CAPACITY ANALYSIS OF MOBIL, KPAKUNGU AND TUDUN WADA ROUNDABOUTS IN MINNA METROPOLIS

BY

Anumiri UCHE Princewill

PGD/CIVIL/2009/072

DEPARTMENT OF CIVIL ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

NIGER STATE.

MARCH 2012.

DECLARATION

I hereby declare that this research was wholly and solely conducted by me Uche Princewill Anumiri under the tutelage, supervision and guidance of Dr. P.N. Ndoke, Civil Engineering Department, Federal University of Technology, Minna.

Uche Princewill Anumiri

PGD/CIVILl2009/072

CERTIFICATION

This is to certify that this work being submitted by Uche Princewill Anumiri has not been submitted before by anybody for any purpose. It meets the requirement governing the award of Diploma Degree of B. Eng (Civil Engineering).

Dr. P.N. Ndoke — Signature/Date

Project Supervisor

Prof. S. Sadiku — Signature/Date

HOD Civil Engineering

Prof M S Abolarin — Signature/Date

Prof (Mrs) S.N. Zubairu — Signature/Date

Dean Postgraduate School

External Supervisor — Signature/Date

DEDICATION

This project is dedicated to GOD ALMIGHTY for His grace, guidance and protection upon me throughout my stay as a post graduate student in F.U.T Minna. I also dedicate this work to my grand mum who past on early this year and my family members.

ACKNOWLEDGEMENTS

First and foremost, I express my heart warming gratitude to my GOD ALMIGHTY, for His protection and guidance in my life and making this work come through. I would like to use this opportunity to thank my supervisor Dr. P.N. Ndoke for his guidance, support and supervision throughout the research work.

I also want to thank the Head of Department Civil Engineering in the person of Dr. S. Sadiku. In addition I wish to thank Prof. O.D. Jimoh, Dr.J I Aguwa, Dr. T.Y. Tsado, Engr. R Adesiji, Engr. S.F. Oritola, Engr. B. Alhaji, Mrs O.A Gbadebo and others I fail to mention.

I would like to appreciate some of my college for their support throughout the programme, Lukeman Suleman, Clara, Joel, Joseph, Idowu, Mr. Sani Adeneyi, Mr. Reuben Azeal K and special thanks to all my friends for their encouragement.

Lastly I wish to thank my parents: Engr and Mrs Anumiri and my siblings for their supports and prayers throughout the programme and that I love them all.

ABSTRACT

This research addresses the most important element of operational performance of Mobil roundabout, Kpakungu roundabout and Tudun Wada roundabout: capacity analysis. The relationship between a roundabout performance measure and capacity is often expressed in terms of degree of saturation (demand volume-capacity ratio). For Kpakungu roundabout which comprises of Bida road, Dutsenkura road, Barkinsale road and Soje A road. Their entry volumes (vehlhr) are as follows: 990, 289, 711 and 234 respectively. Their capacities (vehlhr) are as follows: 779, 546, 764 and 535 respectively. Their control delay (sec/veh) is as follows: 710,46.0,32.0, and 0.6. Their level of service (LOS) is as follows: E, D, D, and B. For Mobil roundabout which comprises of Bosso road, Tunga road, Hospital road and Market road. Their entry vehicles (vehlhr) are as follows: 990, 789, 511 and 234 respectively. Their capacity (vehlhr): 779, 646, 564 and 335 respectively. Their control delay: 17.0, 56.0, 42.1 and 0.6. Their level of service (LOS): E, D, D and B respectively. For Tudun wada roundabout, which comprises of Mobil road, Chanchaga road, Radio.Niger and David Mark road? Their entry vehicles (vehlhr) are as follows: 940,249,621 and 334 respectively. Their capacities (vehlhr): 722, 446, 564 and 490 respectively. Their control delay: 61.0, 36.0, 22.0 and 13.0 respectively. Their level of service (LOS): E, D, D and C respectively. Based on this project a lot was achieved from the research, the physical layout of the entry the roundabout such as the entry width, inscribed diameter appeared to affect its performance and in addition car parks for commercial vehicles should be created at a far distance from the major road in order to reduce traffic delays at Mobil, Kpagungu rounabout and also expansion of the road for pedestrians.

TABLE OF CONTENTS

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Rotaries are reliable means of controlling transportation networks. It is said to be a point where two or more road network intersect, which provides an area for cross movement of vehicles. A service and manufacturing industries require efficient and reliable transportation system to move workers and connect production facilities to the logistics chain.

Nevertheless, classification of intersections can be based on the number of intersecting roads (arms) as 3-way, 4-way, 5-way and 6-way intersections. Also other methods of classification of intersection are by traffic control, it can be classified as; uncontrolled intersection (without sign or signals) and controlled intersection (with sign orland signals).

Roundabout has been used successfully throughout Europe, America, Asia, and in Nigeria. This is done mostly to reduce accident, traffic delays, air pollution, fuel consumption and also the capital needs to be put into consideration too. In the western world it has been used to control traffic in residential areas. It's been said to be one of the safest design models.

Urban cities abroad invest huge amount of capital in order to provide good road network that is highly efficient and can be self-controlled in an orderly manner. A well-organized management with a narrow street will be far more efficient than a wider road without a well thought and effective traffic control at intersection.

This is a step to provide a roundabout system that can be linked to various part of the city to act as a medium to move people and goods efficiently. This system requires coordination, planning and commitment, building cost will be reduced when compared with traffic signals and traffic controllers pay. The early applications of roundabouts failed and as a result roundabouts were rebuilt to a signal intersection as a result of poor capacity estimation and bad accident experiences. Some researches explained that the failures occurred because roundabout s was originally designed to merge and weaving maneuvers at relatively high speeds and this requires large diameters. As a result, the merge distance is very short for the speed and the traffic volume. The high-speed operations and the short distance were too difficult for drivers to maneuver safely.

The capacity of a road way at intersection is bound to improve if a roundabout is able to serve its expected demand. A roundabout assists in the reduction of traffic congestions, self-control traffic, vehicle crashes and the rate of accident. Rotaries are usually created with at least 3 to 4 intersecting road, then the intersecting point can be designated as a rotary or a roundabout.

The objectives of a roundabout are to give priority to safe and free flow traffic at intersection and safe road user from accident. A roundabout should not necessarily be too small or at close intervals. In areas of traffic management, the lack of acceptance can generally be attributed to the problem encountered with traffic in roundabout is built at about 60-70 years ago. In this case the problems encountered are straight entrance, high speed and the right of way being granted to .entering vehicles that will try and merge with circulating traffic.

· The advantages of the modern day roundabout help to provide safety to vehicles yielding at entry to circulating traffic. Roundabouts are often located at key areas of the road or cities and it is done to provide vehicle and motor cycles with direct and barrier free route into town centers.

1.2 Statement of problem

The Mobil roundabout of Minna-Niger state connects four intersecting road which are the bosso road, tunga road, hospital road and market road. The bosso road and the tunga road is mainly a dual or double carriage-way with the carriage-way possessing two lanes while the hospital road and market road is a single carriage-way with each possessing a single lane.

The mobile roundabout possesses no traffic signals or traffic controllers, the roundabout is mainly filled with traffics by taxicab, motorcycle and private car, also the bus, truck and other heavy duty vehicles are less dominant. The state of the road at Mobil is very poor, unmanageable volume of traffic, operating at capacity and as a result of this it makes an unsafe driving condition and difficulty in movement at peak hour.

The kpakungu roundabout of Minna-Niger state is a roundabout that connects four intersecting roads; Barikin Sale road, Dutse Kura, Suleja road and Bida road. The barikin sale road and dutse Kura road are classified into dual or double carriage-way with the carriage-way possesses two lanes. The bida and suje A road is a one or single lane carriage-way with each possessing one lane traffic. The kpakungu roundabout has low traffic control as a result of no traffic signal or traffic controllers or officers, the traffic situation at the roundabout consist of the presence of motorcycle, taxicab, buses and private cars, medium and heavy duty vehicles travelling out of Minna metropolis to the south western part of the country such as Ilorin, Lagos etc.

The Tudun Wada roundabout is situated at the commercial nerve point of Minna Metropolice, it consist of four(4) exit points which two of it is a dual carriage way (i.e. the Mobil round and the Chanchaga road) and the remaining two are single carriage way(i.e. the, David mark road and the radio Niger road). These areas consist of banks, bottling companies and a market place situated closed two the roundabout.

Some of the problems related to capacity of roundabouts are:

i. Necessarily geometric features of roundabouts such as flare and apron do not exist.
ii. In some roundabouts, there are visibilities problems caused by plants or elevated masonry. This causes the entering driver to hesitate on entering the circulating traffic; affecting the capacities of the roundabouts.
iii. Roundabouts' central islands are accessed by pedestrians.
iv. Absence of road marking signs and lights.

These and other inadequacies of the junctions result in a low level of capacities leading to traffic congestion. This study is carried out to evaluate the capacities of roundabouts in Addis Ababa and if possible to establish bases for further studies.

1.3 Aim and Objectives

The purpose of this research is to compare the capacity analysis of traffic flow at roundabout in Minna metropolis.

The objectives are stated as follows;

i) Evaluate the delay of traffic at the 3 selected roundabouts.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 History of Highway

The greatest systematic road builders of the ancient world were the Romans, who were very conscious of the military, economic and administrative advantages of a good road system. The Romans drew their expertise mainly from the Etruscans - particularly in cement technology and street paving - though they probably also learned skills from the Greeks (masonry), Cretans, Carthaginians (pavement structure), Phoenicians, and Egyptians (surveying). Concrete made from cement was a major development that permitted many Rome's construction advances. The Romans began their road-making task in 334BC and by the peak of the empire had built nearly 53,000 miles of road connecting their capital with the frontiers of their far-flung empire. Twenty-nine great military roads via militaries, radiated from Rome. The most famous of these was the Apian Way. Begun in 312BC, this road eventually followed the Mediterranean coast south to Capua and then turned coastward to Benevgentum, where it divided into two branches, both reaching Brundisium (Brindisi). From Brundisium the Appian Way transverse the Adriatic cost to Hydruntum, a total of 410miles from Rome. The typical roman road was bold in conception and construction. Where possible, it was built in straight line from one sighting point to next, regardless of obstacles, and was carried over marshes, lakes ravines and mountains. (Encyclopedia Britannica Article 2008).

With fall of Roman Empire, road building becomes a lost Art. Beginning in 1840's, the rapid development of railroads brought the construction of lightweight Tresaguet - Macadam roads to virtual halts. For the next 60 years, road improvements were essentially confined to city streets or to feeder roads to railroads. Other rural roads become impassable in wet weather. The initial stimulus for a renewal of road building came not from the automobile, whose impact was scarcely felt before 1900, but from the bicycle, for whose benefit road improvement began in many countries during the 1880s and 90s. Nevertheless, while the requirements of lightweight, low speed bicycle were satisfied by the old "Macadamized" surfaces, the automobile began to raise its own seemly insatiable demands as the world entered the ZO" century. Often the building of new roads to alleviate such problems has encouraged further urban sprawl and yet more road travel. To this end, road managers must be concerned not merely with the lines on maps but with number, type, speed and loading of individual vehicles, the safety, comfort and convenience of travelling public and welfare of bystanders and adjoining property owners.

Modern roads can be classified by type or function. The basic type is the conventional undivided two-way road. Beyond this are divided roads, expressways and freeways. An access-controlled road with direct user charges is known as a toll way. In the United Kingdom freeways and expressways are refer4rred to as motorways. Civil engineers continue to research ways of designing and building the most efficient and cost effective roads. New types of road surfacing make roads more durable and easier to construct. Computers play a large role in helping population growth effect road and highway transportation. (Encarta 2008).

ii) Determine the geometric characteristics of the roundabouts.

iii) Identify peak periods through volume studies of the roundabouts.

iv) Determine the traffic volumes of the roundabouts

v) Estimate the capacity of the roundabout.

vi) Based on the results of the analyses, to draw conclusions and recommendation for future considerations during roundabout designs in minna.

1.4 Scope of Work

This research work consists of three phases, which is limited to the improvement to free flow of traffic at rotary intersection. This analysis study covers most of Minna metropolis, which is performed in area as Mobil roundabout, kpakungu roundabout and tudunwada roundabout as case study. Also this achieved by the evaluation of level of service and their capacities using the appropriate formulas.

2.2 Basic Concepts of Roundabouts and Definitions

A roundabout is a channelized intersection at which all traffic moves anticlockwise around a central traffic island. (AACRA Geometric DesignManual, 2003). This definition can be used for traffic circles also because it doesn't mention priority .

Roundabouts are intersections of two or more roads that are made up of a one way-circulating roadway that has priority over approaching traffic. Yield signs control the approaching traffic and the driver can only make a right turn onto the circulating roadway. The only decision the entering motorist needs to make once they reach the yield line is whether or not a gap in the circulating traffic is large enough for them to enter. The vehicles then exit the circulating roadway by making a right turn toward their destination (FHWARD-00-067, 2000). Roundabouts are often confused with traffic circles or rotaries and it is important to be able to distinguish between them. According to FHWA-2000 information guide, roundabouts have five main characteristics that identify them when compared to traffic circles:

1. Traffic control: Yield control is used on all entries at roundabouts. The circulatory roadway has no control.

ii. Priority to circulating vehicles: Circulating vehicles have the right of way in roundabouts. Some traffic circles require circulating traffic to yield to entering traffic.

111. Pedestrian access: Pedestrian access is allowed only across the legs of the roundabout, behind the yield line. Some traffic circles allow pedestrian access to the central island.

IV. Parking: No parking is allowed within the circulatory roadway or at the entries. .Some traffic circles allow parking within the circulating roadway.

v. Direction of Circulation: All vehicles circulate counter-clockwise and pass to the right of the central island of the roundabout. Some neighborhood traffic circles allow left-turning vehicles to pass to the left of the central island. A case in point .can be in countries like In United Kingdom, Japan, India, Australia, New Zealand, South Africa, Kenya, Uganda, Tanzania, Zambia, Zimbabwe, and Malawi. Besides to those five mentioned above, Thaweesak (1998) included additional features of roundabout, which distinguish them from other traffic circles.

Approach Flare: Most roundabout approaches flare out at the entries and allow more vehicles to enter the circulating roadway at a more obtuse angle.

This improves capacity, and allows entering vehicles to enter at similar speeds as the circulating vehicles unless a queue has developed at the entry. The size and angle of the fla~e is generally controlled by a raised traffic island that separates the entering and exiting traffic at an approach. This island also gives pedestrians a safe location to cross the approach in two stages. This is the old English principle and gives high capacity, but low safety due to high speed in some countries.

Deflection: This characteristic is the geometry of the facility that requires vehicles to slow down as they maneuver through the roundabout. The size of the Center Island and angle of approach determine the deflection and potential speeds of entering and circulating vehicles.

Generally, the effect of the roundabout is that traffic is required to slow down to negotiate the curve around the central island, but unlike full stop and signal controlled intersections, vehicles entering a roundabout are not required to stop completely. This makes the facility more efficient under a wide range of traffic volumes, as motorists only need to find an acceptable gap for entrance.

2.3 Development of Highway in Nigeria

The economic development of Nigeria has reflected on the development of her transport systems. This is particularly true if the transport systems which is by far the most widely used mode of transport in the country (Onakomaiya, 1981) of all commodity movement to and from the seaports at least two third are now handled by road transport while 90% of all other internal movement of goods and person takes place by roads. In past, Nigeria has passed through various forms of colonial and post-colonial administrations, each with its own vested interest on different modes of transport. Although, various development programs have been implemented on the basis of some official guidelines or principles of road transport development (Onakomaiya, 1981).

In the past, wheeled transport appears to have been known in Nigeria until the turn of the present century, prior to the arrival of British administration, the dominant mode of overland transportation was by porters and draught animals over bush paths and trails which were, in essence, the easiest line of communication between neighboring settlements (Onakomaiya). The earliest efforts at transport improvement in the north were directed towards the clearing of paths of 10 feet 20 feet (about 3 to 6 meters) wide through the bush. In one case wheeled transport drawn by animals proved a little more expensive than porters, with the seat of the Northern Government Established at Zungeru; a cart road for mule and ox-carts was begun on 1914, for two main reasons.

Firstly, it was hoped that this would "reduce the strain through on the inland provinces in the provision of porters" for the British officials and secondly, that the earth works so created would be suitable for the eventual construction of light railway, Lord Lugard originally want to build the mule road to Zaria and then to Sokoto, Kastina and Maiduguri. However, with the authorization ofBaro-Kano railway in 1907, the efforts of the northern government were concentrated on this railway; the cart-road was abandoned at Tegina, 32 kilometer (20 miles) north ofZungeru (Onakomaiya, 1981).

In the south, where draught animals could not be used owning to tsetse fly, the possibilities of motor transport served was an early stimulus to the building of roads (Onakomaiya 1981). As early as 1903, a super intendent of roads was based in Calabar to begin the survey and construction of road in eastern provinces (from Calabar - Obubra and from Orun - Onitsha, while in the west, roads were built to the railway as it was extended north from Lagos. The railway itself extended its service area by constructing roads from its major stations to neighboring towns (Onakomaiya, 1981).

The first mortorable road in Nigeria was built in 1906 from Ibadan to Oyo which thus became linked by railway - operated road transport service. This was followed by seminar services from Oshogbo to lfe, llesha and Ogbomosho and Ede to Iwo (Onakomaiya, 1981). By the year 1914; there were 3,200Km (2000 miles) of motorable roads in the country.

'Road construction suffered some setback during the First World War and during the construction of Eastern Railway line (PortHacourt - Kaduna). It also suffered some setback during Nigeria Civil War (1967 - 1970). During this period, there was a sharp decline in the implementation of government policy on roads as a result of concentration of all efforts on excessive use by heavy military vehicles and long trailers whose importation was encouraged In order to cope with the back log of export products wanting evacuation by road to the ports owing to the closure of the Eastern railway line and Port of Port Harcourt (Onakomaiya, 1981). In the second national development plan launched immediately after the civil war, the general policy on transport was to promote, and rationalization of investment decisions in the transport sector (Onakomaiya, 1981).

2.4 Modern Roundabouts.

A roundabout is a form of intersection design and control which accommodates traffic flow in one direction around a central island, operates with yield control at the entry point, and gives priority to vehicles within the roundabout (circulating flow).

Figure 2.1 illustrates the basic geometric elements of a roundabout.

Figure 2.1 geometric elements of a roundabout (adapted from aust Road 1993)

Exit Width: The exit width is the perpendicular distance from the right Curb line of the exit to the intersection of the left edge line and the inscribed circle.

Departure Width: The departure width refers to the width of the lanes departing from the roundabout at a point where the width is no longer influenced by the roundabout.

Effective Flare Length: A flare may be used to increase the entry width and capacity of a roundabout by providing additional lanes at the entry. The effective flare length is equal to the distance from the entry width to a pand the approach traveled way width prior to influence from the roundabout.

Entry Radius: The entry radius is the minimum radius of curvature for the compound curve measured along the right curb at entry beginning before the yield line.

Approach Stopping Sight Distance: The approach stopping sight distance is the minimum stopping sight distance to the back of queue or yield line at the roundabout entry..

Circulating Roadway Width: The width of the circulatory roadway depends mainly on the number of entry lanes and the radius of vehicle paths.

2.5 History of Roundabouts

.The first use of the 'roundabout' appeared in the Ministry of Transport and the Town Planning Institute Circular No. 302 in 1929. This circular was the first to give general guidelines for roundabout design. The design allowed a circular or polygon central island shape, depending on the number of legs. The guideline was update? purpose to improve safety. In 1936, Knight and Boddingtons suggested an adaptation to a circular central island, since better performance had been observed.

In the US, the first design guideline for a roundabout (called rotary) was published in 1942 by the American Association of State Highway Officials (AASHO) (Todd 1988). A rotary was defined as an interse3ction where all traffic merges into and merges from a one-way road around a central island. The general concept was that large radii gave long weaving sections, on which both high speeds and high capacities could be maintained. The design was intended for vehicle speeds not less than 25mph *(40kmlh)* and required a central island radius of at least 75 ft (23 m) so that entering vehicles could merge and interweave with those on the circulating roadway. The highest design speed contemplated was 40mph (64 km/h), a speed that required a central island radius of 270ft (82m) ?r more, depending on the super elevation of the circulating roadway.

The 1942 AASHO publication considered the use of rotaries impractical for a total intersection demand above 5000 vehicles per hour. The 1954 and 1965 AASHO 'Blue Books' gave 3000 vehicles per hour as the maximum practical capacity.

In the early roundabout design and operation, roundabouts were operated with weaving sections. There were not set rules for driver behavior at roundabouts and no right of way was given to a particular traffic stream. Later, the "give-way-to-the-right" priority rule was introduced. One main problem of this priority rule was that it created locking within the roundabout. From about 1950, due mainly to the problem of locking and an increasing number of accidents resulting from drivers disobeying the traffic rule, there was a loss of confidence in roundabouts as an effective form of intersection control. Improvements in traffic signals and invention of coordinated traffic signal networks also made roundabouts less preferable and many were replaced. The grid-road network in the US favored the use of coordinated traffic signals. In Germany, roundabout failure was due to a lack of suitable capacity estimatio.n, a high accident rate and congestion due to the misinterpretation of the priority rules.

.In 1996, the survival of roundabouts in the UK was enhanced with the new assigned off-side priority rule (an entering vehicle gives way to circulating vehicles) and the yield-at-entry operation. With this new priority rule, entry was now controlled by the ability of entering drivers to detect gaps in the circulating flow. An entering vehicle simplemerged into any suitable gap in the circulating flow and diverged as it reached the desired exit. This prevented vehicle from entering when no gap in the circulating stream was available, avoiding the locking problem.

Moreover, the capacity of roundabouts was no longer dependent on the waving operation, but on the availability of gaps. This increased both the capacity and safety of roundabouts. Continued improvements based on the priority rule and safety concerns led to the more sophisticated roundabout, now called the modern roundabout.

The success of this modern roundabout provoked a renewal of interest in the use of roundabouts worldwide. Modern roundabouts are reintroduced in France in 1972 and yield at entry imposed in 1983. They were incorporated into the French Highway Code in 1984. More than 1000 locations have been built each year. In Sweden, the new rule was introduced in the mid 1960s. Guidelines on capacity and design for intersections in rural areas were published in 1967 and for urban areas in 1973.

2.6 Importance of Roundabout

The importance of roundabout at intersection is crash reduction. Clearwater Beach, Florida, is the greatest roundabout ever built in the U.S. it carries up to 58,000 vehicles per day and 8,000 pedestrians per day.

There are two basic premises on which roundabouts achieve crash reductions of 50% to 90% when compared to two and four-way stop control and signalized intersections and greatly reduced severity on those few crashes that do occur. One is the simple decision making combined with the low level of conflicts. At a four-way intersection there are 32 possible conflict points between vehicles and only eight at roundabouts. Pedestrians face six conflicts when crossing only one leg of the road whereas at a roundabout they only have two.

2.7 Types of Roundabout

There are two main types of roundabout, namely, conventional and mini roundabout.

2.7.1 Conventional roundabout

A conventional roundabout has a one-way circulatory carnageway around a kerbedisland 4m or greater in diameter, usually with flared approaches to allow several vehicles to enter simultaneously. The recommended number of entry-lanes is usually three or four. Roundabouts are not recommended on dual 3 - lane roads, because a design to provide sufficient junction capacity would probably require a very large roundabout indeed: Based on California's Roundabout Design Guideline, it is also known as normal roundabout.

Fig 2.2 Typical example of a conventional roundabout

2.7.2 Mini-Roundabout

A mini-roundabout has a one-way circulatory carnageway around a flush, or slightly raised, circular marking less than four metres in diameter, with or without flared approaches. Mini-roundabouts can be effective in improving existing urban intersections that suffer overload or accident problems. Their layout should be designed so that drivers are made aware, in good time, that they are approaching a roundabout. They should only be used where all the approaches are subject to a speed - limit of *30km/h* or less.

Fig 2.3Typicai example of a mini Roundabout

2.7.3 TurboRoundabout

This roundabout type provides a forced spiraling flow of traffic, thus requiring motorist to lose their direction before entering the roundabout. By eliminating many conflicting paths and choice on the roundabout itself, traffic safety is increase as well as speed, and as a result, capacity. A turbo roundabout does not allow traveling a full circle. The basic turbo roundabout shape is designed where a major road crosses road with less traffic. Turbo roundabouts are typically built with raised lane separators. Cheaper implementations with only road makings exist, but hurt the efficiency of the design by enabling user to cheat the system.

Fig 2.4 Turbo Roundabout

2.7.4 Rain Drop Roundabout

This roundabout does not form a complete circle and are in raindrop shape. They are appearing at U.s interstate interchanges to provide a free-flowing left turn to the on-ramps and eliminating the need for turn signals and lanes. Since the on and off-ramps are one way, a complete circle is unnecessary. This means that drivers entering the roundabout from the bridge do not need to yield and prevent queuing on narrow, two-lane bridges.

Fig2.5'Rain drop Roundabout

2.7.5 Signal Controlled Roundabout

Some roundabouts are controlled by traffic lights while it may appear to defy the roundabout system at first, it works well to control the traffic flow on the bridges, which themselves are two viaducts creating a roundabout suspended over the ring road itself. Signal controlled roundabouts have been introduced in an attempt to alleviate problems at over capacity roundabout intersection or to prevent some flows of traffic dominating others.

Fig 2.6 Signal controlled Roundabout

2.8 Features of a Modern Roundabout

These design and traffic control features of roundabouts are as follows:

1. Central Island is a raised island around which traffic flows for further channelization of vehicles paths once within the circulatory roadway.
2. Yield controls used on all entries.
3. Circulating vehicles have the right of way.
4. Pedestrian access is allowed only across the legs of the roundabout, behind the yield liner to the circulatory roadway.
5. Each approach to the roundabout has a splitter island- a raised or painted area or an approach used to separate entering from existing traffic, and to channelize and slow entering traffic.

2.9 Roundabout Criticism

As the flow increases and reaches the capacity, weaving generally give way to a stop and go motion as vehicle as vehicle force their way into the rotary, being followed by vehicle waiting in the queue behind them. Under such condition, vehicle, since having got into the roundabout, may be not be able to get out of it, because of vehicle across their path and roundabout may be lockup.

Once the roundabout has lock up, the movement of vehicle completely stops and the traffic will have to be ultimately sorted out by police. Roundabout cannot accominodate more traffic than a proper designed channelized layout. In some cases, roundabouts have been eliminated and replace with a channelized intersection resulting in better operation. Some have argue that roundabout require more land and may not be feasible in built up areas. It is not readily adaptable to stage development. An attempts at stage development generally result in some over design when view from immediate traffic need.

Because of the large and relatively flat land area required, topographic condition in some localities may make impracticable to develop roundabout intersection, and where provide at close interval are troublesome.

2.10 Major geometric Features of a Modern Roundabout

Since some methodologies (like the UK's - regression capacity analysis) depend totally on roundabout geometric features or elements, it is necessary to identify and clearly' understand the geometric features or elements of roundabout. According to the capacity study of roundabouts in the UK., geometric elements of roundabouts play an important part in the efficiency of roundabouts operational performance. Good geometric design will improve not only capacity but also safety, which is a major concern for road design.

2.11 Design of Roundabout

The three fundamental considerations in roundabout design are design speed, capacity, and design vehicle. These parameters result in a series oftradeoffs; while large-diameter roundabouts may provide higher capacity and better truck accommodation, they tend to reduce safety through higher operating speeds. A maximum operating speed of *40km/h* should be used. Atypical range of 25 to *50km/h* is desirable. Speed control at roundabouts is primarily achieved through the deflection of entering vehicles. Operating speeds should be calculated on a move-by move basis, by drawing the fastest path allowed by the roundabout geometry. The designer develops a speed matrix to illustrate that all speed have been checked and that operating speeds do not exceed the maximum. The design of all roundabouts will accommodate a WB-67 design vehicle. In order to keep operating speeds below the allowable maximum, truck apron may be provided.

Emergency vehicles can generally be accommodated at roundabouts that have been designed for Wb-67 design vehicles. Turning paths are checked using Auto Turn software for all allowed movements from each approach, to verify the design vehicle and emergency vehicles can be accommodated. Transit stops are not to be placed within roundabouts. Transit stops located near roundabouts will include bus turnouts to promote traffic flow and increase safety. (U.S DeOpartment of transport, FHWA, 2000)

Although there are 6 categories of roundabout, the design process for all is essentially the same. All categories of roundabout have the same defining physical characteristics. The six categories of roundabout are:

1. Mini-roundabouts
2. Urban compact roundabouts
3. Urban single-lane roundabout
4. Urban double-lane roundabout
5. Rural single-lane roundabout
6. Rural double-lane roundabout

.According to the United States' Federal Highway Administration (FHWA) the process of designing roundabouts requires a significant amount of iteration among geometric layout, operational analysis, and safety evaluation." With roundabout design and using traditional methods, minor geometric adjustments can result in considerable safety, 'operational, and/or performance alteration.

Before components and the geometry are defined, three fundamental elements that must be resolved:

1. The optimal roundabout size
2. The optimal position for the roundabout
3. The optimal alignment and arrangement of the approach legs (Tran soft solutions, 2009)

2.12 The Geometric Features of Roundabout Designs

.According to the capacity study of roundabouts in the UK, geometric elements of roundabouts play an important part in the efficiency of roundabout operational performance. Good design will improve not only capacity but also safety. Basic elements for design considerations of roundabouts are:

1. Design vehicles

ii. Design speed

iii. Design capacity

iv. Inscribed circle diameter

v. Deflection

VI. Sight distance

vii. Central island

Vill. Circulating width/weaving width

IX.. Entry and exit width

x. Splitter island

Xl. Sight distance

2.13.1 Design Speed

One of the keys to the demonstrated success of roundabouts is the improvement in safety. Roundabouts have very low accident and injury rates. The design speed of roundabouts should be between 25 - *40Km/h*

Table 2 2 Recommended maximum entry design speed

Site Category	Recommended Maximum Design Entry Speed
Mini-Roundabout	25km/hr
Urban Compact	25kmlhr
Urban Single Lane	35km/hr
Urban Double Lane	*40km/hr*
Rural Single Lane	*40Km/hr*
Rural Double Lane	50km/hr

(U.S. Department of transport, FHWA - RD - 00 - 067)

2.13.2 Design Capacity

The capacity of roundabout is directly determined by the capacity of each weaving section. The capacity of weaving section is determine by the geometric layout, including entrances and exits, and percentage of weaving traffic. The transport and research laboratory (U.K) which has pioneer research in this aspect, recommends the following formula, which is a modification of the well known war drop form:

WhereQl' = practical capacity of the weaving section of the roundabout in passenger car unit

w = width of the section in meter (range of 6-18m)

e = average entry width of the roundabout

= [el:e~] (ii)

L = length of weaving section between the ends of the channelizing island meters. (Range from 18-90m and *wll* range 0.12 to 0.4)

P = proportion of weaving traffic, i.e. ratio of sum of crossing streams to the traffic on the weaving section. (Ranges 0.4 to 1.0)

= L+::~+d]-------------------------------- (iii)

In the formula, the equivalency factor for use in rotary design recommended by Roundabout; an information guide stipulated by U.S. department of transport are given in the table below:

Table 2.1: Conversion factors for passenger car unit (PCUs)

SINo	Vehicle Type	PCV
1	Cars	1.0
2	Buses and medium heavy commercial vehicles	1.5
3	Truck with Trailer	2.0
4	Motorcycle and tricycle	0.5

(US. Department of transport, FHWA - RD - 00 - 067)

2.14 Inscribed Circle Diameter

.The inscribed cir4cle diameter is the distance across the circle inscribed by the outer curb (or edge) of the circulatory roadway. It is the sum of the central island diameter (which includes the apron, if present) and twice the4 circulatory roadway. The inscribed circle diameter is determined by a number of design objectives. The designer often has to experiment with varying diameters before determining the optimal size at a given location. The inscribed Circle diameter (lCD) depends on the type of vehicle and deflection required for safe speed.

Table 2.2: Recommended inscribed circle diameter ranges

Site Categories	Design Vehicle	Inscribe Circle diameter ranges
Mini-Roundabout	Single - Unit Truck	13 - 25m (45 - 80ft)
Urban Compact	Single - Unit Truck/Bus	25 - 30m (80 - 100ft)
Urban "Single Lane	WB - 15 (WB - 50)	30 - 40m (100 - 130ft)
Urban Double Lane	WB - 15 (WB - 50)	45 - SSm (150 - 180ft)
Rural Single Lane	WB - 20 (WB - 67)	35 - 40m (115 - 130ft)
Rural Double Lane	WB - 20 (WB - 67)	55 - 60m (180 - 200ft)

(US. Department of transport, FHWA - RD - 00 - 067)

2.15 Conditions of Highway

Three conditions of highway facility can be defined as follows:

1. Roadway Conditions

This refers to the geometric characteristics of the street or highway, including the type of facility and its development environment, the number of lanes, lane and shoulder width lateral clearances, design speed, and horizontal and vertical alignments.

2. Traffic Conditions

This refers to the characteristics of the traffic stream using the facility. This is defined by the distribution of vehicle type in the traffic stream, and the directional distribution of traffic.

3 Control Conditions

This refers to the type and specific design of control devices and traffic regulations present on a given facility.

2.16 Level of Service

The concept of level of service is defined as a qualitative measure describing operation conditions within a traffic stream, and their perception by motorist and or passengers. Six levels of service are defined for each facility for which analysis procedures are available which are represented from A - F (HCM, 1995).

1. Level of Service A

This represents free flow. Individual users are virtually unaffected by the presence of others in the traffic stream, freedom to select desired speed and freedom to maneuver.

2. Level of service B

This is the range of stable flow, but the other users presence in the traffic stream begins to noticeable. Freedom to select desired speeds is relatively unaffected, but there is a slight decline in the freedom to maneuver within the traffic stream from LOS A.

3. Level of Service C

This is also the range of stable flow, but marks the beginning of the range of flow in which the operation of individual users becomes significantly affected by interactions with others in the traffic stream. The general level of comfort and convenience decline noticeably at this level.

4. Level of service D

This level represents high-density, but stable flow. Speed and freedom to maneuver are severely restricted, and the driver or pedestrian experiences generally poor level of comfort and convenience.

5. Level of Service E

This level represents operating conditions at or near the capacity level. All speeds are reduced to a low, but relatively uniform value,. Freedom to maneuver within the traffic stream is extremely difficult, and is generally accomplished by forcing a vehicle or pedestrian to "give way" to accommodate such maneuvers. Comfort and convenience levels are extremely poor, and driver or pedestrian frustrating is generally high. Operation at this level is unstable, because small increases in flow within the traffic stream will cause break-downs.

6. Level of Service F

This is used to define force or breakdown flow. This condition exists wherever the amount of traffic approaching a point exceeds the amount, which can traverse the point. Operation with the queue are there is characterized by stop and go waves, and they are extremely unstable. Policemen interfere with the traffic flow to clear the facility. This level is described as the worst.

2.17 Control Delay

Total delay, also called control or overall delay, is defined as the additional time that a driver has to spend at an intersection when compared to the time it takes to pass through the intersection without impedance at the free flow speed.

This additional time is the result of the traffic signals and the effect of other traffic, and it is expressed on a per vehicle basis. In estimating delay at signalized intersections, stochastic steady - state and deterministic delay models are used for under-saturated and oversaturate3d conditions, respectively. Neither model, however, deals satisfactorily with variable traffic demands. Stochastic steady - state delay models are only applicable for under-saturated conditions and predict infinite delay, when the arrival flow approaches the capacity. When demand exceeds the capacity, continuous overflow delay occurs. Deterministic delay models can estimate continuous oversaturated delay, but they do not deal adequately with the effect of randomness when the arrival flow is close to the capacity, and they fail for degrees of saturation between 1.0 and 1.1. Consequently, the stochastic steady state models work well when the degree of saturation is less than 1.0.and the deterministic steady state models work well when the degree of saturation is 1.0 for which the later model predicts zero delay, while the former model predicts infinite delay.

These dependent delay models, therefore, fill the gap between these 2 models and give more realistic results in estimating the delay at signalized intersections.

They are derived as a mix of steady - state and the deterministic models by using the coordinate transformation techniques described by Kimber and Hollis (1978, 1979) here, the coordinate transformation is applied to the steady - state curve to make it asymptotic to the deterministic line. Thus, time dependent delay models predict the delay for both under saturated and oversaturated conditions within having any discontinuity at the degree of saturation 1.0

Table 2.3 describes the amount of delay associated with each level of service

Delay (seconds)	Level of Service
0-10	A
10 - 15	B
15 - 25	C
25 -35	D
35 - 50	E
>50	F

2.18 Global Road Signs

1. Movement within a roundabout in a country where traffic drives on the left. Note the clockwise circulation.

2. Road sign before a traffic circle in the U.S. (right-hand traffic) - A similar sign is used in the Republic ofIreland (with directions reversed).

3. Road sign for a roundabout in Germany (right-hand traffic). In the UK this symbol (with the arrows reversed) is used at mini roundabouts.

4. Traffic sign to identify a roundabout in the UK (left-hand traffic).

5. Give way sign at a roundabout in Australia (left-hand traffic).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of Project Area.

The project area is situated at Minna-Niger state which is the state capital. The local government areas to be considered are the Chanchaga Local Council and Kpakungu Area Council.

The project is been divided into three roundabouts which are the Mobil, Kpakungu and Tudun Wada roundabout which are located in Minna Niger-state, which is at the north central of the federal republic of Nigeria.

The Mobil roundabout is located at the central business area of minna metropolis. It has 4 legs, which three of the legs are dual or double carriage way and one a single carriage way. Two of the dual carriage roads link to bosso and Chanchaga or Tunga, while the third dual carrage Leeds to the hospital or Keterengwarri and the single lane Leeds to the central market. This roundabout has so much commercial activities taken place as a result of the market, shopping complex, petrol station, banks and Motor Park around the area.

The Kpakungu roundabout is located at the western bypass in minna suburbs, the roundabout has 4 legs, of which two of it is a dual carriage way which Leeds to Dutsenkura and to Barkisale and the other two which is a single carriage Leeds to Bida and to Soje A. this roundabout is also a busy area, this is as a result of the schools, police station, pure water industries, supermarkets around the roundabout.

The Tudun Wada roundabout is located along the central business area in Minna Niger State, it has 4 legs, two legs are dual carriage way which leads to Mobil and Paiko road and the other two is a single carriage way which leads to David Mark Road and Shirroro Road. Some commercial activities that can be found around this area are banks (Guaranty Trust Bank, Access Bank), Market and Niger state News line.

Fig 3.0: Road map of minna.

3.2 Data Collection

A study design was done and the appropriate methodology for the study's objectives were established, based on the relevant literature and various forms of analysis that have been done by similar studies.

This requires the collection of data passing the early approach. The following objectives have been taken into consideration in order to achieve the stipulated objectives. To achieve the appropriate time for data collection, a competent team of observers should be available in order to adopt a viable method of data collation and for proper analysis. Also geometric data of each rotary intersect were collected from various location and a material was collected from Niger State Ministry of works and infrastructure for comparism and an informational guide stipulated by the us department of transportation.

The data collected at the roundabout are of two types namely

i) Geometric layout data

ii) Traffic operation data (volume count)

3.3 Geometric Layout Data

The geometric layout data is related to the actual measurement of diameter of the central island, width of the wearing section (w), length of the wearing section and average entry width (e) the measurement was taken directly onsite.

3.4 Traffic Operation Data

The mode of operation was a manual method which was used to achieve the vehicle count in the traffic volume. About ten fields personal were available to achieve this result, the personals took hourly interval of vehicle from 7:00am-8:00pm everyday for a period of one week usually, and the manual pattern of counting vehicle can cause delay of data and about 15 minute count for each hour.

The red and green indicate the use of stop watch to record data's of vehicles at a static or stop position waiting for cars at the roundabout to be cleared to represent the red while that of the moving vehicles represent green time.

This analysis was carried out for 15 minute at every arm of the road simultaneously from morning and the evening peak period. The data's obtained are been analyzed in tables in chapter 4.

Table 3.1 Geometric parameter of Kpakungu Roundabout.

Approach Roads	Entry with (m)	Exit width (m)	Entry radims	Exit radims	Approach width (m)	Departure width (m)	Inscribed diameter (m)
Kpakungu to dutsekura	9.3	9.3	15	18.3	8.3	8.3	45.3
Dutsekura to kpakungu	9.3	9.3	15	18.3	8.3	8.3	45.3
Bida to soje A	8.3	8.3	10.1	20.1	7.2	7.2	45.3
Suje A to Bida	7.3	7.3	10.9	18.1	7.2	6.3	45.3

Table 3.2 Geometric parameter of Mobil roundabout.

Approach Roads	Entry width (m)	Exit width (m)	Entry radims	Exit radims	Approach width (m)	Departure width (m)	Inscribed diameter (m)
Tunga to Bosso	7.5	13.6	10.9	18.3	7.2	8.3	45.3
Bosso to tunga	7.5	13.6	10.1	18.3	7.2	8.3	45.3
Hospital road to market	3.0	13.6	15	20.1	8.3	7.2	45.3
Market to hospital road	3.0	13.6	15	18.1	8.3	6.3	45.3

Table 3.3 Geometric parameter of tudun wada roundabout.

Approach Roads	Entry with (m)	Exit width (m)	Entry radims	Exit radims	Approach width (m)	Departure width (m)	Inscribed diameter (m)
David mark road to roundabout	7.3	7.3	10.9	18.1	7.2	6.3	45.3
Radio Niger to Roundabout	8.3	8.3	10.1	20.1	7.2	7.2	45.3
Mobil to Tunga	7.3	7.3	15	18.3	8.3	8.3	45.3
Tunga' to Mobil	7.3	7.3	15	18.3	8.3	8.3	45.3

3.5 Traffic survey.

This aspect provides the essential technical data required for the design of highway facilities failure to obtain this information may lead to false assessment of the required traffic characteristics in this case.

It also considers areas such as transportation planning process that seeks to information on traffic volume, vehicle speed, accident records, pedestrian movement, and traffic congestion (density) nature of parking and various aspect of vehicle performance. This project is limited to traffic volume survey in order to project the volume of traffic the roundabout can accommodate after re-design.

3.6 Calculations of entry and conflicting flow by lane.

The Barikin sale Mobil road entry (V 1+ V8+ V9) the confliction flow would be equal to v l + v2+ v1O. This method can be extended to roundabouts with more than four legs. In addition, roundabouts are often used to facilitate U-turns, and these may be readily included in the flow calculations.

It is very important to convert the intersection turning movements (volumes vI to vI2 as shown in figure 3.3 below) into entry and circulating flows. For example, the conflicting traffic for the entry comprising streams 7, 8 and 9 are streams 1,2 and 10.

3.7 Determination of inscribed circles diameter

The inscribed circle diameter is the distance from the circle inscribed by the outer curb (or edge) of the circulatory roadway, it is the sum of the central island diameter (which includes the apron ifpresent) and twice the circulatory roadway.

The circumference with reasonable entry and exit recommended inscribed circle diameter ranges tables. Based on the site category a typical design vehicle size, should consider existing approach roads and existing roundabout. It was determined to be 48m.

3.8 Speed Analysis at the Roundabout

The operating speed of typical vehicles approaching and negotiating this roundabout was determined manually by taking the time required for a vehicle to approach and negotiate the roundabout under study.

It has profound impacts on safety; achieving appropriate vehicle speed through the roundabout is the most critical design objectives. A well design roundabout reduces the relative speed between conflicting traffic streams by requiring vehicles to negotiate the roundabout along a curved path.

The operating speed at this roundabout of study was purely observed for one week, but the daily period is the time interval of link kilometer per hour. The data obtained during the practical work were recorded and computed statistically. The graph of data obtained was plotted in order to investigate the behavior of the vehicle or nature of traffic flows at the roundabout.

A graph was plotted as speed *(km/h)* against distance from the center (m), from the graph it was observed that at 20m from the center of the roundabout the speed was 2.8krnlh, at 40m it increases to *3.5km/h* etc, from this observation it implies that vehicles reduces its speed when it gets closer to the roundabout. Therefore the entry speed was determined to be *3.2km/h.*

3.9 Recommended inscribed circle diameter ranges

Table 3.3: Inscribed circle diameter ranges

Site category	Typical design vehicle	Inscribed circle diameter range
Mini - roundabout	Single-unit truck	13 - 25m
Urban compact	Single-unit truck/bus	25 -30m
Urban single lane	WB - 15 (WB-50)	30-40m
Urban double lane	WB - 23 (WB-50)	45 -55m
Rural-single lane	WB - 20 (WB - 67)	35 -40m
Rural double lane	WB - 20 (WB - 67)	55 -60m

Therefore the inscribed circle diameter was chosen to be 48m and angle between the entries to be 90.

3.10 Roundabout Capacity Evaluation

The performance measures such as delay, queue length and stop rate depends on the capacity of the roundabout. The relationship between a given performance measure

Table 4.16 Hourly traffic volume distribution, along Soje A to Kpakungu.

Time	Bikes	private car	taxi cab	Buses	Truck	Volume
07:00	91	21	-	9	1	122
08:00	104	19	-	13	7	144
09:00	117	32	-	17	3	169
10:00	121	29	-	8	-	158
11:00	113	18	-	13	-	141
12:00	107	13	-	10	-	130
13:00	87	16	-	5	3	111
14:00	69	10	-	7	2	88
15:00	81	18	-	12	4	119
16:00	127	24	-	18	8	177
17:00	.109	17	-	14	-	140
18:00	132	37	-	21	2	192

The result above indicates double peak and a hence good level of service and good operating performance. And it has a capacity of 345veh/hr and the degree of saturation of 0.30 (30% saturation). This value is below design saturation of modern roundabout approach and is under-saturated. The approach control delay is 13sec/veh and its queue length is 3veh. Suja A road is operates at LOS B. The result above is indicates that, the heavy traffic flow in the roundabout are from barikin sale, dutse kura and bida road.

,

Table 4.17 showing conflicting traffic from Bosso to Mobil at peak hours.

Time	Turning Traffic	Bikes	private car	taxi cab	Buses	Truck	Volume'
08:00	LT	250	140	128	8	-	526
	TH	563	180	135	18	2	898
	RT	523	172	134	10	-	839
09:00	LT	400	145	110	6	-	661
	TH	721	186	118	12	1	1038
	RT	702	175	112	9	-	998
10:00	LT	541	120	101	15	1	778
	TH	820	135	110	14	1	1081
	RT	620	132	109	12	-	873
11:00	LT	618	122	97	8	-	845
	TH	750	123	107	17	2	999
	RT	732	125	107	12	3	979
16:00	LT	607	41	66	8	-	722
	TH	668	102	66.	13	-	849
	RT	650	97	66	10	-	823
17:00	LT	649	81	94	10	-	834
	TH	673	99	93	11	4	880
	RT	673	120	93	9	0	895
18:00	LT	800	92	73	10	0	975
	TH	878	96	92	10	3	1079
	RT	874	91	91	4	0	1060

Table 4.18. Showing conflicting traffic from market road to Mobil at peak hours.

Time	Turning Traffic	Bikes	private car	taxi cab	Buses	Truck	Volume
08:00	LT	19	258	166	10	-	453
	TH	19	2	-	13	1	35
	RT	193	21	75	16	-	295
09:00	LT	38	244	120	8	-	410
	TH	1	2	-	-	-	3
	RT	340	66	149	5	-	560
10:00	LT	42	211	76	14	-	343
	TH	2	1	1	-	-	4
	RT	357	69	129	17	-	572
11:00	LT	111	146	B9	33	-	429
	TH	114	1	-	2	-	117
	RT	231	146	104	7	-	488
16:00	LT	180	200	56	9	-	445
	TH	3	6	2	2	-	13
	RT	321	180	323	19	4	847
17:00	LT	134	81	104	1	-	320
	TH	2	7	4	-	-	13
	RT	350	227	178	21	-	776
18:00	LT	260	167	147	38	-	612
	TIl	2	2	-	-	-	4
	RT	210	179	144	4	3	540

Table 4.19. Showing conflicting traffic from chanchaga road to Mobil at peak hours.

Time	Turning Traffic	Bikes	private car	taxi cab	Buses	Truck	Volume
08:00	LT	-	110	2	36	-	148
	TH	105	180	247	33	1	566
	RT	396	1	-	-	-	397
09:00	LT	3	126	40	52	-	221
	TH	371	191	230	2	2	796
	RT	237	-	-	-	-	-
10:00	LT	-	106	52	37	1	196
	TH	574	164	158	4	4	904
	RT	8	9	-	2	-	19
11:00	LT	8	116	86	32	-	242
	TH	268	174	198	1	-	641
	RT	324	-	1	1	-	326
16:00	LT	7	298	75	28	-	408
	TH	665	100	226	1	7	999
	RT	-	-	-	1	-	1
17:00	LT	8	192	49	29	-	278
	TH	195	123	236	8	-	562
	RT	417	-	1	3	-	421
18:00	LT	3	269	63	32	1	368
	TH	243	80	226	1	1	551
	RT	458	9	2	-	-	469

Table 4.20. Showing conflicting traffic from market road to Mobil at peak hours

Time	Turning Traffic	Bikes	private car	taxi cab	Buses	Truck	Volume
08:00	LT	189	18	10	7	-	224
	TH	234	2	-	4	-	240
	RT	233	-	17	2	-	236
09:00	LT	454	8	-	5	-	474
	TH	151	1	I	-	-	152
	RT	150	1	-	2	-	154
10:00	LT	343	10	-	-	-	353
	TH	2	3	-	2	-	7
	RT	90	2	-	-	-	92
11:00	LT	230	12	1	-	1	244
	TH	222	2	-	-	-	224
		223	2	-	1	-	226
	RT	320	12	-	2	4	338
16:00	LT	134	3	-	-	-	137
	TH	200	3	-	-	1	204
	RT	692	18	-	-	-	71
17:00	LT	692	18	-	-	-	710
	TH	8	3	-	-	-	11
	RT	43	2	-	-	-	45
18:00	LT	804	17	4	5	-	830
	TH	213	2	1	6	9	231
	RT	215	2	1	3	-	221

Table 4.21 Showing conflicting traffic from Dutsenkura to Kpakungu at peak hours.

Time	Turning Traffic	Bikes	private car	taxi cab	Buses	Truck	Volume
08:00	LT	250	140	128	8	-	528
	TH	563	180	135	18	2	898
	RT	523	172	134	10	-	839
09:00	LT	400	145	110	6	-	661
	TH	721	186	118	12	1	1038
	RT	702	175	112	9	-	998
10:00	LT	541	120	101	15	1	778
	TH	820	135	no	14	1	1081
	RT	620	132	109	12	-	873
11:00	LT	618	122	97	8	-	845
	TH	750	123	107	17	2	999
	RT	732	125	107	12	3	979
16:00	LT	607	41	66	8	-	722
	TH	668	102	66	13	-	849
	RT	650	97	66	10	-	823
17:00	LT	649	81	94	10	-	834
	TH	673	99	93	11	4	880
	RT	673	120	93	9	0	895
18:00	LT	800	92	73	10	0	975
	TH	878	96	92	10	3	1079
	RT	874	91	91	4	0	1060

Table 4.22. Showing conflicting traffic from Bida to Kpakungu at peak hours.

Time	Turning Traffic	Bikes	private car	taxi cab	Buses	Truck	Volume'
08:00	LT	19	258	166	10	-	453
	TH	19	2	-	13	1	35
	RT	193	21	75	16	-	295
09:00	LT	38	244	120	8	-	410
	TH	1	2	-	-	-	3
	RT	340	66	149	5	-	560
10:00	LT	42	211	76	14	-	343
	TH	2	1	1	-	-	4
	RT	357	69	129	17	-	572
11:00	LT	111	146	139	33	-	429
	TH	114	1	-	2	-	117
	RT	231	146	104	7	-	488
16:00	LT	180	200	56	9	-	445
	TH	3	6	2.	2	-	13
	RT	321	180	323	19	4	847
17:00	LT	134	81	104	1	-	320
	TH	2	7	4	-	-	13
	RT	350	227	178	21	-	776
18:00	LT	260	167	147	38	-	612
	TH	2	2	-	-	-	4
	RT	210	179	144	4	3	540

Table 4.23. Showing conflicting traffic from Soje A to Kpakungu at peak hours.

Time	Turning Traffic	Bikes	private car	taxi cab	Buses	Truck	Volume
08:00	LT	-	110	2	36	-	148
	TH	105	180	247	33	1	566
	RT	396	1	-	-	-	397
09:00	LT	3	126	40	52	-	221
	TH	371	191	230	2	2	796
	RT	237	-	-	-	-	-
10:00	LT	-	106	52	37	1	196
	TH	574	164	158	4	4	904
	RT	8	9	-	2	-	19
11:00	LT	8	116	86	32	-	242
	TH	268	174	198	1	-	641
	RT	324	-	1	1	-	326
16:00	LT	7	298	75	28	-	408
	TH	665	100	226	1	7	999
	RT	-	-	-	1	-	1
17:00	LT	8	192	49	29	-	278
	TH	195	123	236	8	-	562
	RT	417	-	1	3	-	421
18:00	LT	3	269	63	32	1	368
	TH	243	80	226	1	1	551
	RT	458	9	2	-	-	469

Table 4.24. Showing conflicting traffic from Barikinsale to Kpakungu at peak hours.

Time	Turning Traffic	Bikes	private car	taxi cab	Buses	Truck	Volume
08:00	LT	189	18	10	7	-	224
	TH	234	2	-	4	-	240
	RT	233	-	17	2	-	236
09:00	LT	454	8	-	5	-	474
	TH	151	1	1	-	-	152
	RT	150	1	-	2	-	154
10:00	LT	343	10	-	-	-	353
	TH	2	3	-	2	-	7
	RT	90	2	-	-	-	92
11:00	LT	230	12	I	-	1	244
	TH	222	2	-	-	-	224
	RT	223	2	-	1	-	226
16:00	LT	320	12	-	2	4	338
	TH	134	3	-	-	-	137
	RT	200	3	- .	-	1	204
17:00	LT	692	18	-	-	-	710
	TH	8	3	-	-	-	11
	RT	43	2	-	-	-	45
18:00	LT	804	17	4	5	-	830
	TH	213	2	I	6	9	231
	RT	215	2	I	3	-	221

Table 4.25 showing conflicting traffic from Shirorro road to Tudun Wada at peak hours.

Time	Turning Traffic	Bikes	private car	taxi cab	Buses	Truck	Volume
08:00	LT	250	140	128	8	-	526
	TH	563	180	135	18	2	898
	RT	523	172	134	10	-	839
09:00	LT	400	145	LIO	6	-	661
	TH	721	186	118	12	1	1038
	RT	702	175	112	9	-	998
10:00	LT	541	120	LOI	15	1	778
	TH	820	135	110	14	1	1081
	RT	620	132	109	12	-	873
11:00	LT	618	122	97	8	-	845
	TH	750	123	107	17	2	999
	RT	732	125	L07	12	3	979
16:00	LT	607	41	66	8	-	722
	TH	668	102	66	13	-	849
	RT	650	97	66	10	-	823
17:00	LT	649	81	94	10	-	834
	TH	673	99	93	11	4	880
	RT	673	120	93	9	0	895
18:00	LT	800	92	73	10	0	975
	TH	878	96	92	10	3	1079
	RT	874	91	91	4	0	1060

Table 4.26. Showing conflicting traffic from chanchaga to tudun wada at peak hours.

Time	Turning Traffic	Bikes	private car	taxi cab	Buses	Truck	Volume
08:00	LT	19	258	166	10	-	453
	TH	19	2	-	13	1	35
	RT	193	21	75	16	-	295
09:00	LT	38	244	120	8	-	410
	TH	1	2	-	-	-	3
	RT	340	66	149	5	-	560
10:00	LT	42	211	76	14	-	343
	TH	2	1	1	-	-	4
	RT	357	69	129	17	-	572
11:00	LT	111	146	139	33	-	429
	TH	114	1	-	2	-	117
	RT	231	146	104	7	-	488
16:00	LT	180	200	56	9	-	445
	TH	3	6	2	2	-	13
	RT	321	180	323	19	4	847
17:00	LT	134	81	104	1	-	320
	TH	2	7	4	-	-	13
	RT	350	227	178	21	-	776
18:00	LT	260	167	147	38	-	612
	TH	2	2	-	-	-	4
	RT	210	179	144	4	3	540

Table 4.27. Showing conflicting traffic from David mark road to Tudun Wada at peak hours

Time	Turning Traffic	Bikes	private car	taxi cab	Buses	Truck	Volume
08:00	LT	-	110	2	36	-	148
	TH	105	180	247	33	1	566
	RT	396	1	-	-	-	397
09:00	LT	3	126	40	52	-	221
	TH	371	191	230	2	2	796
	RT	237	-	-	-	-	-
10:00	LT	-	106	52	37	1	196
	TH	574	164	158	4	4	904
	RT	8	9	-	2	-	19
11:00	LT	8	116	86	32	-	242
	TH	268	174	198	1	-	641
	RT	324	-	1	1	-	326
16:00	LT	7	298	75	28	-	408
	TH	665	100	226	1	7	999
	RT	-	-	-	1	-	1
17:00	LT	8	192	49	29	-	278
	TH	195	123	236	8	-	562
	RT	417	-	1	3	-	421
18:00	LT	3	269	63	32	1	368
	TH	243	80	226	1	1	551
	RT	458	9	2	-	-	469

Table 4.28. Showing conflicting traffic from Mobil to Tudun Wada at peak hours

Time	Turning Traffic	Bikes	private car	taxi cab	Buses	Truck	Volume
08:00	LT	189	18	10	7	-	224
	TH	234	2	-	4	-	240
	RT	233	-	17	2	-	236
09:00	LT	454	8	-	5	-	474
	TH	151	1	1	-	-	152
	RT	150	1	-	2	-	154
10:00	LT	343	10	-	-	-	353
	TH	2	3	-	2	-	7
	RT	90	2	-	-	-	92
11:00	LT	230	12	1	-	1	244
	TH	222	2	-	-	-	224
	RT	223	2	-	1	-	226
16:00	LT	320	12	-	2	4	338
	TH	134	3	-	-	-	137
	RT	200	3	-	-	-	204
17:00	LT						
	TH						
	RT						
18:00	LT						
	TH						
	RT						

4.2 Data Analysis

Table 4.29. Showing traffic movement for 15 minute peak period.

	Given Volumes	Bosso Road	Hospital	Chanchaga road	Market
1	LT Traffic	Vt=244	V4=153	V7=92	Vto=208
2	TH Traffic	V2=270	Vs=1	V8=502	V11=58
3	RT Traffic	V3=265	V6=135	V9=117	V12=55

	Entry flow (vehlhr)	Entry Volume Ve
4	Bosso road, VeBR = Vt+V2+V3 entry	VeBR =244+270+265 =779
5	Hospital road, VeHR = V4+V5+V6 entry	VeHR =153+1 +135 =289
6	Chanchaga road, VeCR = V7+V8+V9 entry	VeCR =92+502+ 117 =711
7	Market road, VeMR = Vto+Vtt+Vt2 entry	VeMR =208+58+55 =321'

	Conflicting flow (veh/hr)	Conflicting volume Vc
8	vcs« =V7+V10+Vtt	VcBR =92+270+208 =355
9	VcHR =Vt+V2+V10	VcHR =244+270+208 =722
10	VcCR .=Vt+V4+Vs	VcCR =244+153+1 =398
11	VcMR =V4+V7+V8	VcMR =153+92+502 =747

Table 4.30. Showing traffic movement for 15 minute peak period.

Given Volumes		Kpakungu	kparikinsale	Bida	SojeA
1	LTTraffic	V,=244	V_4=153	V_7=92	VIQ=208
2	TH Traffic	V2=270	V5=1	Vg=502	V_{ll}=58
3	RT Traffic	V_3=265	V6=135	V9=117	V_{12}=55
Entry flow (vehlhr)			Entry Volume Ve		
4	Bosso road, VeBR = V,+V2+V_3 entry		VeBR =244+270+265 =779		
5	Hospital road, VeHR = V_4+V5+V6 entry		VeHR =153+1 +135 =289		
6	Chanchaga road, VeCR = V_7+Vg+V9 entry		VeCR =92+502+ 117 =711		
7	Market road, VeMR = VIQ+V_{ll}+V'2 entry		VeMR =208+58+55 =321		

Conflicting flow (veh/hr)		Conflicting volume Vc
8	VcHK =V_7+VIQ+V_{ll}	VcBR =92+270+208 =355
9	VcHR =V,+V2+VIQ	VcHR =244+270+208 =722
10	VcCR =V,+V_4+V5	VcCR =244+153+1 =398
11	VcMR =V_4+V_7+Vg	VcMR =153+92+502 =747

Table 4.31. Showing traffic movement for 15 minute peak period.

Given Volumes		Mobil	Shirorro road	David mark road	Chanchaga
1	LT Traffic	VI =244	V4=153	V7=92	VIO=208
2	TH Traffic	V_2=270	V_S=1	Vg=502	Vll~58
3	RT Traffic	V_3=265	V6=135	V9=117	V_{12}=55

Entry flow (vehlhr)		Entry Volume Ve
4	Bosso road, VeBR = $V_1+V_2+V_3$ entry	VeBR =244+270+265 =779
5	Hospital road, VeHR = V4+VS+V6entry	VeHR=153+1+135 =289
6	Chanchaga road, VeCR = V7+Vg+V9 entry	VeCR =92+502+117 =711
7	Market road, VeMR = V 10+V 11+V 12 entry	VeMR =208+58+55 =321

Conflicting flow (vehlhr)		Conflicting volume Vc
8	VcHK =V7+VIO+V11	VcBR =92+270+208 =355
9	VcHR =V_1+V_2+VIO	VcHR =244+270+208 =722
10	VcCR =V_1+V4+VS	VcCR =244+153+1 =398
11	VcMR =V4+V_7+Vg	VcMR =153+92+502 =747

BIDAROAD

Capacity

CBR = 1130e(-llOOlOVc)

=1130e(-o.0010.3S5)=792veh/h.r

Degree of saturation VlesR = 779/990 = 0.79

Control delay,

= $\frac{3600}{990}$ +90.0 +(0.25) [$\frac{779}{990}$ -1+ ' l. (($\frac{779}{990}$ -1)2+ ($\frac{3600}{792}$) ($\frac{779}{990}$) / 450 (0.25) 1

= 4.55+ 225[-0.016+ 0.00027+ $\frac{4.47}{112.5}$]

= 4.55 +225 (0.184)=45.95=46 Seconds/veh

Bida road operates LOS E (evening peak)

Approach control delay = 46 sec/veh.

Cl-~)a c + (T)C~)(~)I 150T

$$= 900(0.25)\left[\frac{779}{990} - 1 + \sqrt{\left(\frac{779}{990} - 1\right)^2 + \frac{\left(\frac{3600}{990}\right)\left(\frac{779}{990}\right)}{150T}}\right] \left(\frac{990}{3600}\right)$$

$$= 225[-0.016 + \sqrt{0.00027 + \frac{4.S}{37.S}}]\ (0.22) = 16veh$$

BOSSO ROAD

Capacity

$$C_{BR} = 1130e^{(-0.0010V_c)}$$

$$= 1130e^{(-0.0010 \times 0.3SS)} = 792veh/hr$$

Degree of saturation $V/C_{BR} = 779/990 = 0.79$

Control delay,

$$d_{BR} = \frac{3600}{c} + 900T\left[\frac{V}{c} - 1 + \sqrt{\left(\frac{V}{c} - 1\right)^2 + \frac{\left(\frac{3600}{c}\right)\left(\frac{V}{c}\right)}{450T}}\right]$$

$$= \frac{3600}{990} + 900 + (0.25)\left[\frac{779}{990} - 1 + \sqrt{\left(\frac{779}{990} - 1\right)^2 + \frac{\left(\frac{3600}{792}\right)\left(\frac{779}{990}\right)}{450\ (0.25)}}\right]$$

$$= 4.55 + 225[-0.016 + \sqrt{0.00027 + \frac{4.47}{112.5}}]$$

= 4.55 +225 (0.184)=45.95=46 Seconds/veh

Bida road operates LOS E (evening peak)

Approach control delay = 46 sec/veh.

(1-~r~+ (~)(~)(Joo)l
c 150T

= 900(0.25) [779 - 1+ (1- 779)2 + (~)(~)) (990
990 792 150T 3600

= 225[-0.016 + 0.00027+ 4.5] (0.22) = 16veh
37.S

CHANCAHGA ROAD

Capacity

e_{BR} = 1130e(-o.0010Vc)

=1130e(-llIiOiO.355)=792veh/hr

Degree of saturation V/e_{BR} = 779/990 = 0.79

Control delay,

d_{BR} = 3600/e + 900T [V/c - 1 + (V/c - 1)^2 + (3600)(V/c) / 450T]

= 3600/990 + 900 (0.25) [779/990 - 1 + ((779/990) - 1)^2 + (3600/792)(779/990) / 450 (0.25)]

„

$$= 4.55 + 225[-0.016 + 0.00027 + \frac{4.47}{112.5}]$$

= 4.55 +225 (0.184)=45.95=46 Seconds/veh

Bida road operates LOS E (evening peak)

Approach control delay = 46 sec/veh.

$$= 900(0.25) [\frac{779}{990} - 1 + \sqrt{(\frac{779}{990} - 1)^2 + \frac{(3600)(\frac{779}{990})}{(990)(\frac{150}{3600})}}]$$

$$= 225[-0.016 + 0.00027 + \frac{4.5}{37.5}] (0.22) = 16veh$$

Table 4.32: Summary of Result

	Bida road	Dutsenkura road	Barikinsale road	Soje A road
Entry volume (veh/hr)	990	289	711	234
Capacity (veh/hr)	779	546	764	535
Control delay, (sec/veh)	71.0	46.0	32.0	0.6
LOS	E	D	D	B
Approach control delay (sec/veh)	46.0	13.0	36.0	16.0
Intersection control delay (sec/veh)	27.8	27.8	27.8	27.8
95^{th} percentile queue, (veh)	16.0	3.0	19.0	31.0

~

Table 4.33: Summary of result

	Bosso road	Chanchaga road	Radio niger road	David mark road
Entry volume *(veh/hr)*	940	249	621	334
Capacity (veh/hr)	722	446	564	490
Control delay, *(sec/veh)*	61.0	36.0	22.0	13.0
LOS	E	D	D	C
Approach control delay *(sec/veh)*	46.0	13.0	36.0	19.0
Intersection control delay *(sec/veh)*	27.8	27.8	27.8	27.8
95th percentile queue, (veh)	16.0	3.0	19.0	30.0

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The results indicate that the roundabout is still under debate, many experts believe that a remarkable signalized intersections show a better performance in most circumstances. To settle this argument at least to a partial degree, then quantitatively exploring the basic features of roundabout in order to have a better insight into the problem is of great importance

In this research work the importance of traffic at an isolated roundabout has been investigated; for this purpose, performance of the various roundabouts (Mobil, Kpakungu and Tudun-wada) has been analyzed and developed and the most important of which is throughput. The result shows that overall throughput is significantly affected by driver's behaviour.

Two important findings from this research are:

I) Throughput decreases as LT rate increases i.e. vehicles on average need to travel longer distances on the roundabout

II) Throughput increases linearly with arrival rate when the entrance road is not in a saturated situation. It reaches a maximum when arrival rates reach their maximum and it also depends on the turning rates.

Even the modern roundabout, driving (traffic) rules are to be applied to Mobil, Kpakungu and Tudun-wada roundabouts. Some of the important geometric elements do not exist at the roundabouts. Therefore 'the geometric characteristics of the rotary intersection affect the capacity of the rotary; even the business, social and economic activities also determine the practical capacity of the rotary.

The higher the circulating flow, the smaller the critical gap and the higher the number of conflict.

5.2 RECOMMENDATIONS

The following are important in achieving good traffic performance during and after the construction a roundabout.

1. Commercial activities around the roundabout should never be encouraged and eventually allowed (now or in the next future) in order to enhance drivers sight distance and increase the capacity of the approach lane.
2. Parking activities within and outside round about area should not be allowed in order to arrest congestion to a minimal condition that can allow the free flow of vehicles.
3. Transport development policy which will affect carriage way width and financial implication should be made.
4. The driver's behaviour has an important role to play in the performance of the roundabout and individual roads. Moderate, urgent and conservative behaviours leads to easy free-flow for all arrival/turning rates considered, whereas radical behaviour can result to congestion. There are differences between moderate and urgent behaviour with respect to throughput. Conservative behaviour leads to decreased throughput. Compared to moderate, urgent behaviour has a good performance with higher throughput when all arrival rates are < 0.25. In

Table 4.34: Summary of result

	Mobil road	Tunga road	Hospital road	Market road
Entry volume (veh/hr)	990	789	511	234
Capacity (veh/hr)	779	646	564	335
Control delay, (sec/veh)	71.0	56.0	42.0	0.6
LOS	E	D	D	B
Approach control delay (sec/veh)	46.0	13.0	36.0	16.0
Intersection control delay (sec/veh)	27.8	27.8	27.8	27.8
95th percentile queue, (veh)	16.0		20.0	30.0

particular, when 0.45 > all arrival rates> 0.25, saturation occurs for moderate behaviour.

5. As the number of vehicles in Minna metropolis is increasing rapidly year in year out, from the collected data especially at peak hour, more than 1500 number of vehicles exists at each intersection per hour from my observation result. If the number of cars is higher than 500 then the flow at traffic light junction is higher than the roundabouts and it impl ies that junctions needs to be replaced with traffic light to optimize both capacity and traffic performance at the roundabout
6. Transport organization and even the road safety officials to put a stop of commercial driver peaking passengers before or after the round about
7. The delay of stop and search during peak periods should be reduced by the security agents.
8. It is better to separate the pedestrians from vehicles traffic on the roundabout where high pedestrians flow were observed, since they affect the normal traffic flow of the roundabouts. Besides, it is necessary for the safety of the pedestrians too.
9. After extra study and data collected at roundabout, it can be recommended that the single lane along bypasses should be dualize in other to meet up with the modern roundabout characteristics.

CHAPTER 4

DISCUSSION OF RESULT

4.1 Data Collection

The following table below show the result obtained from field (traffic) study

Table 4.1: Hourly traffic volume distribution, along Mobil to Bosso leg.

Time	Bikes	private car	taxi cab	Buses	Truck	Volume
07:00	322	88	68	36	-	514
08:00	900	172	130	49	4	1255
09:00	1235	212	205	28	3	1683
10:00	1730	378	292	31	3	2434
11:00	1260	292	241	29	2	1824
12:00	1370	362	272	37	-	2041
13:00	1329	283	202	21	2	1837
14:00	1531	211	165	38	5	1950
15:00	1622	248	199	34	2	2105
16:00	2003	215	153	39	4	2414
17:00	2003	390	298	30	7	2749
18:00	2003	405	410	17	3	3634

,

Table 4.2: Hourly traffic volume distribution, along Bosso to Mobil leg

Time	Bikes	private car	taxi cab	Buses	Truck	Volume
07:00	375	111	97	35	3	603
08:00	999	330	261	40	3	1633
09:00	1343	500	404	42	3	2292
10:00	1831	514	349	33	2	2729
11:00	1989	395	329	49	4	2766
12:00	2109	378	320	45	6	2858
13:00	1733	289	308	40	7	2377
14:00	1217	213	203	31	7	1671
15:00	1635	229	185	33	8	2090
16:00	1934	248	205	38	-	2425
17:00	2003	400	289	40	5	2737
18:00	2560	289	266	30	4	3149

The hourly traffic result of volume distribution for Bosso road indicate that, the traffic approaching and leaving the Mobil roundabout is four times greater than the capacity of Bosso leg (Demand volume which it can carry any specific period of time under free flow condition). This indicates more than double peak.

The capacity for Bosso road is 792veh/hr and its degree of saturation is 0.98(98%). Modern roundabout are design for degree of saturation of 0.85(85% saturation), this is over saturation. Bosso leg operates at LOS E at evening peak with a control delay of *46sec/veh* and queue length of 16 veh/hr

Table 4.3: Hourly traffic volume distribution, along Mobil to Chanchaga leg.

Time	Bikes	private car	taxi cab	Buses	Truck	Volume
07:00	277	60	50	38	2	427
08:00	658	178	135	35	8	1014
09:00	950	264	230	39	3	1486
10:00	1630	341	282	30	2	2285
11:00	1527	300	248	39	3	2117
12:00	1219	290	222	35	3	1769
13:00	1210	260	211	29	4	1714
14:00	969	322	280	22	3	1596
15:00	1200	440	281	33	14	1968
16:00	1316	352	398	40	9	2115
17:00	1995	352	280	40	5	2672
18:00	1900	300	249	28	7	2484

Table 4.4: Hourly traffic volume distribution, along Chanchaga to Mobil leg.

Time	Bikes	private car	taxi cab	Buses	Truck	Volume
07:00	353	110	78	28	-	569
08:00	298	197	198	46	2	741
09:00	509	300	254	44	2	1109
10:00	626	322	280	59	3	1290
11:00	597	288	220	50	6	1161
12:00	610	300	294	48	-	1252
13:00	801	240	202	44	2	1289
14:00	470	242	211	38	3	964
15:00	580	312	251	29	2	1174
16:00	615	404	310	38	5	1372
17:00	630	325	295	46	2	1298
18:00	712	364	300	39	1	1416

The result of the hourly traffic volume distribution for tunga /chanchaga road indicate double peak. This approach leg has a capacity of 759 veh/hr. But the peak of 15-minute flow indicates a volume of 711veh/hr. The peak hour of the leg occur at 18:00hr with a volume of 1488 veh/hr with a degree of saturation of 0.94(94% saturation). Since the saturation value exceeds 0.85(85%), the roundabout is over-saturated.

This approach operates at LOS E (evening peak) with a control delay of 36sec/veh and queue length of 19veh.

Table 4.5: Hourly traffic volume distribution, along Mobil to market leg.

Time	Bikes	private car	taxi cab	Buses	Truck	Volume
07:00	148	58	34	16	1	257
08:00	299	160	84	17	3	550
09:00	642	145	128	16	3	934
10:00	567	145	110	6	6	834
11:00	208	133	16	5	1	363
12:00	1062	125	98	8	-	1293
13:00	1045	85	91	12	-	1233
14:00	852	65	65	25	2	1013
15:00	710	125	54	12	3	904
16:00	612	45	68	14	-	739
17:00	585	85	96	14	-	780
18:00	1263	105	6	30	5	1409

Table 4.6: Hourly traffic volume distribution, along Market to Mobil leg.

Time	Bikes	private car	taxi cab	Buses	Truck	Volume
07:00	165	29	26	16	-	236
08:00	388	70	15	9	2	48445
09:00	658	19	12	13	-	702
10:00	758	9	9	7	-	783
11 :00	435	15	1	2	-	452
12:00	675	17	2	1	1	696
13:00	755	8	2	-	-	765
14:0'0	455	3	2	-	3	463
15:00	565	15	5	1	1	587
16:00	654	20	-	2	5	681
17:00	743	25	1	2	1	766
18:00	1232	25	6	14	9	1286

The result above shows double peak and hence a good level of service and good operating performance. The delay experience at this approach is as a result. of heavy pedestrian volume and market activities. It has a capacity of 535veh/hr and degree of saturation of 0.6 (60% saturation). This value is below design saturation of modern roundabout approach and is under-saturated. The delay experience by vehicle is 16 seconds and its queue length is 31veh/hr. market road operates at LOS C.

,

Table 4.7: Hourly traffic volume distribution, along Mobil to hospital leg.

Time	Bikes	private car	taxi cab	Buses	Truck	Volume
07:00	178	99	50	26	1	354
08:00	560	178	98	43	-	879
09:00	762	292	142	52	-	1248
10:00	863	309	159	63	1	1395
11:00	830	248	168	53	2	1101
12:00	966	249	200	46	2	1463
13:00	878	228	150	40	2	1298
14:00	450	239	147	34	3	873
15:00	920	310	138	25	3	1396
16:00	800	402	148	40	1	1391
17:00	697	322	149	40	-	1208
18:00	1106	370	162	45	1	1684

,

Table 4.8: Hourly traffic volume distribution, along Hospital to Mobil leg.

Time	Bikes	private car	taxi cab	Buses	Truck	Volume
07:00	-155	75	60	15	-	305
08:00	206	159	187	46	3	598
09:00	237	288	247	32	2	806
10:00	384	319	275	16	-	1994
11:00	408	288	211	35	1	943
12:00	462	300	250	46	-	1056
13:00	399	227	200	43	1	870
14:00	428	245	208	34	2	917
15:00	447	350	249	27	5	1078
16:00	512	392	388	34	4	1330
17:00	493	322	292	26	-	1133
18:00	480	355	298	47	3	1183

The result above indicates double peak and hence good level of service and good operation performance. And it has a capacity of 549veh/hr and degree of saturation of 0.53(53% saturation). This value is below design saturation of modern roundabout approach and is under-saturated. The approach control delay is 13sec/veh and its queue length is 3.0veh. Hospital road operation at LOS B. The result above indicates that, the heavy duty traffic flow in the roundabout are mainly from Bosso road and Tunga/Chanchaga road.

~

Table 4.9: Hourly traffic volume distribution, along Kpakungu to Barikinsale leg.

Time	Bikes	private car	taxi cab	Buses	Truck	Volume
07:00	1280	368	222	68	18	1956
08:00	1384	444	348	73	10	2259
09:00	1400	472	292	70	18	2252
10:00	1362	424	340	79	4	2209
11:00	1345	419	330	47	8	2149
12:00	1324	390	250	67	4	2035
13:00	1356	321	300	32	8	2017
14:00	1330	310	255	35	8	1938
15:00	1385	320	235	70	20	2030
16:00	1525	560	360	55	10	2510
17:00	1473	460	319	50	8	2310
18:00	1784	579	410	49	6	2829

Table 4.10: Hourly traffic volume distribution, along barikinsale to kpakungu leg.

Time	Bikes	private car	taxi cab	Buses	Truck	Volume
07:00	1280	370	89	30	2	1741
08:00	1299	390	250	30	7	1976
09:00	.1336	446	395	35	5	2217
10:00	1323	425	340	25	3	2116
11:00	1218	382	325	40	3	2068
12:00	1300	364	320	35	5	2385
13:00	1326	290	317	33	7	1973
14:00	1309	350	198	34	6	1897
15:00	1328	240	222	41	5	1836
16:00	1467	495	300	33	5	2300
17:00	1395	460	280	56	3	2194
18:00	1752	547	256	60	8	2623

The result of hourly traffic volume distribution for Barikin Sale road indicate that, the traffic approaching and existing traffic Kpakungu roundabout is four times more than the capacity of Barikin Sale leg (Demand volume which it can carry at a specific period of time under free flow condition). This indicates more than double peak.

The capacity for Barikin Sale road is 822veh/hr and its degree of saturation is 0.98(98%). Modern roundabout area design for degree of saturation of 0.85(85% saturation), this is over-saturation. Barikin sale leg operates at LOS E at evening peak with a control delay of 57sec/veh and queue length of 16veh/hr.

Table 4.11 Hourly traffic volume distribution, along Kpakungu to Dutsenkura leg.

Time	Bikes	private car	taxi cab	Buses	Truck	Volume
07:00	1315	310	300	95	18	2038
08:00	1325	389	308	107	15	2144
09:00	1367	399	280	89	13	2148
10:00	1387	286	194	76	7	1950
11:00	1396	356	301	65	10	2128
12:00	1317	383	284	72	15	2071
13:00	1334	306	274	56	5	1975
14:00	1356	329	236	45	9	1975
15:00	1324	319	334	58	3	2038
16:00	1555	478	388	94	5	2520
17:00	1427	408	356	82	8	2281
18:00	1679	555	398	107	19	2758

f

Table 4.12 Hourly traffic volume distribution, along Dutsenkura to Kpakungu leg.

Time	Bikes	private car	taxi cab	Buses	Truck	Volume
07:00	1237	342	219	45	5	1848
08:00	1334	375	247	67	7	2030
09:00	1392	379	318	61	12	2162
10:00	1384	406	342	54	4	2149
11:00	1343	364	276	38	7	2028
12:00	1354	289	231	21	3	1898
13:00	1305	317	237	17	-	1876
14:00	1346	298	224	27	8	1903
15:00	1289	360	308	38	4	1999
16:00	1389	417	345	57	7	2215
17:00	1369	390	287	65	10	2121
18:00	1692	495	384	171	14	2743

The result of hourly traffic volume distribution for bida road indicate double peak. This approach leg has a capacity of 955veh/hr. But its peak 15-minute flow indicates a volume of 811veh/hr. The peak hour of the leg occur at 18:00hr with a volume of 1488vehlhr, with a degree of saturation of 0.96 (96% saturation). Since the saturation value exceeds 0.85 (85%) the roundabout is over-saturated.

This approach operates at LOS E (evening peak) with a control delay of 36sec/veh and queue length of27veh.

Table 4.13 Hourly traffic volume distribution, along Kpakungu to Bida road leg.

Time	Bikes	private car	taxi cab.	Buses	Truck	Volume
07:00	1377	246	189	81	12	1905
08:00	1383	289	238	120	17	2047
09:00	1432	341	212	103	6	2094
10:00	1399	408	172	91	9	2079
11:00	1356	438	183	67	5	2035
12:00	1342	376	280	45	6	2049
13:00	1327	273	273	39	8	1921
14:00	1287	330	189	37	9	1850
15:00	1374	327	219	56	3	1979
16:00	1643	452	239	72	14	2420
17:00	1590	383	283	62	8	2379
18:00	1788	597	495	238	27	3145

t

Table 4.14 Hourly traffic volume distribution, along Bida road to Kpakungu leg.

Time	Bikes	private car	taxi cab	Buses	Truck	Volume
07:00	1382	342	246	63	9	2042
08:00	1409	358	269	78	12	2126
09:00	1439	378	273	81	17	2188
10:00	1421	384	273	67	7	2152
11:00	1412	340	239	54	19	2064
12:00	1357	333	212	58	11	1971
13:00	1320	317	201	40	8	1886
14:00	1330	270	183	48	6	1837
15:00	1367	283	219	51	10	1930
16:00	1549	391	279	72	16	2307
17:00	1507	374	266	77	14	2238
18:00	1765	545	494	117	21	2924

The result above indicates double peak and a hence good level of service and good operating performance. The delay experience at this approach is as a result of heavy vehicle and pedestrian volume and business activities. It has a capacity of 879vehlhr and degree of saturation of 0.99 (99% saturation). This value is above design saturation of modern roundabout approach and is over-saturated. This experience by vehicle is 10 minutes and its queue length is 70veh/hr. Bida road operates at LOS E.

Table 4.15 Hourly traffic volume distribution, along Kpakungu to Soje A leg.

Time	Bikes	private car	taxi cab	Buses	Truck	Volume
07:00	130	24	-	3	2	159
08:00	160	32	-	5	4	201
09:00	100	32	-	9	-	141
10:00	157	29	-	4	-	190
11:00	163	19	-	5	-	187
12:00	149	9	-	3	1	162
13:00	138	22	-	-	2	162
14:00	120	19	-	1	4	144
15:00	98	12	-	3	3	119
16:00	178	21	-	4	5	208
17:00	87	17	-	5	3	113
18:00	187	28	-	9	6	230

~

REFERENCES

Blackmore, F. C. (1963). "Priority at roundabouts." *Traffic Engrg.* & *Control,* London, 5(6), 104-106.

Country Roads Board. (1979). "Guidelines for the design and Installation of roundabouts." *Tech Bulletin* No. 30,"Sydney, Australia.

Crown R.D, (1987). An Alternative Approach to Roundabout Design, published in Washington D. C pp (22-48).

DeArgao, P. (1992). *Circles and roundabouts: A historical review,* Istitute of Transportation and Planning, Swiss Federal Institute of Technology, Lausanne, Switzerland.

Donald Appleyard Circa, (1977). Speed reduction and Traffic calming, London Edward . Arnold Publisher Limited pp(625-631).

FHWA. (2000).Roundabouts: An information guide, Washington, D.C, USA. Federal Highway Administration. U.S. Department of transport.

Flannery, A., Elefteriadou, L., Koza, P., and McFadden, J. (1997). "Safety, delay, and capacity of single-lane roundabouts in the United States." *Transp. Res. Rec. 1646,* Transportation Research Board, National Research Council, Washington, D.C., 63-70.

Florida Department of Transportation (FOOT). (1995). *Florida roundabout design guide,* Tallahassee, Fla.

HCM. (2000). Traffic level of service criteria, Transport Research Board, Washington, D.C

http://www.azdot.govt/roudabouts/performance.asp January 18, 2010

http://www.ash.state.md.us/roundabouts/history.asp January 18,2010

http://www.sha.state.md.us/safety/oots/roLindabouts/safety.asp January 18, 2010.

Highway Traffic Analysis and design, R.J. Salter., 183-184. Third edition.

Kadiyali I.R and Lal N.B, (2008) "Principles and Practices of Highway Engineering (including expressways and airport engineering)" Khanna Publishers, 163-173 Fifth edition, 2008.

Kimber R M and Hollis EM. (1978)"Peak Period Traffic Delay at Road junctions and other bottlenecks" Traffic Engineering and control, pp 19,442-446.

Kimber R M and Hollis EM.(1979,1997). Traffic Queues and Delays at road junctions, Transportation Road Research Laboratory, TRRL90 Berkshire, Growthorn, England.

Krogscheepers J.C and Roebuck C.S (2000). Unbalance Traffic Roundabouts, Fourth International Symposium on Highway capacity Transport Research Circular, E-COI8, Transport Research Board, pp 446-458.

Maryland Department of Transportation (MOOT). (1995). *Roundabout design guidelines,* Hanover, Md.

McDonald, M., and Noon, C. (1978). "Delays at roundabouts caused by Geometric design factors." *J Inst. OfHwy. Engrs.,* Dec., 9-13.

Myers, EJ. (1994). "Modern roundabouts for Maryland." *ITE J,* Oct., 18-22.

Science direct (2008). "Environmental Impacts of Modern Roundabout" *International journal of ergonomics, 38(2).*

Troutbeck, RJ. (1984). "Capacity and delays at roundabouts - A literature review." *Australian Road Res. Board,* 14(4),205-216.

U.S. Department of transportation, roundabout: "An informational Guide", Federal Highway Administration, Publication No. FHWA - RD - 00 - 067. (2000).