Traffic Management System in Abuja City Center, using Geographic Information Systems (GIS) and Global Positioning System (GPS). A case study of FCT, Nigeria

A H Ashara¹, S Saleh²,³, U Hassan¹ and M J Kaura¹

¹Lecturer, Department of Civil Engineering, Ahmadu Bello University, Zaria, Nigeria
²Lecturer, Department of Civil Engineering, Hassan Usman Katsina Polytechnic, Katsina State Nigeria
³PhD Scholar, School of Civil Engineering, Universiti Teknologi Malaysia, Johor Bahru Malaysia

samailasaleh2003@yahoo.com

Abstract. In any city in the world, moving from one point to another is an endurance task. Regardless of the social status of the traveller, the situations under which persons travel are becoming challenging gradually. The condition of Abuja traffic is no diverse. Efforts were made in this study, to map traffic conditions along selected corridors of Federal Capital Territory (FCT) Abuja using Geographical Information System (GIS) and Global Positioning System (GPS) Techniques. The primary data used includes the geographical coordinates of the chosen traffic corridors using GPS, the extent of vehicle traffic congestion and traffic counts along the corridors. Whereas the secondary data used are Abuja FCT’s topographical and road map from the Abuja Geographical Information System (AGIS). The data obtained were entered and used to develop an information system for traffic conditions (TCIS). Data recovered and attribute spatial analysis were displayed using ArcGIS 10. The results were presented in a map format, making it easy to interpret and quick to make decisions. The results display different levels of congestion and vehicular volume along digital traffic corridors. The results will be beneficial for agencies in charge of traffic conditions planning and management in Abuja FCT. GIS-GPS are powerful tools for both spatial and non-spatial data analyses. From the analysis, it can provide traffic data (Speed, Level of Service, Traffic and Delay Time) to transport planners in road controlling authorities in order to understand congestion better, determine its causes and prioritise investment where it is most needed.

Keywords: Traffic Congestion; GIS; Traffic Management; GPS; F.C.T Abuja

1. Introduction
Transport is fundamentally important to the growth of nations as it is not only a necessity of life but has an impact on all facets of our lives [1,2]. Thus transport is the life wire of an urban environment. Life, as it is today, would be inconceivable without transportation; as it is central to the flow of information, materials and people[3]. In the life of a city and cities around the world, transportation remains the core of an economy where public mainly meet to exchange goods and interacts. Over the years, cities are witnessing an explosive growth rate[4].
One of the leading causes of the level of physical growth in Nigerian cities is the rapid growth of the urban populace [5]. The worldwide transportation sector is generally in a state of crisis, especially in recent times. Nigerian cities have continued to expand, and the supply of transportation has dropped below demand. Nigeria is experiencing increasing rates of urban mobility problems amid opportunities in cities [2,3]. The issue of urban transport started with growing urbanisation and population leading to problems of urban transport such as congestion of traffic.

Congestion of road traffic is a significant problem for Nigerian cities. Congestion happens once road networks in the city cannot be able to accommodate the traffic volume; this raises travel costs and creates psychological and physical distress [6–8]. The chaotic condition in Abuja is noticeable in almost all the selected corridor with the junction in Phase 1 Abuja. Abuja is one of the rapidly developing cities in Nigeria. For rapidly growing in the cities, it is traditionally right to expect a high rate of travel demand [9]. Data from various sources such as spatial data, which is necessary to curb the essences of traffic congestion and its consequences, is needed for optimal decision-making [10].

Various experiments and studies have been performed around the world on information system design using the combination of GPS-GIS integration. Some of the literature referred to for the review has been illustrated as follows. For example, [11] discovered a new process of traffic data collection by incorporation of GIS technologies with GPS. The method measurements the pairs of speeds and longitude-latitude at regular intervals. Compared with the old method where the driver recorded the data manually, the new method is more efficient. It is now possible to achieve efficient vehicle monitoring by integrating data derived from GPS. Similarly, [12] used GPS to collect travel time, speed and delay data on 64 major roads across Delaware State. A comparative statistical analysis between the GPS and traditional method data proved that the GPS method is reliable like the conventional method and in term of the workforce is 50% more efficient.

The concerns of road traffic jamming are beyond individual traveller’s problems. Environmental quality, road safety and access to the city are parts of the worth of life that occur in congested areas. Congestion control can identify accidents and assess the position and duration of jams [13,14]. While GIS is used in transport years back to the 1960s, the capability of a GIS-GPS system to view and explore travel information has evolved exponentially in recent years as GIS's processing speed and usability have increased [15].

Therefore, this paper will explore the traffic management system in phase 1 Abuja City Center Nigeria, using Geographic Information Systems (GIS) and Global Positioning System (GPS).

2. **Study area and methodology**

2.1. *The Study Area*

The Study Area for this research is Abuja, the Federal Capital Territory (FCT) situated in Nigeria's geographic centre. The coordinates of Abuja are 9 ° 4'0"N (9.066667° N) 7 ° 29'0"E (7.483333° E). Abuja has 8,000 square kilometres of land. FCT has borders with Kaduna, Niger, Nasarawa and Kogi states on the north, west, south-east and south-west respectively. FCT was formed in 1976 from parts of previous Nasarawa, Kogi and Niger states. FCT was built primarily in the 1980s and is a planned city. On 12 December 1991, Abuja officially became the capital of Nigeria. The population of Abuja was 778,567 at the 2006 census. Abuja was created in phases. Abuja Phase 1 consist of five districts Asokoro, Central, Garki, Maitama and Wuse. Similarly, Abuja Phase 2 also consists of five districts Durumi, Gudu, Jabbi, Kado and Utako. Phase 3 of Abuja has four districts Gwarimpa, Katampe, Mabuchi and Wuye. The current research covers Abuja Phase 1. The roads networks are Expressway, Arterial, Collector and Local roads. Other significant transportation facilities built include footpaths, grade separation, zebra crossings, parking facilities, bus stops, feeder roads tarring, streetlights and traffic lights. Figure 1 shows the map of the study areas.
2.2. Data
The data used comprises two sources, primary and secondary data. The primary source of data includes the direct observation of field information. The primary source data collected includes; the geographic coordinates of the selected traffic corridors, traffic counts of selected corridors and the nature of congested traffic. The secondary source of data includes information from current documents, such as the report of traffic situations, topographical and road map. The traffic report and maps were obtained from the Vehicle Inspection Officers (VIO), Abuja ministry of Lands and Abuja Ministry of Transport respectively.

![Figure 1](image1.png)

**Figure 1.** Digital Map of the Study Area with Road Networks and selected junctions

![Figure 2](image2.png)

**Figure 2.** The Methodology Flow charts
2.3. Data Processing
The Abuja road network's maps were geo-referenced and digitised using Arc GIS 10 through the on-screen digitisation process. The study area's road networks were digitised as line features, and locations of selected corridors were plotted as point features using the space analysis tool. The primary source data were then structured in a GIS system implementation format and were linked to the digitised features as their attributes, which also used for database creation. Figure 2 shows the methodology flowchart of data collection and processing.

3. Data presentation, analysis and discussions

3.1. Traffic situation valuation.
The evaluation of the traffic condition performed involves traffic volume count and traffic density estimation (using the GPS receiver). The relocation of the federal government from Lagos to Abuja affected the rise in the number of vehicles in Abuja. The transportation infrastructure in the city could not accommodate all the vehicles; thereby increase the congestion of traffic in the city. Likewise, the enhancement in civil servants’ income and the boon of the private sector influence the level at which individuals purchase cars. Instead of using mass transit, which aids in reducing traffic volume, everyone desires to ride private vehicles and that lead to an increase in the number of vehicles on the road and resulting in congestions.

3.2. Traffic volume count
In Abuja city centre, seven major junctions are selected to examine their traffic condition by counting traffic volume. The junctions are Barnex, Hilton Transcrop, Area 10, Area 3, Area 11, MTN and British Council junctions as shown in Figure 3. One week traffic condition summary, as shown in Figure 4 based on data collected from vehicle counting conducted as part of the travel survey conducted for this study.

![Figure 3. Sample Congested road junctions for traffic volume count](image)

The following are reasons for the higher traffic volume count at Barnex junction: -

a) Vehicles usually pass through this junction from the expressway, either to Wuse or to the Federal Secretariat.

b) There is a property in the area, including the existence of various banks where people usually come for different transactions.
c) The junction location is a business environment that attracts public and private vehicles.

d) Also at this junction, there are two gas stations where vehicles come to buy fuel.

Figure 4. Condition of Traffic volume per day in some selected junctions in Abuja city centre

Area 10 Junction: records the lowest volume from Monday to Friday as the junction serves few business areas with alternative routes; besides, some of the roads leading to these junctions are blocked for security reasons. However, due to the shopping complex, cultural centre and some churches located in the environment, it has a reasonable volume on Saturday and Sunday when compared with others.

British council junctions: British council junctions have almost the same volume of traffic every day from Monday to Friday, as the atmosphere is more of government offices and private firms with various attractions and departures. Usually, the junction is less in the volume of traffic on Saturdays and much less on Sundays because on these days’ civil servants are not going to work.

MTN Junction: MTN junction is usually the highest on Saturdays and Sundays because on Saturdays vehicles are still passing this junction mostly for business purposes, and this is generally less in order junctions.

3.3. Maps of traffic conditions

In this analysis, the traffic condition maps, as shown in Figure 5a, was created using Arc GIS 10, by creating a digital database of all the variables selected as described and mapped below. The analyses were performed using both the overlay methodology and the unique method in the legend editor. The results of the analyses showed the congestion of the selected traffic corridors strongly, highly, fairly and reasonably. Likewise, the technique discussed above was also used to build the selected traffic corridors in hard, medium, very, very low and voluminous rates as shown in Figure 5a & b.

3.4. Measurements of traffic density with GPS Receiver.

GPSmap76Cx (GARMIN) was used for the measurements of traffic density. The GPS receiver was mounted on a car. The car was driven along selected corridors for Abuja City Center Phase 1 to determine traffic condition (congestion data) within the city centre. Following the general traffic flow, the vehicle was pushed floating in the traffic stream to catch the anticipated traffic conditions both
morning and evening. The collected data were transferred to the computer after field measurements for further processing and analysis by connecting the GPS to a computer.

![Figure 5](image)

**Figure 5.** Traffic condition maps of (a) Selected traffic corridors, (b) congestion level per corridors,

3.5. **Traffic valuation condition information of Ahmadu Bello Way from GPS receiver with the aide of map source**

Traffic condition information on Ahmadu Bello Way within Abuja city centre, FCT, Nigeria, is shown in Figure 6a using map source software. Figure 6b shows the GPS information on Google Earth and Figure 6c showing GPS traffic congestion on Google Earth.

**Ahmadu Bello Way (Federal Secretariat to Diamond Bank junction)** Morning peak period (AM)

- Distance (3.5km), mean peak travel time (295s) and mean peak travel speed (45km/h)
- Mean Peak Running Speed km/hr = (65+71+72+75+83+85+81+66)/9 = 75km/h
- Total Peak Delay = [(Mean Peak Running Speed) – (Mean Peak Travel Speed)] / Mean Peak Running Speed mean Peak Travel Time = [(75-45)/75] 295 = 118sec.
- Percent Time Delay (%) = (Total Peak Delay/Mean Peak Travel Time) 100 = (118/295)100 = 40%.

Similarly, the computation of LOS for the evening peak of Ahmadu Bello Way (Federal secretariat to Diamond Bank junction) was conducted and the result is presented in Table 1. Furthermore, Table 1 presents the LOA results of both morning and evening peaks of Diamond Bank junction to Barnex junction.

**Table 1. Traffic condition Data on Ahmadu Bello Way (Federal Secretariat to Barnex junction)**

| Route                | Ahmadu Bello Way                                      |
|----------------------|-------------------------------------------------------|
|                      | Federal Secretariat To Diamond Bank junction          |
|                      | Diamond Bank Junction To Barnex junction              |
| Am / Pm              | Am / Pm                                               |
| Distance (km)        | 3.5 / 3.5                                            |
| Mean peak travel time (seconds) | 295 / 419 | 285 / 319   |
| Mean peak travel speed (km/h) | 45 / 30     | 20 / 18    |
| Total peak delay (seconds) | 118 / 216   | 195 / 199  |
| Total peak delay (seconds) | Signal/Congestion | Signal/Congestion |
| Mean peak running speed (km/h) | 75 / 62            | 58 / 48   |
| Per cent time delay (%) | 40 / 52                      | 55 / 62  |
Level of Service (LOS) expresses the performance of a highway at Traffic volumes less than capacity.

**LOS A:** Percent Time Delay ranges from 35-40%

**LOS B:** Percent Time Delay ranges from 40-55%

**LOS C:** Percent Time Delay ranges from 55-65%

**LOS D:** Percent Time Delay ranges from 65-80%

**LOS E:** Percent Time Delay ranges from 80-85%

**LOS F:** Percent Time Delay ranges from 85-100% [16]

![Ahmadu Bello Way on GPS MapSource](image1)
![Ahmadu Bello Way on GPS Google Earth](image2)
![Ahmadu Bello Way (showing Traffic Congestion) on GPS Google Earth](image3)

**Figure 6.** Traffic condition Data on Ahmadu Bello Way

3.6. **Identified Congested and Uncongested Roads**

GIS system's ability to respond to queries. Through a query, the road name, road ID, the distance covered by the road in question and the type of congestion could be obtained on such roads. It is also possible to query items such as road junctions and point of contact between roads and rivers. This data
has many consequences for preparation. For example, as shown in Figure 7, the data could be used to identify congested roads and junctions

![a) Congested Road](image1) ![b) Congested Junction](image2)

**Figure 7.** Result of query determining for (a) Congested Road & (b) Congested Junction

The GIS system can also query "T" and cross junctions

Invoking the following questions are raised: [Point ID] = "T junction" and [Point ID] = "Cross junctions" respectively. Figure 8 shows the examples of this form of query. Depending on the type of traffic information and for what management reason, these queries might be appropriate.

3.7. Importance of the GIS system in the study area traffic monitoring

Appropriate queries that can trigger a graphical response that can be used to manage traffic congestion. The result can be achieved by a reliable method of data capture, such as the use of a moving camera. When using this video machine to cover the situation on the ground and relay it to people, the visual status of the traffic incident on each network can be relayed, as shown in Figure 9.

![a) Junctions and their locations](image3) ![b) Number of congested junctions](image4)

**Figure 8.** Result of query determining types of (a) Junctions and their locations & (b) number of congested junctions

If a moving camera (video) is used to capture traffic conditions and such information is relayed to an existing television station via a remote sensing gadget, this type of pictorial view could be used to
present traffic conditions to commuters on TV. Similarly, information about traffic conditions could also be passed on to commuters and drivers via radio house during peak periods. This type of information will allow road users to make rational decisions about which route to take in the face of traffic information that is transmitted from time to time and for different city routes.

3.8. Area prone to traffic congestion was displayed using the ArcGIS system buffer tool. Entering the query:[Bufferdis] = 100, 200 and 300 meters] using the GIS system's MultipleRingBuffer. The result of this query provided a map showing areas to the junctions with traffic congestion within 100 m, 200 m and 300 m range, as shown in Figure 10.

In transport planning, the buffer zones that can be in 100, 200 and 300 meters to "T" and cross junctions have much involvement. It could be used to determine the location of the city's parking areas. It can also be used to decide where the "no parking" zone should be demarcated. Therefore, in
addition to existing ones, buffer zones for different junctions can be used to enforce traffic management measures to create a sustainable traffic situation in urban areas.

4. Conclusions
This paper presents some digital mapping techniques. It shows that it is possible to use digital technology to monitor traffic conditions and speed efficiency. It also offers an insight into Abuja F.C.T’s most congested and voluminous traffic corridors. This paper has also shown that GIS-GPS Technology is capable of managing traffic mapping conditions along traffic corridors. The findings have been presented in map format, making it easy to understand and quick to make decisions. Geographic Information System-Global Positioning System is a useful tool for viewing various congestion rates and the number of vehicles along electronic traffic corridors. The use of GIS-GPS allows for the rapid processing and display of specific traffic conditions information on a map. GIS-GPS has also been used as a method to locate heavily congested and large traffic corridors, which in turn will help enhance the decongestion of heavily congested and broad traffic corridors with successful planning and management. It can also promote the exchange of spatial information between the transport department and other government agencies within transportation agencies.

References
[1] Ogunbodede E 2008 Urban Road Transportation in Nigeria From 1960 To 2006: Problems, Prospects And Challenges. *Ethiop. J. Environ. Stud. Manag.* 1 7–18
[2] Solanke M O 2013 Challenges of urban transportation in Nigeria *Int. J. Dev. Sustain.* 2 891–901
[3] Salau T 2015 Public transportation in metropolitan Lagos, Nigeria: analysis of public transport users’ socioeconomic characteristics *Urban, Plan. Transp. Res.* 3 132–9
[4] Mahabir R, Crooks A, Croitoru A and Agouris P 2016 The study of slums as social and physical constructs: challenges and emerging research opportunities *Reg. Stud. Reg. Sci.* 3 399–419
[5] WorldBank and UNCHS 2006 *Cities Alliance for Action Plan for Moving Slum Upgrading to Scale... Cities Without Slum*
[6] Hau T D 1992 *Congestion Charging Mechanisms for Roads An Evaluation of Current Practice* (Infrastructure and Urban Development Department The World Bank)
[7] Amelsfort D van 2015 *Introduction to Congestion Changing A Guide for Practitioners in Developing Cities* (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH Asian Development Bank)
[8] Alaigba D B, Soumah M and Banjo M O 2017 Heterogeneity index for the assessment of relationship between land use pattern and road traffic congestion in Apapa - Oworosoki expressway, Lagos metropolis *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* XLII 6–9
[9] Litman T 2013 Smarter congestion relief in Asian cities *Transp. Commun. Bull. Asia Pacific* 1–18
[10] Issa S and Saleous N 2018 *Modeling the Environment with Remote Sensing and GIS: Applied Case Studies from Diverse Locations of the United Arab Emirates (UAЕ)* (IntechOpen)
[11] Owusu J, Afakaar F and Prah B E K 2006 Urban Traffic Speed Management : The Use of GPS / GIS *Shaping the Change XXIII FIG Congress* (Munich, Germany) pp 1–11
[12] Faghri A and Hamad K 2002 Travel time, speed, and delay analysis using an integrated GIS / GPS system *Can. J. Civ. Eng.* 29 325–8
[13] Quiroga C A and Bullock D 1998 Travel time studies with global positioning and geographic information systems: an integrated methodology *Transp. Res. Part C* 6 101–27
[14] Quiroga C and Bullock D 1999 Travel Time Information Using Global Positioning System and Dynamic Segmentation Techniques *Transp. Res. Rec.* 1660 48–57
[15] Milla K A, Lorenzo A and Brown C 2005 GIS, GPS, and Remote Sensing Technologies in
Extension Services: Where to Start, What to Know J. Ext. 43 1–6

[16] Garber N J and Hoel L A 2009 Traffic and Highway Engineering