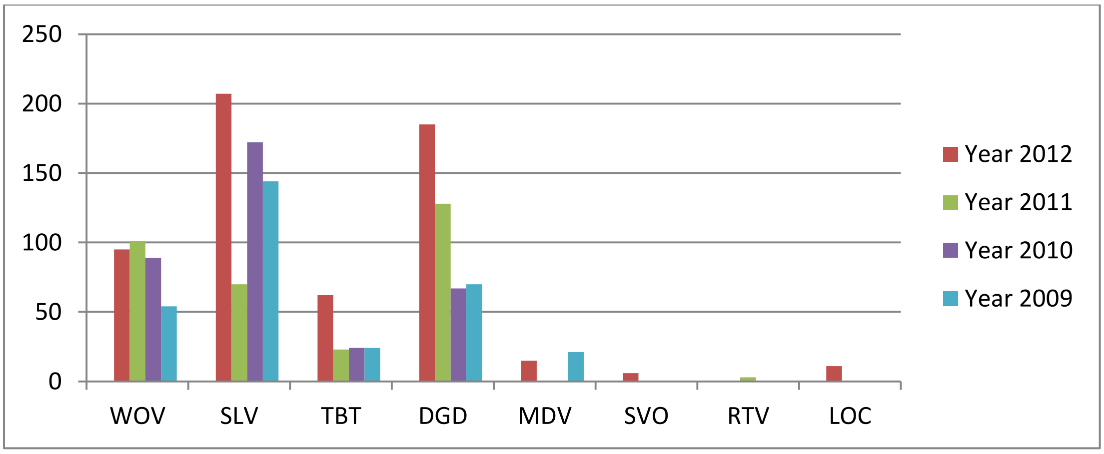

Figure A 3 Chart Showing Summary for Inury

Table A 5 Accident Data for 2009

S/N	Date	Vehicle Type	Location	Total Injury	Total Fatality	Cause
1	04/01/2009	M/C	ZOGAWARA/WDL-KN	2	0	SLV
2	04/01/2009	CAR	K BABALE/WDL-KN	0	0	TBT
3	05/01/2009	CAR,BUS	G DAU/WDL-KN	4	0	GDG
4	05/01/2009	BUS	J GANO/WDL-KN	7	0	WOV
5	06/01/2009	BUS	POLAC/WDL-KN	7	0	TBT
6	08/01/2009	CAR	GANO/WDL-KN	16	0	WOV
7	09/01/2009	BUS, CAR	JEMAGU/WDL-KN	0	0	DGD,SLV
8	31/01/2009	M/C	MAKOLE/WDL-KN	2	0	SLV
9	01/02/2009	JEEP, M/C	G DAU/WDL-KN	2	0	DGD
10	09/02/2009	BUS	GANO/WDL-KN	3	0	DGD,SLV
11	14/02/2009	M/C	WUDIL/WDL-MAI	3	0	SLV
12	22/02/2009	CAR,TRUCK	GANO/WDL-KN	1	0	WOV,DGD
13	22/02/2009	CAR	G DAU/WDL-KN	0	0	DGD
14	03/03/2009	CAR,M/C	SHAGOGO/WDL-MAI	1	0	DGD
15	05/03/2009	BUS	GANO/WDL-KN	7	4	SLV
16	14/03/2009	M/C	J GANO/WDL-KN	2	0	SLV
17	16/03/2009	BUS	POLAC/WDL-KN	1	0	OLV
18	19/03/2009	CAR	MAKOLE/WDL-KN	2	0	SLV
19	23/03/2009	CAR	POLAC/WDL-KN	1	0	TBT
20	23/03/2009	CAR,M/C	MAKOLE/WDL-KN	3	0	DGD
21	27/03/2009	CAR,BUS	YAR GAYA,WDL-KN	13	0	WOV
22	02/04/2009	TRUCK	POLAC/WDL-KN	0	1	WOV
23	05/04/2009	M/C	WUDIL/WDL-MAI	2	1	WOV
24	11/04/2009	CAR	YAR GAYA/WDL-KN	14	0	SLV
25	16/04/2009	M/C	GANO/WDL-KN	1	0	SLV
26	18/04/2009	CAR,M/C	YAR GAYA/WDL-KN	2	0	SLV
27	29/04/2009	TRUCK	GANO/WDL-KN	1	0	SLV
28	04/05/2009	CAR,BUS	GANO/WDL-KN	12	3	SLV,DGD

Table A 5 Accident Data for 2009 (Continuation)

29	06/05/2009	CAR	WUDIL/WDL-KN	0	1	SLV
30	08/05/2009	CAR	MAKOLE/WDL-KN	0	0	SLV
31	08/05/2009	CAR,M/C	POLAC/WDL-KN	2	0	SLV
32	13/05/2009	CAR	POLAC/WDL-KN	0	1	WOV
33	14/05/2009	TRUCK,M/C	WUDIL/WDL-MAI	1	0	WOV
34	18/05/2009	CAR,BUS	D FOREST/WDL-MAI	6	7	WOV
35	19/05/2009	N/A	G DAU/WDL-KN	4	0	WOV
36	08/06/2009	M/C	G DAU/WDL-KN	2	0	DGD
37	12/06/2009	BUS	KANYA/WDL-KN	1	1	SLV
38	14/06/2009	BUS	WUDIL/WDL-MAI	1	0	DGD
39	25/06/2009	M/C	DANBAGINA/WDL-KN	2	0	SLV
40	06/07/2009	M/C	WUDIL/WDL-MAI	2	0	SPV
41	18/07/2009	CAR	B/4 GANO	5	0	SLV
42	19/07/2009	BUS		10	1	SLV
43	19/07/2009		T/GUMSAU	5	0	SLV
44	22/07/2009	CAR,M/C	GANO/WUDL-KN	0	1	DGD,SLV
45	22/08/2009	M/C	WUDIL/WDL-MAI	2	0	SLV
46	22/08/2009	CAR,M/C	G DAU/WDL-KN	1	0	SLV
47	26/08/2009	M/C	WDL JUNCTION	2	0	SLV
48	07/09/2009	CAR	G DAU/WDL-KN	2	0	SLV
49	10/09/2009	CAR,TRUCK	KANYA/WDL-KN	8	0	DGD
50	10/09/2009	CAR,BUS,TRUCK	KANYA/WDL-KN	10	3	DGD
51	15/09/2009	CAR	T GUNSAU	5	0	SLV
52	16/09/2009	CAR.M/C	MAKOLE	6	2	SLV,GDG
53	18/09/2009	M/C	G DAU	1	0	SLV,DGD
54	18/09/2009	CAR,BUS	T GUNSAU	1	0	SLV
55	19/0/2009	BUS	GAYA/WDL-MAI	9	1	SLV
56	22/09/2009	CAR,M/C	D GAU/WDL-KN	1	0	SLV
57	28/09/2009	BUS	WUDIL/WDL-KN	10	0	TBT
58	28/09/2009	BUS,CAR	MARIRI/WDL-KN	11	3	SLV
59	29/09/2009	CART	K/LAMIRE	6	1	SLV
60	06/10/2009	JINCHENG	OPP.TOTAL	3	2	DGD
61	12/10/2009	J5	OPP. TOTAL	20	0	MDV
62	15/10/2009	BUS	DUN-DUN AJINGI	0	8	TBT
63	21/10/2009	CAR	ITALIYAR HAUSAWA WDL-BAU	2	0	TBT

Table A 5 Accident Data for 2009 (continuation)

64	31/10/2009	M/CYCLE	FRSC BASE	2	0	SLV
65	05/11/2009	CAR	GANO WDL-KN	2	2	SLV
66	14/11/2009	CAR	GANO WDL-KN	8	0	SLV
67	16/11/2009	CAR	POLAC WDL-KN	5	0	SLV
68	20/11/2009	P/UP	T/GUNSAU	5	1	SLV
69	23/11/2009	CAR,BUS	YAR GAYA	8	0	DGD
70	25/11/2009	CAR	GSSS WDL	2	0	SLV
71	27/11/2009	2 M/CYCLE	OPP. AMANA HOSPITAL	2	0	SLV
72	30/11/2009	CAR	ZUMBULAWA WDL-BAU	2	4	TBT
73	30/11/2009	M/CYCLE	OPP.AUDU MANAGER F/STATION WDL TOWN	2	0	SLV
74	03/12/2009	BUS	MAKOLE WDL-KN	2	0	WOV
75	05/12/2009	CAR,TYT BUS	R/GWANGWAN WDL-KN	13	6	DGD
76	07/12/2009	CAR,M/CYCLE	G/DAU WDL-KN	3	0	SLV
77	09/12/2009	BUS	J/ALH. ADO WDL-KN	3	0	SLV
78	10/12/2009	CAR,BUS	J/GANO WDL-KN	2	0	WOV
79	11/12/2009	CAR,TRAILER	WDL BRIDGE	2	0	TBT

Table A 6 Accident Data for Year 2010

S/N	Date	Vehicle type	Location	Injury	Fatality	Cause
1	26/03/2010	P/UP	ZOGARAWA/WDL-KN	2	1	WOV
2	31/03/2010	M/C	G/DAU/WDL-KN	2	0	SLV
3	04/04/2010	CAR	ZOGARAWA/WDL-KN	10	0	SLV
4	05/04/2010	CAR/M/C	YAR GAYA/WDL-KN	1	1	SLV
5	10/04/2010	CAR	POLAC/WDL-KN	0	1	SLV
6	11/04/2010	CAR	GANO/WDL-KN	0	0	SLV
7	15/04/2010	M/C	J/GANO/WDL-KN	1	0	SLV
8	20/04/2010	BUS/CAR	R/GON-GON/WDL-KN	4	0	WOV
9	22/04/2010	BUS	JUNC/WDL-MAI	1	0	SLV
10	23/04/2010	BUS	MAKOLE/WDL-KN	1	1	SLV
11	24/04/2010	CAR	SCI.GAYA/WDL-MAI	1	0	SLV
12	01/05/2010	CAR	TOTAL/WDL-KN	1	0	DGD
13	02/05/2010	BUS	MARYAM/WDL-KN	29	2	SLV
14	03/05/2010	BUS	D/NA’ABBA	10	0	SLV
15	04/05/2010	M/C	WDL PARK/WDL-KN	1	0	DGD
16	06/05/2010	BUS/TRUCK	DANBAGINA/WDL-KN	2	0	DGD
17	13/05/2010	M/C	DANBAGINA/WDL-KN	3	0	TBT
18	15/05/2010	CARS	MAKOLE/WDL-KN	3	0	SLV
19	16/05/2010	BUS,TRUCK,BUS,BUS,	MEGA/WDL-KN	0	1	DGD
20	22/05/2010	CAR	BRIDGE/WDL-KN	1	0	DGD
21	24/05/2010	M/C	WDL-KN	3	0	SLV
22	20/06/2010	BUS/CAR	GANO/WDL-KN	16	1	SLV
23	29/06/2010	A CARS, M/C	R/GWAN-GWAN/WDL-KN	3	0	WOV
24	29/06/2010	BUS,CAR, TRUCK	YAR GAYA/WDL-KN	5	0	DGD
25	20/07/2010	M/C	TOTAL/WDL-KN	2	0	SLV
26	29/07/2010	TRUCK/BUS	YAR GAYA/WDL-KN	7	7	SLV
27	31/07/2010	BUS	KUST/WDL-MAI	8	0	TBT
28	01/08/2010	BUS	GANO/WDL-KN	4	0	SLV

Table A 6 Accident Data for Year 2010 (continuation)

29	01/08/2010	BUS	POLAC/WDL-KN	2	0	TBT
30	02/08/2010	M/C	POLAC/WDL-KN	1	0	SLV
31	02/08/2010	TRUCK/CA R	R/GWAN-GWAN/WDL-KN	4	1	SLV
32	03/08/2010	M/C	POLAC/WDL-KN	1	0	SLV
33	07/08/2010	P/UP	MAKOLE/WDL-KN	2	1	SLV
34	08/08/2010	CARS	ZOGARAWA/WDL-KN	7	0	WOV
35	09/08/2010	CAR	POLAC/WDL-KN	0	0	WOV
36	10/08/2010	CAR	D/BAGINA/WDL-KN	7	0	WOV
37	14/08/2010	M/C	BRIDGE/WDL-KN	2	0	SLV
38	16/08/2010	CAR	YAR GAYA/WDL-KN	5	0	WOV
39	17/08/2010	CAR	YAR GAYA	3	0	SLV
40	17/08/2010	CAR, BUS	MAKOLE/WDL-KN	3	0	WOV
41	20/08/2010	M/C	G/DAU/WDL-KN	3	0	SLV
42	21/08/2010	CAR	UTAI/WDL-KN	0	1	SLV
43	21/08/2010	M/C	POLAC/WDL-KN	1	0	DGD
44	23/08/2010	M/C, BUS	MAKOLE/WDL-KN	1	0	DGD
45	25/08/2010	CAR	JIDO/WDL-KN	5	0	DGD
46	27/08/2010	BUS	MAKOLE/WDL-KN	5	0	TBT
47	31/08/2010	P/UP, CAR	R/GWAN-GWAN/WDL-KN	6	0	WOV
48	31/08/2010	BUS, CAR,	ZOGARAWA/WDL-KN	9	3	DGD
49	01/09/2010	TRUCK	GAYA/WDL-KN	0	0	SLV
50	01/09/2010	BUS	GANO/WDL-KLN	0	0	SLV
51	01/09/2010	CAR	GANO/WDL-KN	0	1	SLV
52	02/09/2010	BUS, CAR	G/DAU/WDL-KN	3	1	TBT
53	03/09/2010	BUS, P/UP	D/NA’ABBA/WDL-KN	2	0	WOV
54	05/09/2010	BUS, CAR, TRUCK	R/GWAN-GWAN/WDL-KN	8	5	SLV
55	05/09/2010	CAR	POLAC/WDL-KN	1	0	TBT
56	13/09/2010	TRUCK, CAR	GWAN-GWAN/WDL-KN	8	1	DGD
57	13/09/2010	V/WAGEN	GANO/WDL-KN	7	0	SLV
58	17/09/2010	CAR	POLAC/WDL-KN	0	0	SLV
59	24/09/2010	CAR, M/C	YAR GAYA/WDL-KN	0	1	SLV

Table A 6Accident Data for Year 2010 (continuation)

60	25/09/2010	BUS	GANO/WDL-KN	1	0	WOV
61	26/09/2010	CAR	GANO/WDL-KN	0	0	SLV
62	26/09/2010	CAR	ZOGARAWA	3	0	WOV
63	26/09/2010	BUS	GWAN-GWAN/WDL-KN	0	1	SLV
64	26/09/2010	CAR, M/C	TOTAL/WDL-KN	2	0	WOV
65	29/09/2010	CAR	G/DAU/WDL-KN	2	1	SLV
66	29/09/2010	M/C	POLAC/WDL-KN	1	0	SLV
67	03/10/2010	CAR	GWAN-GWAN/WDL-KN	3	0	SLV
68	03/10/2010	TRUCK	GANO/WDL-KN	1	1	DGD
69	07/10/2010	CAR,M/C	GARIN DAU/WDL-KN	1	1	SLV
70	12/10/2010	BUS,DAF,BUS	ZANGO/WDL-KN	6	1	DGD
71	16/10/2010	M/C	ZOGARAWA/WDL-KN	10	1	WOV
72	16/10/2010	CAR	MAKOLE/WDL-KN	2	0	SLV
73	18/10/2010	M/C	LAMIRE/WDL-BAU	2	0	SLV
74	30/10/2010	BUS	AMARAWA	2	0	TBT
75	02/11/2010	TRUCK	J/GANO/WDL-KN	2	0	SLV
76	05/11/2010	CAR	POLAC/WDL-KN	0	1	DGD
77	07/11/2010	M/C	MAKOLE/WDL-KN	0	2	DGD
78	08/11/2010	CAR	G/DAU/WDL-KN	1	0	DGD
79	11/11/2010	CAR	JAM’ARE/WDL-KN	4	0	SLV
80	15/11/2010	M/C	GWAN-GWAN/WDL-KN	1	0	SLV
81	19/11/2010	CAR	G/DAU/WDL-KN	2	0	SLV
82	23/11/2010	M/C	J/ADO/WDL-KN	3	0	DGD
83	26/11/2010	2M/C	BRIDGE/WDL-KN	1	0	SLV
84	27/11/2010	2 M/C	AMARAWA/WDL-MAI	5	2	DGD,SLV
85	29/11/2010	BUS	MAKOLE/WDL-KN	2	0	WOV
86	03/12/2010	TRUCK,CAR,M/C	BRIDGE/WDL-KN	2	0	DGD
87	05/12/2010	BUS,P/UP	GANO/WDL-KN	7	4	SLV
88	06/12/2010	CARS	POLAC/WDL-KN	11	0	WOV
89	09/12/2010	CARS	GANO/WDL-KN	1	1	DGD
90	11/12/2010	P/UP, M/C	MAKOLE/WDL-KN	11	1	WOV
91	13/12/2010	TRUCK	WDL TOWN	1	0	SLV
92	16/12/2010	BUS, CAR	MARIRI/WDL-KN	0	1	SLV

Table A 6 Accident Data for Year 2010 (continuation)

93	17/12/2010	M/C	G/DAU/WDL-KN	12	0	DGD
94	17/12/2010	CAR	OPP.0TEL/WDL-MAI	2	0	DGD
95	18/12/2010	CAR	SHAGOGO	1	1	SLV
96	21/12/2010	CAR	YAN AUDU/WDL-MAI	2	0	SLV
97	21/12/2010	TRUCK	SHAGOGO/WDL-MAI	0	1	SLV
98	22/12/2010	CAR, TRUCK	POLAC/WDL-KN	0	0	MDV
99	22/12/2010	CAR	MAKOLE/WDL-KN	5	0	WOV
100	23/12/2010	CAR	GANO/WDL-KN	4	0	WOV
101	24/12/2010	CAR	POLAC/WDL-KN	1	0	WOV
102	25/12/2010	CAR, BUS	YAR GAYA/WDL-KN	17	0	SLV
103	29/12/2010	CAR	GANO/WDL-KN	0	1	TBT
104	30/12/2010	CAR	POLAC/WDL-KN	1	0	SLV

Table A 7 Accident Data for Year 2011

S/N	Date	Vehicle type	Location	Injury	Fatality	Cause
1	04/01/2011	2 BUS, P/UP	GWAN-GWAN/WDL-KN	23	0	WOV
2	11/01/2011	CAR, M/C	HOTORO/WDL-KN	1	0	WOV
3	22/01/2011	CAR	GANO/WDL-KN	8	3	WOV
4	30/01/2011	P/UP	G/DAU/WDL-KN	1	0	SLV
5	09/02/2011	TRUCK, M/C	GWAN-GWAN/WDL-KN	4	2	TBT
6	12/02/2011	CAR	J/GANO/WDL-KN	0	1	SLV
7	12/02/2011	M/C	POLAC/WDL-KN	3	0	RTV
8	17/02/2011	BUS, P/UP	ZOGARAWA/WDL-KN	2	0	WOV
9	17/02/2011	P/UP	MAKOLE/WDL-KN	3	1	SLV
10	17/02/2011	TRUCK, M/C	J/GANO/WDL-KN	0	0	DGD
11	19/02/2011	TRUCK, BUS	GOGEL/WDL-KN	1	0	WOV
12	20/02/2011	M/C	MAKOLE	4	0	SLV
13	20/02/2011	CAR	J/ADO/WDL-KN	2	0	DGD
14	23/02/2011	M/C	J/GANO/WDL-KN	2	1	DGD
15	01/03/2011	JEEP	GANO/WDL-KN	1	0	SLV
16	01/03/2011	BUS, M/C	MAKOLE	1	0	DGD
17	04/03/2011	CAR,BUS, BUS	GANO/WDL-KN	6	0	DGD
18	05/03/2011	BUS CAR, BUS	GANO/WDL-KN	7	0	DGD
19	08/03/2011	BUS, CAR	GANO/WDL-KN	6	1	WOV
20	10/03/2011	CAR	UTAI/WDL-KN	2	0	TBT
21	11/03/2011	P/UP	J/ADO/WDL-KN	5	0	SLV
22	12/03/2011	TRUCK, CAR	GAYA/WDL-KN	4	5	SLV
23	12/03/2011	CAR	GWAN-GWAN/WDL-KN	7	0	WOV
24	12/03/2011	M/C	D/NA’ABBA/WDL-KN	2	0	DGD
25	13/03/2011	BUS,	GANO/WDL-KN	10	0	DGD
26	13/03/2011	TYT, M/C	G/DAU/WDL-KN	2	1	SLV
27	13/03/2011	TRUCK	GWAN-GWAN/WDL-KN	1	0	WOV
28	21/03/2011	CAR, BUS, TRUCK	J/GANO/WDL-KN	10	4	WOV
29	24/03/2011	BUS	NNPC/WDL-KN	6	0	WOV
30	26/03/2011	CAR	ZOGAEAWA/WDL-KN	6	1	WOV

Table A 7 Accident Data for Year 2011 (continuation)

31	26/03/2011	CAR	GWAN-GWAN/WDL-KN	3	2	SLV
32	26/03/2011	P/UP	J/GANO/WDL-KN	2	0	SLV
33	13/05/2011	CAR	G/DAU-WDL-KN	1	0	DGD
34	17/05/2011	TRUCK	GANO/WDL-KN	2	0	DGD
35	19/05/2011	TYT BUS/M/CYCLE	WDL R/ABOUT	1	0	DGD
36	19/05/2011	N/A	GAYA	8	0	WOV
37	23/05/2011	CAR	G/DAU-WDL-KN	1	1	SLV
38	03/06/2011	BUS	J/GANO/WDL-KN	5	0	WOV
39	06/06/2011	TRAILER/BUS/CAR	YARGAYA	8	3	WOV
40	06/06/2011	BUS/M/CYCLE	GARINDAU/WDL-KN	1	0	DGD
41	10/06/2011	M/CYCLE/	WDLTOWN	2	0	DGD
42	10/06/2011	M/CYCLE	U/WUDILAWA-WDL-M	2	0	DGD
43	11/06/2011	CAR/BUS	R/GONGONWDL-KN	6	0	DGD
44	11/06/2011	N/A	GANO-WDL-KN	2	0	DGD
45	14/06/2011	BUS	POLACWDL-KN	4	0	LSV
46	16/06/2011	BUS 2 M/CYCLE	YARGAYAWDL-KN	5	0	WOV
47	17/06/2011	3BUS,CAR	POLAC WDL-KN	20	0	DGD
48	21/06/2011	CAR,M/CYCLE	G/DAU WDL-KN	1	1	DGD
49	23/06/2011	BUS,CAR	J/GANO WDL-KN	14	2	DGDS
50	27/06/2011	M/CYCLE	POLAC WDL-KN	2	0	WOV
51	30/06/2011	BUS,M/CYCLE	G/DAU WDL-KN	2	0	DGD
52	05/07/2011	M/CYCLE	G/DAU WDL-KN	3	0	DGD
53	05/07/2011	BUS,CAR	DOGON MARKE-WDL-KN	6	2	DGD
54	08/07/2011	CAR,BUS	J/GANO WDL-KN	10	0	LSV
55	20/07/2011	CAR,M/CYCLE	DORAWA WDL-KN	2	0	DGD
56	29/07/2011	M/CYCLE	G/DAU WDL-KN	2	0	DGD
57	02/08/2011	CAR,M/CYCLE	POLAC WDL-KN	1	0	SLV
58	18/08/2011	BUS,M/CYCLE	WDLTOWN	2	0	SLV
59	20/08/2011	CAR	D/NAABBA WDL-KN	3	1	DGD
60	27/08/2011	CAR,P/UP	POLAC WDL-KN	3	1	DOV
61	01/09/2011	2 M/CYCLE	WDL-BRIDGE	2	0	SLV
62	13/09/2011	BUS,M/CYCLE	POLAC WDL-KN	3	0	DGD
63	19/09/2011	2 BUS	GANO WDL-KN	8	0	DGD

Table A 7 Accident Data for Year 2011 (continuation)

64	23/09/2011	CAR	GAYA WDL-KN	2	0	SLV
65	04/10/2011	CAR	G/DAU WDL-KN	2	0	DGD
66	28/10/2011	P/UP,CAR,P/UP,BUS	R/GWANGWAN WDL-KN	17	0	TBT
67	03/11/2011	CAR,ARTICULATED VEH.	G/DAU WDL-KN	1	0	DGD
68	07/11/2011	BUS	POLAC WDL-KN	5	0	DGD
69	09/11/2011	TANKER,M/CYCLE	J/GANO WDL-KN	1	0	DGD
70	09/11/2011	M/CYCLE	GANO WDL-KN	1	0	DGD
71	14/11/2011	BUS	POLAC WDL-KN	7	0	SLV
72	16/11/2011	CAR,M/CYCLE	WDL TOWN	3	0	DGD
73	16/11/2011	M/CYCLE	GANO WDL-KN	2	0	WOV
74	18/11/2011	BUS	GANO WDL-KN	6	0	SLV
75	23/11/2011	M/CYCLE	WDL TOWN	1	0	DGD
76	26/11/2011	N/A	J/ALI WDL-KN	1	0	DGD
77	28/12/2011	CAR,M/CYCLE	J/ALH. ADO WDL-KN	2	0	DGD
78	31/12/2011	CAR,BUS	J/GANO WDL-KN	10	0	SLV

Table A 8 Accident Data for Year 2012

S/N	Date	Vehicle type	Location	Injury	Fatality	Cause
1	01/01/2012	CAR,M/CYCLE	GANO WDL-KN	0	1	DGD
2	03/02/2012	BUS	GANO WDL-KN	11	0	DGD
3	17/02/2012	CAR,BUS	J/GANO WDL-KN	13	0	SLV
4	08/03/2012	CAR,M/CYCLE	K/BABALE WDL-KN	5	0	SLV
5	16/03/2012	CAR,BUS	GANO WDL-KN	4	0	SLV
6	18/03/2012	CAR	G/DAU WDL-KN	1	0	DGD
7	22/03/2012	CAR,BUS	WDL BRIDGE	6	0	DGD
8	24/03/2012	2 CARS	J/GANO WDL-KN	0	0	DGD
9	25/03/2012	BUS,M/CYCLE	FRSC GATE	1	0	DGD
10	28/03/2012	TANKER,TRAILER	YARGAYA WDL-KN	3	0	DGD
11	08/04/2012	BUS	J/GANO WDL-KN	3	0	SLV
12	14/04/2012	2 CARS	ZOGARAWA WDL-KN	1	0	DGD
13	16/04/2012	CAR	HADEJIA RIVER BASIN WDL-KN	6	0	DGD
14	19/04/2012	N/A	WDL TOWN	3	0	DGD
15	20/04/2012	CAR	MAKOLE WDL-KN	3	0	SLV
16	21/04/2012	N/A	POLAC WDL-KN	0	1	SLV
17	21/04/2012	M/C	WDL BRIDGE	1	0	DGD
18	26/04/2012	CAR	MAKOLE/WDL-KN	0	1	WOV
19	04/05/2012	CAR	J/GANO/WDL-KN	7	0	SLV
20	07/05/2012	BUS, TRUCK	GWAN-GWAN/WDL-KN	0	1	SLV
21	13/05/2012	CAR	POLAC/WDL-KN	2	0	TBT
22	13/05/2012	BUS, M/C	MAKOLE/WDL-KN	2	0	SLV
23	18/05/2012	BUS, TRUCK	POLAC	8	0	SLV
24	23/05/2012	CAR	N/A	2	0	SLV

Table A 8 Accident Data for Year 2012 (continuation)

25	24/05/2012	BUS,CAR	WDL JUNCTION	2	0	DGD
26	30/05/2012	CANTER	N/A	11	0	DGD
27	02/06/2012	M/CYCLE	G/DAU	2	0	SLV
28	05/06/2012	2 CARS,BUS	N/A	3	0	SLV
29	07/06/2012	TRAILER	POLAC WDL-KN	0	1	SLV
30	11/06/2012	M/CYCLE	MAKOLE	2	0	DGD
31	22/06/2012	P/UP,TRAILER	GANO WDL-KN	11	1	DGD
32	23/06/2012	2 CAR	T/COLLEGE WDL WDL TOWN	3	0	SLV
33	28/06/2012	2 CAR,BUS	G/DAU WDL-KN	10	0	SLV
34	29/06/2012	BUS,M/CYCLE	M/PARK WDL-KN	1	0	DGD
35	30/06/2012	BUS	ZOGARAWA WDL-KN	4	0	SLV
36	05/07/2012	BUS	WDL-BRIEDGE	1	0	SLV
37	07/07/2012	2 CAR	WDL-BRIEDGE	1	0	SLV
38	12/07/2012	CAR,M/CYCLE	GANO WDL-KN	1	0	SLV
39	15/07/2012	CAR	K/GARKO WDL-KN	0	0	DGD
40	20/07/2012	BUS,2 M/CYCLE	WDL-BRIEDGE	1	0	DGD
41	20/07/2012	CAR,M/CYCLE	GIDAN TAKARDA WDL-KN	0	0	DGD
42	23/07/2012	BUS,CAR	ZOGARAWA WDL-KN	8	0	WOV
43	24/07/2012	CAR,BUS	MAKOLE WDL-KN	4	0	SLV
44	25/07/2012	HILUX,JEEP	R/GWANGWAN WDL-KN	2	0	DGD
45	02/08/2012	M/C	POLAC	3	0	SLV
46	05/08/2012	CAR	MAKOLE	3	0	DGD
47	05/08/2012	3BUS, CAR	GANO/WDL-KN	5	0	WOV
48	08/08/2012	ACCORD	POLAC	6	0	WOV
49	11/08/2012	N/A	GANO	25	1	DGD
50	18/08/2012	N/A	GACHI	4	0	SLV
51	20/08/2012	TYT	KONAR G/ALI	7	5	WOV/SLV

Table A 8 Accident Data for Year 2012 (continuation)

52	24/08/2012	CANTER	GADAR JANNA	16	1	SLV
53	26/08/2012	CANTER	POLAC	5	0	SLV
54	02/09/2012	HIACE	KA0N	16	1	TBT
55	10/09/2012	HIACE	500M AFTER	11	0	SLV
56	22/09/2012	P/UP	DA0	2	1	SLV
57	22/09/2012	M/CYCLE	WUDIL BRIDGE	3	0	SLV
58	22/09/2012	M/CYCLE	H/JAMA'ARE	2	0	SLV
59	23/09/2012	GOLF	DARKI	8	1	LOC
60	23/09/2012	CAMRY	GANO	16	1	DGD
61	24/09/2012	N/A	POLAC	3	1	LOC
62	24/09/2012	CANTER	NEAR GAYA	6	1	WRONG PARKIN G
63	26/09/2012	N/A	UTAI BEND	5	0	TBT
64	29/09/2012	HIACE	KANYAR	12	1	SLV
65	30/09/2012	GOLF	KWANAR GOGORADO	6	0	SLV
66	06/10/2012	CIVIC	GADAR JANNA	11	0	SLV
67	14/10/2012	TYT	POLAC	3	2	DGD
68	17/10/2012	LITEACE	JIGAWAR GANO	3	1	TBT
69	18/10/2012	HIACE HIACE	KWANAR GARKO	32	0	SLV
70	19/10/2012	BUS	SHAGOGO	15	0	TBT
71	19/10/2012	LITEACE	OPP STADIUM WDL	30	3	DGD,SLV
72	23/10/2012	STARLET	POLAC	3	0	DGD
73	25/10/2012	M/CYCLE	FRSC GATE	3	0	DGD
74	01/11/2012	GOLF	KANYAR UTAI	6	0	DGD
75	01/11/2012	HIACE	GARIN DAU	12	0	SLV
76	02/11/2012	TANKER GOLF	WUDIL BRIDGE	7	0	TBT
77	08/11/2012	TIPPER	NEAR POLAC	3	0	SLV
78	08/11/2012	M/CYCLE	GARIN DAU	3	0	SLV
79	16/11/2012	LITEACE	JIGAWAR GANO	14	0	TBT
80	17/11/2012	CIVIC	H/JAMA'ARE	4	0	WOV
81	19/11/2012	SIENNA	KANYAR UTAI	10	0	WOV
82	22/11/2012	CANTER	KWANAR LAMIRE	15	0	MDV
83	27/11/2012	HIACE	NEAR POLAC	12	0	DGD
84	29/11/2012	CIVIC	GANO	6	1	DGD

Table A 8 Accident Data for Year 2012

85	06/12/2012	COROLLA	NEAR YAR'GAYA	9	0	WOV
86	08/12/2012	N/A	OPP WDL LG SEC	2	0	WOV
87	14/12/2012	MAZDA	MAKOLE	5	1	WOV
88	14/12/2012	FORD	GANO BEND	12	0	DGD
89	17/12/2012	M/CYCLE	FRSC GATE WDL	3	0	DGD
90	22/12/2012	VECTRA	MAKOLE	19	0	WOV
91	23/12/2012	ACCORD	MAKOLE	3	0	SLV
92	23/12/2012	SPACE RUNNER	GIDAN KAYA	3	0	OLV,SLV
93	26/12/2012	SHARON	'YAN TUKWANE	20	0	WOV

APPENDIX B

Traffic Volume Count

Table B 1 Manual Traffic Count for Kano- Maiduguri

MANUAL TRAFFIC COUNT SHEET				
Road section	Kano-Wudil			
Date	27-06-2013			
Weather	Partly cloudy			
Observer	Ibrahim Khalil			
Direction	Kano-Maiduguri			
Time	Vehicle	Tally	Total	Percentages
8-9	Cars		496	
	Trucks		74	
	Total		570	
9-10	Cars		536	
	Trucks		60	
	Total		596	
10-11	Cars		689	
	Trucks		97	
	Total		786	
11-12	Cars		528	
	Trucks		110	
	Total		638	
12-13	Cars		557	
	Trucks		82	
	Total		639	
13-14	Cars		605	
	Trucks		96	
	Total		701	
14-15	Cars		579	
	Trucks		85	
	Total		664	
15-16	Cars		750	
	Trucks		109	
	Total		89	
16-17	Cars		898	
	Trucks		18	
	Total		1006	
	Cars			
	Trucks			
	Total			

Table B 2 Manual Traffic Count for Maiduguri - Kano

MANUAL TRAFFIC COUNT SHEET				
Road section	Kano-Wudil			
Date	27-06-2013			
Weather	Partly cloudy			
Observer	Ibrahim Khalil			
Direction	Maiduguri-Kano			
Time	Vehicle	Tally	Total	Percentages
8-9	Cars		648	
	Trucks		34	
	Total		682	
9-10	Cars		677	
	Trucks		56	
	Total		733	
10-11	Cars		763	
	Trucks		48	
	Total		811	
11-12	Cars		622	
	Trucks		77	
	Total		699	
12-13	Cars		571	
	Trucks		78	
	Total		649	
13-14	Cars		56	
	Trucks		74	
	Total		730	
14-15	Cars		496	
	Trucks		45	
	Total		541	
15-16	Cars		573	
	Trucks		76	
	Total		636	
16-17	Cars		115	
	Trucks		751	
	Total			
	Cars			
	Trucks			
	Total			
	Cars			
	Trucks			
	Total			

Table B 3 Summary of Manual Traffic Count for Maiduguri - Kano Road

MANUAL TRAFFIC COUNT SHEET					
Road section	Kano-Wudil				
Date	27-06-2013				
Weather	Partly cloudy				
Observer	Ibrahim Khalil				
Direction					
TIME		KAN-MAID	MAID-KAN	TOTAL	% OF TRUCKS
8-9		682	570	1252	
	TRUCK	**34**	**74**	**108**	**8.63**
9-10		733	596	1329	
	TRUCK	**56**	**60**	**116**	**8.73**
10-11		811	786	1597	
	TRUCK	**48**	**97**	**145**	**9.08**
11-12		699	638	1337	
	TRUCK	**77**	**110**	**187**	**13.98**
12-13		649	639	1288	
	TRUCK	**78**	**82**	**160**	**12.42**
13-14		730	701	1431	
	TRUCK	**74**	**96**	**170**	**11.88**
14-15		541	664	1205	
	TRUCK	**45**	**85**	**130**	**10.78**
15-16		649	859	1508	
	TRUCK	**76**	**109**	**185**	**12.27**
16-17		751	1006	1757	
	TRUCK	**115**	**108**	**223**	**12.69**

APPENDIX C

Rating of Temporary Traffic Control Devices

Table C 1 Advance Warning Signs

ELEMENTS	**REQUIREMENTS BY MUTCD**	**Score**
Shape	Diamond	0
Size	1.2m X1.2m	1
Height	≤ 2.1m	1
Color	Black on orange background	0
Illumination and retro-reflectorizing	All signs used during hours of darkness shall be made of retro-reflective material or illuminated	0.5
Night Visibility	Excellent	0.5
Distance from hazard	450m	0.8
Spacing between signs	150m	1
Number	3	1
Lateral offset	1.8-3.6m	0.8
Sign placement	All Signs should be placed at the right of the road except stated otherwise	0.8
Legends height (H)	15cm	1
Legends Width	-	1
Spacing between words(cm)	1.5times H	0.8
Grade		10.2

Total Grade = 10.2

Number of scored elements = 14

Score = 10.2*10 /14 = 7.3

Table C 2 Channelizing Devices

DEVICE	PROPERTY	Score
Traffic cone	Color	1
	Height	1
	Material	1
	Stability	1
		4
Barricades	Diagonal stripes	0.8
	Adequacy	0.5
	Spacing between rails	1
	Stability	1
	Upper rail	1
	Stripes	1
	Visibility by road users.	1
	Placement	0.5
	Spacing	0.5
	Maintenance	0
Drums	Height	1
	Width	0.8
	Material	0.7
	Top	0.7
	Maintenance	0
	Markings	0,5
	Ballast	1
	Placement	0.5

Device Score = total score / number of scored items * 10

Table C 3 Channelizing Devices Score

Device	Score	Number of scored elements	Device score	Remark
Barricade	6.8	11	6.6	Above Average
Cone	4	4	10	Excellent
Drums	5.5	8	6	Average

APPENDIX D

Additional Case Study pictures

Figure D 1 Improper Access of users into Work Zone

Figure D 2 Damaged Sign

Figure D 3 Missing Buffer

Figure D 4 Safe Keeping of Equipments After Work

Figure D 5 Posted Speed Limit Through Work Zone

Figure D 6 Dangerous Pedestrian Device

Figure D 7 Transition Zone at Km 7+800

Figure D 8 Transition Zone at 15+025

Figure D 9 Transition Zone at 25+025

Figure D 10 Work Equipment Accident

Figure D 11 Tipper Struck Median and Enters Working Area

Figure D 12 Truck Left Unattended After Accident

Figure D 13 Long Truck Accident

Figure D 14 Accident While Dumping