OPEN ACCESS

Vol 4, No. 2, 2017, 171-186

Geoplanning
Journal of Geomatics and Planning
E-ISSN: 2355-6544
http://ejournal.undip.ac.id/index.php/geoplanning
doi: 10.14710/geoplanning.4.2.171-186

MAPPING AND ASSESSMENT OF TRAFFIC CONGESTION ON MAJOR ROADS IN MINNA, NIGERIA (A CASE STUDY OF CHANCHAGA L.G.A)

O. G. Ajayi [a], A. T. Oluwunmi [a], J. O. Odumosu [a], T. J. Adewale [b]

[a] *Department of Surveying and Geoinformatics, Federal University of Technology, Minna, Nigeria*
[b] *Department of Surveying and Geoinformatics, Moshood Abiola Polytechnic, Ogun State, Nigeria*

Article Info:
Received: 10 July 2017
in revised form: 29 September 2017
Accepted: 17 October 2017
Available Online: 30 October 2017

Keywords:
Urbanization, traffic mapping, geospatial modeling, dynamic road segmentation, land use, Traffic Information System.

Corresponding Author:
Ayodeji Timothy Oluwunmi
Department of Surveying and Geoinformatics, Federal University of Technology, Minna, Nigeria
Email: dejioluwunmi@gmail.com

Abstract: *The level of urbanization in the developing world indicates that more people live in cities nowadays than before. As urbanization increases, road usage also proportionately increases which sometimes introduce some strains to the existing road. As a consequence, it constitutes some impediments to free traffic flow. The situation described above is located on Chanchaga Local Government Area of Niger State, an urban center in North central, Nigeria. In order to investigate the probable causes and degree of severity of this menace, attempt has been made in this research to investigate and map out the nature of traffic congestion frequently experienced on some selected roads within Chanchaga LGA. These road networks include: Kpakungu-Gidan Kwano road, Bosso-Mobil route, Bosso–Mekunkele route, Kpakungu–city gate road and Book roundabout–Mobil Route. Using a 1m Pan-Sharpened spatial resolution IKONOS Image, handheld GPS receivers, and manual traffic count, the traffic patterns of the selected road networks within the study area were assessed and mapped out. A Geo-Database was also designed for the routes which provide information about the road pavement condition, average traffic volume, adjacent land use, etc. Analysis of results and other performed queries revealed that the most probable causes of traffic congestion in Chanchaga LGA were due to narrow road width, bad road pavement and indiscriminate parking of vehicles along the road corridors, especially by commercial cab drivers. Conclusively, it was observed that the Kpakungu axis of Minna – Bida road is the most congested route of the entire road networks considered, closely followed by the Bosso-Mobil Road. The traffic gridlock along these routes is most prominent on Mondays and Wednesdays (around 8am and 4pm) and correspondingly on Fridays (around 1-4pm). Furthermore, a free traffic flow is frequently experienced on Saturdays by 8am which gradually builds a synchronized flow around the evening time on all the considered road networks.*

How to cite (APA 6th Style):
Ajayi, O. G., et al. (2017). Mapping and assessment of traffic congestion on major roads in Minna, Nigeria (a case study of Chanchaga L.G.A). *Geoplanning: Journal of Geomatics and Planning, 4*(2), 171-186. doi:10.14710/geoplanning.4.2.171-186

1. INTRODUCTION

Traffic congestion has been one of major issues that most metropolises are facing. In order to mitigate this congestion, many measures have been taken (Rao & Rao, 2012). It is believed that the identification of congestion characteristics is the first step for such efforts as an essential guidance for selecting appropriate measures (Rao & Rao, 2012). Congestion; both in perception and in reality, impacts the movement of people, freight. It is deeply tied to the history of high levels of accessibility and mobility. Traffic congestion wastes time and energy, causes pollution and stress, decreases productivity and imposes costs on society (Rao & Rao, 2012).

The United Nations estimates that urban areas are currently home to 50% of the world's population, and predicts that estimated figure will reach 70% by 2050 (United Nations Expert Group, 2009). Growing urbanization provides both opportunities and challenges from the perspectives of transportation mobility, climate change and air quality. Higher population densities generally support greater levels of transit and can make destinations more easily accessible by walking or cycling. This further provides increased mobility while allowing reduced usage of passenger vehicles (Pike, 2010).

Urban population growth and urbanization are major factors influencing decisions with regards to worldwide Central Business District (CBD) development activities. Of significance, traffic congestion is issued as a global phenomenon in the management of city's CBDs, giving the level of population and activity concentration. United Nations (2011) first reported the urban population dominance in 2010, revealing that urban areas are home to 3.5 billion (50.5%) of world's population and that cities' population is expected to increase to 5.2 billion in 2050.

Paradoxically, the CBD remains the economic dynamics and geography of city's core activities and businesses, among which are international finance and business, retail and wholesale shopping hierarchy as well as leisure, culture and entertainment, thereby generating thousands of employment opportunities and supporting residences. CBDs are bisected by (1) complex socio-economic problems; such as inadequate housing, social infrastructural facilities and services shortages, as well as traffic and transportation challenges, (2) essentially inadequate public transport provision; resulting in mobility crisis. This has significant implications on traffic congestion, adverse effects on the economic and people's social life-style with increasing social cost of congestion (Willett, 2006).

Traffic congestion is a situation which occurs on road networks when the number of vehicles on the road exceeds the capacity of the vehicles which the road can accommodate. This congestion is indicated by slower speeds, delay in travel time, and long queues. Traffic congestion is an expected occurrence on road networks in major cities of the world. The frequency of its occurrence is a concern to all road users. These circumstances have driven transport researchers to carry out adequate research on traffic congestion and in so doing model development to help reduce congestion on road networks (Victoria Transport Policy Institute, 2010).

Lindsey and Verhoef (2009) on congestion modeling, postulated that there is no single best way to model traffic flow and congestion but that the level of detail at the driver's behavior should be modeled, depending on the object of the analysis. Ogunbodede (2007) examined traffic problems in Akure, Nigeria, using a GIS application for the development of a Traffic Information System (TIS). TIS was used in providing solution to traffic congestion in the study area in two ways: (i) by providing traffic information and (ii) by determining queries that can be used to tackle traffic congestion in the study area. Aworemi et al. (2009) identified and investigated some major variables as factors causing congestion in Lagos state. These variables are: poor road condition, road accidents, inadequate road infrastructure, and absence of integrated transport system, inadequate traffic planning and driver's behavior. The results obtained from the research showed that poor road condition, road traffic accidents, inadequate road infrastructure, absence of integrated transport system, inadequate traffic planning and driver's behavior made a significant contribution of approximately 70.7% to the traffic congestion situation of Lagos State.

Also, according to Okagbue et al. (2015) congestion in Lagos State was partly caused by road users themselves since they have developed attitude of gross impatience and disobedience to traffic rules. He further stated that traffic congestion can be caused by the inability of a driver to give way for another motorist. He said that the effect of traffic congestion equally sometimes affect the wellbeing and behavior of the drivers. Furthermore, they begin to exhibit rude gestures towards one another, verbal insults, deliberately driving in an unsafe manner, threats, collisions which may further result to injuries and deaths.

Onasanya and Akanmu (2002) opined that GIS can be utilized in the design of TIS (Traffic Information System) in curbing of incessant traffic congestion. The significance of TIS in cities bedeviled with traffic congestion can no longer overstressed. This is because the old ways of traffic controlling such as one way, odd and even numbers, flyovers, construction of new routes, park and ride system, have not been able to eliminate traffic congestion in places such as Lagos, Benin-city, Port Harcourt. Hence, there is a serious need to set in place vital TIS structure to observe congestion in these cities before it is too late. Olusina and

Olaleye (2013) also opined that that Intelligent Transportation Systems (ITS) is an alternative technology which holds promise for relieving congestion.

Intelligent Transportation Systems include (1) Advanced Traffic Management Systems that optimize traffic signals and freeway ramp controls, (2) Advanced Vehicle Control Systems that allow closely-spaced platoons of vehicles to operate at high speeds, and (3) Motorist Information Systems that provide real-time information and advice to individuals about travel conditions. The dynamic road segmentation of the road networks in Bosso LGA of Minna was examined by Ajayi et al. (2015). The research identified three major adjacent land uses in Minna which includes: residential, commercial and industrial land uses. It also established the impact of adjacent land use on road traffic situations.

Urban traffic management therefore is an important aspect of transportation planning that attracts the attention of transport experts and governments in both developed and developing countries in the world (Ajala, 2011). Preliminary investigations revealed that there is a gradual increase in the volume of automobile that plies the road networks within the study area. It is one of the major causative factors of the traffic gridlock frequently experienced by road users (Ajayi et al., 2015). Therefore, the need to investigate and map out the current traffic situation of the selected roads within the study area will serve as a base map for providing probable solutions to the menace of traffic congestion. Factors such as traffic count, adjacent land use along the road corridors, road pavement condition, road width and availability of parking space are indispensable factors in modeling traffic congestion. While many other researchers have invested efforts in Transport GIS and integrating it with Remote Sensing using each of the aforementioned parameters, only few have attempted to integrate these parameters. However, none of such exists in studying the traffic situation of the major road networks within the study area, hence the importance of this research which integrated all the six parameters in assessing and mapping severity of traffic congestion on the major routes in Chanchaga LGA. The outcome of this research could (1) aid road users in making informed decisions by providing detailed geospatial information concerning the traffic situation of each of the selected roads per time and (2) also provide viable recommendations to road users and policy makers.

2. DATA AND METHODS

2.1. Study Area

Chanchaga LGA is located in Minna on Latitude 9˚37’ to 9˚39’ North and Longitude 6˚30’ to 6˚33’ East in Niger state which is one of the states in Nigeria, created on the 3rd of February 1976 out of the North-Western region of Nigeria. Minna, the state capital of Niger State sits on an approximate land mass of 73.4 sq km, with an estimated population of about 304,113 and 2,744 density per sq km and it is predominantly inhabited by the Gbagyi, Nupe and Hausa people. Chanchaga LGA is one of the nine LGAs of Niger State at creation. Others include: Rafi, Bangi, Gbako, Etswan, Suleja, Mariga, Magama and Lavun. Figure 1 presents a plate containing three different maps describing the relationship between the study area, Niger state and Nigeria while Figure 2 shows the Ikonos image used to produce the road map of the study area. The study area itself is presented as Figure 3.

One of the first roads constructed in Chanchaga LGA is the Nnamdi Azikwe road which links Pigry to Morris axis. Unfortunately, this road has been abandoned since its construction over 18 years ago. The initial earthworks on the Minna-Bida road were carried out in two stretches (Minna–Kataeregi and Kataeregi-Bida) in 1983 (Olatunji & Diugwu, 2013) even though this study considers the Kpakungu-Gidan kwano axis only of the first stretch. The Ikonos 1m resolution image used for the study was obtained from the National Space Research and Development Agency (NASRDA), and imported into ArcMAP software environment; road features within the area of study were digitized and grouped into layers.

doi: 10.14710/geoplanning.4.2.171-186

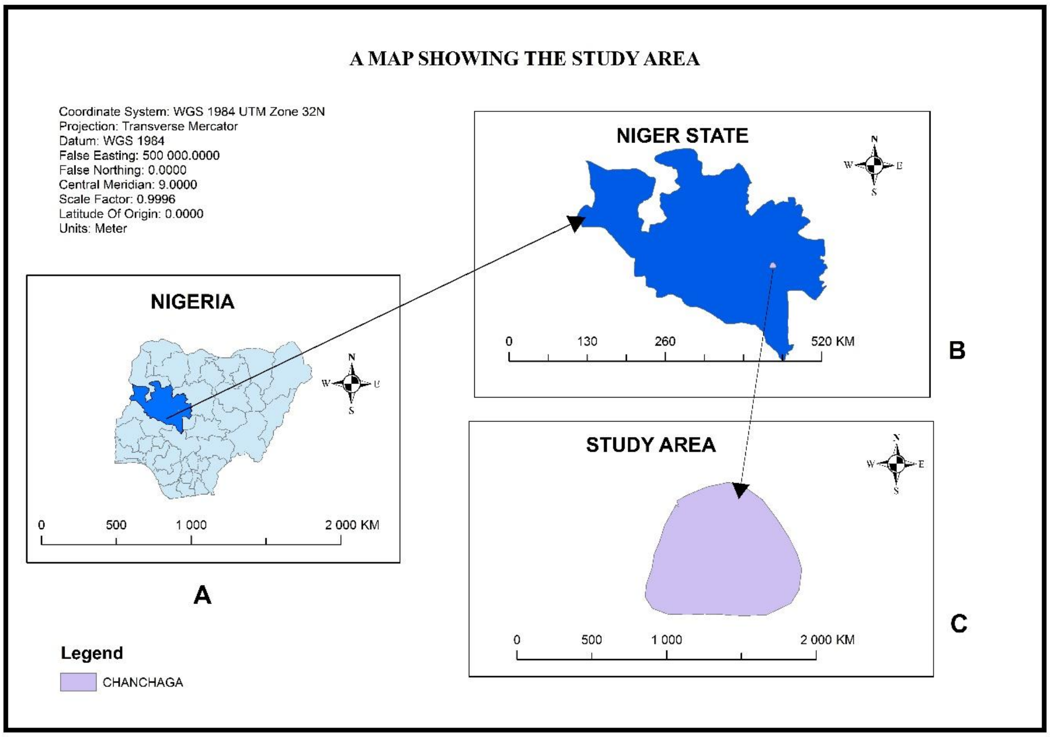

Figure 1. Plate of maps depicting the study area

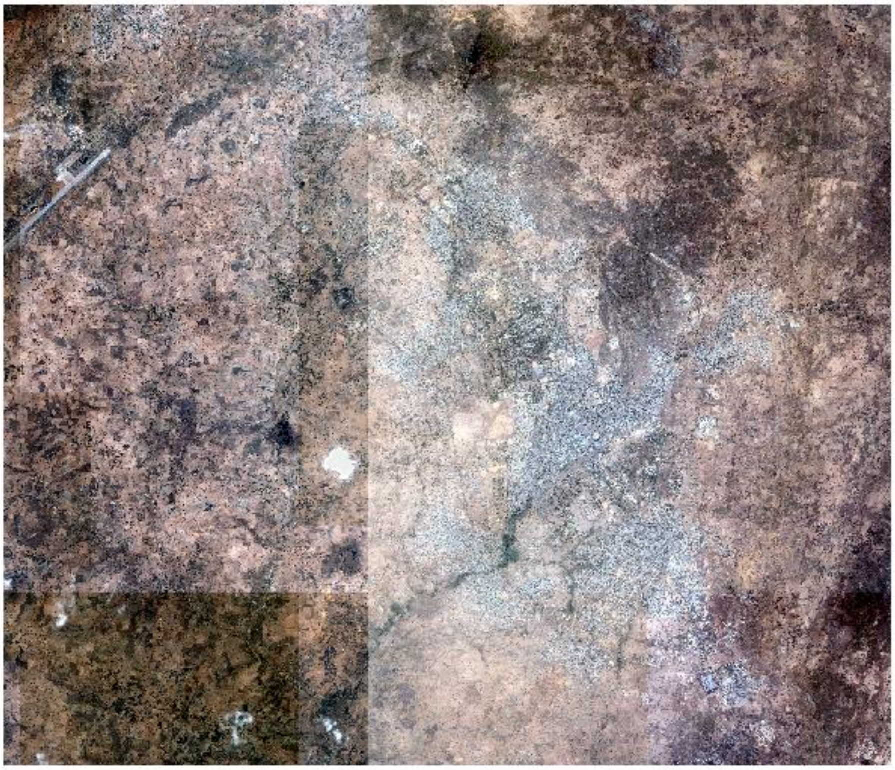

Figure 2. Ikonos image used for the study (NASRDA, 2014)

doi: 10.14710/geoplanning.4.2.171-186

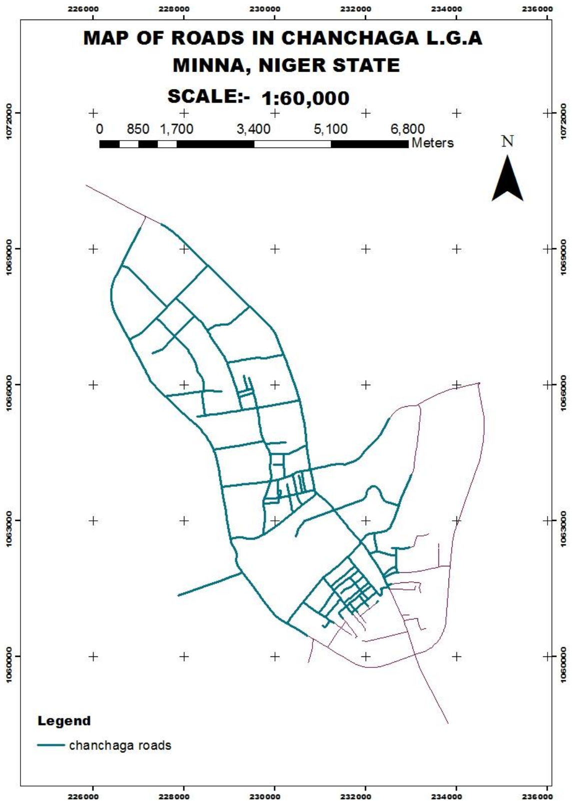

Figure 3. Road network of Chanchaga local government (Author, 2015).

2.2. Methods

Reconnaissance was the first task executed in the process of conducting this research. It refers to the planning task, which is carried out to facilitate a smooth field observation and an appropriate understanding of the resources required for the job execution. The reconnaissance survey entails both the field and office recce. During the recce, a choice was made on the roads to be considered for the study based on the volume of vehicles that ply them, adjacent land use or road segmentation, nature of the road surface, etc. Major decisions concerning the nature and approach of vehicular counting system were equally made. For this research, five (5) major road networks were considered including Kpakungu-Gidan Kwano road, Bosso-Mobil route, Bosso–Mekunkele route, Kpakungu–city gate road and Book roundabout–Mobil Route. In addition, due to the unavailability of digital traffic counting devices, manual approach was adopted for the vehicular count. This counting activity entails stationing of field personnel at strategic road nodes to assess the type and number of vehicles, tricycles and motorcycles that plies the routes. Furthermore, it was discovered during the field recce and from the output of the conducted social survey that the traffic congestion system in the study area is notable only on Mondays, Wednesdays Fridays and Saturdays. Therefore, the study and traffic count was restricted to these days.

The traffic count was conducted at two different time epochs (8am and 4pm) for the selected days for a total duration of one week after which, the percentage average of the recorded results was computed and documented in Table 1. These two time epochs were selected due to the historical records obtained from the responses of the residents of the study area. The results suggests that the traffic congestions gradually attain its peak in the morning around 8am, being a rush hour for both students and workers to get to their schools and work places respectively, and in the afternoon around 4pm when most offices and schools closes for the day. Two hundred questionnaires were administered while 186 were duly filled by the respondents and returned in.

Before proceeding for the field work, an IKONOS satellite image of 1-meter spatial resolution was used for the digitization of the roads to be considered for this research. This formed the base map used for the database creation and traffic modeling. Also, a Handheld Garmin 76csx map GPS Receiver was used for the acquisition of (x and y) node coordinates of the roads used for the dynamic segmentation. The adjacent land use along the road corridors was observed using direct physical observation method together with some oral interview sessions. All acquired data were processed in the ARCGIS 10.1 software environment and the Microsoft Office Suite package. A three-criterion decision rule was adopted before deciding whether a road is prone to traffic congestion or not. The factors that made up this decision rule are nature of the road pavement (good, fair or bad), volume of vehicles plying the route and the roads' adjacent land use. These three factors were modeled in order to be able to assess the traffic congestion condition of each of the roads and the most probable causes. The step by step processes involved in the execution of this research is shown in Figure 4.

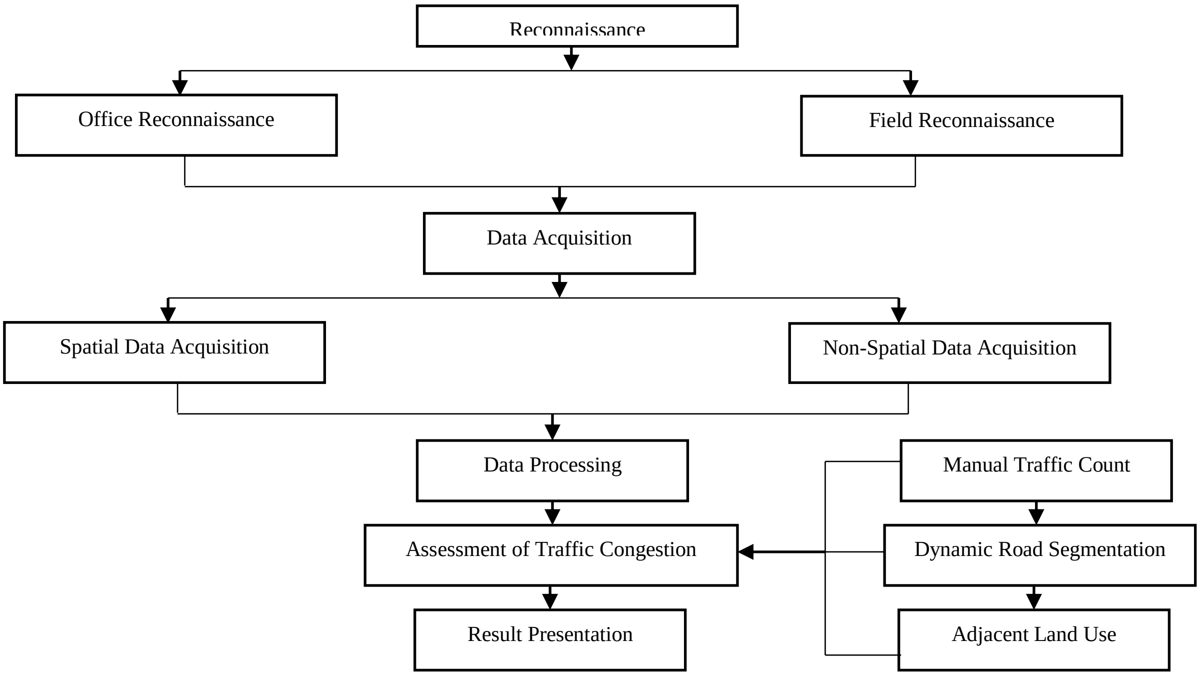

Figure 4. Process flow diagram of the adopted methodology

3. RESULTS AND DISCUSSION

Figure 5 shows the major road networks within the study area while Figure 6 shows the road segments adjudged to be in good condition. Table 1 shows the percentage volume of traffic congestion in some selected road networks within the study area. Table 2 and Figure 7 shows the areas affected by traffic congestion according to the results from the social survey while Figure 8 shows the adjacent land use of the considered road networks while the adjacent land use along the corridors of the major roads in Minna is presented in Figure 9. The nature of traffic flow experienced on the considered road networks during each day of the week are shown in Figures 10-17. Figure 10 shows the nature of the traffic flow pattern experienced on Mondays by 8am while Figure 11 shows traffic flow pattern often experienced on the same day by 4pm. Figure 12 presents the nature of the traffic flow pattern experienced on Wednesdays by 8am while Figure 13 shows the traffic flow pattern as observed on the same day by 4pm. The nature of the traffic flow pattern experienced on Fridays by 8am and 4pm are presented in Figure 14 and Figure 15, respectively. Finally, Figure 16 and Figure 17 presents the nature of traffic flow pattern experienced on the selected road networks on Saturdays by 8am and 4pm, respectively.

The nature of traffic flow was modeled according to a three phase-traffic theory developed by Boris Kerner to describe the empirical spatio-temporal features of vehicular traffic (Kimathi, 2012). The three-phase theory is divided into three classes viz: Free flow, Synchronized flow and Jam Free flow. In free flow traffic situations, there is no significant speed drop and as such, the flow rate is nearly proportional to the density (its slope tends to decrease as the density increases). However, when the density reaches the maximum density for the free flow, the transition to congestion occurs (Park, 2012). In the synchronized traffic flow, the vehicular speed drops significantly, though; it is a continuous traffic flow with no significant stoppage. However, there is no noticeable change in the traffic flow rate. This is due to the increase in the density of vehicle, such that the product of the speed and the density remains nearly the same. The term synchronized reflects the synchronization of speed of the vehicles in different lanes (Park, 2012). Finally, the wide moving jam can only spontaneously occur through Jam free flow. At this stage, both flow rate and velocity drops significantly, and they become relatively uniform than the synchronized flow (Park, 2012).

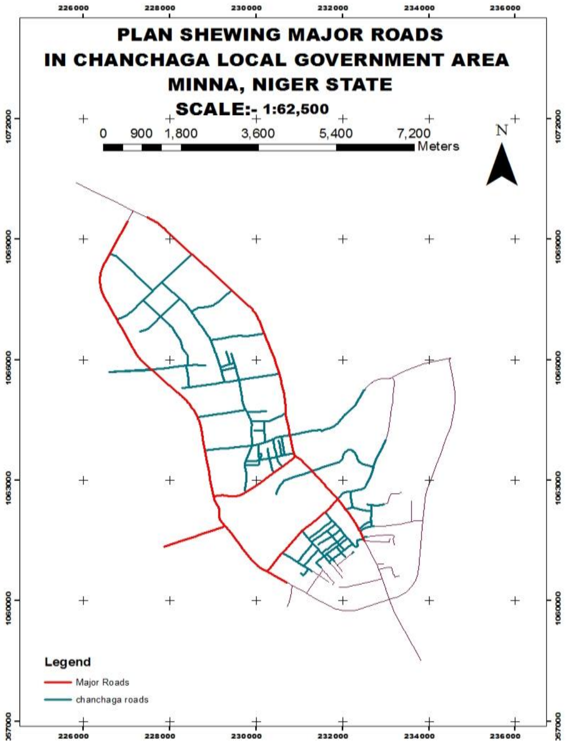

Figure 5. Major roads and all existing road networks in the study area

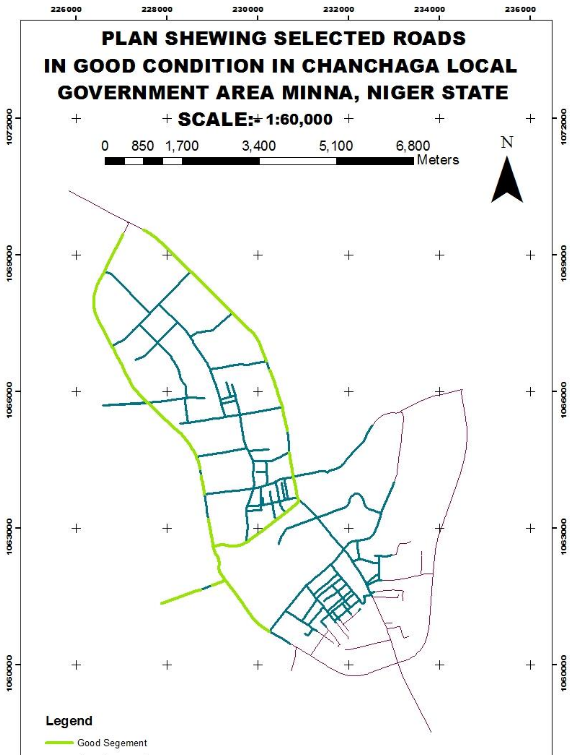

Figure 6. Roads with good segments in the study area

Table 1. Percentage Volume of Traffic for the selected days and time epochs

ROUTES		MONDAY(%)	WEDNESDAY(%)	FRIDAY(%)	SATURDAY(%)
KPAKUNGU	Motorcycle	43.53	38.68	40.40	41.95
To	Car	31.85	32.24	32.97	31.27
GIDAN KWANO	Bus	1.53	1.35	1.33	0.97
	Truck	1.24	1.58	1.56	0.78
	Tricycle	21.85	26.16	24.00	25.02
MOBIL	Motorcycle	23.36	26.99	28.50	34.65
TO	Car	41.85	32.81	36.04	33.68
BOSSO	Bus	0.36	0.30	0.31	0.30
	Truck	0.19	0.03	0.08	0.19
	Tricycle	34,24	35.11	35.06	43.22
BOSSO	Motorcycle	31.29	35.01	34.21	35.02
TO	Car	41.85	43.68	41.99	29.15
MEKUNKELE	Bus	0.36	0.37	1.05	0.18
	Truck	0.19	0.37	1.28	0.07
	Tricycle	25.86	19.87	21.47	35.57
KPAKUNGU	Motorcycle	35.10	37.37	37.29	39.84
TO	Car	39.18	34.06	36.48	34.92
CITY GATE	Bus	1.01	1.00	1.45	0.44
	Truck	1.32	1.76	0.82	1.63
	Tricycle	23.39	25.80	23.96	23.16
BOOK ROUND ABOUT	Motorcycle	37.06	43.82	39.24	41.85
TO	Car	35.74	25.88	34.27	23.95
MOBIL	Bus	0.87	0.28	0.63	0.61
	Truck	0.10	0.50	0.53	0.49
	Tricycle	25.44	29.26	25.32	33.10

Table 2. Percentages of Traffic congestion on major roads within the study area

LOCATION	PERCENTAGE (%)
Kpakungu	72.5%
Mobil	25%
Tunga	2.5%

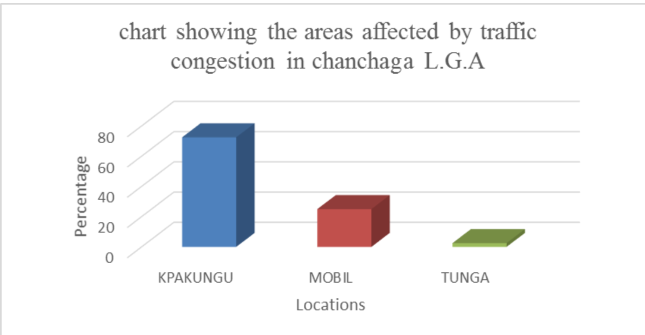

Figure 7. Statistical histogram of the respondents' suggestion on traffic congestion prone areas.

All the major existing roads in Chanchaga LGA are shown in Figure 5 while the roads in good working condition are presented in Figure 6. The pavement of the road surface was the major factor considered in determining whether a road is in good working condition or not. Roads whose asphalt surface are still intact are considered to be in good condition while roads riddled with potholes, rough or worn out asphalt surfaces, failed spots and uneven terrain surfaces are considered to be in poor condition. Table 1 shows percentage volume of traffic congestion for Mondays, Wednesdays, Fridays and Saturdays. The table shows an unusual increase in the volume of motor bikes that plies the routes around Kpakungu axis between Monday and Saturday. This could be caused by the narrow road width (of 8 m wide) which cannot comfortably accommodate the volume of vehicles plying the routes thereby resulting into traffic congestion.

It was also observed that more cars ply the Kpakungu–city gate route as compared with other routes considered for this study. Since this route is one of the major bypasses which connects Minna with other towns or cities, most of the road users that uses this route were found to be travelers who are habitually on transit and are just bypassing Minna, except for those residing within the axis. The combination of the effect of the large volume of vehicles plying Kpakungu–City gate route and Bida–Kpakungu route, the narrow road width and the bad road pavement, results into a severe traffic congestion around the Kpakungu roundabout axis. This has led to sporadic increase in the number of Road Traffic Crashes (RTC) recorded on these routes (Ajayi et al., 2015). Summarily, the major causes of traffic congestion on this route include: narrow road width, bad road pavement, indiscriminate parking of cars by the road corridors, lack of traffic light, reckless driving and commercial viability of the axis (adjacent land use). This is similar to the traffic situation in Akure as presented by the findings of Ogunbodede and Aribigbola (2003). In addition, it is also in agreement with the outcome of the social survey and interviews conducted which submitted that 72.5% of Minna's traffic congestion is experienced around the Kpakungu roundabout axis while 25% and 2.5% were experienced around Mobil and Tunga axis, respectively.

Also, the Mobil to Bosso route has more percentage of cars plying the route than other vehicle types. Due to the rate of indiscriminate stopovers especially by commercial vehicles, and inaccurate timing of the traffic light on this route, traffic congestion occurs almost at every hour of the day but they are more noticeable around 7:45–8:45am and 5–6pm. Furthermore,the route experiences severe traffic congestion between 1:30pm and 6pm on Fridays (see Figure 15). Most road users agreed that the causative factor of this scenario is the friday prayers of the Muslims since the Minna central Mosque is located along the route, apart from the gradually deteriorating nature of the road pavement.

Figure 8 generally shows the adjacent land use along selected road corridors in the study area while Figure 9 shows the adjacent land use in Minna. Four (4) different adjacent land use categories were observed to be predominant within the study area. These include: Residential land use, Commercial land use, Industrial land use and Commercial-Residential land use. It was also observed that commercial - residential land use was the most predominant land use within the roads under study. This situation can be described as when commercial shops are constructed directly in the frontage of residential buildings. It was observed that roads which are located along the commercial-residential areas (such as Kpakungu, Mobil, etc.) tend to experience traffic congestions (see Figures 10, 11, 12 and 13) while in cases where such areas do not experience impediment in free traffic flow, synchronized flow of traffic is often experienced (see Figure 15 and Figure 17) and roads along industrial areas tend to experience more of a free flow of traffic (see Figure 14).

The result of the traffic flow shows that a severe traffic gridlock is frequently experienced on the Kpakungu-Gidan kwano road on Mondays by 8am (Figure 10) and correspondingly by 4pm (Figure 11), Wednesdays by 8am (Figure 12) and by 4pm (Figure 13). This gridlock becomes critical around the Kpakungu roundabout axis thereby making synchronized traffic flow the predominant traffic flow type that best describes the nature of the traffic situation frequently experienced on this route during these observed epochs.

Meanwhile, free flow of traffic is always experienced on all the observed routes around 8am on Saturdays. This suggests that there is a very light volume of vehicles on each of these routes around this time (See Figure 16) as compared to the volume of the vehicles plying the roads on week days which means that Chanchaga LGA experiences less traffic activity on weekends when compared to the week days. On the other hand, synchronized flow is experienced on all the routes on Saturdays by 4pm except for the Bosso area of Bosso – Mobil road (see Figure 17). This is however at variance with the result observed on Fridays which even though it happens to be the last day of the working week preceding the weekend, it experiences more of the synchronized flow on the major roads and serious traffic impediment around Tunga area (central mosque axis) at around 4pm (see Figure 16) while free flow is only experienced around Bosso axis on Fridays around 8am only (See Figure 14).

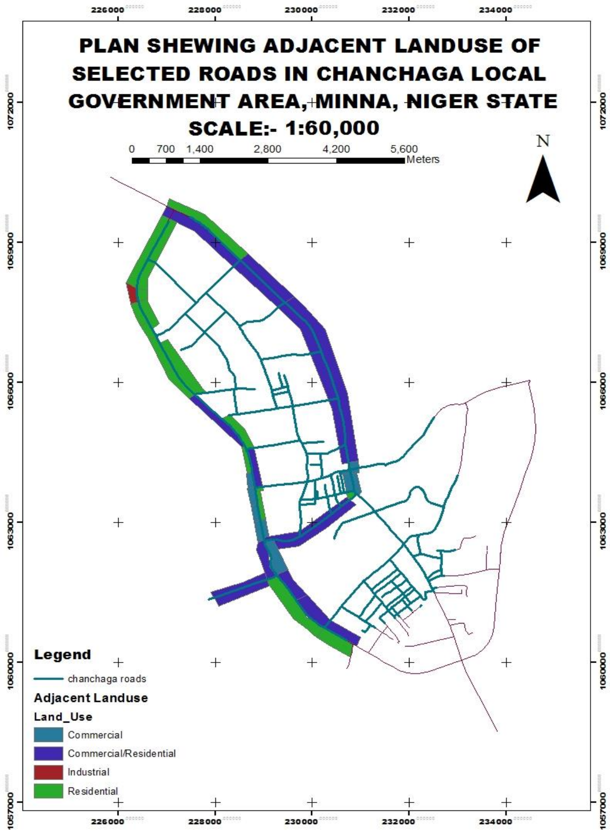

Figure 8. Adjacent land use on some selected roads in Chanchaga L.G.A

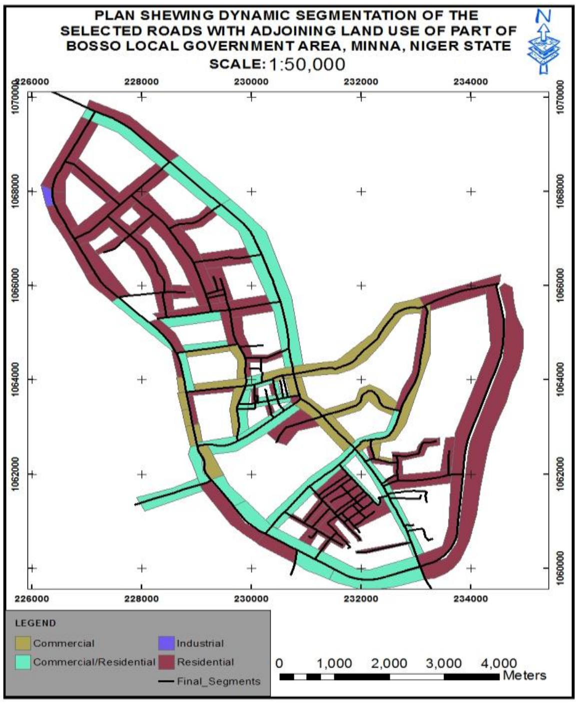

Figure 9. Adjacent land use of major road corridors in Minna (Ajayi *et al.,* 2015b).

doi: 10.14710/geoplanning.4.2.171-186

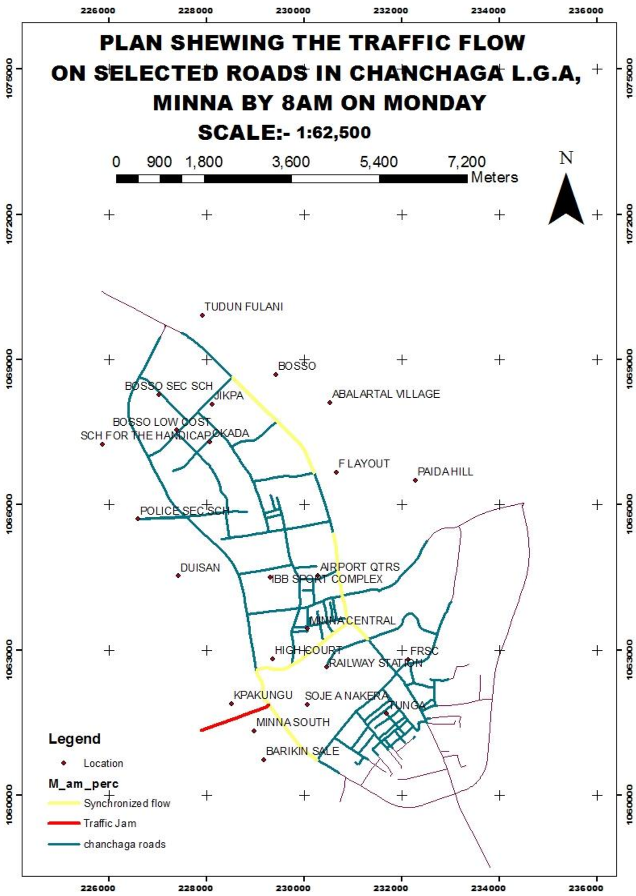

Figure 10. Traffic flow on Chanchaga roads by 8am on monday

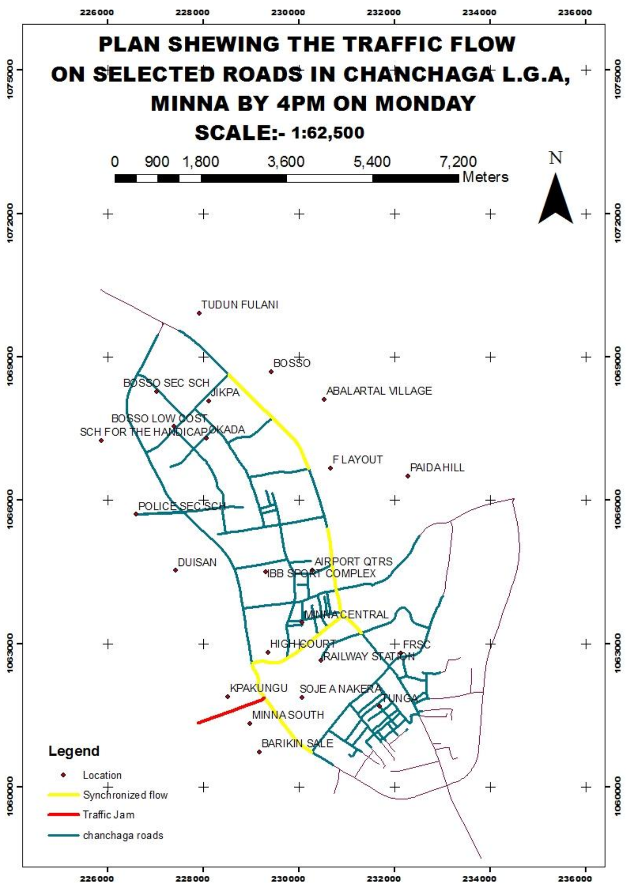

Figure 11. Traffic flow on Chanchaga roads by 4pm on monday

doi: 10.14710/geoplanning.4.2.171-186

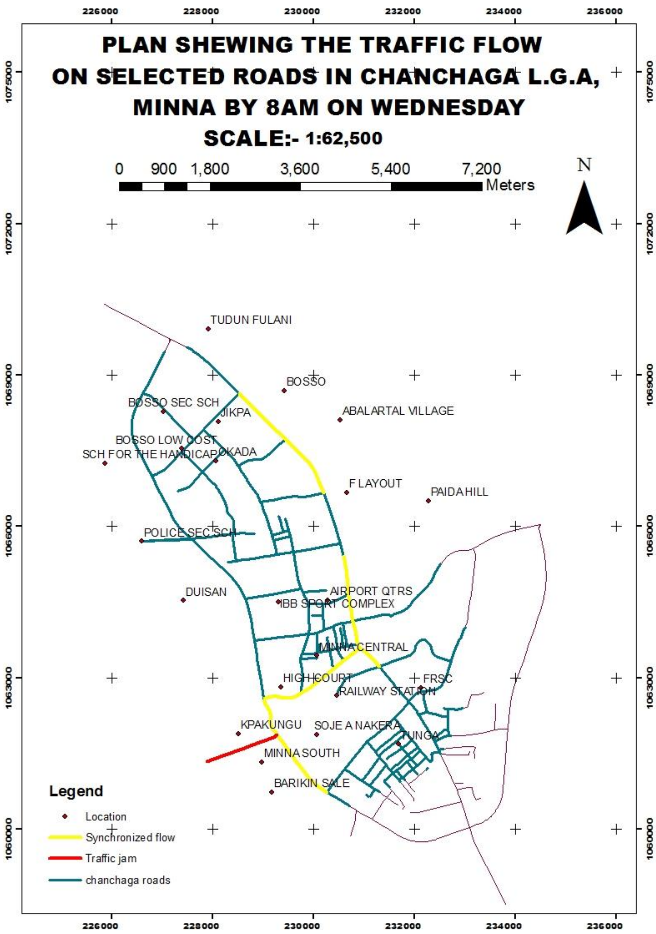

Figure 12. Traffic flow on Chanchaga roads by 8am on wednesday

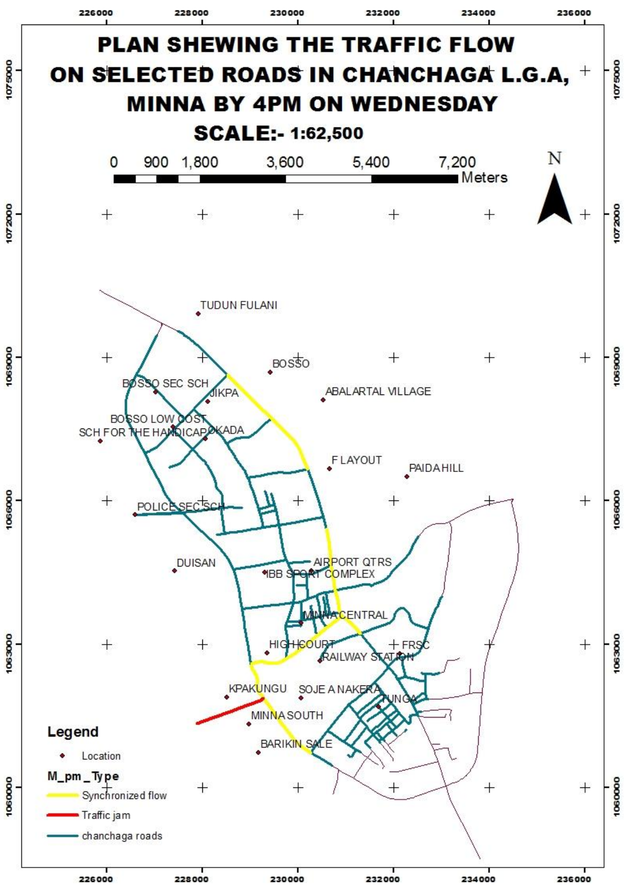

Figure 13. Traffic flow on Chanchaga roads by 4pm on wednesday

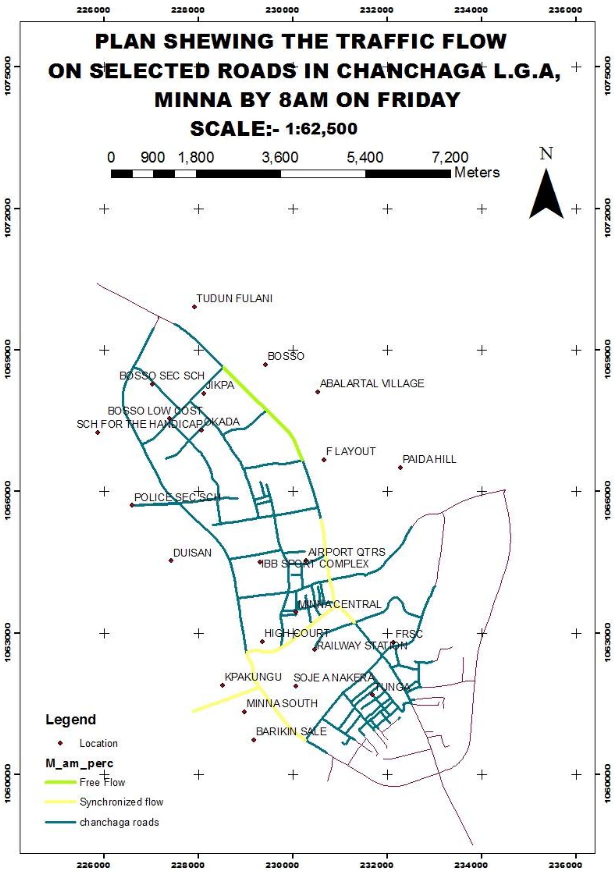

Figure 14. Traffic flow on Chanchaga roads by 8am on friday

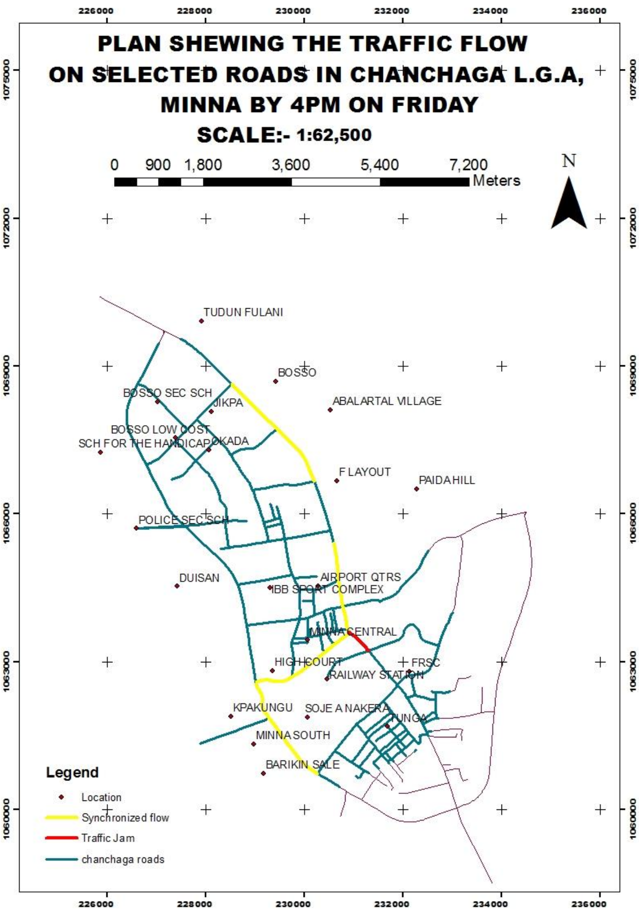

Figure 15. Traffic flow on Chanchaga roads by 4pm on friday

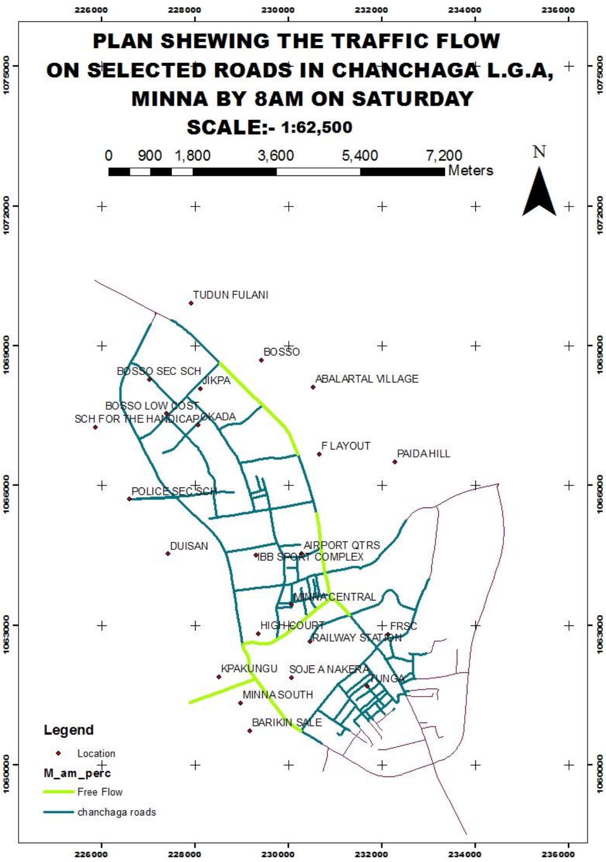

Figure 16. Traffic flow on Chanchaga roads by 8am on saturday

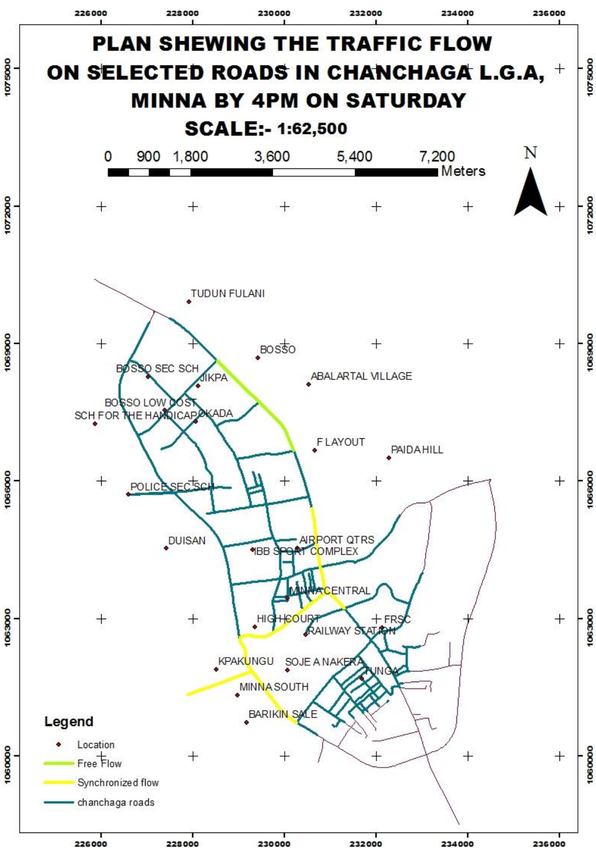

Figure 17. Traffic flow on Chanchaga roads by 4pm on Saturday

4. CONCLUSION

The application of GIS has helped in the proper assessment of the causes of traffic congestion within Chanchaga metropolis. From this research, it was discovered that Kpakungu axis of Minna–Bida road is the most congested route of the entire road networks considered, closely followed by the Bosso-Mobil Road. The traffic gridlock along these routes is most prominent on Mondays, Wednesdays by around 8am and 4pm and on Fridays around 1-4pm. Also, a free traffic flow is often experienced on Saturdays by 8am which gradually builds into a synchronized flow around the evening time on all the road networks considered. It was also discovered that there is no parking space along Minna–Bida road which is one of the major causes of traffic congestion due to incessant parking of vehicles along the road corridors. Other notable causes include: narrow road width, bad road pavement, indiscriminate parking of cars by the road side, lack of traffic light, reckless driving and commercial viability of the axis. The major adjacent land uses alongside the roads in Chanchaga LGA are residential and commercial land uses.

It is strongly recommended that necessary government agencies should quickly consider prompt repairs of the fast deteriorating Minna–Bida road. They should correspondingly consider converting this road into a dual-carriage way because of the increased volume of vehicles that plies it daily and in order to mitigate the traffic gridlock that is often experienced by road users on daily basis. In addition to this, the provision of well programmed traffic control and monitoring system is strongly recommended for strategic junctions of all the road networks. In conjuction, the Federal Road Safety Corps (FRSC) should embark on aggressive sensitization campaign to inform the road users on how to use the roads with caution and safety oriented mind set.

5. REFERENCES

Ajala, D. O. (2011). Challenges of Traffic Management in Osogbo as an Emergent State Capital. In *PhD Research Thesis submitted to the Department of Urban and Regional Planning, Federal University of Technology, Akure, Nigeria.*

Ajayi, O. G., Odumosu, J. O., Samaila-Ija, H. A., Zitta, N., Adesina, E. A., & Olanrewaju, O. J. (2015). Dynamic Road Segmentation of Part of Bosso Local Government Area, Niger State. *American Journal of Geographic Information System, 4*(2), 64–75.

Ajayi, O. G., Onuigbo, I. C., Odumosu, J. O., Adewale, T. J., & Gbedu, A. M. (2015). Mapping Road Traffic Accident Hotspots and evaluating the causative factors of their probable causes in Minna, Niger State. In *6th International Conference on HealthGIS- 2015. GeoICT for Epidemic Control and HealthCare, 19 -21 November, 2015, Mysore, India*.

Aworemi, J. R., Abdul-Azeez, I. A., Oyedokun, A. J., & Adewoye, J. O. (2009). A study of the causes, effects and Ameliorative Measures of Road Traffic Congestion in Lagos Metropolis. *European Journal of Social Sciences, 11*(1), 119–128.

Kimathi, M. E. M. (2012). Mathematical models for 3-phase traffic flow theory.

Lindsey, R., & Verhoef, E. (2009). Traffic Congestion and Congestion Pricing. *Tinbergen Institute Discussion Papers 00-101/3, Tinbergen Institute, 2000.*

Ogunbodede, E. F. (2007). Assessment of traffic congestions in Akure (Nigeria) using GIS approach: lessons and challenges for urban sustenance. In *Proc. Conf. on Whole Life Urban Sustainability (pp. 1–25).*

Ogunbodede, E. F., & Aribigbola, A. (2003). Traffic Management Practices and Problems in Akure, Nigeria. *Indian Journal of Transport Management, 27*(3), 305–322.

Okagbue, H. I., et al. (2015). On the Motivations and Challenges Faced by Commuters Using Bus Rapid Transit in Lagos, Nigeria. *The Social Sciences, 10*(6), 696–701.

Olatunji, A., & Diugwu, I. A. (2013). A Project Management Perspective to the Management of Federal Roads in Nigeria: A Case Study of Minna-Bida Road. *Journal of Finance and Economics, 1*(4), 54–61. [Crossref]

Olusina, J. O., & Olaleye, J. B. (2013). Transaction-Based Intelligent Transportation System (TBITS) Using Stochastic User Utility Model. *Transactions in GIS, 17*(1), 109–123. [Crossref]

Onasanya, A., & Akanmu, J. O. (2002). Quantitative Estimates of Traffic Congestion on Lagos--Abeokuta Road, Lagos, Nigeria. Journal of Civil Engineering, Nigeria Institution of Civil Engineering.

Park, M. J. (2012). Three phase traffic theory.

Pike, E. (2010). Congestion charging: challenges and opportunities.

Rao, A. M., & Rao, K. R. (2012). Measuring urban traffic congestion – A Review. *International Journal for Traffic and Transport Engineering, 2*(4), 286–305. [Crossref]

Willett, K. (2006). Stuck in traffic and stuck for solutions: Brisbane's congestion crisis'. In *Australian institute of Transport Planning and Management (Qld) Seminar*.