EVALUATION OF TRAFFIC FLOW AT SIGNALIZED INTERSECTIONS: A CASE STUDY OF KANO CITY, NIGERIA.

A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES OF NEAR EAST UNIVERSITY

By
AISHA HALADU BICHI

In Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering

NICOSIA, 2018

Aisha Haladu BICHI: EVALUATION OF TRAFFIC FLOW AT SIGNALIZED INTERSECTIONS: A CASE STUDY OF KANO CITY, NIGERIA.

Approval of Director of Graduate School of Applied Sciences

Prof. Dr. Nadire ÇAVUŞ

We certify this thesis is satisfactory for the award of the degree of Masters of Science in Civil Engineering

Examining Committee in Charge:

Prof. Dr. Hüseyin Gökçekuş	Committee Chairman, Civil Engineering Department, NEU
Assist. Prof. Dr. Salem Mokhtar Tarhuni	Committee Member, Architecture Department, NEU.
Dr. Shaban Ismael Albarka	Supervisor, Civil Engineering Department, NEU.

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name:

Signature:

Date:

ACKNOWLEDGEMENTS

I will like to acknowledgement with sincere appreciation the effort and help of my supervisor Dr. Shaban Ismael Albarka. He has put me through all the stages of the writing of my thesis. Without his constant guide and instruction, this thesis might not have reached its completion stage.

I would also like to thank Prof. Dr. Kabir Sadeghi for his fatherly advice and encouragement.

Above all, my utmost gratitude goes to my dearest Parents and family for their love, support and loyalty. I would like to thanks my husband for giving me a support and encouragement throughout my program.

Finally, I would like to thank a friend Ikenna D. Uwanuakwa for his helping hand and support through writing this thesis and the program as a whole; I sincerely appreciated thanks once again.

To my parent…

ABSTRACT

The efficiency of a road network can be evaluated with different performance parameters one of which includes the flow of traffic at its intersection. For any given intersection, congestion would be experienced during rush hours particularly within the location. In this study, the congestion at selected three leg intersections in Kano metropolis a commercial town in northern part of Nigeria was evaluated. Two different peak hours (morning: 9-10am; evening: 4-5pm) were identified for analysis. The traffic data collected over a period of one hour was converted to passenger car unit corresponding to the standard conversion factors as specified in Highway Capacity Manual. The data were analysed using Sidra Intersection Software within boundaries of three optimization criteria (Flow scale, Design life, and Sensitivity). The target Level of Service was class D while degree of saturation of a satisfactory proposed design was expected to be less than 1.0. The result of the three criteria for morning and evening peak hours were analysed independently. The optimal selected design for a given intersection was based on average delay and queue distance with respect to available demand flow and the rank of the level of service for the intersection. The result indicated that the design life criteria has the optimal performance on the three selected intersections. A 92 % average reduction of the total delay in seconds was optimised within the three intersections which accounted for about 63 % savings in the fuel consumption in litres per hour under design life analysis criteria.

***Keywords**:* Intersection; Congestion; Capacity; Level of Service; Sidra Intersection

ÖZET

Kano şehir metropolünde nüfus artışı ve kentsel göç, özellikle yol ağları için altyapıya ciddi bir tehdit oluşturmaktadır. Üç bacak kavşağı mevcut koşullarda, etkili bir trafik akışını destekleyemez ve tıkanıklık, insan-saat kaybı, aşırı gecikme ve yakıt tüketiminde artış ve sera gazı emisyonları ile sonuçlanır. Bu çalışma, Kano şehir metropolünde bulunan üç ayaklı kavşağın performansını değerlendirmek için kullanılabilecek en iyi analitik yaklaşımı değerlendirmeyi amaçlamıştır. En yüksek trafik sıkışıklığı olan üç farklı kavşak, saha verilerine ve Google harita havadan görünümüne göre seçildi. Her bir kesişim için iki farklı tepe saatte (sabah 9-10 ; akşam: 4-5) trafik hacmi kaydedildi ve binek otomobili ünitesine dönüştürüldü. Veriler, üç optimizasyon kriterinin sınırları dahilinde (Akış ölçeği, Tasarım ömrü ve Hassasiyet) Sidra Intersection Yazılımı kullanılarak analiz edildi. Hedeflenen Hizmet Seviyesi D sınıfı iken, tatmin edici bir tasarımın doygunluk derecesinin 1.0'dan daha az olması beklenmektedir. Üç kriterin sonucu sabah ve akşam yoğun saatleri için bağımsız olarak analiz edildi. Belirli bir kavşak için en uygun seçilmiş tasarım, mevcut talep akışına ve kavşak için hizmet seviyesinin derecesine göre ortalama gecikme ve kuyruk mesafesine dayanmaktadır. Sonuçlar, tasarım ömrü kriterlerinin seçilen üç kesişme noktasında optimum performansa sahip olduğunu gösterdi. Saniyede toplam gecikmenin %92'lik ortalama azaltımı, tasarım ömrü analizi kriterleri altında saatte litre olarak yakıt tüketiminde yaklaşık %63'lük bir tasarruf sağlayan üç kesişim içinde optimize edilmiştir.

Anahtar kelimeler: Kavşak; Tıkanıklık; Kapasite; Servis Seviyesi; Sidra Kavşağı

TABLE OF CONTENTS

ACKNOWLEDGEMENT………………………….…………………………….... ii

ABSTRACT………………………………...………………………………… iv

ÖZET…………………………………...…………………………………... v

TABLE OF CONTENT……………………..……..…………………………….. vi

LIST OF FIGURES……………………………..…………………………… x

LIST OF TABLES……………………..……………………………………….. xi

LIST OF ABBREVIATIONS ..…………..……………………………………….. xiv

CHAPTER 1: INTRODUCTION

1.1 General overview…………………………………………………………. 1

1.2 Problem Statement………………...………………………………………… 2

1.3 Need of Studies……………………………………………...…………… 2

1.4 Research Aims and Objectives……………………………………………… 2

1.5 Scope of Study……………………………………………...………………. 3

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction………………………...…………… 4

2.2 Road Interconnection and Economic Development……………………………… 4

2.3 Intersection……………………………………………………….……………… 5

2.3.1 Signalized Intersection……………………………………………….…… 6

2.3.2 Non-Signalized Intersection……………………………………………… 6

2.3.3 Traffic Control at Intersection……………………………….…………… 7

2.3.4 Intersection Geometry……………………..…………………………… 7

2.3.5 Traffic Congestion at Intersection……………...………………………… 7

2.3.6 Causes of Traffic Congestion………………...………………………… 9

2.3.7 Previous Studies on Congestion in Nigeria………………………………. 9

2.4 Performance Measures……………………………………………………… 10

2.4.1 Traffic Delay at Intersection……………………………………………… 11

2.4.2 Control Delay…………………………………...…………………… 12

2.4.3 Forms of Delay…………………………………………………………… 12

2.4.4 Queue Length……………………...…………………………………… 13

2.5 Capacity……………………………………………..………………… 13

2.6 Saturation Flow…………………………………...………………………… 14

2.6.1 Saturation Flow Rate……………………...…………………………… 15

2.7 Level of Service (LOS) ……………………………..……………………… 16

2.7.1 Factors that affect LOS…………………………………………………… 17

2.8 Overview of the Sidra Software……………………………………………….. 17

2.8.1 Sidra intersection………………………………………………………………. 17

2.8.2 Intersection evaluation and design……………………………………………... 18

2.8.3 Traffic model…………………………………………………………………... 19

2.8.4 Previous studies on Sidra software…………………......………………… 20

CHAPTER 3: MATERIALS AND METHODOLOGY

3.1 Introduction……………………………………………………………………… 25

3.2 Location of Study Area…………………………...………………………… 25

3.3 Case Study……………………………………………..……………… 28

3.4 Data Collection……………………………………………...……………… 29

3.4.1 Duration of data compilation……………………...……………………… 29

3.4.2 Apparatuses and tools used for data collection…….………...………… 29

3.4.3 Traffic count…………………………………………………………… 31

3.5 Movement And Phases…………………………………...………………… 31

3.5.1 Signal cycle…………………………………..…………………… 32

3.6 Sidra Input Data Screen Overview……………………..…………………… 32

3.6.1 Intersection dialogue…………………...……………………………… 33

3.6.2 Geometry……………………………………..………………… 34

3.6.3 Volumes Dialogue………………………...………………………… 35

3.6.4 Path data dialogue………………………...………………………… 36

3.6.5 Movement Data Dialogue…………………….…………………….. 37

3.6.6 Priorities dialogue……………………………….………………….. 38

3.6.7 Gap-Acceptance Data Dialogue……………………………………….. 39

3.6.8 Model settings dialogue……………………………………………….. 39

3.6.9 Demand and sensitivity dialogue……………………………………… 41

3.6.10 Pedestrians dialogue…………………………………………………… 41

3.7 Field Study Data……………………………………..………………… 42

3.8 Sidra Intersection Output Data……………………..…………..………… 45

3.8.1 Definition………….…………………...……………………………… 45

3.8.2 Calibration ………………………………..……………………… 45

3.8.3 Acceptance performance criteria……………………….………… 45

CHAPTER 4: RESULTS AND DISCUSSION

4.1 General Overview……………………...…………………………………… 47

4.2 Suggestion For Optimization………………………….…….………………… 47

4.3 Results Of The Analysis From Before And After Improvement AM 48

4.4 Capacity Performance of Existing and Optimized………………..…………… 51

4.5 Average Delay Performance of Existing and Optimized …………………….….. 54

4.6 Fuel consumption Performance of Existing and Optimized ……….…………. 55

4.7 Total Effective Stops Performance of Existing and Optimized ……………… 57

4.8 Roundabout Conversion AM……………………………………………….……. 60

4.9 Roundabout Conversion PM……………………………………………….…….. 62

CHPATER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion…………………………………………………………..……. 65

5.2 Recommendation…………………….………………..…………………….……. 66

REFERENCES…………………………..…..………………………………….……… 67

LIST OF FIGURES

Figure 3.1: Kano traffic flow……………………..…………..………………… 26

Figure 3.2: Aminu Kano Intersection…………………………………………….. 27

Figure 3.3: Dan Agundi intersection…………………………...……………… 27

Figure 3.4: Civic Centre intersection……………….…………………………… 28

Figure 3.5: Apparatuses and Tools of Data Collection…………..………………. 30

Figure 3.6: Intersection Dialogue (screen shot sample from the software)…….. 33

Figure 3.7: Geometry Dialogue (Lane Data Tab)…………………..…………. 34

Figure 3.8: Sample Screen Shot Volumes Dialogue…………..…….…………… 35

Figure 3.9: Sample Screen Shot of the Path Data Dialogue………..…………….. 36

Figure 3.10: A sample of screen shot showing default values of this dialogue…… 37

Figure 3.11: Sample Screen Shot of the Priorities Dialogue……………...……….. 38

Figure 3.12: Sample Screen Shot of the Gap-Acceptance Data Dialogue………… 39

Figure 3.13: Sample Screen of Model Settings Dialogue (Options)…….………… 40

Figure 3.14: Sample Screen of Model Cost……………………………….…… 41

Figure 3.15: Sample Screen Shot of the Pedestrian Dialogue………...…………… 42

Figure 4.1: Capacity performance of Aminu Kano intersection………………..… 52

Figure 4.2: Capacity performance of Civic Centre intersection……………….……. 53

Figure 4.3: Capacity performance of Dan Agundi intersection…….……………. 53

Figure 4.4: Average delay performance of Aminu Kano intersection……...……. 54

Figure 4.5: Average delay performance of Civic Centre intersection……...…….. 55

Figure 4.6: Average delay performance of Dan Agundi intersection……………. 55

Figure 4.7: Fuel consumption performance of Aminu Kano intersection……….. 56

Figure 4.8: Fuel consumption performance of Civic Center intersection ……….. 57

Figure 4.9: Fuel consumption performance of Dan Agundi intersection………… 57

Figure 4.10: Total stops performance of Aminu Kano intersection……………….. 58

Figure 4.11: Total stops performance of Civic Center intersection……………… 59

Figure 4.12: Total stops performance of Dan Agundi intersection……………….. 59

LIST OF TABLES

Table 2.1: Level of Service classification……………………………….………… 17

Table 3.1: List of Intersections in Kano metropolis…………………………….. 28

Table 3.2: Corresponding converting factors………………..……………..……. 31

Table 3.3: Field study data intersection 1; Dan Agundi AM…………..…..…… 43

Table 3.4: Field study data intersection 1; Dan Agundi PM……………......…… 43

Table 3.5: Field study data intersection 2; Aminu Kano Way AM…………..…. 43

Table 3.6: Field study data intersection 2; Aminu Kano Way PM…..........……. 44

Table 3.7: Field study data intersection 3; Civic Centre AM……………...……. 44

Table 3.8: Field study data intersection 3; Civic Centre PM…………...……..…. 44

Table 3.9: Practical Degree of Saturation Limits ..……………………………… 46

Table 4.1: Performance measures of existing and proposed flow scale analysis AM…………………………………………………………………… 48

Table 4.2: Performance measures of existing and proposed flow scale analysis PM ……………………………………………………...………. 49

Table 4.3: Performance measures of existing and proposed design life analysis AM …………………..……..…………………………...………… 49

Table 4.4: Performance measures of existing and proposed design life analysis PM ……..…………………..……..………………..….…………… 50

Table 4.5: Performance measures of existing and proposed sensitivity analysis 50

AM ……………………………………………………….……..………

Table 4.6: Performance measures of existing and proposed sensitivity analysis PM ………………………………………………………………..... 51

Table 4.7: Performance measures of existing and proposed flow scale (Conversion) analysis AM ……………………………………..…… 60

Table 4.8: Performance measures of existing & proposed design life (Conversion) analysis AM ………………………..……………..... 61

Table 4.9: Performance measures of existing & proposed Sensitivity (Conversion) analysis AM ………………………….…………….… 62

Table 4.10: Performance measures of existing and proposed flow scale (conversion) analysis PM ……………..………….……….....……. 62

Table 4.11: Performance measures of existing and proposed design life (Conversion) analysis PM …………………………..………….… 63

Table 4.12: Performance measures of existing and proposed sensitivity analysis (Conversion) PM …………………………………………………. 64

LIST OF ABBREVIATIONS

AM	Ante Meridiem
AVCAS	Ant-based Vehicle Congestion Avoidance System
AVD	Average Delay
FUC	Fuel Consumption
HCM	Highway Capacity Manual
KAROTA	Kano Road Traffic Agency
LOS	Level of Service
MOE	Measure of Effectiveness
PCU	Passenger Car Unit
PI	Performance Index
PM	Post Meridiem
SIDRA	Signalized And Un-Signalized Intersection Design, And Research Aid
TTT	Total Travel Time
VTRS	Vehicle Traffic Routing Systems

CHAPTER 1
INTRODUCTION

1.1 General Overview

The bedrock of an economy is built on the back of efficient movement of human, goods and services within locations support by road networks. Whereas good road network depends on its interconnectivity among individual roads forming the network and the efficiency of the up and down stream vehicular movement.

Therefore, in any nation, the road system is a major part of its infrastructure. A well-organized road system provides smooth and sufficient daily traffic movement which can improve economic growth.

Mobility is essential to the serviceability of municipalities because it influences the daily activities of the citizens. Limitation to+ effective mobility is road traffic congestion. This is a reason behind the continually growing urbanization, social activities and the subsequent extensive reliance on road transport that permits increment in the number of various categories of vehicles on the roadways. (Olagunju, 2015)

Based on statistics, road transportation is the leading mode of transport in Africa and almost 95% in Nigeria; causing road traffic congestion. The impact of congestion includes increment in unwanted prolonged delays, environmental pollutions, accidents, additional operative costs and road users' discomfort. (Biliyamin & Abosede, 2012)

Traffic control at intersections is a serious problem, particularly in urban regions where traffic demand is continuously increasing. Currently, there is existed numerous approaches which focus on this problem. But, due to the complication of traffic control issue, the approach used in a particular traffic location could not be suitable in another environment. The advancement methodology of the cities is significant for the investigation of throughway and city road networks. To decrease the congestion on highways, moreover, the design of transport facilities is required. (Bui & Jung, 2017)

In a highly populated and business city of Kano, Nigeria, it is often watched that traffic congestion and long queues at intersection happen in the city throughout the day, which compounds during rush hours.

1.2 Problem Statement

Kano metropolis is an industrial and business base centre in Northern part of Nigeria as well as, being the subsequent biggest city after Lagos, in Nigeria. Kano has been one of the most populous cities in Nigeria its economic status attract people and firms towards the city which lead to the increasing number of the vehicles beyond the capacity of the roads and hence outcome the unfortunate traffic congestion.

1.3 Need of Studies

The extent of the congestion made Kano State Government to established Kano Road Traffic Agency KAROTA to have enough officers which will assist Traffic Police Officers in overruling movement signals and controlling traffic, especially at the intersection during peak hours. The contention behind this well-known practice is that signals neglect to perform proficiently within peak periods prompting long lines and in some cases locking of the junctions. The study will come up with an appropriate solution to eliminate this old modern way of controlling traffic flow in the city.

1.4 Research Aims And Objectives

1 To study traffic at intersections and the factors that controls the density of congestion at intersection.
2 To evaluate the existing rank of the level of service in morning and evening peak hours for each intersection independently using Sidra intersection software.

3 To measure the loss of time resulting in delay and total stops at selected intersections.
4 To establish a comparative study of the road performance parameters of morning and evening peak hours for each intersection.
5 To optimize traffic flow and minimize the delay at intersections using effective, low-cost methods such the introduction of a roundabout island.

1.5 Scope of Study

This study focuses on Identifying intersection performance parameters; obtain a geometric measurement of the intersections and evaluating the performance of three leg intersections (Morning and Evening peak hour) within Kano metropolis. The obtained data will be to analyse using SIDRA software based on delays, queue length, system travel speed, total stops, travel time, operating costs as well as fuel consumption on the intersections. After the analysis, the at-grade intersection below specified criteria will be redesigned.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The importance of intersection in a road network cannot be over emphasized. This chapter attempt to review previous literature on the correlation of intersection on the growth of an urban economy. Further details were provided on the performance criteria of an intersection and it effect on the movement of road network. The section also provided the information on the analytical tool used in assessing the performance criteria of a road intersection.

2.2 Road Interconnection and Economic Development

An efficient control strategy of the intersection would maximize capacity, minimize delays and minimize clashes. Certainly the signal control devices are the best powerful instruments used for city traffic control and their accurate installation as well as management will improve both traffic flow and the safety of the road users. If compared with other available traffic developments, signals can be termed as moderately low cost demanding. Due to high traffic density in the metropolitans, it is a common act in most African region during peak period the police officers to be overruling traffic signals and control the vehicles at signalized intersections. Such a practice is very common in Kano State and other parts of Nigeria (Mfinanga, 2014).

The capacity of a particular approach or road network of an intersection is a function of its allocated green time, the cycle length and saturation flow rate of the intersection. Traffic delay is resulted from the amount of the motor vehicles waiting to have the right way and is utilized to calculate the LOS (level of service) of the intersection. The data collected from the traffic volume counts, the average headway of the vehicles, the saturation flow rate and the geometry factors of the intersection (such as lane length and width and the number of lanes) were utilized as inputs to the SIDRA software package and the output obtained includes lane capacity, level of service LOS and delay for sign operations (Mfinanga, 2014).

The metropolitan traffic network comprises numerous different services such as different level roadways and basic intersections. City roads convey massive movement volumes for vehicles which they were not basically planned. The expected result is delay, congestion, and need for safety (Fan, Jia, Tian, & Yun, 2014).

Urbanization and traffic have grown together since the early age of expansive migration to the cities. The facilities that attract citizens to accumulate in most urban regions likewise lead to some of the time unbearable ranks of traffic congestion on urban roads and streets. (Ukpata & Etika, 2012).

Traffic control devices are one of the foremost effective instruments of directing traffic. They are utilized to isolate crashing traffic movements at crossing points. (Oskarbski, Guminska, Miszewski, & Oskarbska, 2016).

As traffic congestion proceeding to develop in urban regions worldwide, increasingly signalized intersections are worked under oversaturated conditions. Oversaturation is a condition when road traffic demands go beyond the capacity of the intersection, in this condition normal traffic control techniques failed to work as proficiently as needed (Sun, Wu, Wang, & Yu, 2015).

2.3 Intersection

An intersection is a part of the road or a point of interchange; it is a meeting or crossing point of two or more roads. Its main purpose is to give the road users the chance to change their route direction. Different street markings, traffic signs, and traffic control lights were used to guide the lines of vehicles towards the intersection at applicable speeds and avoid vehicle crashes (Wang, Wang, Song, & Raghavan, 2017).

Intersections are composite road units due to many conflicting traffic movements happen at these locations and are influenced by signalization and visibility conditions (Ferreira & Couto, 2013).

The intersection is a significant service within the city traffic network. The intersection capacity controls the productivity of the city traffic system. (Zhu, Gao, Wang, & Liu, 2016)**.** With the aim of investigation the faces of movement flow of the intersection, various replication models are recommended (Fan et al., 2014). Oversaturation has been a severe tricky for urban intersections, particularly the jam intersections that cause queue spillover and network holdup (Sun et al., 2015).

Intersections are a vital part of transportation systems and their performance significantly setbacks the effectiveness and ability of city traffic. Intersections can be classified into two different types based on the existence or absence of control devices such as sign lights (Yao, Jia, Zhong, & Li, 2018).

2.3.1 Signalized intersection

Signalized intersections are crossing points which are organized by signs such as movement lights and thus give motorists less freedom. Nevertheless, non-signalized intersections, which need such sign control devices, act much contrarily from their signalized counterparts. At such crossing points, the movement condition is generally dictated by the associations between the drivers (Yao et al., 2018).

2.3.2 Non-signalized intersection

A non-signalized intersection operates without been controlled by a signal device and that gives a few vehicles chances to disregard the movement directions to cross through the intersection as quickly as likely. These practices could cause numerous traffic clashes and car accidents (Fan et al., 2014).

2.3.3 Traffic control at intersection

As traffic intensity increments, in any case, there is an improved probability of “cycle failures”. Specifically, a few cycles will start to encounter a surplus line of vehicles that couldn't release from a past cycle. This phenomenon happens randomly, subject to which cycle happens to encounter higher-than-capacity flow rates (Rouphai, Tarko, & Li, 1992).

Traffic control at intersections is a severe problem, particularly in urban regions where traffic demand is continuously increasing. Currently, there is existed numerous approaches which focus on this problem. But, due to the complication of traffic control issue, the approach used in a particular traffic location could not be suitable in another environment (Bui & Jung, 2017).

2.3.4 Intersection geometry

The complete topography of an intersection defines its capacity towards productivity and carefully serving road user request. Pedestrians are regularly passing paths of traffic, while transfer, bikes, and vehicles traffic are utilizing the movement paths offered by the intersection. The sum of traffic lanes accommodated each phase make a major effect on the ability of the intersection then, subsequently, the capacity for sign control timing to effectively serve the request. For instance, traffic discharged by two lanes as opposed to one lane has a greater capacity and in this manner needs less green time to meet the demand. Nevertheless, increasing the lanes on a specific approach of the crossing point similarly increments the least pedestrian passing time through that approach, which through adding clearance times would counterbalance some of the increment in capacity (Koonce, 2008).

2.3.5 Traffic congestion at intersection

Congestion on a road segment of the traffic system under control of movement signals is a circumstance when the normal span of the vehicle delay surpasses the length of the movement signaling phase. For this situation, the line length may expand, achieving the length of the roadway intersection (Chubukov et al., 2017).

Congestion is a comparative phenomenon used to compare the difference concerning the expected performance of the road system and how the system operates. (Ukpata & Etika, 2012).

Congestion causes an increment in time of travel which might inevitably end up progressively variable and random as congestion increments. Levels of congestion are not constant from time-to-time on the same roadway because of variations in factors that impact congestion is certainly not similar. Road users can be late before or after their distinct appointments (Biliyamin & Abosede, 2012).

Road traffic congestion is referred to a situation of movement delay (traffic moving slower than practical speeds) since the volume of vehicles demanding to utilize the road go beyond the capacity of the traffic network (Adebambo & Adebayo, 2009).

Traffic congestion has to turn out to be a serious issue in numerous cities, particularly in big cities. To relieve traffic jams, and increase the levels of service and proficiencies of the transportation system in urban areas, an effective traffic management, and control system is a common target. Assessing traffic flow congestion ranks of roadway systems is essential for traffic control and management because it can allow the relevant organizations to precisely and locate congested roads and time of congestion in the road network. Subsequently, it is fundamental to assess traffic congestion circumstances for metropolitan roadways traffic networks utilizing applicable assessment measures (He, Yan, Liu, & Ma, 2016).

Congestion at the intersection is a major part of traffic congestion in the urban region. It is a result of unbalance among travel time, road capacity and transportation demands. Through realistic organizing intersection movement flow, we can assign traffic right and increase traffic effectiveness to reduce traffic jam (Zhu et al., 2016).

2.3.6 Causes of traffic congestion

A traffic jam occurred when the traffic volume of movement or integrated split generates needs for road space higher than the existing roadway capacity; the situation is ordinarily termed saturation. Several particular circumstances cause or accumulate jamming; the majorities of them diminish the capacity of a highway at a certain place or along a definite distance or increase the number of automobiles needed for a particular capacity of individuals or products.

Traffic study yet can't absolutely foresee under which conditions a "traffic jam" (instead of vast, so far simply flowing movement) might unexpectedly happen. It was revealed that specific events, (e.g., accident or possibly a vehicle slow down extremely in a previously smooth flow) could affect gradually outstretching effects (a falling disappointment) which at that time spread out and make a succeeded jammed driving situations when unusual, typical flow may have progressed for quite a while longer.

2.3.7 Previous studies on congestion in Nigeria

Joseph & Anderson (2012), carried out a study on Traffic Congestion in Major Cities of Nigeria. The research highlight poor driving habit as the maximum significant source of traffic jam in Nigerian metropolitan cities, additional foremost sources of traffic jam consist of: illegal parking behaviors, poor road system, insufficient road space, absence of parking services, unfortunate traffic management and control, inadequate drainage system, amount of heavy trucks, poorly planned interchanges and roundabouts and absence of effective mass transport system.

Popoola et al., (2013), carried out a research on Traffic Congestion on Highways in Nigeria Causes, Effects, and Remedies; The outcome from this research indicated the sources of traffic jam as insufficient road capacity, lack of good road pavement, unfortunate traffic organization, inadequate drainage system, lack of good driving and parking behaviors, poorly planned interchanges and roundabouts, existence of heavy vehicles, absence of pedestrian services, absence of parking conveniences, etc.

Olagunju (2015), carried out a study on Evaluating Traffic Congestion in Developing Countries – A Case Study of Nigeria. Lagos has been a mega city with high pollution of over 15 million is selected to be a case study, as a fastest developing metropolis in Africa. Main causes of traffic congestion consist of road indiscipline, high volume of traffic, inadequate road system carrying space, unfortunate traffic control and management, lack of supportive facilities like lay-bye, and low reaction to removing broken down / crashed cars.

Raheem et al., (2015), carried out a study on; The Cause, Effect and Possible Solution to Traffic Congestion on Nigeria Road. According to this research, the effect of traffic jam in the research location is Time waste, Traffic delay, Accident, Failure to estimate travel time, Extra fuel utilization, and environmental pollution. The research point out; Dualization the Roadways, Provision of Sufficient Parking facilities, Construction of adequate Drainage System and Installation of Signal Control Devices as a possible solution to a traffic jam in the study area.

2.4 Performance Measures

According to user perceptive, the two principal operational measures utilized to assess the performance of distinct crossing points are traffic delays and queues length.

2.4.1 Traffic delay at intersection

The metropolitan roadways carry huge traffic volumes for vehicles which they were not basically planned. The unavoidable outcome is delay, congestion, and need for safety. The delay is basic execution degree on interrupted - flow services. The traffic delay at an intersection is characterized as the contrast in travel time experienced by a vehicle because it is influenced and unaffected by the traffic control at a crossing point (Hunter, Wu, Kim, & Suh, 2012).

Movement delay is among the main standards used in deciding the efficiency or level of service of traffic performance of controlled intersections. The total congestion level, road user, comport, fuel consumption and an average waste of travel time, etcetera, may all be accredited to traffic delay. Traffic delay is similarly a region of concentration in traffic design, signal control plan and traffic management and control (Xi, Li, Wang, & Wang, 2015).

Delay is a significant measure of efficiency in traffic research, as it introduces the immediate cost of fuel utilization and circuitous cost of time misfortune to drivers. Delay, nevertheless, is a parameter that is hard to assess because it incorporates the delay related with vehicle decelerating to stop, stopped delay, as well as the delay related with vehicle accelerating from a stop (Bivina, Landge, & Kumar, 2016).

Delay within the perimeter of intersections under signal control is related to vehicle and driver time lost as a result of the procedure of the sign in addition to the existing geometric feature and traffic situations of the intersection. Whereas delay based on the HCM 2000 manual is outlined as the distinction between the traveled time spent and the reference traveled time that may result throughout ideal circumstances; when there is no traffic sign control, no geometric delay, no any incidents, and in the absence of other associated vehicles on the roadway (Darma, Karim, Mohamad, & Abdullah, 2005).

Signalized intersection level of service could be evaluated based on numerous criteria. The most significant among these criteria is vehicle delay because it is directly related to the lost time that a vehicle encounter while passing through an intersection. Traffic delay is used for performance evaluation, of similar traffic situations. Traffic delay is a factor that couldn't be easy to calculate as a result of the non-deterministic manner of the entrance and leaving procedures of motor vehicles at junctions also due to the impact of various variables that have doubts and indistinctness, particularly for unrelated traffic situations. Modelling traffic delay becomes a remarkable topic for transportation designers and traffic engineers. Numerous models have been established to determine the normal delay/vehicle at signalized intersections, used for uniform and worst lane controlled traffic (Preethi, Varghese, & Ashalatha, 2016).

2.4.2 Control delay

The overall delay practiced by a motorist/passenger could be termed as the variance between the traveled time truly spent and the bench-mark traveled time that will determine outcome when there is no road traffic sign control, fluctuations in speed as a result of geometric disorders, any events, and the relations with any other road users. Moreover, control delay is part of delay that is attributable to the traffic sign control in addition to the time while slowing down to join a line, waiting time in line, and time when speed up from a line. In place of usual complete phase sequence at a signal control crossing point, control delay and total delay are unchanged when there is no any incident (Koonce, 2008).

Overall delay (control delay) may be classified into slowing down delay, clogged delay and speeding up delay. The clogged delay is easier to estimate, whereas total delay reflects well the competence of traffic signal process (Darma et al., 2005).

2.4.3 Forms of delay

Movement delay at an intersection is commonly computed in the subsequent forms:

- Stopped delay: Is the period when a vehicle is stationary while waiting to cross an intersection.
- Approach delay: Is the time waste when a car slowdown from its average speeds to stop and when accelerating from the stop to its usual speed.
- Travel-time delay: Is the variance among the real time that it takes a vehicle to cross an intersection and the time spent for a vehicle to cross the intersection when the drivers are allowed to move with their desired speed.
- Time-in-queue delay: Is the overall time spent by a vehicle when joining a queue to its discharge to cross the stop line of an intersection (Jiang, Li, & Zhu, 2005).

2.4.4 Queue length

Queue length could be an estimation of the road space cars would occupy while holding up to pass across a junction. It is generally utilized to estimate the total capacity essential for turn paths and to decide whether the motor vehicles from one interchange will substantially overflow into a connecting intersection. Numerous line length approximations are commonly utilized with signalized crossing points. Normal queues, as well as 95th-percentile line, are usually assessed for the time interval for which the control sign turn red. Though, it is occasionally valuable to incorporate the queue founding that happens during green whereas the front of the line is discharging and receiving incoming vehicles from the back. Lines measured in this manner are frequently famous as normal back of the queue (Koonce, 2008).

2.5 Capacity

Capacity investigation attempts to provide a clear understanding of the amount of traffic a particular road could accommodate. Capacity is characterized as the highest amount of vehicles, travelers, or relevant, in a particular time, which could be served in given conditions with a sensible probability of incidence. Capacity is autonomous of the request. It talks approximately the physical sum of automobiles and travelers a street can accommodate.

It is independent of the total amount of vehicles requesting facility. Alternatively, it is subject to traffic situations, roadways geometric pattern and so on. For instance, an inclined or bent roadway has reduced volume equated to flat or straight roadways. Road capacity is conveyed regarding units of a few particular things (vehicles, passengers, etc.), which likewise depend on the road traffic alignment as well as environmental conditions. Capacity may be a probabilistic degree, and it changes concerning time and location. Therefore it isn't continuously likely to absolutely originate the capacity logically. In general, it is achieved, through site investigations (Marfani, Shihora, Kanthariya, & Kansara, 2018).

The capacity of a particular approach of the signal control intersection is principally a function of a total of lanes and their respective movement flow, the direction of flow circulation, basic saturation flow and signal green time proportion (Bang, Wahlstedt, & Linse, 2016).

Capacity for a particular movement of a signalized intersection is characterized by two components: saturation flow rate of the vehicles passing through a particular point in a period under predominant situations and the proportion of time through which automobiles can cross the intersection (Koonce, 2008).

2.6 Saturation Flow

The geometric design and amount of clash between the conflicting vehicle and in some cases pedestrian activities which are cleared in the same signal phase determined the saturation flow of each lane (Bang et al., 2016)**.** Saturation flow is a significant factor used to estimate delay. It happens to be a measure of the concentrated rate of traffic flow which might be attained if possibly hundred percentage green time was given to an individual approach. In the current research, the saturation flow of the selected intersections was obtained based on traffic count of different classes of vehicles, as they pass across the stop line as an unbroken queue during the green (Preethi et al., 2016).

For a signal control lane its saturation flow is definite as stopped traffic flow at line discharge which is influenced by many factors; Geometric design (includes width and length of the lane, either inclined, flat or curve), Proportion of left and right turns of the traffic, the degree of clash with conflicting vehicle movements and in some cases with pedestrians that received green in the same phase (Bang et al., 2016).

The most significant roadway movement operational measure of the determined rate of traffic flow is saturation flow. It is generally utilized in control and design of signalized intersection. Saturation flow defines the number PCU (passenger car units) out of the high volume of traffic flow in a certain lane group of the intersection. Saturation flow can be explained in another words as, if the approach sign of an intersections were possible to be kept green for a whole hour, and the density of the traffic flow across that intersection were as much as might be predictable, then the saturation flow rate will be the total amount of PCU (passenger car units) that passed across the intersection within that hour (Bester & Meyers, 2007).

2.6.1 Saturation flow rate

The saturation flow rate is a significant factor used for assessing the performance of an individual lane movement. Saturation flow rate for a road network is a directly related to the function of vehicles speed and the gap in between. These are in line with functions of a variety of factors, comprising the total of lanes, lane width, grades, and influencing factors that restrain vehicle movement, for example, conflicting vehicle, illegal parking and pedestrian movements. Accordingly, a saturation flow rate differs with time, movement, and locality and generally ranges from 1,500 to 2,000 (pcph) passenger cars per hour per lane and according to HCMthe ultimate saturation flow rate, is normally expected to be 1,900 passenger cars per hour per lane.

For example, if the automobiles leaving from a line has an average headway of 2.2 seconds the saturation flow rate is calculated as 3600 / 2.2 = 1636 vehicles per hour per (Koonce, 2008).

2.7 Level of Service (LOS)

Capacity is a word closely connected to and regularly mixed up with it is ability capacity. As capacity provides a quantitative amount of traffic, on the other hand level of service (LOS) tries to give a qualitative measure. Facility capacity is a maximum amount of vehicles, road users, or related, which a particular facility or road system can accommodate for a given period under certain conditions at a particular level of service.

In a specific facility or roadway, capacity might be steady. On the other hand, actual traffic flow can differ for a particular day at a different time. The main purpose of LOS is to relate the quality of traffic facility to a particular traffic flow rate. It is a phenomenon that elects a series of functioning circumstances on a specific form of the facility. It could be a term that assigns a run of operational conditions on a specific category of service. HCM (Highway capacity manual) make available some technique to define the level of service. It categorizes the quality of traffic flow into six levels ranging from level A to level F, with level A which symbolizes the best quality of traffic stream where the motorist has the freedom and comfort to drive at or above posted speed and level F been the worst quality of traffic flow. Level of service is characterized based on the MOE (a measure of effectiveness). Ordinarily, three factors are utilized as the MOE's; travel speed and time, traffic density, and delay.

The quantity of time consumed in traveling is one of the vital measures of service quality. Hence, travel time and speed are measured to be more compelling in characterizing the level of service (LOS) of a facility. Density gives the closeness of other motor vehicles in the traffic stream. Subsequently it affects the capability of drivers to maneuver in the traffic stream; it is as well used to define LOS. Traffic delay is a term that outlines extra or unpredicted time spent in travel. Numerous definite delay measures are defined and utilized as MOE's in HCM (highway capacity manual) (Marfani et al., 2018).

Table 2.1: Standard level of service (Highway Capacity Manual, 2000)

Level of service	Average control delay (sec/ veh.)	General description (signalized intersection)
A	6.10	Free flow
B	10.1–20.0	Stable flow (slight delays)
C	20.1–35.0	Stable flow (acceptable delays)
D	35.1–55.0	Approaching unstable flow (tolerable delay, occasionally wait through more than one signal cycle before proceeding)
E	55.1–80.0	Unstable flow (intolerable delay)
F	>80.0	Forced flow (jammed)

2.7.1 Factors that affect LOS

The LOS could be obtained from a roadway operating with different characteristics and volume of traffic. Factors that affect LOS (level of service) are listed below:

1. Travel speed and time
2. The extent of traffic interruptions and or restrictions
3. Freedom to travel with the desired speed
4. Motorist comfort and convenience
5. Cost of operating. **(**Marfani et al., 2018)

2.8 Overview Of The Sidra Software

2.8.1 Sidra intersection

Currently, there are several traffic modeling tools / software's available on the market. The single leading is collection of software concerns traffic flow operations. The software tools used for traffic procedures have a wide-ranging of applications. Some part of the software provides an alternate to the standard usage of commonly utilized highway capacity analysis methods. While other parts use simulation for assessment of the effect of altering traffic designs, geometric patterns, and control approaches. Similarly, some apparatuses have surrounded optimization abilities to permit the improvement of the best control devices. Among the variety of these soft wares are SIDRA, TRANSYT-7F, PASSER IV, PASSER IV, HCS2000, etc.

The Signalized and Un signalized Intersection Design, and Research Aid (SIDRA) is a software bundle utilized as assistance meant for design as well as the valuation of system capacity, timing, level of service and execution analysis of individual intersections and networks of intersections. SIDRA is an influential analytical package for intersection under signal control; two-way stops, and or all way stop-signal controlled and roundabouts which may have up to eight legs. Besides, improving the phase systems, separations, and cycle lengths, SIDRA contains a good graphic display of geometric features of the intersection, comprising the sum of the lanes, turning lanes and networking.

SIDRA possibly is the foremost MOE available based on intersection database. It deals MOEs, for example, total and average delay, volume-per-capacity proportions, speeds, queues, stops, fuel utilization, productions, and operating expenses. SIDRA is the main program that ascertains capacity-based MOEs concerning a lane-by-lane foundation for all phases, besides the whole intersection MOEs.

2.8.2 Intersection evaluation and design

SIDRA software model could be utilized to estimate and equate capacity, LOS (level of service) and operation of different managements relating signalized intersections, two-way stop, roundabouts, all-way, stop sign control, give-way (yield) signal control, single-point city junctions, and signalized midblock passages for foot-travelers, all enclosed in one bundle. Intersections with Up to 8 legs approaches, individually as a two-way street, one-way approach or one-way exit may be modeled easily. Models are in the case for investigation of zebra crossings, integration, and simple freeway sections. The facility is prepared for analysis of closely related intersections.

2.8.3 Traffic model

1. ***Model consistency:*** SIDRA is software package guarantees model stability in estimating another intersection management. This applies to different forms of crossing points comprising signalized junctions, two-way stop, all-way stop sign control, roundabouts, give-way /yield sign-control, single-point city interchanges, signalized pedestrian passages and others (Akçelik, 1997).
2. ***Lane-by-lane model:*** It enables the design of intersection geometry which includes lane use schedules taking benefit of the exceptional lane-by-lane ability and operation investigation method is utilized by permitting for special lanes and inadequate lane utilization. This technique is better than approach-based and lane-group models utilized in related software bundles (Akçelik, 1997).
3. ***Drive-cycle model:*** It's also contained a Drive-cycle (modal analysis) system for forecasting of performance characteristics such as operational cost, fuel utilization, greenhouse gaseous emissions, and vehicle delay constituents which includes, accelerating delay, decelerating delay, queuing delay, stopped delay and geometric delay.
4. ***Model features:*** It also provides the user with traffic calibration models based on the study area conditions. Moreover, perform sensitivity investigates to calculate the effect of variations on factors in place of intersection geometry as well as driver actions. Analyze oversaturated circumstances taking in to account the queue length, time-reliant delay, and stop rate models. Study consequences of different dimensions models via advanced model settings.
5. ***Defaults system:*** SIDRA is a software package that ensures wide defaults method that covers traffic model parameters and maximum input data. The user can generate the personal customized model and change the default factors set for individual determinations, for example, to standardize some factors for study area environments.
6. ***Design life:*** Perform a flow scale or a design life investigation to evaluate the influence of usual traffic progression or effect of growths. Permit for different developing rates for distinct movements and use alternatives for locating different analysis purposes

plus the Concluding period, a target Level of Service has to be chosen for Worst Movement and Lane, the Capacity as well as Practical Capacity.

7. ***Intersection geometry:*** Intersections which might have Up to 8 legs can be handling, individually with two-way traffic or one-way, short lanes or, and one-lane multi-lane approaches, continuous, give way and stop slip bypass lanes as well as turn slabs as appropriate. Evaluate various design changes to improve the intersection and network geometry, control sign phasing stipulating different approaches to adjustment. Analyze the effect of intersection widening via short lanes (turn lane bays, lanes with carpark upstream, and reduction of a lane by the departure side). Analyze complex problems of opposed turns and shared lanes; for example, give ways and stops phases slip lanes, turns during red.
8. ***Vehicles and drivers:*** Analyze impacts of heavy trucks on interchanges functioning. Use HV&E for model adjustment to permit for big trucks in definite traffic flows. Using SIDRA software output on car lanes passing across the intersection (approach distance, turning ratio, and speed) a particular intersection design can be checked. Investigate the ability of the driver to respond time estimations related to queue discharge. The information can be utilized for calibration of microsimulation models (Akçelik, 1997).

2.8.4 Previous studies on Sidra software

CHEN Tianzi et al., (2010), directed a near investigation of VISSIM and SIDRA on signalized interchange this paper emphases on two reproduction programming: VISSIM and SIDRA. In light of this present reality movement information taken from the West Wenhua Road and Changchun Road of Xianyang City, their highlights and assessment consequences of signalized intersections have been dissected from the viewpoint of task straightforwardness and the yield blunder. Results demonstrate that SIDRA s task is less demanding while VISSIM s yield is more precise.

This paper examined the effortlessness of task and production-error of VISSIM and SIDRA about west Wenhua Road and Changchun street crossing point in Xianyang city. The conclusion is following:

(1) From the straightforwardness of activity, SIDRA is better than VISSIM as far as system manufacture, stage setting, yield speed and so forth.

(2) We aligned and balanced VISSIM and SIDRA independently, in view of vehicle normal delay as the assessing marker. As indicated by the error of the production comes about, VISSIM is nearer to the real esteem contrasted with SIDRA.

(3) While reenacting a signalized crossing point, if the precise vehicle normal delay is required, VISSIM is an appropriate decision; if the normal vehicle delay is just utilized as reference information, at that point, SIDRA is favored, for its benefit of the task. This paper just considers factors like the simplicity of activity and the production error in view of vehicle normal delay.

Xuanwu Chen & Ming S. Lee (2014), completed an investigation on, three remote programming bundles: RODEL discharge 1.9.9 from the U.K., SIDRA variant 3.2.2 from Australia, and VISSIM form 5.10 from Germany. For a client to create limit and delay gauges that imitate the field working conditions, these three programming bundles offer altogether different alignment capacities. RODEL does not give adjustment parameters. In any case, clients can lead some level of alignment through the alteration of the catch term of the resultant relapse condition. SIDRA variant 3.2.2 has two alignment parameters for roundabout execution investigation: ecological factor and passage/coursing flow change. VISSIM has various factors for alignment, which can be partitioned into two gatherings: driver's practices and need rules. Driver's conduct parameters incorporate vehicle following conduct, route change practices, et cetera. Need rules incorporate least gap time, least progress, et cetera.

Jabbarpour et al., (2015), carried out a research on Green vehicle traffic routing system using the ant-based algorithm. Finding an appropriate answer for traffic congestion is a substantial challenge because of the variable and dynamic nature of the network topology of traffic conditions, predominantly in urban areas. Vehicle Traffic Routing Systems (VTRSs) remains a standout amongst the best significant answers on behalf of this issue. Albeit the greater part of the current VTRSs got likely outcomes used in diminishing travel timing or enhancing traffic stream, they can't ensure decrease of the movement related irritations, for example, air contamination, sounds, and fuel utilization. Henceforth, in this research, a green VTRS was an exhibit to diminish petroleum utilization, and therefore CO2 discharges using ant-based algorithm joined with petroleum utilization display.

Ant-based Vehicle Congestion Avoidance System (AVCAS) is a VTRS that utilizes SIDRA software petroleum utilization and emanation display in its traffic directing method. This method is termed AVCAS + SIDRA which uses a different paradigm, for example, normal travel time, speed, distance, vehicle thickness alongside guide division to decrease fuel utilization however much as could reasonably be expected by finding the minimum congested briefest ways to lessen the vehicle traffic blockage and their contamination outflows.

The trial comes about directed on three unique situations (such as different traffic densities, framework use rates, and mischance circumstance) considering travel speed, travel distance, normal travel time, and fuel utilization as estimation measurements. The acquired outcomes demonstrate that the AVCAS + SIDRA out plays out the current methodologies as far as normal travel time, normal travel speed and petroleum utilization rate, with an Average of 25.5%, 19.5%, and 17%, separately. Therefore, the research suggested green VTRS eases vitality utilization as it isn't just winding up rare and costly yet additionally causing an emotional, environmental change and outflow.

Smart Dumba et al., (2016), Methodological issues in displaying signalized conjunction limit under casual open transport tasks: a Case study, Harare, Zimbabwe. The paper gives two essential experiences into the methodological issues (show alignment difficulties and vehicle grouping) when leading crossing point limit estimation in light of investigative systems in a commonplace developing country.

To start with, from the methodological angle, this investigation has given the observational proof that amid the night crest hour when the kombi driver conduct turns out to be more mind-boggling, the HCM and expository model (SIDRA INTERSECTION) ended up being not to be amiable with such situations. As far as the future work, it is important to consider the conceivable outcomes of joining expository models with reproduction models all the while for better application in creating world settings, notwithstanding the traffic being named homogenous.

Akcelik (2016), studied by comparing lane based and lane-group based models of signalized intersection network:.Two paths utilize situations in the lane-based investigative system display, and the lane-group based system demonstrate path that prepares not consider path utilize are dissected utilizing the SIDRA INTERSECTION programming, and the subsequent signal unit appearances plus the delay and line length gauges are thought about utilizing a stunned T intersection organize illustration. It is demonstrated that noteworthy contrasts can come about between these models.

The significance of the displaying of unequal path use at firmly divided convergences is accentuated. This strategy combined with a lane-based model considering the retrogressive spread of overcrowding and maximum upstream m limitation, and in addition highlights, for example, short path overflow, are required to create better outcomes in evaluating signal coordination quality and upgrading signal balances.

Mfinanga (2014), carried out a study on infective human control of signalized intersections in developing countries; an instance of Dar es Salaam city. This investigation has analyzed the execution of two noteworthy signalized crossing points in Dar es Salaam city in Tanzania while working under control of the traffic signal as well as when the traffic police are monitoring the conjunction. Outputs demonstrate that the traffic police officer isn't enhancing the execution of the crossing point yet relatively ensures that motorists abide by movement directions. The limit and delay were enhanced on some methodologies of intersections and compounded on others.

The discoveries question the broadly believed opinion that traffic police officers complete a greater work more than the signs. It ensures in this way remained reasoning for straightforward changes in signal timing and enhancing motorist's conduct via enhanced requirement of movement directions can improve and cost-viably enhance the execution of intersections

CHAPTER 3
METHODOLOGY

3.1 Introduction

Three major intersections in Kano city were chosen for the analysis; Mal. Aminu Kano (Figure 3.2), Dan Agundi (Figure 3.3) and Civic Centre (Figure 3.4) intersections. These three are among the most congested among various intersections of major roads in Kano city. A combination of aerial, geometric and traffic data was used in the selection of the intersection. This Chapter itemized the steps followed in the selection, data collection and the analysis employed in this research.

3.2 Location of Study Area

Kano metropolis is an industrial and business base centre in Northern part of Nigeria as well as, been the subsequent biggest city after Lagos, in Nigeria with a high population of 9,383,682 as at census 2006, and last known population is approximately 11 087 800 (the year 2011), this was 6.77% of total Nigeria population with a growth rate of 3.36 % per year. Road transportation is the dominant mode of transport which linked Kano with most of the neighbouring African cities, convoys of heavy trucks, buses and others connect it with various municipalities in Chad, Cameroon, Niger and Republic of Benin (Barau, 2007).

Kano City is the capital of Kano State located at the central western part of the state lying at equatorial latitude between 11059´59.57 – 12002´39.570N and longitudinally between 8033´19.69 – 8031´59.690E. It is located in the north central border of Nigeria and 840km away from Sahara desert and 1,140 km from the Atlantic Ocean. The overall area of the Metropolis presently is 499 square kilo metres (193 square miles) and comprises eight Local Government Areas (LGAs):- Dala, Kano Municipal, Fagge, Gwale, Nassarawa, Tarauni, Ungogo and Kumbotso (see Figure 3.1) (Okunola, Uzairu, Gimba, & Ndukwe, 2012).

The study area consists of 3 intersections were selected as shown in Figures 3.2 – 4 below, after field visits to the regions to select intersections which are characterized by congested traffic in peak hours and the names of roads are as listed in Table 3.1.

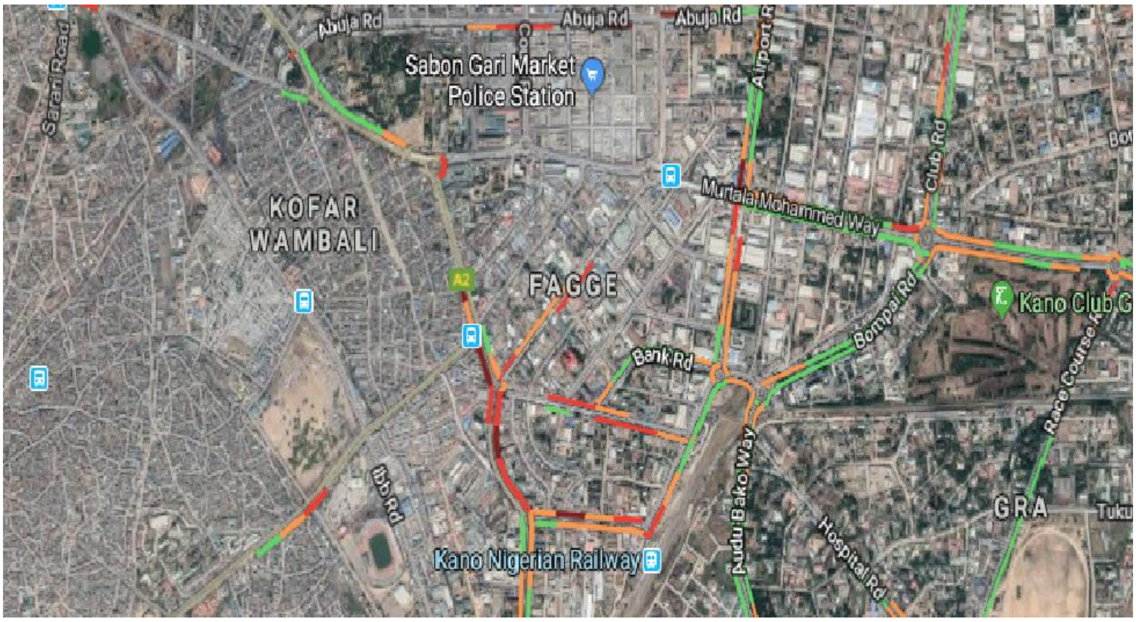

Figure 3.1: Kano traffic flow of the selected intersections within the metropolis

Figure 3.2: Aminu Kano Intersection

Figure 3.3: Dan Agundi intersection

Figure 3.4: Civic Centre intersection

3.3 Case Study

Three major intersections located along the busiest roads within the metropolis were selected. The selected intersections include: Gidan Mal. Aminu Kano / Goron Dutse junction (Figure 3.2), Dan Agundi (Figure 3.3) and Ibrahim Taiwo / Civic center road junction (Figure 3.4), and.

Table 3.1: List of Intersections in Kano metropolis

Intersection no	Names
1	Dan agundi Intersection
2	Ibrahim Taiwo / Civic centre road Intersection
3	Gidan Mal. Aminu Kano / Goron Dutse Intersection

3.4 Data Collection

3.4.1 Duration of data compilation

Data were collected within weekday periods in the morning and evening peak hours. It is viewed as suitable because extensive variety of unit sizes were recorded. Information was not gathered amid harsh climate or strange movement conditions like a car crash.

3.4.2 Apparatuses and tools used for data collection

Field data collections were carried out at the selected site using types of Equipment such as:

- Camera.
- Distance measuring wheel.
- Google Earth.
- Stopwatch.

Figure 3.5: Apparatuses and tools of data collection

In this research the utilization of Google Earth (Figure 3.5c) to decide the underlying research area, after that it used to estimate the spaces between convergences of the perspective of the absence of estimation of the separation between each other. And furthermore the necessities of information gathering is camera (Figure 3.5d) because of absence of capacity to ascertain the quantity of vehicles on the grounds that the expansive inflow of vehicles on the crossing points and the stopwatch (Figure 3.5b) utilized for computing the period for data collection lastly a distance measuring wheel (Figure 3.5a) used to gauge dimensions such as the width of lane at intersection.

3.4.3 Traffic count

Volume was counted up in 15 min interims all through the peak hour toward the beginning of the day and evening. The traffic tallies at every crossing point were repeated in one week. The vehicles inflow into the intersections can be categorized into the accompanying classes:

- Cars
- Commercial Buses
- Trucks
- Tricycle

Data obtained from the study area stored in the schedules coordinated and then convert the period of a quarter-hour to an hour and convert to Percentage Car Unit (PCU), to get flow volume for every lane or link .as shows in Table 3.2.

Table 3.2: Corresponding converting factors

Type of Vehicle	**Tricycles**	**Cars**	**Mini Buses**	**Trucks**
Value in PCU	0.8	1.0	2.2	4

3.5 Movement And Phases

Each different line prompting the junction and represented by its bearing, path use and right of way arrangement is known as a movement. The signal phasing framework controls the distribution of privileges of approach to singular movement.

Signal phase is a condition of the signs within which at least one movement gets right of way. Signal phases will be characterized such that when there is a difference in right of way, that is the point at which a movement is halted and another begun, there is a phase change. A phase is recognized by no less than one movement receiving the right of the path toward its beginning and no less than one movement losing right of path toward its termination.

A movement which gets right of the path during more than one stage is called an overlay movement (Akcelik, 1981).

3.5.1 Signal cycle

One full series of signal phases is known as a signal cycle. The time from the finish of the green time frame on one phase to the start of the green time frame on the following phase is known as the intergreen time (I). It comprises yellow and every single red period. Amid the all-red time frame, both the ending and beginning stages/movements are displayed red signal at the same time.

The stage change times (F) are characterized as stage ending times which happen toward the finish of the period, and the intergreen period is the starting part of the stage. In this way, the green time frame begins at the time (F + I). On the off chance that the showed green time for a stage is G, at that point the green time frame closes at the time (F + I + G). This is the phase change the time for the following stage. The cycle chart can be developed by setting the principal phase change time to zero and including the (I + G) estimation of the primary stage to locate the second stage change time, et cetera. The aggregate of all stage intergreen and green times is the cycle time:

$$C = \sum (I + G)$$

This is the time at which the last stage green period closes; thus it is the primary stage change time in the following sign cycle (Akcelik, 1981).

3.6 Sidra Intersection Input Data

SIDRA Intersection is a technical software bundle that replicas traffic intersections comprising light vehicles (cars, mini bus, tricycle, etc.), heavy vehicles (trucks, lorries, bus, van, etc.) and pedestrians. The main function of the software is to model numerous situations for both current and upcoming intersections to control their performance under range of conditions. The software permits the input of various parameters which make provisions for the changeable conditions, containing vehicular, human and geometric characteristics appropriate for each intersection.

3.6.1 Intersection dialogue

The intersection dialogue as shown in Figure 3.6; includes the following minimum input requirement:

- Title of the intersection or (name of the intersection) as well as site and determination
- Intersection identification number
- Signal System Analysis contains the existing or future intersection process which is simply applicable to signalized intersections
- Peak hour flow and unit time for traffic volumes which is based on the data collected from the intersection traffic counts and the maximum unit time for traffic volumes is one hour (60 minutes)

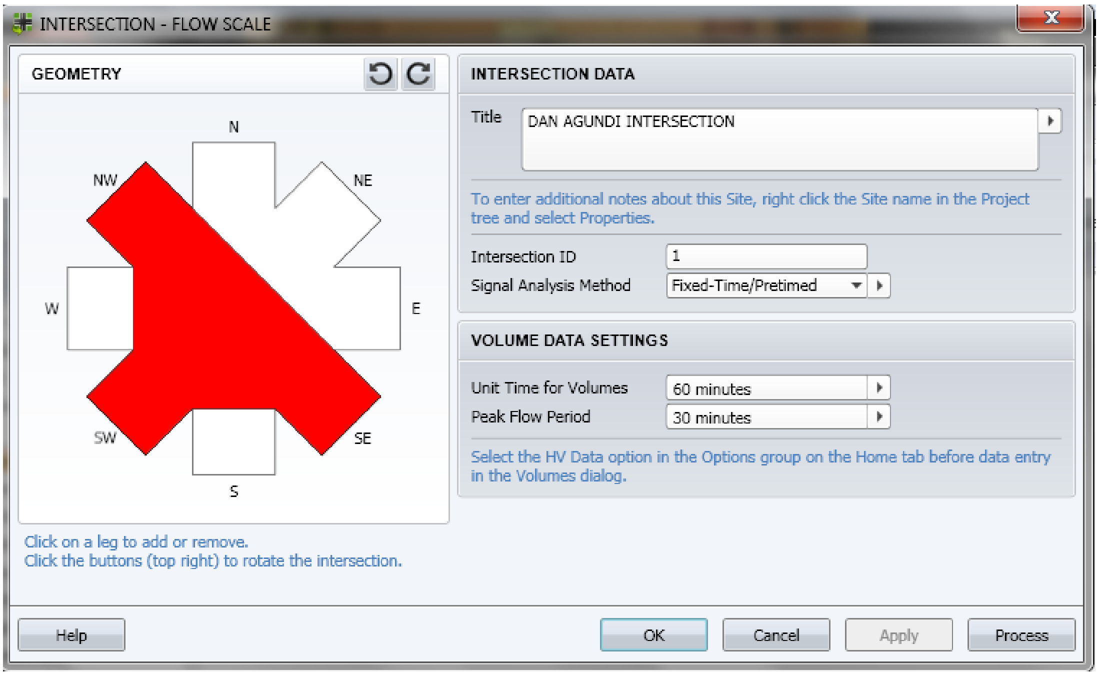

Figure 3.6: Intersection dialogue (screenshot sample from the software)

3.6.2 Geometry dialogue

The Geometry Dialogue includes; Approaches & Lanes Dialogue which enclosed the following minimum requirement:

- Lane data for both approach and exit lanes include: (lane name, lane length and width, medians, lane type, grade, lane discipline, short lane, and approach control) of the existing geometry for constructed intersections.
- To insert or add a slip or continuous lanes in any existing approach a correct selection is needed in this dialogue
- The selection of maximum basic saturation flow to be used is according to Table 1 provided for urban roadways and Table 2 which contains a provision for rural roads. Higher values need to be supported by appropriate study data.

Figure 3.7 and 3.8 below shown Geometry Dialogue and Volume Dialogue for intersection.

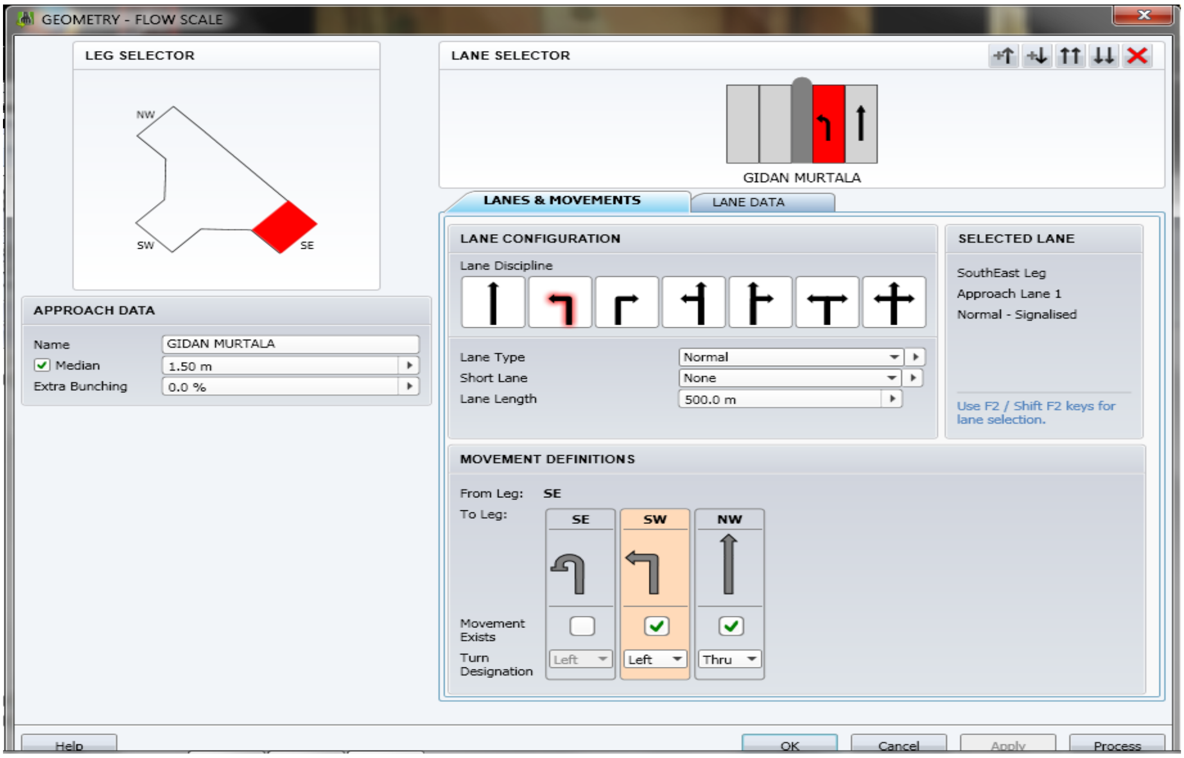

Figure 3.7: Geometry dialogue (lane data tab)

3.6.3 Volumes dialogue

The vehicular traffic volumes inputted most to be based on the current survey data counted from each intersection. The characteristics of the study of the collected data are to dictate the PFF utilized. Supporting discussion is to be provided justifying the factor utilized.

The growth rate factor may be utilized in a design life analysis of the intersection is completed. Validation of the method utilized to determine these values should be contained in the final report.

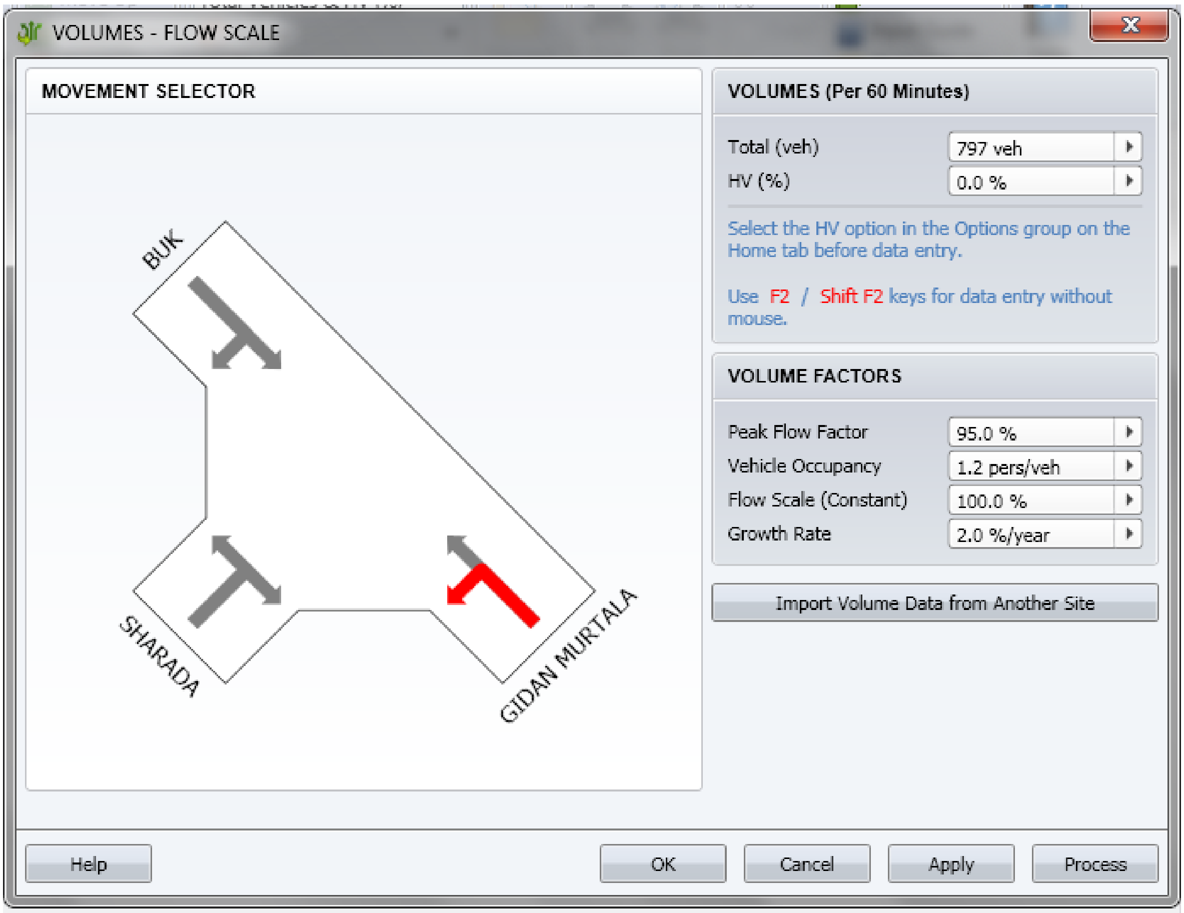

Figure 3.8: Sample screenshot volumes dialogue

3.6.4 Path data dialogue

The input data for existing intersections in this dialogue as shown in Figure 3.9 include Approach Cruise Speed and Exit Cruise Speed which reflect the current conditions (generally posted plus 10%). Whereas the Approach Cruise Speed and Exit Cruise Speed for planned or upcoming intersections had better reflect the hierarchy based design speed.

The Approach Travel Distance of the dialogue was changed to base on the operation of the existing intersection. The Negotiation Radius and Negotiation Distance may be physically overwritten to reflect the physical factors for cases where an intersection has uncommon geometric features.

Validation must be specified for the values utilized due to the intersection being of uncommon nature. Any additional item used in this dialogue must be as per the defaulting values or calculation methods.

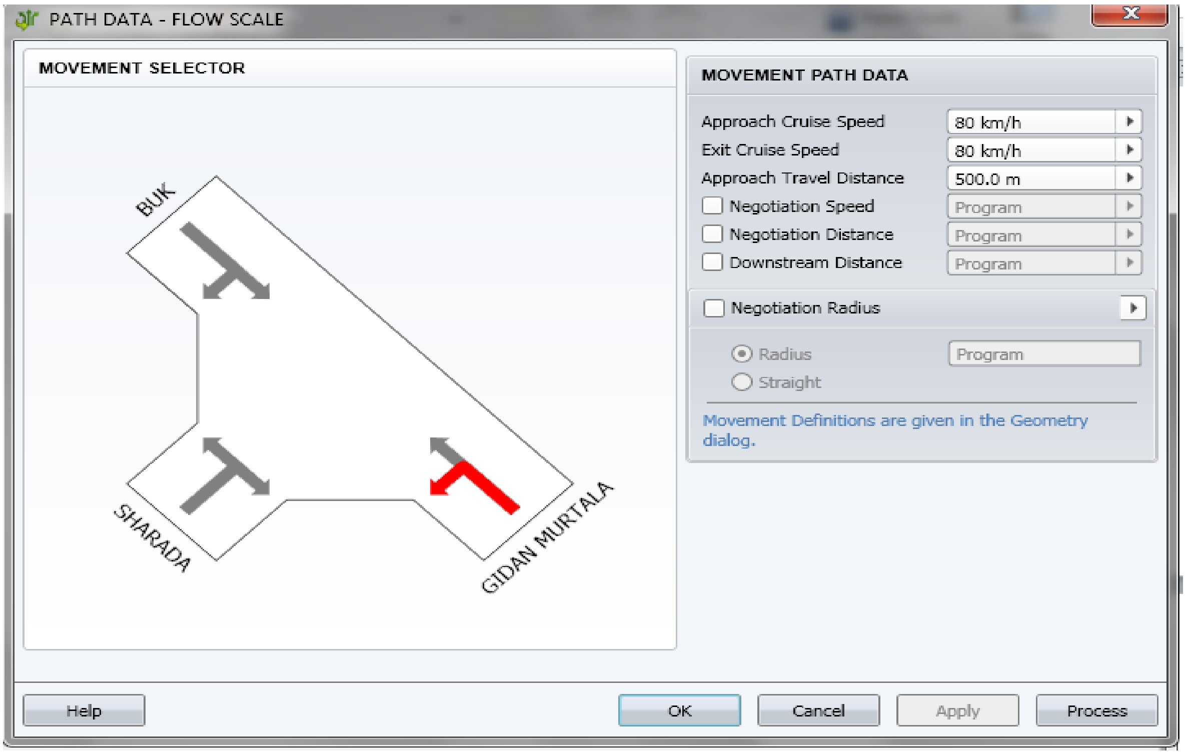

Figure 3.9: Sample screenshot of the path data dialogue

3.6.5 Movement Data Dialogue

All the default standards used in this dialogue as shown in Figure 3.10 will only be utilized if evidence could be given which specifies that the changed level is applicable. The defaults are as shown in the screenshot. The red arrow in this figure outlines the data that is only applicable for signals. The number of pedestrians might be inputted into the 'Pedestrian Effects' sector of this dialogues however justification is necessary.

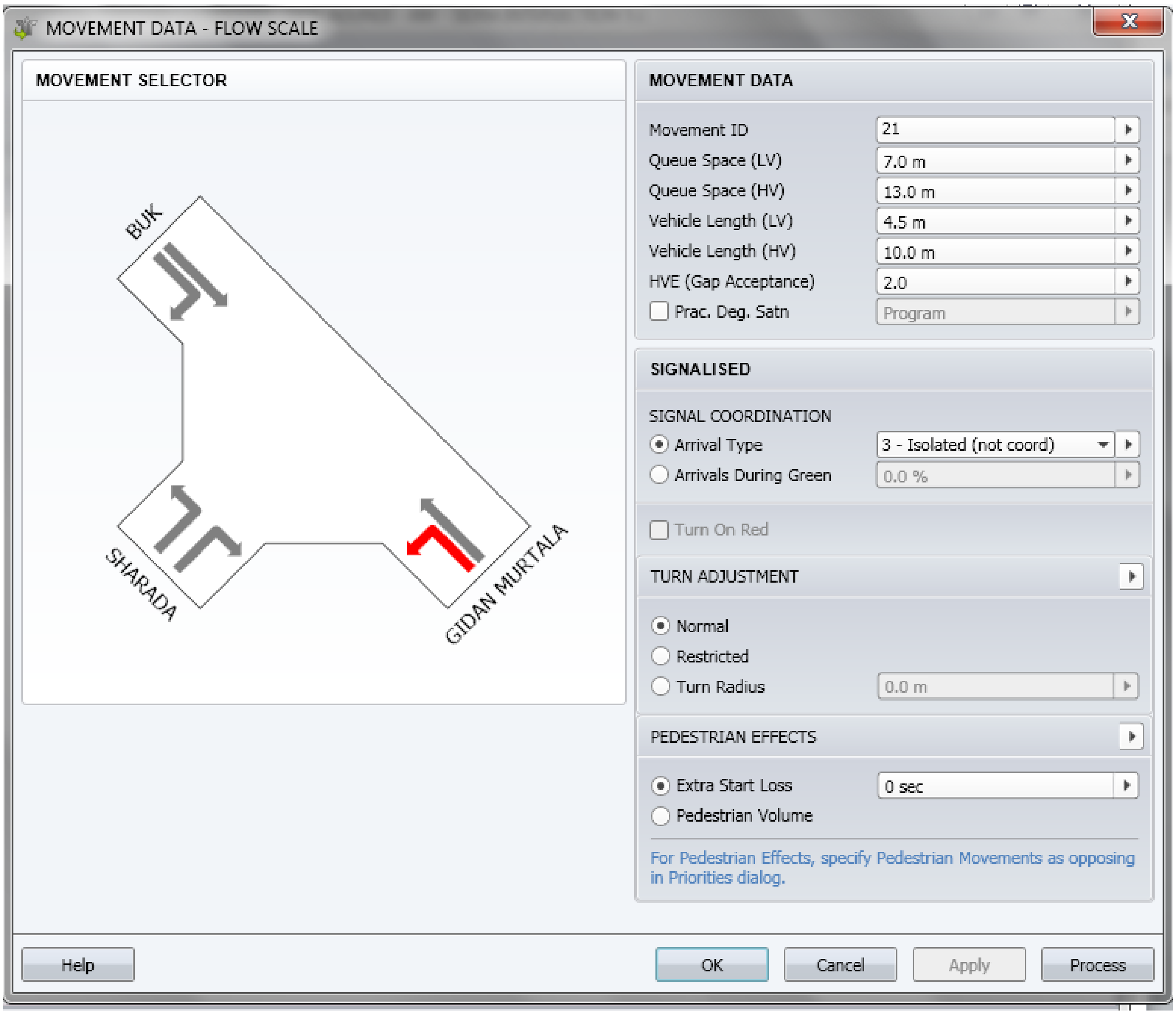

Figure 3.10: A sample of a screenshot showing default values of this dialogue

3.6.6 Priorities dialogue

The opposing movements provided by this dialogue can only be changed unless evidence could be provided to indicate that the real opposing movements are different (Figure 3.11). This might be the situation for intersections with uncommon geometry, turn descriptions or particular treatments.

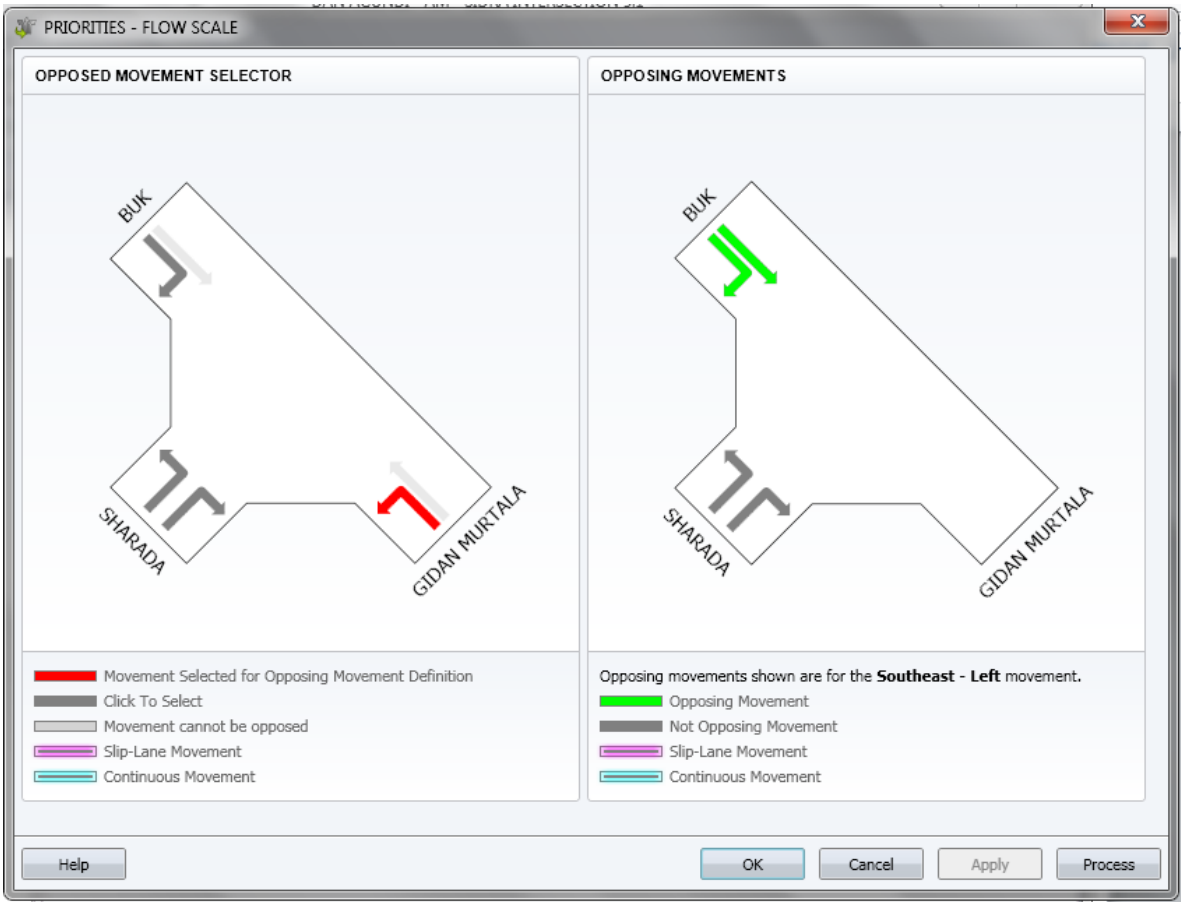

Figure 3.11: Sample screenshot of the priorities dialogue

3.6.7 Gap-acceptance data dialogue

a) This should be applied to left-turn movements and slip-lane left-turn movements from the minor road

b) This situation is related to two-way major road circumstances with the opposing road from one direction of the major (one - lane, two-lane or three-lane).

c) The situations stated (a one - way, or two lanes two - way, four lanes two - way, six lanes two - way) should be related to the opposing movement lanes on the major road.

d) The speeds of the opposed movement should be related to the assigned posted speed of the major road except when the only opposing traffic is on the Minor roads in that case the speeds should be associated with the minor road (Figure 3.12).

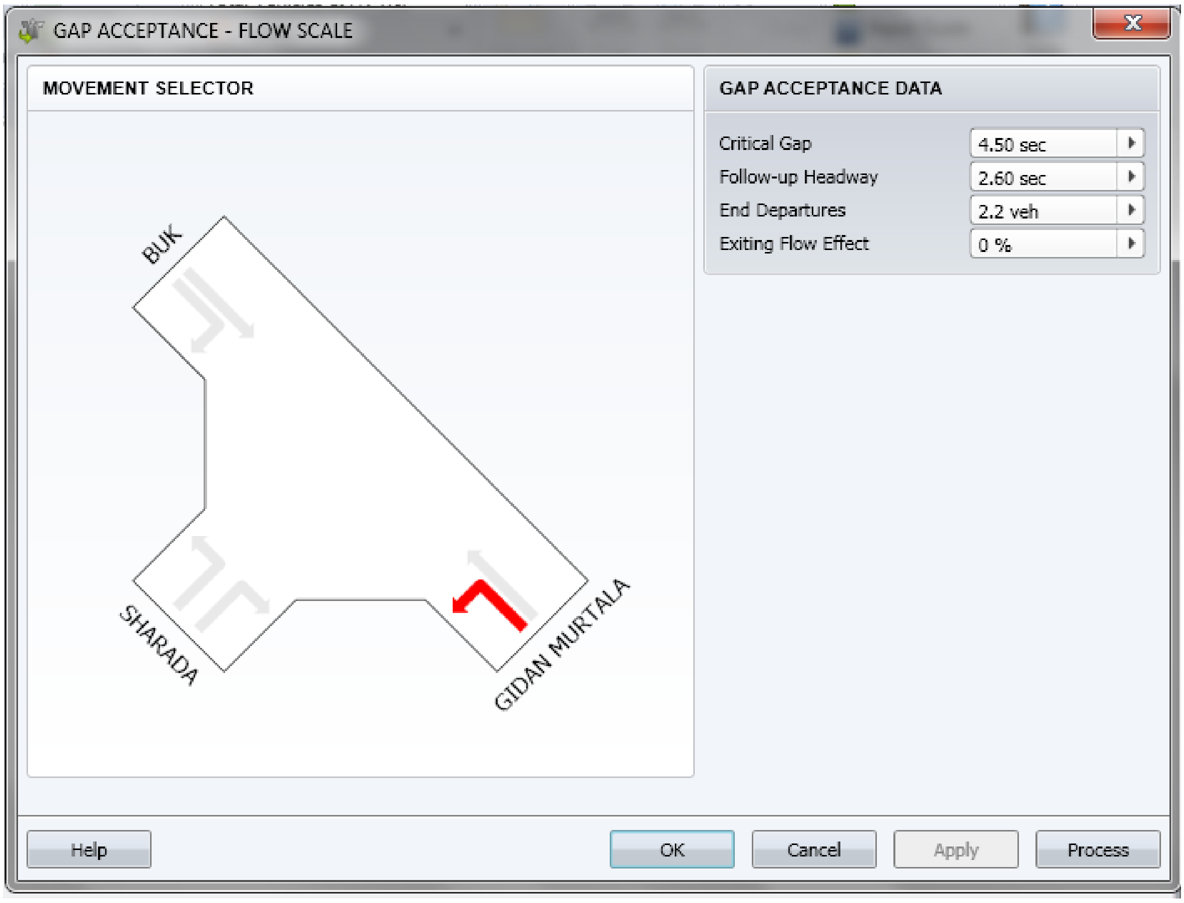

Figure 3.12: Sample screen shot of the gap-acceptance data dialogue

3.6.8 Model settings dialogue

Software default parameters are to be used for the Model Settings Dialogue as per Figure 3.13 and 3.14 except for:

- The Intersection LOS Method

- The Level of Service Target.

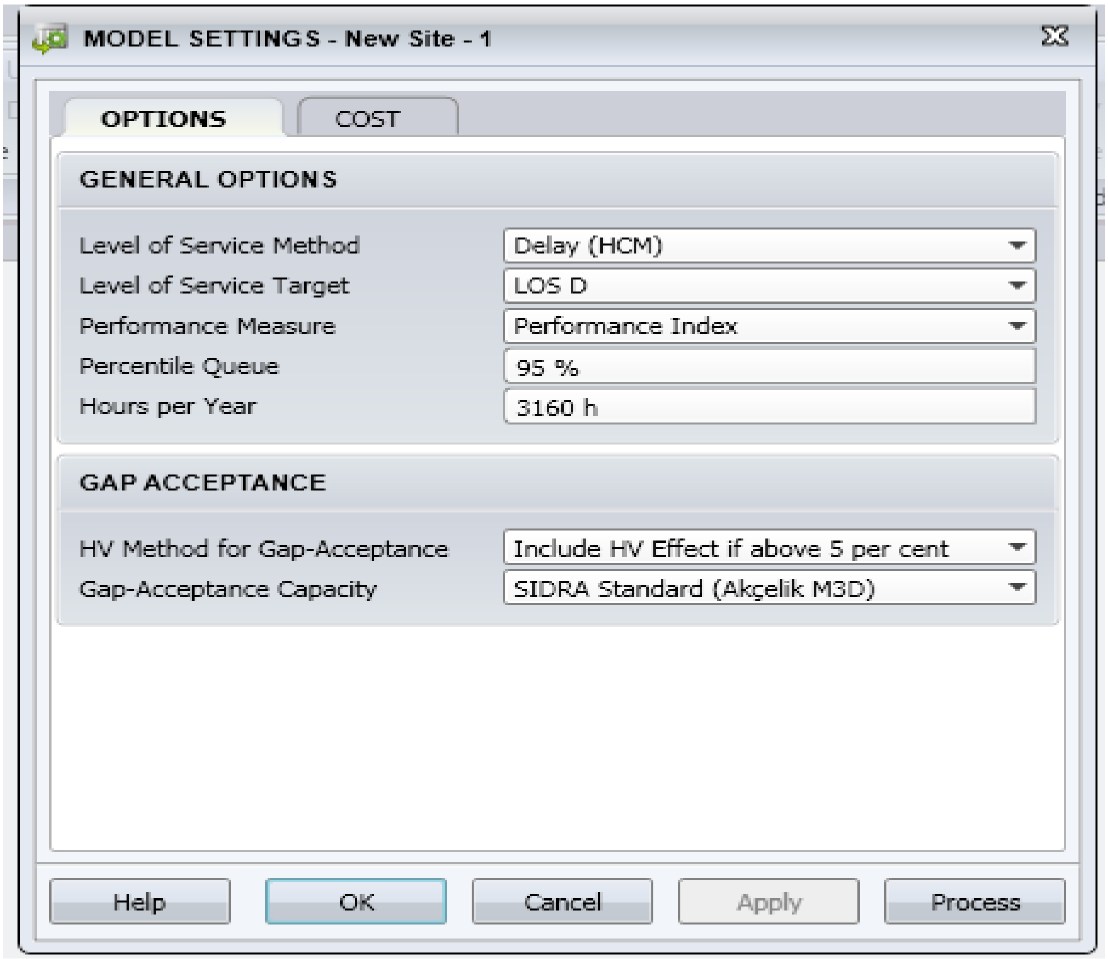

Figure 3.13: Sample screen of model settings dialogue (options)

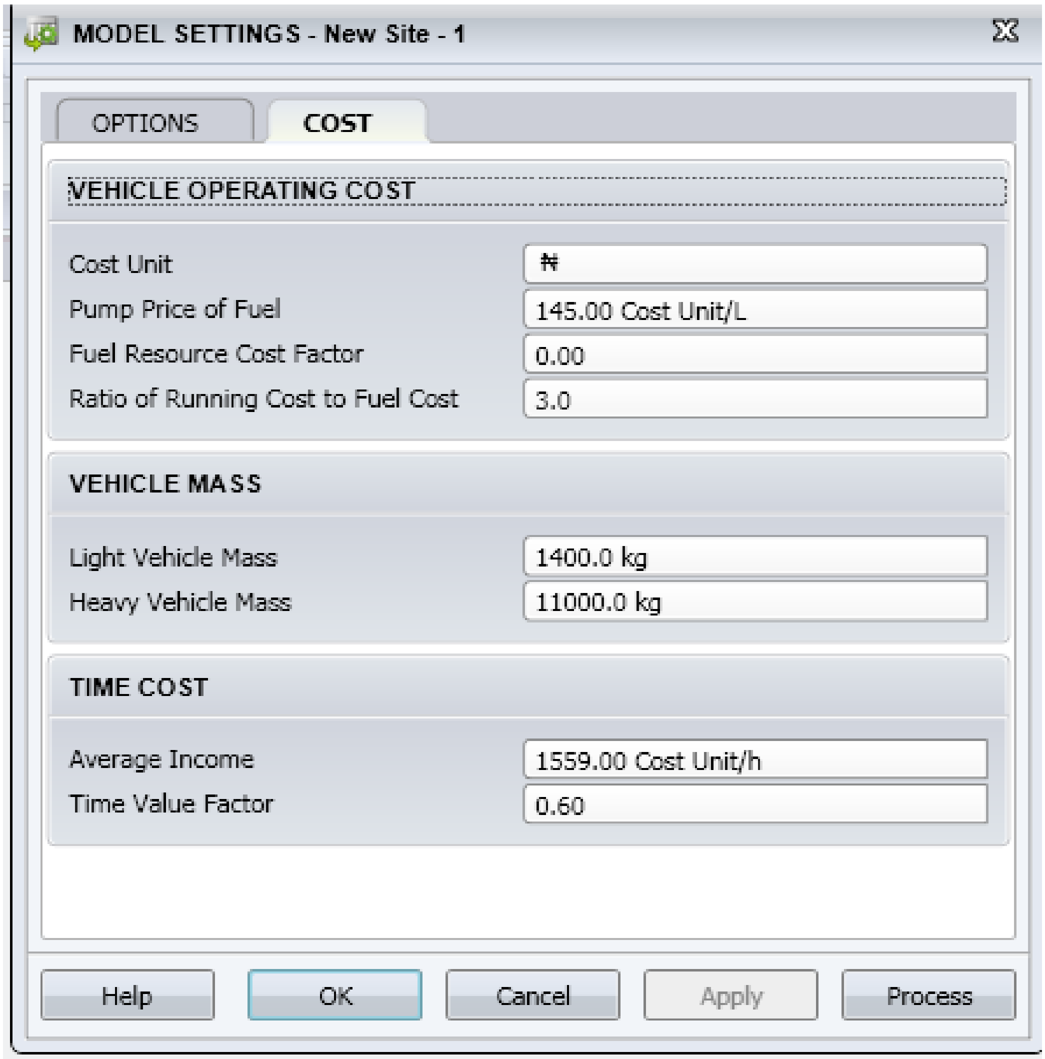

Figure 3.14: Sample screen of model cost

3.6.9 Demand and sensitivity dialogue

All methods in the Demand and Sensitivity can be used as required for analysis purposes of the intersection. For each method used (if any), the related scenarios are required to be included in the SIDRA Intersection file.

3.6.10 Pedestrians dialogue

The pedestrian's volume and PFF (Peak Flow Factor) are to be changed in accordance with the intersection traffic counts obtained to passage distance. Likewise, the approach travel distance and its downstream distance may be altered according to the geometry of the intersection if dimensions are obtainable. Hence, default values are to be utilized for all the available volume of pedestrians and PFF may be changed according to the intersection traffic counts obtained. Figure 3.15 showed the Pedestrian Dialogue.

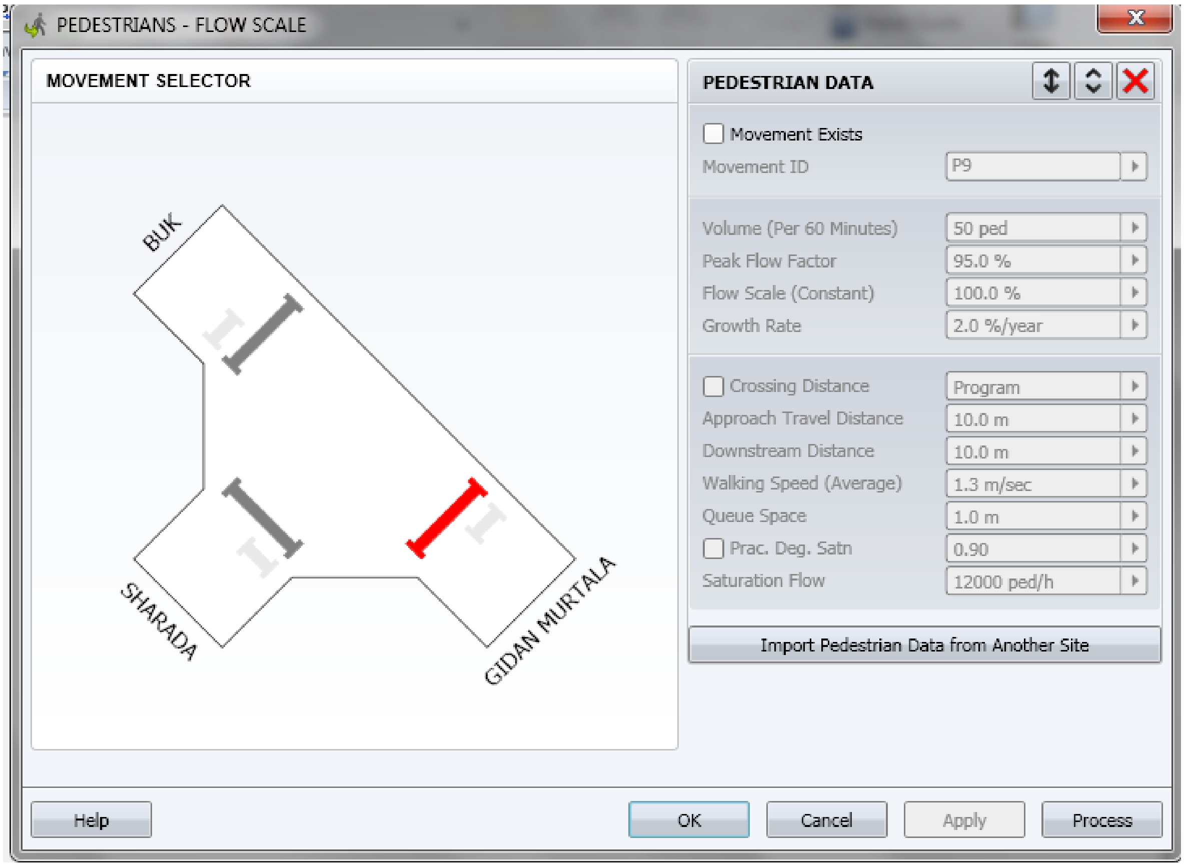

Figure 3.15: Sample Screen Shot of the Pedestrian Dialogue

3.7 Field Study Data

This study is mainly based on data collected from field work and used therefor the analysis. The data for each intersection is shown in Tables 3.3, 3.4, 3.5, 3.6, 3.7 and 3.8 as follows

Table: 3.3: Field study data intersection 1; Dan Agundi AM

Phase number	Route	PCU volume	Phase Green Time
	Left	-	
Φ1	Through	1770	30
	Right	1077	
	Left	752	
Φ2	Through	-	25
	Right	1074	
	Left	797	
Φ3	Through	-	30
	Right	1799	

Table: 3.4: Field study data intersection 1; Dan Agundi PM

Phase number	Route	PCU volume	Phase green time
	Left	-	
Φ1	Through	1875	30
	Right	1121	
	Left	824	
Φ2	Through	-	25
	Right	1114	
	Left	751	
Φ3	Through	-	30
	Right	1853	

Table: 3.5: Field study data intersection 2; Aminu Kano Way AM

Phase number	Route	PCU volume	Phase Green Time
	Left	371	
Φ1	Through	950	40
	Right	-	
	Left	-	
Φ2	Through	752	35
	Right	302	
	Left	918	
Φ3	Through	-	40
	Right	363	

Table: 3.6: Field study data intersection 2; Aminu Kano Way PM

Phase Number	Route	PCU Volume	Phase Green Time
	Left	493	
Φ1	Through	1141	40
	Right	-	
	Left	765	
Φ2	Through	-	35
	Right	312	
	Left	377	
Φ3	Through	-	40
	Right	830	

Table: 3.7: Field study data intersection 3; Civic Centre AM

Phase Number	Route	PCU Volume	Phase green time
	Left	-	
Φ1	Through	1048	40
	Right	504	
	Left	646	
Φ2	Through	-	35
	Right	438	
	Left	569	
Φ3	Through	1132	40
	Right	-	

Table: 3.8: Field study data intersection 3; Civic Centre PM

Phase Number	Route	PCU Volume	Phase Green Time
	Left	-	
Φ1	Through	1048	40
	Right	504	
	Left	646	
Φ2	Through	-	35
	Right	438	
	Left	569	
Φ3	Through	1132	40
	Right	-	

3.8 Sidra Intersection Output Data

This section outlines the minimum performance levels and calibration requirements needed to achieve an acceptable solution

3.8.1 Definitions

The following section clarifies the definition of particular output performance criteria. 95% Back of Queue Distance – This value is referring to the storage length of a particular lane.

3.8.2 Calibration

For existing intersections, a calibrated scenario is required to be set up before any future scenarios are explored. The calibration process is to be in accordance with the numerous traffic studies and interpretations. Any single change needed for calibrating the model is to be specified and well documented with a description and validation of the change. SIDRA User Guides should be referred to for possible calibration methods.

3.8.3 Acceptable performance criteria

The fundamental performance features that must be utilized to evaluate a single intersection in SIDRA Intersection software are the Level of Service (LOS) (based on Delay) and Practical Degree of Saturation. It must be noted that all additional performance features need to be evaluated as they increment the fundamental criteria.

i. ***The degree of saturation (DOS):*** The Practical Degree of Saturation is a performance indicator that shows either the intersection passed or failed; hence if the obtained value for any lane is higher than the corresponding values contained in Table 3.9 below, this indicates that the intersection is not acceptable (unless evidence can be provided of why the values should be changed).

Table 3.9: Practical Degree of Saturation Limits (SIDRA, 2009)

Intersection Type	Maximum Practical Degree of saturation
Signals	0.9
Roundabout	0.85
Sign-controlled	0.8
continuous	0.98

ii. Level of Service (LOS)

- The acceptable minimum LOS for each leg/lane is to be assessed as per the limits identified in Table 8 for Urban Roads and Table 9 for Rural Roads.
- The LOS will depend on the hierarchy of the intersecting roads.
- The delay criteria for each LOS have been identified in Table 2 (for vehicles) and Table 3 (for pedestrians).
- The leg with the highest LOS standard as identified in (urban roads) and (rural roads) is to be used as the overall intersection minimum acceptable Level of Service Target.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 General Overview

The continuous urbanization in Kano metropolis lead to the growth of traffic congestion which was marked as a serious problem in the city, it has a significant impact on the economy, travelling behaviour, environment, and road users.

The results of Sidra application show the percentage of variation between the performance measures before and after optimization of the selected intersection. It was presented in this chapter the reduction in Total Travel Time (TTT), Average Delay (AVD), Total Stops, and Fuel Consumption (FUC) while in the other hand the percentage increase in Capacity, Travel Speed, and Level of Service (LOS).

The results compared the variation between the existing and proposed condition as follows;

- Results of the analysis from before and after improvement AM

- The result of the analysis from before and after improvement PM

In the analysis of the two cases mentioned above, three different approaches were considered;

- The flow scale
- Design life for 20 years
- Sensitivity analysis

4.2 Suggestion For Optimization

- Addition of lanes to each existing approach of the intersection that failed to pass the analysis with the target LOS specified.
- Addition of slips lanes to the intersection for right turn vehicles.

- Converting the intersection which failed to pass the given criteria with four lanes at an approach.

Performance criteria were discussed according to total travel time, average delay and degree of saturation, travel speed, operation cost, the level of service, etc.

4.3 Results Of The Analysis From Before And After Improvement AM

The results of the analysis of the morning period (AM) were presented in this section according to flow scale, design life and sensitivity of the intersection. To better understand the margin and improvement from the existing and proposed design, results of each performance criteria were outlined accordingly.

1. Flow scale analysis criteria AM

Table 4.1: Performance measures of existing and proposed flow scale analysis AM

Performance measures	**Aminu Kano Intersection**		**Civic Centre Intersection**		**Dan Agundi Intersection**	
	Before	**After**	**Before**	**After**	**Before**	**After**
Capacity (veh/h)	2251	3946	1767	3535	2681	7530
LOS	F	C	F	D	F	C
TTT (sec)	537.4	103.0	196.1	117	1399.6	104.6
AVD (sec)	504.4	30.4	162.5	43.4	1366.4	31.3
Travel Speed (km/h)	4.6	22.4	12.6	19.8	1.8	22.2
FUC (L/h)	1167.9	349.8	354	295	4972.5	694.3
Travel Dist. (m)	684	643	686	644	685	647
Total Stops (veh/h)	8563	3528	2880	2283	21793	6735
Degree of Sat.	1.709	0.859	1.243	0.781	2.853	0.894
PI	1027.8	187.2	276.8	195.9	4540.4	402.8

2. Flow scale analysis criteria PM

Table 4.2: Performance measures of existing and proposed flow scale analysis PM

Performance measures	Aminu Kano Intersection		Civic Centre Intersection		Dan Agundi Intersection	
	Before	**After**	**Before**	**After**	**Before**	**After**
Capacity (veh/h)	2455	4014	1751	3669	2682	7828
LOS	F	C	F	D	F	D
TTT (sec)	528.3	105	274.7	214.2	819.3	113.7
AVD (sec)	495.2	32	241.1	44	786.1	40.4
Travel Speed (km/h)	4.7	22	9.0	19.7	3.0	20.5
FUC (L/h)	1244.8	369.1	464.1	321.1	2338.1	741
Travel Dist. (m)	685	643	686	644	685	647
Total Stops (veh/h)	8068	3872	3617	2506	13241	6510
Degree of Sat.	1.680	0.884	1.362	0.817	2.070	0.892
PI	1132.7	201.5	386	214.2	2170.8	498.6

3. Design life analysis criteria AM

Table 4.3: Performance measures of existing and proposed design life analysis AM

Performance measures	Aminu Kano Intersection		Civic Centre Intersection		Dan Agundi Intersection	
	Before	**After**	**Before**	**After**	**Before**	**After**
Capacity (veh/h)	2251	4804	1767	4583	2681	7805
LOS	F	E	F	D	F	E
TTT (sec)	537.4	136.2	541.9	121.7	1399.6	136.4
AVD (sec)	504.5	63.3	508.2	48	1366.4	63.1
Travel Speed (km/h)	4.6	17.0	4.6	19.1	1.8	17.1
FUC (L/h)	1167.9	496.4	964	444.4	4972.5	883.0
Travel Dist. (m)	684	643	686	644	685	647
Total Stops (veh/h)	8563	4181	6783	3650	21793	7950
Degree of Sat.	1.709	0.897	1.776	0.890	2.853	0.980
PI	1027.8	389.6	875.4	307.2	4540.4	698.5

4. Design life analysis criteria PM

Table 4.4: Performance measures of existing and proposed design life analysis PM

Performance measures	Aminu Kano Intersection		Civic Centre Intersection		Dan Agundi Intersection	
	Before	**After**	**Before**	**After**	**Before**	**After**
Capacity (veh/h)	2453	4633	1751	5246	2682	7593
LOS	F	D	F	D	F	E
TTT (sec)	528	124.3	646.4	128.2	1497.7	153.1
AVD (sec)	494.9	51.3	612.7	54.5	1464.6	79.8
Travel Speed (km/h)	4.7	18.6	3.8	18.1	1.6	15.2
FUC (L/h)	1243.6	466.2	1187.7	526.1	5455.9	969.6
Travel Dist. (m)	685	643	686	644	685	647
Total Stops (veh/h)	8061	4301	7771	4644	23035	8890
Degree of Sat.	1.680	0.907	1.946	0.896	2.957	1.045
PI	1131.6	323.7	1078.2	381.1	4956.2	806

5. Sensitivity analysis criteria AM

Table 4.5: Performance measures of existing and proposed sensitivity analysis AM

Performance Measures	Aminu Kano Intersection		Civic Centre Intersection		Dan Agundi Intersection	
	Before	**After**	**Before**	**After**	**Before**	**After**
Capacity (veh/h)	2702	4084	2121	3667	3218	7805
LOS	F	E	F	D	F	E
TTT (sec)	353.5	148	341.3	120.9	1032.3	136.4
AVD (sec)	320.5	75.1	307.6	47.2	999.2	63.1
Travel Speed (km/h)	7.0	15.6	7.2	19.2	2.4	17.1
FUC (L/h)	891.7	462.2	711.7	340.6	3932.3	883
Travel Dist. (m)	684	643	686	644	685	647
Total Stops (veh/h)	7378	4058	5565	2763	20515	7950
Degree of Sat.	1.425	0.943	1.480	0.856	2.378	0.980
PI	742.5	381	610.8	234.1	3583.4	698.5

6. Sensitivity analysis criteria PM

Table 4.6: Performance measures of existing and proposed sensitivity analysis PM

Performance measures	Aminu Kano Intersection		Civic Centre Intersection		Dan Agundi Intersection	
	Before	**After**	**Before**	**After**	**Before**	**After**
Capacity (veh/h)	2946	4173	2101	5246	3219	8135
LOS	F	F	F	D	F	E
TTT (sec)	350.8	162.6	430.1	115.7	1114.4	134.1
AVD (sec)	317.6	89.5	396.5	42.3	1081.3	60.7
Travel Speed (km/h)	7.0	14.2	5.7	20	2.2	17.4
FUC (L/h)	954	520.1	898.5	362	4334.3	907.5
Travel Dist. (m)	685	643	686	644	685	647
Total Stops (veh/h)	6968	4740	6605	2733	21818	8076
Degree of Sat.	1.400	0.988	1.622	0.649	2.464	0.975
PI		449.8	784.4	237.6	3936.5	711.6

4.4 Capacity Performance of Existing and Optimized

The capacity of a particular approach of the signal control intersection is principally a function of a total of lanes and their respective movement flow, the direction of flow circulation, basic saturation flow and signal green time proportion. Therefore with the addition of number lanes during the optimization, the average capacity of all the intersections increased with 43.3 % and 38.4 % for AM and PM sections at Aminu Kano, 51.2 % and 59.6 % for Civic Center and 62.9 % and 63.6 % for Dan Agundi AM and PM sections respectively as shown in the Figure 4.1, Figure 4.2 and Figure 4.3 this automatically improved the Level of Service LOS of the intersections.

Within the Figures, flow scales are represented as FS, design life as DL while the sensitivity as SE. These abbreviations are same cross in the Figures used in this Chapter.

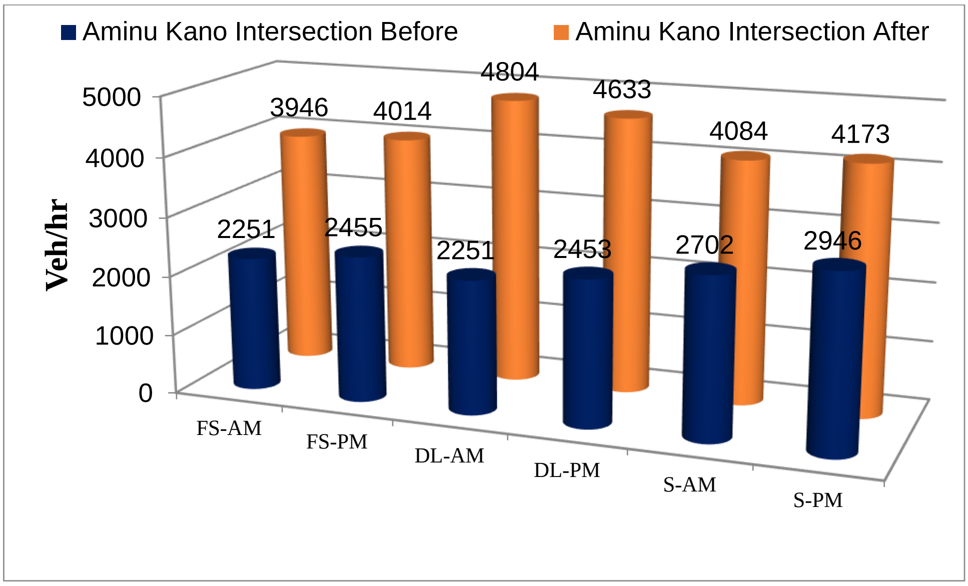

Figure 4.1: Capacity performance of Aminu Kano intersection

The results in Figure 4.1 suggest that the intersection capacity at Aminu Kano intersection can be improved higher where design life is the function of optimisation. Under design life optimisation criteria, there was a significant shift in the capacity of the intersection from the existing to the optimised design which is expected to serve for 20 years under 2 % uniform growth of the population for both AM and PM congestion period. Similarly, flow scale optimisation function performed better than the flow rate sensitivity criteria which gave a small difference between the existing and the proposed design.

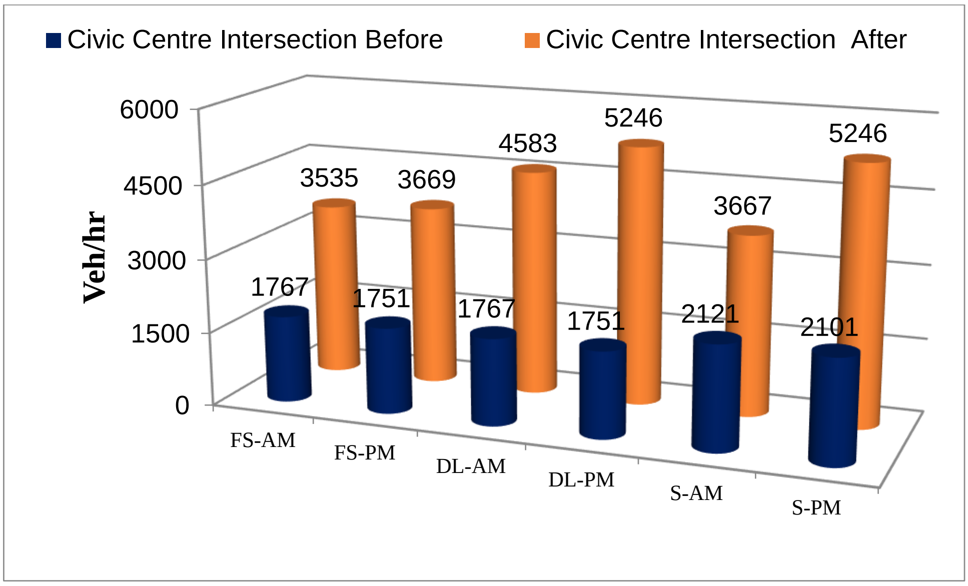

Figure 4.2: Capacity performance of Civic Centre intersection

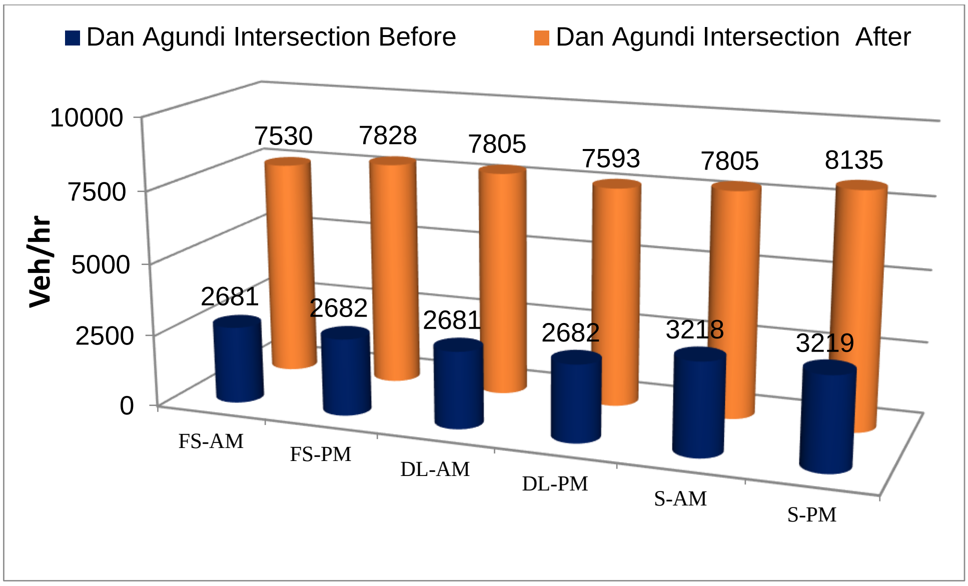

Figure 4.3: Capacity performance of Dan Agundi intersection

When compared with the increase between the existing capacity and the proposed, the design life criteria perform better than flow scale and the sensitivity analysis for all three intersections under review.

4.5 Average Delay Performance of Existing and Optimized

After the optimization the LOS of each intersection was improved, which directly have a positive impact on mobility and driving comfort, likewise, it reduces the travel delay. There were 94 %, 87 % and 77 % reduction for AM section at Aminu Kano intersection (Figure 4.4) from flow scale, design life, and sensitivity analysis optimisation criteria respectively. At PM section respective reduction was 94% 90% and 72 % AVD for the three optimisation criteria.

Within the Civic Centre intersection (Figure 4.5), the results was similar, with 73 %, 82 % and 85 % respective reduction at AM section from flow scale, design life and sensitivity analysis optimisation criteria. PM section was 82 %, 91% and 89 % respective reduction.

However, the optimisation for the average delays at Dan Agundi intersection (Figure 4.6) was improved significantly for both AM and PM section. 97 %, 95 %, and 94% were recorded with the aforementioned respective optimisation criteria for AM section. Whereas at PM section all the optimisation criteria were 95 % except for sensitivity analysis with 1 % reduction from the rest.

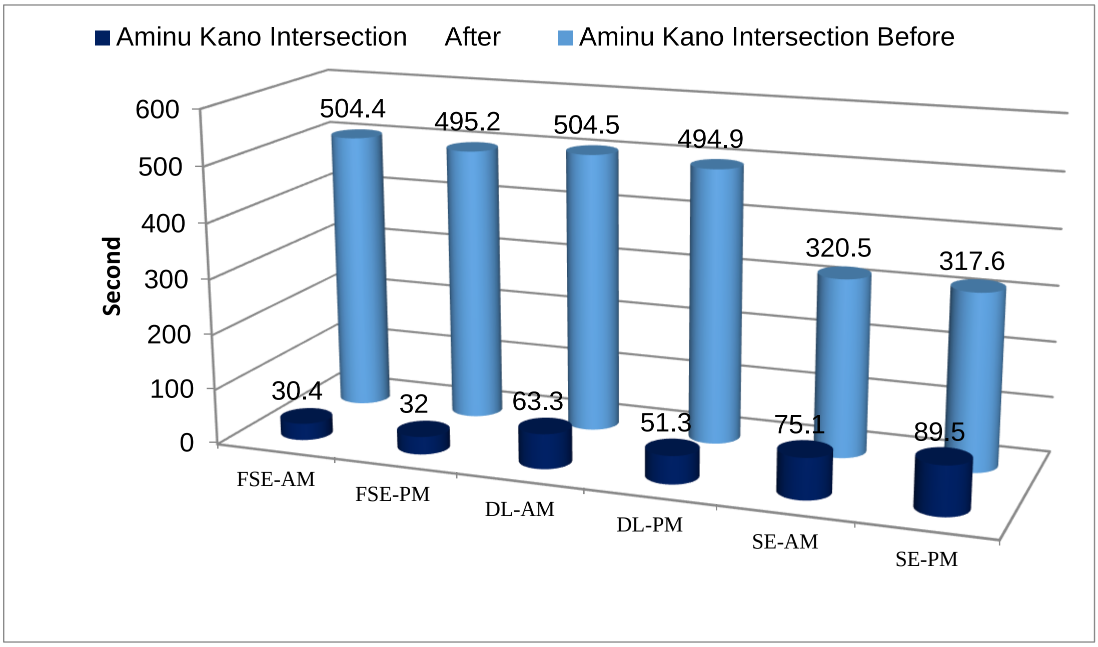

Figure 4.4: Average delay performance of Aminu Kano intersection

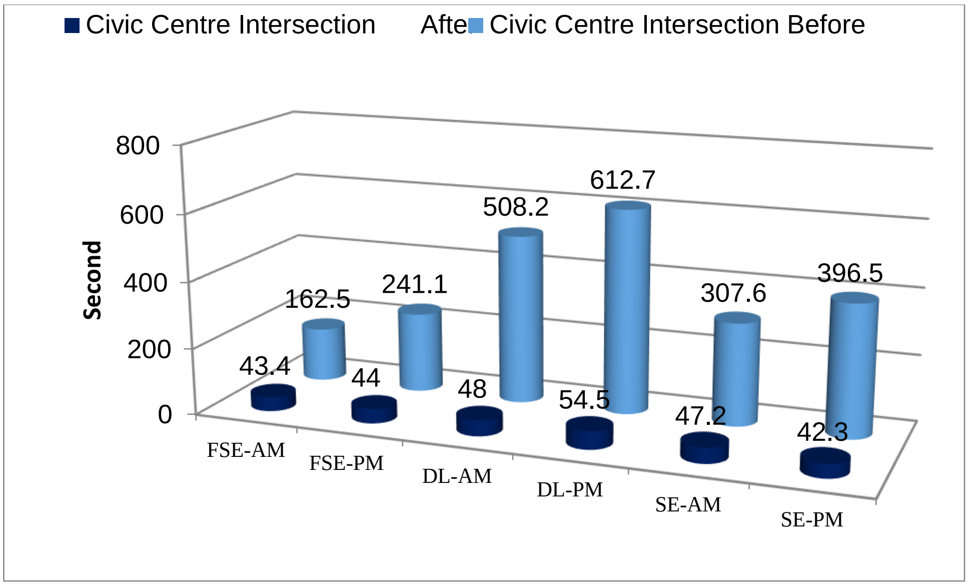

Figure 4.5: Average delay performance of Civic Centre intersection

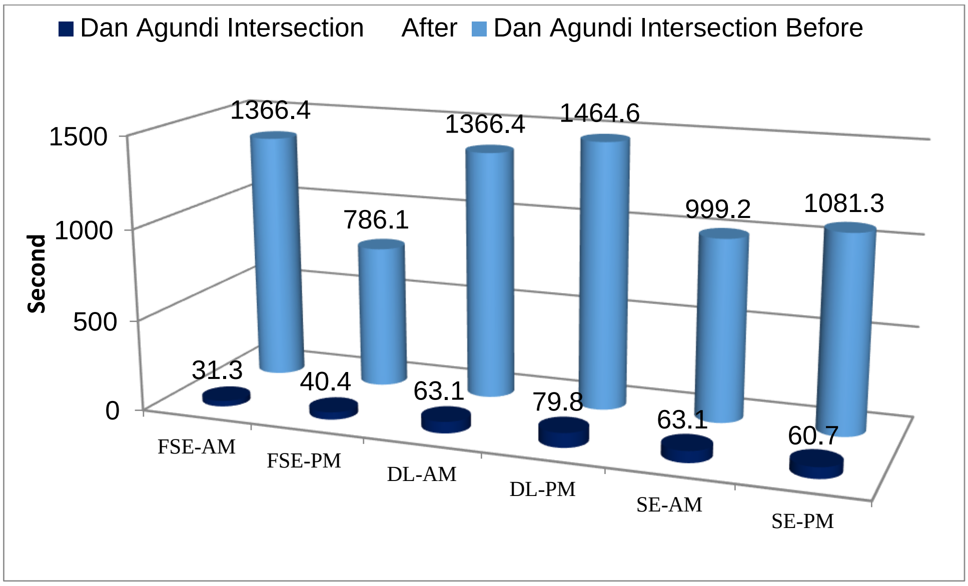

Figure 4.6: Average delay performance of Dan Agundi intersection

4.6 Fuel consumption Performance of Existing and Optimized

The results of the optimisation for fuel consumption are presented in Figures 4.7 – 4. 9. Fuel consumption is an important economic criterion to be considered. With the reduction of the fuel expended at the intersection, two essential criteria would be optimised; economically motorist gets reduced operation cost, and the amount CO_2 released into the atmosphere is also reduced.

The optimisation for fuel consumed at the three referenced intersections was also evaluated under three analytical criteria previously mentioned. In general, the results in the aforementioned

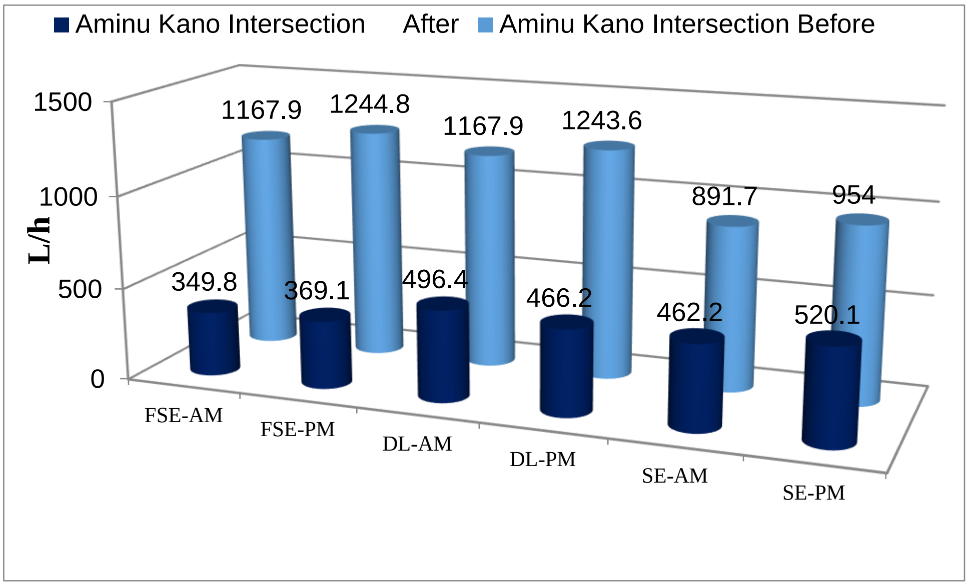

Figure 4.7: Fuel consumption performance of Aminu Kano intersection

Figures for three referenced intersection was reduced significantly. The design life optimisation criteria were observed to have the optimal performance in the reduction of the operational cost a function of the fuel expended at all three intersections. The results further show that at the two referenced sections of the congestion experienced at the intersection, there was 58.5 % and 59.4 % average reduction for fuel consumed at Aminu Kano intersection for AM and PM sections respectively. Fuel optimised at the Civic Centre intersection with the additional one lane was the lowest for all the three intersections for both AM and PM sections with 40.9 % and 48.7 % respective reduction. Whereas, Dan Agundi was had better results with 81.9 % and 76.5 % for AM and PM sections.

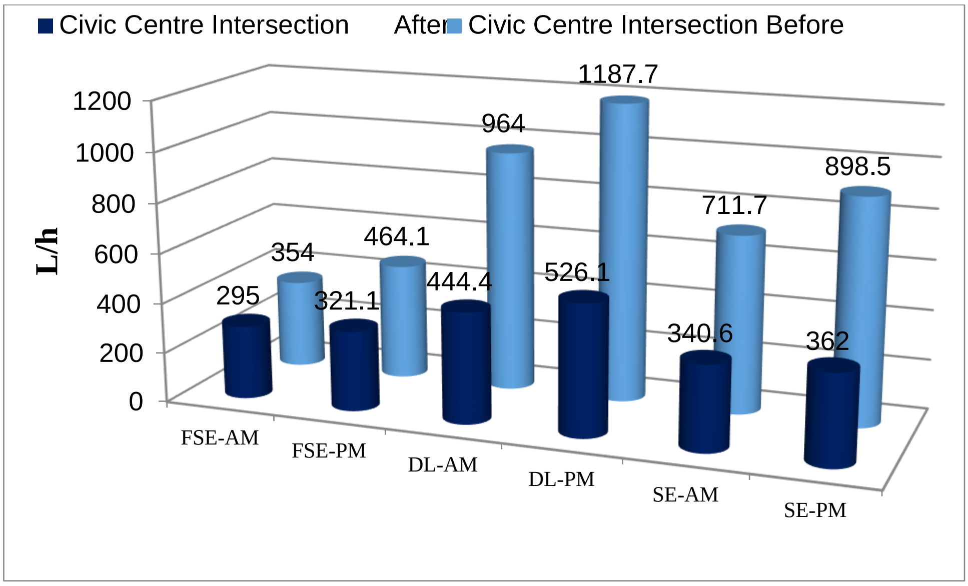

Figure 4.8: Fuel consumption performance of Civic Center intersection

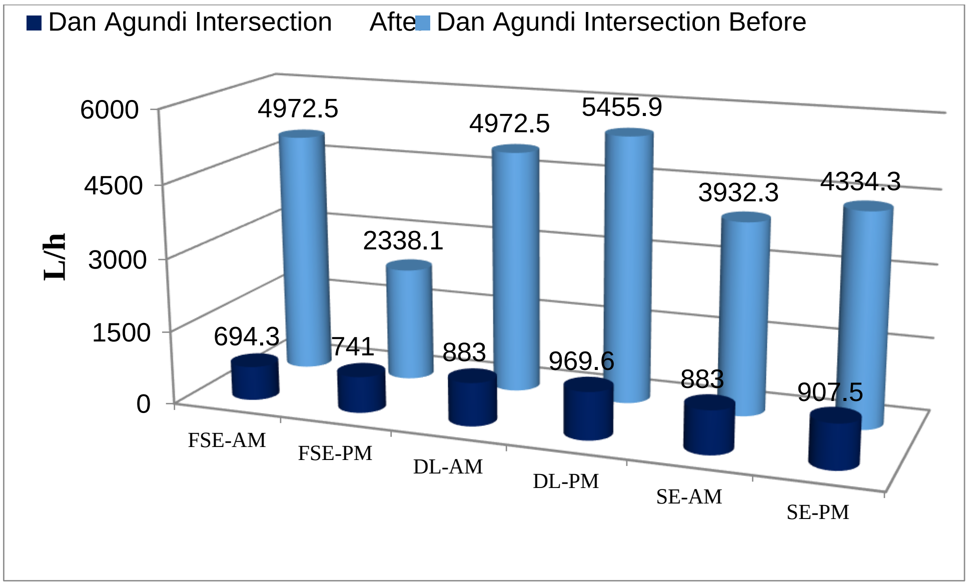

Figure 4.9: Fuel consumption performance of Dan Agundi intersection

4.7 Total Effective Stops Performance of Existing and Optimized

The results of the total effective stops presented in this section present the only the total vehicle stop excluding the pedestrian stops measured in ped/h. In the Figures 4.10, 4.11 and 4.12 below, the effective stops for a vehicle at the three intersections were also evaluated within the Sidra Intersection. The results show that with the addition of one lane to each leg of the intersection have a significant effect of increasing the capacity of the intersection and likewise reducing the number vehicle that might stop at the intersection. The reduction in the number of vehicular stops would enhance the performance of the intersection and reduce delay. It should be noted here that performance criteria for evaluation of an intersection are interlinked. For example, the reduction in delay at the intersection implies that amount of cars stopping at the intersection would be reduced; also these actions are expected to minimise the total travel time and increase the flow at the intersection.

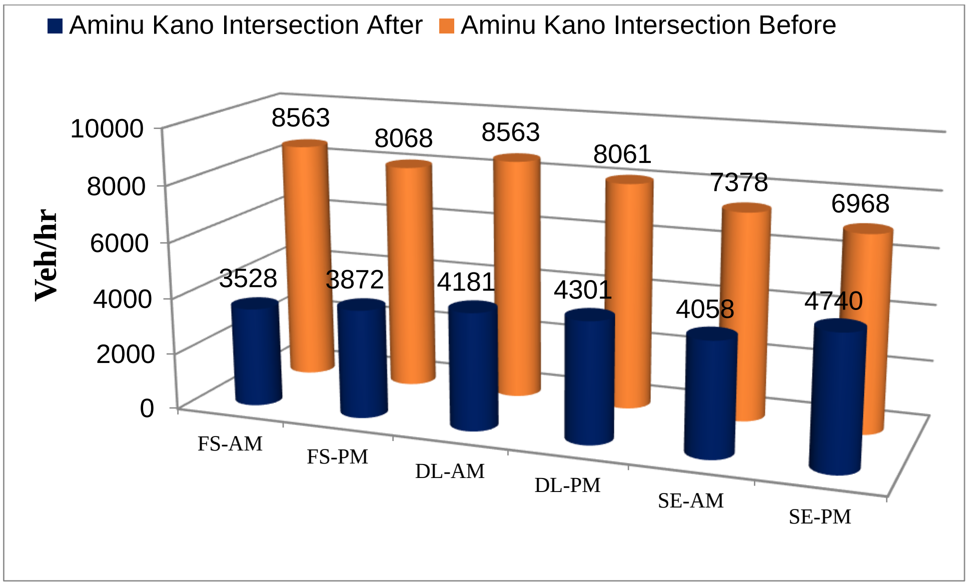

Figure 4.10: Total stops performance of Aminu Kano intersection

From the results of the figures shown herewith, on average for the two sections under review, Dan Agundi intersection (Figure 4.12) had the highest reduction across the three optimisation criteria at the AM section. The least optimised intersection was Civic Centre (Figure 4.11) which recorded 20.7 % for AM section if optimised under flow scale and 30.7% and 46.2 % for design life and sensitivity criteria. With such performance, it would be ideal to further seek for better cost-effect approach to improve the performance and reduce the number of vehicular stops.

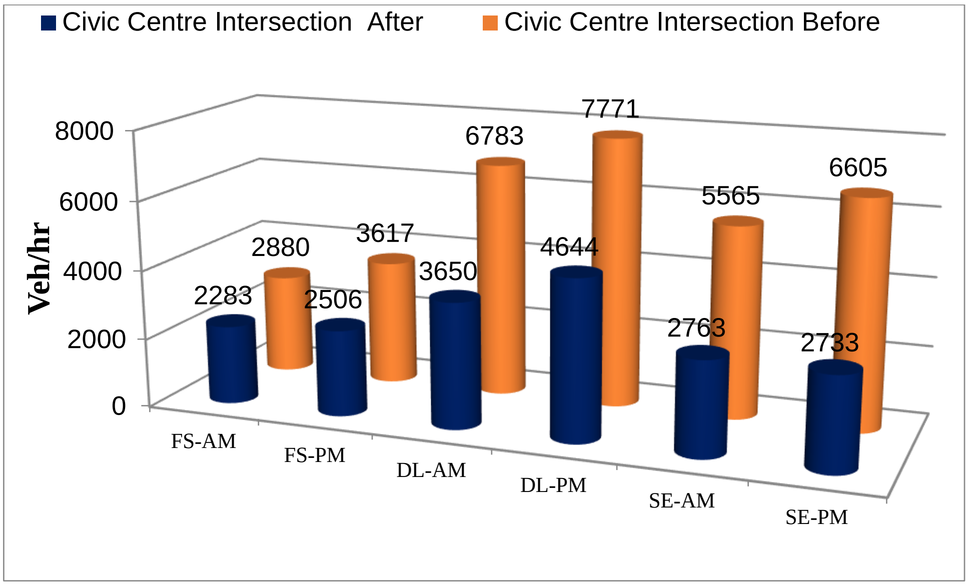

Figure 4.11: Total stops performance of Civic Center intersection

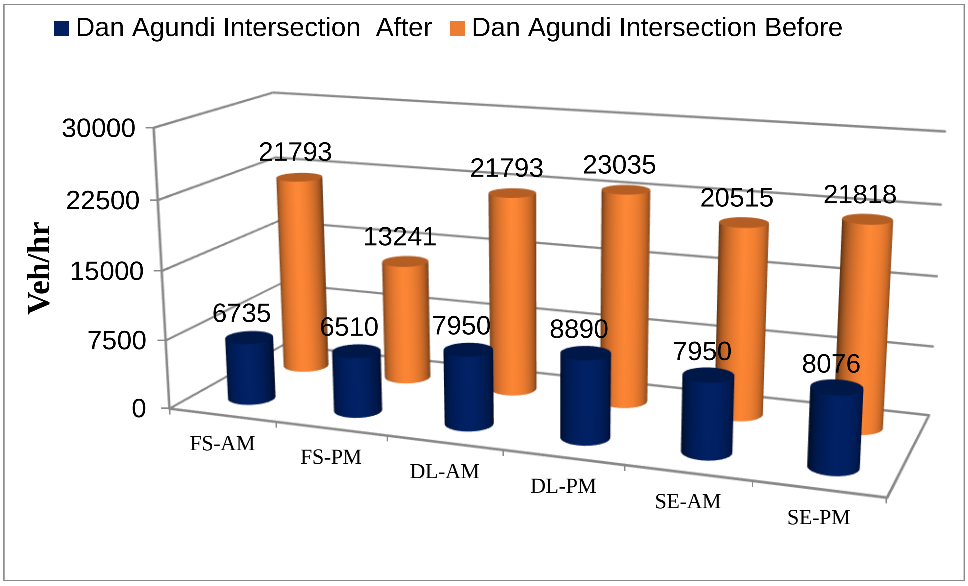

Figure 4.12: Total stops performance of Dan Agundi intersection

4.8 Roundabout Conversion AM

In this section, the results of the intersection converted into a roundabout are presented in the tables below and therein discussed. The value mentioning here was that, intersection whose results were omitted meets the minimum performance criteria for all lanes contained in the legs.

The results were compared with the performance of the existing intersection. In Table 4.7, the results show that the introduction of a roundabout improved the performance of the existing design considerably. The average LOS of the intersections were increased to B and with about 27 % and 55 % increase in the intersection capacity for Civic Centre and Dan Agundi intersections respectively.

Table 4.7: Performance measures of existing and proposed flow scale (Conversion) analysis AM

Performance measures	Aminu Kano Intersection		Civic Centre Intersection		Dan Agundi Intersection	
	Before	**Roundabout**	**Before**	**Roundabout**	**Before**	**Roundabout**
Capacity (veh/h)		-	1767	2424	2681	5900
LOS		-	F	B	F	B
TTT (sec)		-	196.1	B	1399.6	88.1
AVD (sec)		-	162.5	14.6	1366.4	18.5
Travel Speed (km/h)		-	12.6	27.4	1.8	26.2
FUC (L/h)		-	354	213.6	4972.5	532.4
Travel Dist. (m)		-	686	644	685	641
Total Stops (veh/h)		-	2880	2476	21793	7441
The degree of Sat.		-	1.243	0.906	2.853	0.908
PI		-	276.8	84.6	4540.4	224.5

Also, the average delay was reduced to as low as 14.6 and 18.5 seconds for Civic Centre and Dan Agundi intersections respectively. With the new design, the degree of saturation was kept below standard as well the reduction in the fuel consumption cost.

Table 4.8: Performance measures of existing & proposed design life (Conversion) analysis AM

Performance measures	Aminu Kano Intersection		Civic Centre Intersection		Dan Agundi Intersection	
	Before	**Roundabout**	**Before**	**Roundabout**	**Before**	**Roundabout**
Capacity (veh/h)	2251	4460	1767	3289	2681	7840
LOS	F	B	F	C	F	C
TTT (sec)	537.4	83.6	541.9	90.1	1399.6	96.7
AVD (sec)	504.5	17.2	508.2	20.3	1366.4	26.5
Travel Speed (km/h)	4.6	27.6	4.6	25.8	1.8	24.3
FUC (L/h)	1167.9	375.4	964	315.4	4972.5	790.4
Travel Dist. (m)	684	641	686	645	685	653
Total Stops (veh/h)	8563	4822	6783	4617	21793	13827
Degree of Sat.	1.709	0.865	1.776	0.954	2.853	0.976
PI	1027.8	152.3	875.4	138.4	4540.4	372.9

In the Tables 4.8, the performance of the existing condition did not improve appreciably as compared with the findings associated with analysis based on flow scale criteria. The results in Table 4.8 were the output of the analysis for the design life of the intersection over a period of 20 years. It can observe that although concerning design life criteria, the capacity of the intersection was increased for Dan Agundi, but that did not translate to other parameters.

When compared with the findings in Table 4.9 which was the about of the analysis based on the sensitivity of the roundabout island diameter. The LOS remained the same as was the case with the design life in all cases. The average delay experienced by a motorist is expected to be higher; this implied that if the loss in person-hour will increase due to increased transportation operational cost. The results further showed that concerns concerning concerning the sensitivity of the proposed island diameter to the operations at the intersection, the fuel consumption is estimated at 375.4, 323.6 and 778 L/h for Aminu Kano, Civic Centre and Dan Agundi intersections respectively. All the values of the respective total stops for the intersections above were 35, 6% and 28 % reduction from the existing design.

Table 4.9: Performance measures of existing & proposed Sensitivity (Conversion) analysis AM

Performance measures	Aminu Kano Intersection		Civic Centre Intersection		Dan Agundi Intersection	
	Before	**Roundabout**	**Before**	**Roundabout**	**Before**	**Roundabout**
Capacity (veh/h)	2702	4460	2121	3189	3218	7668
LOS	F	B	F	C	F	C
TTT (sec)	353.5	89.4	341.3	95.2	1032.3	99
AVD (sec)	320.5	17.2	307.6	25.6	999.2	31.7
Travel Speed (km/h)	7.0	27.6	7.2	24.5	2.4	23.4
FUC (L/h)	891.7	375.4	711.7	323.6	3932.3	778
Travel Dist. (m)	684	641	686	24.2	685	642
Total Stops (veh/h)	7378	4822	5565	5188	20515	14736
Degree of Sat.	1.425	0.865	1.480	0.984	2.378	0.998
PI	742.5	152.3	610.8	150.8	3583.4	390.5

4.9 Roundabout Conversion PM

The analysis for the flow scale at the even section was only carried on Dan Agundi intersection since the other two intersections meet the performance criteria under flow scale analysis function.

Table 4.10: Performance measures of existing and proposed flow scale (Conversion) analysis PM

Performance measures	Aminu Kano Intersection		Civic Centre Intersection		Dan Agundi Intersection	
	Before	**Roundabout**	**Before**	**Roundabout**	**Before**	**Roundabout**
Capacity (veh/h)	-	-	-	-	2682	6095
LOS	-	-	-	-	F	B
TTT (sec)	-	-	-	-	819.3	85.3
AVD (sec)	-	-	-	-	786.1	15.3
Travel Speed (km/h)	-	-	-	-	3.0	27.3
FUC (L/h)	-	-	-	-	2338.1	541.7
Travel Dist. (m)	-	-	-	-	685	647
Total Stops (veh/h)	-	-	-	-	13241	7262
Degree of Sat.	-	-	-	-	2.070	0.911

Table 4.11: Performance measures of existing and proposed design life (Conversion) analysis PM

Performance measures	Aminu Kano Intersection		Civic Centre Intersection		Dan Agundi Intersection	
	Before	**Roundabout**	**Before**	**Roundabout**	**Before**	**Roundabout**
Capacity (veh/h)	-	-	1751	4275	2682	7383
LOS	-	-	F	B	F	D
TTT (sec)	-	-	646.4	84.7	1497.7	112.2
AVD (sec)	-	-	612.7	15	1464.6	42
Travel Speed (km/h)	-	-	3.8	27.4	1.6	21
FUC (L/h)	-	-	1187.7	346.2	5455.9	874.5
Travel Dist. (m)	-	-	686	644	685	653
Total Stops (veh/h)	-	-	7771	4383	23035	17633
Degree of Sat.	-	-	1.946	0.829	2.957	1.074
PI	-	-	1078.2	139.6	4956.2	471

The design life and the sensitivity of the intersection island diameter are for the evening sections are presented in Table 4.10-11. It can be observed that the capacity of the intersections was increased considerably. However other parameters the design life of the intersections is critical to its performance. The average of the average delay at the intersection converted for the evening section was higher for 20years design life evaluation. Average LOS for all three intersections under review was lowest with design life criteria. The results further suggest that at the end of the 20 years operation, the estimated degree of saturation for Dan Agundi will rise above 1.0 which is above acceptable criteria. Similar the total stops are expected to be 17633 and 4383 vehicles per house for Dan Agundi and Civic Centre respectively.

Table 4.12: Performance measures of existing and proposed sensitivity analysis (Conversion) PM

Performance measures	Aminu Kano Intersection		Civic Centre Intersection		Dan Agundi Intersection	
	Before	**Roundabout**	**Before**	**Roundabout**	**Before**	**Roundabout**
Capacity (veh/h)	2946	5127	2101	4221	3219	7949
LOS	F	B	F	B	F	C
TTT (sec)	350.8	78.2	430.1	83.5	1114.4	94.5
AVD (sec)	317.6	11.6	396.5	27.6	1081.3	24
Travel Speed (km/h)	7.0	29.5	5.7	27.6	2.2	25.2
FUC (L/h)	954	389.5	898.5	330.8	4334.3	807.4
Travel Dist. (m)	685	641	686	641	685	660
Total Stops (veh/h)	6968	4513	6605	4005	21818	13306
Degree of Sat.	1.400	0.804	1.622	0.807	2.464	0.998
PI		141.3	784.4	130.1	3936.5	370.2

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study focused on the evaluation of traffic flow at the signalized intersection within the metropolis of Kano city, for three selected intersection. The criteria's adopted for the selection of these three intersections include site survey, current traffic data collected and google traffic map aerial picture.

The selected intersections were Aminu Kano way / Munbayya Intersection, Ibrahim Taiwo road / Civic Centre Intersection, and Dan Agundi / BUK road Intersection. All the selected Intersections were three legs intersection selected within the most congested locations in the city.

The traffic volumes were collected for morning and evening peak hours for one week. To have real a data, working days were considered. The traffic data collected for different categories of vehicles were converted to passenger Car Unit PCU, the standard given by Highway Capacity Manual HCM.

The obtained data were analysed using Sidra Intersection software taking into account three analytical procedures; Flow Scale, Design Life, and Sensitivity analysis. The performance criteria for optimal design for a particular intersection were based on the target level of service (LOS) rank D and the degree of saturation which should be below 1.0.

All the existing conditions for the three selected intersections based on the above mention criteria failed after the analysis with LOS rank F which is the worst. Therefore, an optimization was evalauted with the addition of one lane to a particular approach or the whole leg of the intersection; the program was processed again to get a new output. Some of the intersection passed based on Flow Scale criteria and failed for sensitivity criteria and design life.

All the lanes within each leg of the intersection are expected to pass with a minimum LOS class D, where these conditions are not satisfied, the intersection was converted to a roundabout which is more economical with sufficient the level of service.

Finally, an optimal solution was developed for the proposed design with an increased in the capacity and quality of flow, the average delay and queue length was drastically reduced as such the total fuel consumption, and gaseous emission was also decreased.

Design life analytical criteria, was seen to have optimal improvement on the measured performance criteria.

5.2 Recommendation for future work

This work was carried out within one hour window period for morning and afternoon section. Further studies could focus on traffic conditions from morning to evening section.

Also, four-leg intersections with similar congestions within the Kano metropolis should be studied.

REFERENCES

Adebambo, S., & Adebayo, I. (2009). Impact of bus rapid transit system (BRT) on passengers' satisfaction in Lagos Metropolis, Nigeria. *International Journal of Creativity and Technical Development, 1*(3), 106-119.

Akcelik, R. (1981). *Traffic signals: capacity and timing analysis*.

Akçelik, R. (1997). Lane-by-lane modelling of unequal lane use and flares at roundabouts and signalised intersections: the SIDRA solution. *Traffic Engineering+ Control, 38*(7), 388-399.

Bang, K., Wahlstedt, J., & Linse, L. (2016). Methodology for timing and impact analysis of signalized intersections. *Transportation Research Procedia, 15*, 75-86.

Barau, A. S. (2007). *The great attractions of Kano*: Research & Documentation Directorate.

Bester, C., & Meyers, W. (2007). Saturation flow rates. *SATC 2007*.

Biliyamin, I. A., & Abosede, B. A. (2012). Effects of Congestion and Travel Time Variability along Abuja-Keffi Corridor in Nigeria. *Global Journal of Research In Engineering, 12*(3-E).

Bivina, G., Landge, V., & Kumar, V. S. (2016). Socio Economic Valuation of Traffic Delays. *Transportation Research Procedia, 17*, 513-520.

Bui, K.-H. N., & Jung, J. J. (2017). Cooperative game-theoretic approach to traffic flow optimization for multiple intersections. *Computers & Electrical Engineering*.

Chubukov, A., Kapitanov, V., Monina, O., Silyanov, V., & Brannolte, U. (2017). Calculation of Traffic Capacity of Signaled Intersections. *Transportation Research Procedia, 20*, 125-131.

Darma, Y., Karim, M. R., Mohamad, J., & Abdullah, S. (2005). *Control delay variability at signalized intersection based on HCM method.* Paper presented at the Proceedings of the eastern Asia society for Transportation Studies.

Fan, H., Jia, B., Tian, J., & Yun, L. (2014). Characteristics of traffic flow at a non-signalized intersection in the framework of game theory. *Physica A: Statistical Mechanics and its Applications, 415*, 172-180.

Ferreira, S., & Couto, A. (2013). Traffic flow-accidents relationship for urban intersections on the basis of the translog function. *Safety science, 60*, 115-122.

He, F., Yan, X., Liu, Y., & Ma, L. (2016). A traffic congestion assessment method for urban road networks based on speed performance index. *Procedia engineering, 137*, 425-433.

Hunter, M. P., Wu, S. K., Kim, H. K., & Suh, W. (2012). A probe-vehicle-based evaluation of adaptive traffic signal control. *IEEE Transactions on Intelligent Transportation Systems, 13*(2), 704-713.

Jiang, Y., Li, S., & Zhu, K. Q. (2005). Traffic delay studies at signalized intersections with global positioning system devices. *Institute of Transportation Engineers. ITE Journal, 75*(8), 30.

Koonce, P. (2008). Traffic signal timing manual: United States. Federal Highway Administration.

Marfani, S., Shihora, D., Kanthariya, C., & Kansara, H. (2018). Traffic Improvement for Urban Road Intersection, Surat. *Traffic, 5*(03).

Mfinanga, D. A. (2014). Ineffective human control of signalised intersections in developing countries; Case of Dar es Salaam city. *Transportation Research Part F: Traffic Psychology and Behaviour, 27*, 174-181.

MO, P., & SO, A. Traffic Congestion on Highways in Nigeria Causes, Effects and Remedies.

Okunola, O. J., Uzairu, A., Gimba, C., & Ndukwe, G. (2012). Assessment of gaseous pollutants along high traffic roads in kano, nigeria. *International Journal of Environment and Sustainability, 1*(1).

Olagunju, K. (2015). *Evaluating traffic congestion in developing countries: A case study of Nigeria.* Paper presented at the A paper presented at the.

Oskarbski, J., Guminska, L., Miszewski, M., & Oskarbska, I. (2016). Analysis of signalized intersections in the context of pedestrian traffic. *Transportation Research Procedia, 14*, 2138-2147.

Preethi, P., Varghese, A., & Ashalatha, R. (2016). Modelling Delay at Signalized Intersections under Heterogeneous Traffic Conditions. *Transportation Research Procedia*, *17,* 529-538.

ROUPHAIL15, N., TARKO16, A., & LI17, J. (1992). Traffic flow at signalized intersections.

Sun, W., Wu, X., Wang, Y., & Yu, G. (2015). A continuous-flow-intersection-lite design and traffic control for oversaturated bottleneck intersections. *Transportation Research Part C: Emerging Technologies, 56*, 18-33.

Ukpata, J. O., & Etika, A. A. (2012). Traffic congestion in major cities of Nigeria. *International Journal of Engineering and Technology, 2*(8), 1433-1438.

Wang, J., Wang, C., Song, X., & Raghavan, V. (2017). Automatic intersection and traffic rule detection by mining motor-vehicle GPS trajectories. *Computers, Environment and Urban Systems, 64*, 19-29.

Xi, J., Li, W., Wang, S., & Wang, C. (2015). An Approach to an Intersection Traffic Delay Study Based on Shift-Share Analysis. *Information, 6*(2), 246-257.

Yao, W., Jia, N., Zhong, S., & Li, L. (2018). Best response game of traffic on road network of non-signalized intersections. *Physica A: Statistical Mechanics and its Applications, 490,* 386-401.

Yoshino, N., & Nakahigashi, M. (2000). The Role of Infrastructure in Economic Development (Preliminary Version). *Unpublished manuscript*.

Zhu, Y., Gao, N., Wang, J., & Liu, C. (2016). Study on traffic flow patterns identification of single intersection intelligent signal control. *Procedia engineering, 137*, 452-460.