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TRAFFIC CONGESTION ASSESSMENT OF AKURE CENTRAL BUSINESS DISTRICT USING GEOGRAPHIC INFORMATION SYSTEM (GIS)

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Abstract: Increased traffic levels have exacerbated traffic congestion in many cities, including Akure, Ondo State, Nigeria, due to a range of causes such as inappropriate parking, slow vehicle speeds, and mixed vehicular and pedestrian traffic. The use of technology to alleviate traffic congestion concerns, as well as traffic planning and management using applications such as Geographic Information Systems (GIS) is gaining traction. As a result, this study used GIS to assess traffic congestion pattern in Akure's central business district. The study methodology involved the use of ArcGIS 10.7 and QGIS 3.18, which were integrated with Google Earth and Maps, as well as a physical survey at the site to generate spatial and non–spatial data for the study. The study's findings demonstrated that, using GIS it is possible to make well–informed decisions when it comes to resolving traffic congestion problems. According to the study, traffic congestion caused delays at the intersection, resulting in a class F level of service. However, with the use of alternative routes established using GIS, motorists' journey times can be greatly decreased as the intersection will be less crowded. According to the study, traffic congestion is caused by a combination of human, physical, and technical factors. In addition to enforcing traffic restrictions, the study recommended good land use practices, road user education, and the use of technology such as traffic control devices and CCTV to monitor and control traffic situations.
Keywords: traffic congestion, GIS, traffic planning, level of service, transport infrastructure

1. INTRODUCTION

Road transportation problems exacerbated by traffic congestion are becoming more prevalent in developing–world cities, leading to urban environmental issues and rising global greenhouse gas emissions (Anderson, 2017). Well–designed transportation networks can meet mobility and people's needs, as well as provide protection and environmentally sustainable vehicles (Ogryzek *et al.*, 2019). When several cars are stuck in one spot and movement on roads is delayed, it causes traffic congestion which is a barrier to smooth traffic flow. Unnecessary vehicles coming from multiple directions can generate traffic congestion, which can often result in a gridlock and increased journey time (FHWA, 2020; Goyal & Kataria, 2015; Falcocchio & Levinson, 2015).

Congestion has become a big problem in many cities, particularly large ones (Feifei *et al.*, 2016). According to Sougata (2017), traffic congestion is one of the city's most unpleasant challenges, resulting from an unexpected growth in private transportation and negatively impacting the urban society and business. Large transportation needs exist in a geographically constrained space as a result of the concentration of economic potential and population in metropolitan regions, and when these needs are met at the same time, congestion arises (Aleksandra & Dagmara, 2018). Congestion has an impact on citizens' psychological well–being, in addition to financial losses and unfavorable environmental and social dangers. Congestion has also created artificial obstacles to the flow of commodities and people through city streets (Popoola *et al.*, 2013). Congestion further increases the likelihood of traffic accidents (Retallack & Ostendorf, 2019).

Traffic congestion poses several negative effects for road users and the environment in contradiction of the sustainable development goals (SDGs) numbers 3, 8, 13 as the health and wellbeing of road users are impaired due to stress encountered in traffic, economic growth is limited as productive time is lost is traffic and release of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) from the car exhaust contributes to greenhouse gas effect. The capacity of a road facility to be congested is exacerbated at highway intersections, particularly in city centers, because current transportation infrastructures have frequently failed to keep up with commuters' growing mobility demands (Adanikin *et al.*, 2017).

Intersections, according to Ukpata and Etika (2012), are important aspects of the urban road network that can cause traffic congestion due to vehicle convergence from multiple directions at the intersection, whereas traffic congestion, according to Momoh (2011), is caused by an over–reliance on automobiles and a lack of an integrated transportation system. Trading activities, illegal parking, illegal bus stops, passenger pick–up and drop–off, vehicle breakdown, narrow road sections, religious activities, poor drainage, high

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traffic volume, lack of parking space, lack of traffic lights to coordinate vehicle flow, and driver inattention at some road intersections are all contributing factors to traffic congestion (Olorunfemi *et al.,* 2014, Ogundare & Ogunbodede, 2014, Jeremiah, 2017, Olorundare, 2022). Incremental delays, vehicle operational costs such as fuel consumption, pollution emissions, and stress are all generated by vehicle interference in the traffic flow. Hence, studies on traffic congestion could result in enhanced mobility, increased economic production, and a more livable environment (SougaLine ta, 2017).

A Geographic Information System (GIS) is a collection of computer software, hardware, data, and personnel that enables users to enter, manipulate, analyze, and present data and information about a specific area on the planet's surface (Ershad, 2020). Traffic congestion, transportation networks, and other relevant subjects can all be integrated into a GIS platform for spatial analysis. Non–spatial data, such as traffic volume for different vehicle categories at a given moment, can also be linked into a GIS platform to aid in decision–making. Traffic pattern studies are vital in locations where traffic congestion is severe as this will aid in providing the best solution to traffic congestion (Sureshkumar *et al.,* 2017). By automating changes and providing more interaction between data providers and data users, GIS is a smart solution that can help manage traffic data more efficiently (ICMA, 2018).

Traffic congestion of a road is closely linked to the level of service (LOS) for the given road. The level of service is a measure of the efficiency of transportation infrastructure, such as roads, lanes, intersections, and intersection approaches. LOS describes the facility's operating characteristics in terms of speed, transit duration, maneuverability, traffic disruptions, comfort, and convenience. The LOS scale goes from A (lowest congested) to F (highest congested).

Table 1: Approximate volume to capacity ratio for various Level of service (LOS)

Scale	Meaning	Volume to Capacity ratio (v/c)
A	Free flow (traffic flows at or above speed limit and motorists have complete mobility between lanes)	<0.6
B	Reasonably free flow (slightly more congested, with some impingement of maneuverability)	0.60–0.84
C	Stable flow (more congested than B, ability to pass or change lanes is not always assures, posted speed is maintained	0.85–0.94
D	Approaching unstable flow (speeds somewhat reduces, motorists hemmed in by other vehicles)	0.95–1.04
E	Unstable flow (flow becomes irregular, speed varies widely & rarely reaches speed limit, consistent with over capacity)	1.05–1.10
F	Forced or broken flow (constant traffic jam)	>1.10

Source: AASHTO (2018) and Darshana and Rao (2020)

This study therefore investigated traffic congestion in the study area by identifying the causes of traffic congestion, analyzing the traffic patterns, developing a data base of the traffic attributes and suggesting practical solutions for reducing traffic congestion with the aid of GIS.

2. MATERIALS & METHODS

This study involved all road networks around the NEPA junction in Akure, Ondo State, Nigeria as shown in Figure 1. Because of the large inflow and outflow of vehicles on a daily basis, the location was chosen specifically because it is recognized as a prominent center of traffic activities. Road segments were selected based on the responses of residents, commercial motorists as well as the Federal Road Safety Corps (FRSC) officials in Akure, as elicited from the questionnaires and key informant interview.

The primary source of data collection was employed in this study and this involved 94direct collection of information on the field, using traffic counts, and observations. Traffic counts were conducted manually to estimate the volume of traffic at the intersections. The traffic count was conducted based on junction peak period (7:30am–8:30am and 5:00pm–6:00 pm) for seven days spanning from Monday to Sunday. The secondary source of data collection involved sourcing information from existing records. Such data includes very high–resolution imagery with spatial resolution of 0.6m (QuickBird) of the year 2020, traffic counts from different road junctions in the area of study collected from the FRSC, topographical and street guide maps of the year 2020 which was obtained using Digital mapping. The spatial–temporal analysis for provision of information and queries were displayed using GIS tools including ArcGIS 10.7, and QGIS 3.18.

Creation of spatial database involving the design and the construction phase was undertaken. The design phase of the database consisted of reality view, conceptual data modeling, logical design and physical design. The view of reality shows the phenomenon as it actually exists, including all aspects, which may or may not be perceived by individuals. In this study, the view of reality that was abstracted for application is all traffic related objects such as roads, parks, junctions, and pothole zones. A vector representation scheme of the traffic hotspots (points) was adopted as primitives. In vector approach, it was assumed that individual terrain objects, such as roads, structures, junctions, bridges, obstacles etc. fill the space.

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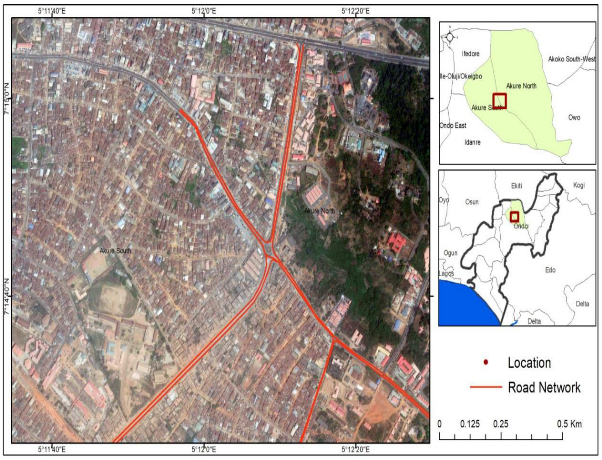

Figure 1: Study Area

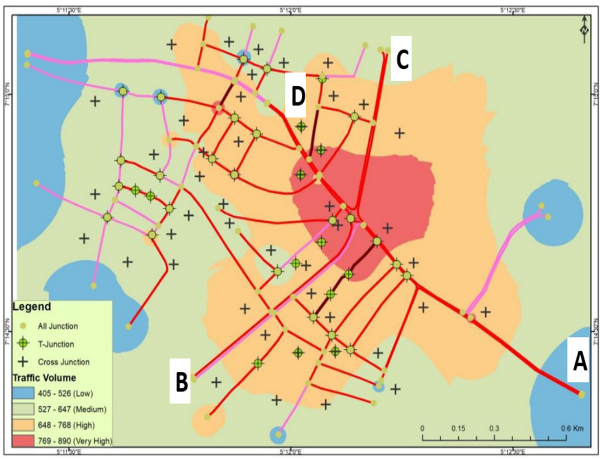

Figure 2: Traffic Volume along the Study Corridor

3. RESULTS & DISCUSSIONS

According to Figure 2, there are low traffic volumes in the range of 405–526, medium traffic volumes in the range of 527–647, high traffic volumes in the range of 648–768, and very high traffic volumes in the range of 769–890.

Figure 3 show the routes with the highly and less congested traffic. The study findings shows that majority of the study routes are highly congested with traffic volume between 648–890 veh/hr with higher traffic volume and congestion experienced at NEPA junction which is the central junction and acts as a collector for traffic from all directions A, B, C, D.

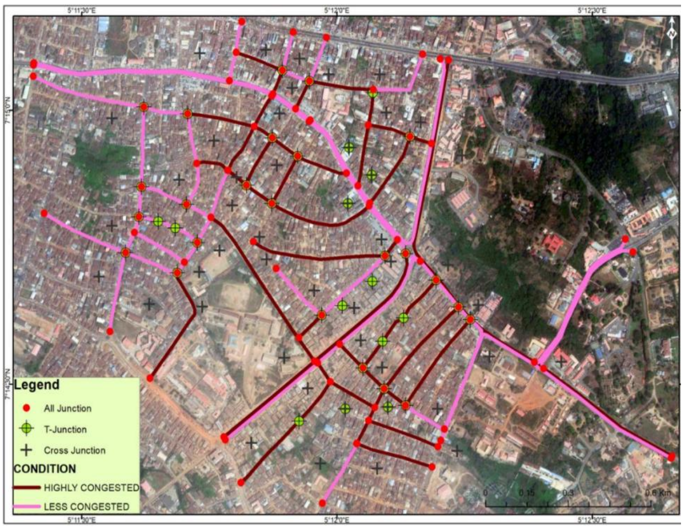

Figure 3: Congestion Condition

Based on roads classification by technical standards of highways according to Guozhu *et al.* (2017), the study road is classified as a Class II Road with a design speed of 60 km/hr and capacity of 900 veh/hr. Table 2 presents the Level of Service (LOS) for the study route.

Table 2: Level of Service (LOS) for the study route

Day of the Week	Period (Peak)	Passenger Car Unit (PCU)/hr (Volume)	Design Service Volume (DSV)/hr (Capacity)	Volume Capacity (V/C) Ratio	Level of Service (LOS)
Monday	Morning	1083	900	1.20	F
	Evening	961	900	1.07	E
Tuesday	Morning	1192	900	1.32	F
	Evening	1289	900	1.43	F
Wednesday	Morning	1030	900	1.14	F
	Evening	1301	900	1.45	F
Thursday	Morning	996	900	1.11	F
	Evening	1019	900	1.13	F
Friday	Morning	1225	900	1.36	F
	Evening	897	900	1.00	D
Saturday	Morning	764	900	0.85	C
	Evening	1208	900	1.34	F
Sunday	Morning	573	900	0.64	B
	Evening	813	900	0.90	C
Average				1.14	F

Estimating the level of service (LOS) for the roads using the volume/capacity ratio based on formulas obtained from Laddha (2021), iTRaC (2017) and Noor *et al.* (2021), the study reveals as shown in Table 2 that the volume/capacity ratio for the road is 1.14. This is greater than 1.1 thereby classifying the road LOS as F with the traffic state leading to breakdown flow. The road ideally should have a volume/capacity ratio value between 0.00 to 0.90 (LOS values between A and D). These would have led to a road segment with free flow of traffic or stable flow of traffic with high vehicle density that would have been expected at the central business district.

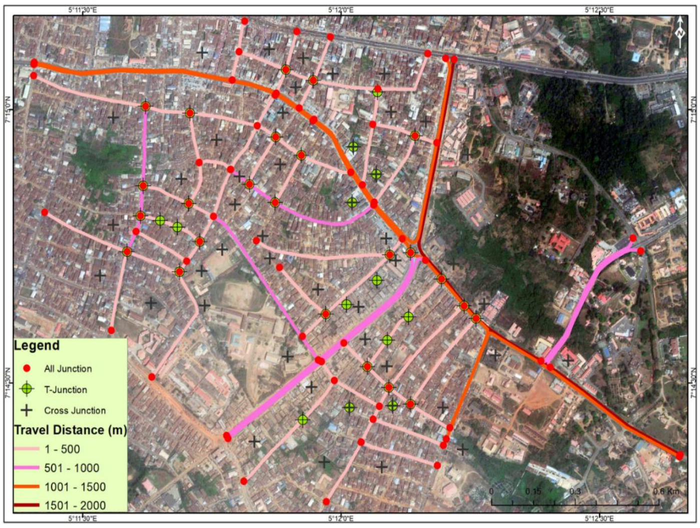

Figure 4: Travel Distance

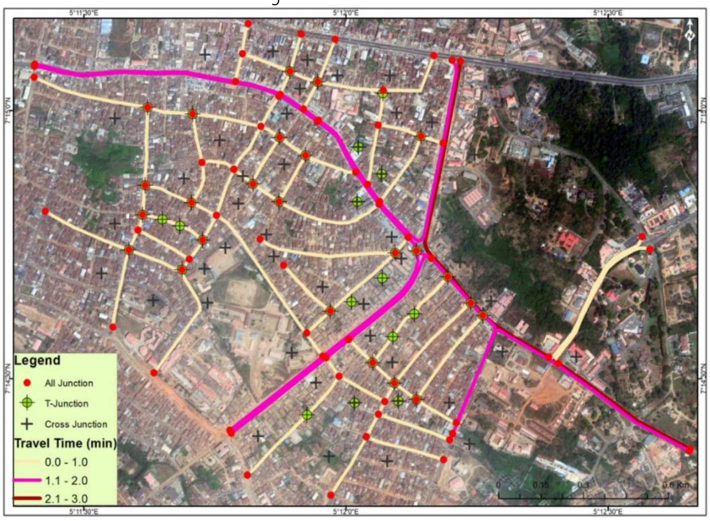

Figure 5: Travel Time

The traffic congestion experienced along the study routes considerably affects travel time by the road users. Figures 4 and 5 show the travel distance (m) and time (min) in the study area respectively. The traffic congestion occasioned by the volume/capacity ratio on the road results in longer travel time than expected considering the travel distance. This results in loss of valuable time to road users, increasing noise pollution due to car horns, air pollution from car exhaust while stuck, increasing fuel consumption and in most times, increasing transport fare as public transport drivers also factor in expected/actual lost time in traffic congestion while estimating transport fare.

It can be deduced that millions of naira will be lost by road users based on the findings of Pishue (2017) that billions of dollars are lost to traffic congestion by drivers due to lost time, wasted fuel, and carbon emitted during congestion.

According to the study objectives and field survey, several physical, human, land use and technical factors are found to have contributed to traffic congestion along the road corridor. Vehicular and human traffic at NEPA Junction is extremely high, because it connects several roads together hence, any small impedance factor is likely to cause traffic gridlock. The area also serves as an industrial, commercial, and residential area and this generates a lot of traffic. A huge number of hawkers, vendors, and roadside traders, as well as various stores and shops line up along the road, creating a suitable setting for traffic congestion. Every vehicle driver appears to be in a hurry, frustrated and intolerant as a result, resulting in traffic congestion. As a result, there is a high rate of violations of traffic rules and regulations. Due to their lack of manners and indiscipline, they are also likely to be arrogant and rebellious to traffic wardens. There's also the issue of a lack of traffic wardens, and those that do exist appear to be compromising their principles by ignoring careless parking alongside a major route. Technical factors involving the ugly practice of installing canopies that stretch almost to the drainage line, so restricting parking places was also observed by commercial centers owners along the road corridor. Customers are thus compelled to park on the street, causing traffic congestion.

4. CONCLUSION & RECOMMENDATIONS

Understanding traffic congestion patterns is fundamental for traffic planning and management, and as shown in this study, this may be done using a Geographic Information System (GIS). Based on the study conducted and results obtained, the following conclusions are drawn.

- Traffic congestion is a major menace in the study area and it results in increasing travel time which have several negative effects for road users.

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- The study reveals that the volume/capacity ratio for the road is 1.14 indicating a road with a level of service class F indicating a road segment with forced or broken flow in contrast to what would have been expected at the central business district.
- Several physical, human, land use and technical factors are found to have contributed to traffic congestion along the road corridor.

The following are some recommendations for resolving traffic congestion issues in the study area:

- The roundabout should be removed entirely because it limits the effective land area available for through traffic. It is advised that the intersection be channelized and signalized utilizing an actuated traffic signal, especially considering that it appears that most vehicle drivers in the study area respect traffic lights more than traffic wardens. It is also advised that effective traffic control equipment and infrastructure be used, such as the installation of CCTV to monitor traffic conditions at key intersections.
- Relevant government entities should be mandated to remove defective vehicles from the road, and they should be well equipped to do so. The implementation of public transportation plans that provide financial advantages while discouraging the use of private cars in central business districts should be adopted.
- Along the study route, proper land use planning should be done so that large land users that attract and produce traffic congestion are relocated. Roadside hawking is to be discouraged, while terminal facilities such as bus stations, lay–bys for loading and offloading passengers, should be provided. It is advised that transit–oriented development that produces a mixed–use city and encourages people to live, work, and shop near transit while reducing their reliance on cars is recommended.
- Traffic education that emphasizes traffic rules, highway regulations, road and traffic signals, driving responsibilities, respect for traffic control officers and devices, and concern for the safety of all road users should be undertaken.

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