Vehicular Traffic Control and Road Transport Infrastructure in Kano Metropolis, Nigeria

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ABSTRACT

The purpose of this study was to find whether road infrastructure affected vehicular traffic conflicts in Kano Metropolis, Nigeria. The study specifically focused on how network connections, nodal clustering, and ancillary infrastructure such as bus stops, pedestrian crossings, and speed bumps contribute to these conflicts. The study gave an empirical understanding of the link between road infrastructure and traffic performance as well as suggestions for bettering traffic flow and thereby lowering conflict. To meet its objectives, the study used geographic information systems (GIS). GIS methods evaluated the road network connection and the geographical distribution of traffic nodes in Kano Metropolis.

The results of the study showed that Kano Metropolis's Road network connection was usually inadequate, with notable gaps between main routes. Lack of consistent links between nodes revealed by the GIS helped cause regular traffic congestion and bottlenecks. Cluster analysis found that high-density traffic nodes concentrated around city core areas and main junctions, which caused localized congestion. In essence, the study showed that improving road infrastructure, especially in terms of connection and the strategic placement of ancillary buildings, can greatly reduce traffic conflicts and enhance traffic flow in Kano Metropolis. Future urban design projects should prioritize building traffic lights at important intersections for the development of pedestrian bridges and overhead bridges, thereby enhancing connectivity.

(Keywords: traffic control, road infrastructure, road network connectivity, transport, traffic congestion)

INTRODUCTION

Transportation systems are critical to the socio-economic development of developing nations, providing essential links for trade, mobility, and regional integration. In Nigeria, different modes of transport, including rail, water, air, and road, play varying roles in national and regional development. Historically, rail transport was significant for moving bulk goods over long distances, but the sector has suffered from decades of neglect and underinvestment, limiting its current effectiveness (Olagunju, Olawale, and Yusuf, 2022).

Water transport, which is useful along Nigeria's rivers and coastal areas for transporting goods, especially agricultural products, remains underdeveloped due to inadequate infrastructure and navigational challenges. At the national level, road transport systems are crucial for linking different regions, promoting domestic trade, and supporting the mobility of population. In many developing countries, road transport is particularly significant due to the relative underdevelopment of other modes of transportation, such as rail and air.

The effects of road traffic conflicts are multi-faceted, impacting not only public health but also the economy and the overall functionality of the road network. The Federal Road Safety Corps (FRSC, 2023) reports that road traffic accidents are the second leading cause of violent deaths in Nigeria, with thousands of fatalities recorded annually. The economic costs of these conflicts are staggering, including medical expenses, loss of productivity, and the financial burden of property damage. Moreover, road traffic conflicts contribute to longer travel times, increased fuel consumption, and the deterioration of vehicles due to the constant stop-start nature of congested traffic. These conflicts also undermine the efficiency of the road network, hindering the movement of goods and people and slowing down economic activities.

Road traffic setting in the ancient cities of Nigeria reflects a complex interplay between traditional urban structures and modern transportation demands. In cities such as Ibadan, Benin, and Sokoto, narrow streets originally designed for pedestrian and animal traffic have struggled to adapt to the influx of motorized vehicles. As these cities developed, road networks expanded without significant planning, leading to irregular and congested traffic systems. Today, these cities experience heavy traffic congestion, particularly in market areas and along main roads that were not built to accommodate high vehicular volumes. The increasing reliance on motorcycles and tricycles as public transport options has exacerbated the pressure on urban roads, contributing to frequent traffic jams and road conflicts.

Kano Metropolis, the largest urban center and commercial hub for businesses in Northern Nigeria, with a projected population of 4,490,734 million (NPC, 2024), serves as a vital commercial hub for the region. Its economic prominence has resulted in an influx of people, businesses, and vehicles, placing significant pressure on the city's road transport infrastructure. Road transport accounts for nearly 98% of intra-city movement (Gwadabe, 2012; Bichi, 2018), yet the existing road network is insufficient to handle the ever-increasing vehicular traffic. This situation has led to chronic traffic congestion, delays, and a rise in road traffic conflicts, undermining the socioeconomic growth of the metropolis (Haruna and Ibrahim, 2020).

In urban areas, such as Kano Metropolis, vehicular traffic conflicts are exacerbated by a combination of factors, including poor road design, inadequate maintenance, inadequate ancillary infrastructure, growing vehicular density, high traffic volumes, and poor traffic management. The prevalence of mixed traffic, which includes pedestrians, motorcyclists, and vehicles of varying sizes, often leads to chaotic road conditions where conflicts between road users are frequent.

A critical issue lies in the inadequacies of Kano's road infrastructure, especially at intersections and other vital points such as bus stops and pedestrian crossings. These poorly designed intersections and insufficient ancillary infrastructure such as speed bumps and pedestrian bridges significantly disrupt traffic flow and induce road conflicts. Specifically, these induced traffic conflicts arise from poorly planned infrastructure that reduces the effective flow capacity of the road network. For instance, bus stops in Kano are often positioned directly on major roads without proper lay-byes, causing vehicles to halt suddenly. This, in turn, creates rear-end and side-swipe conflicts as other vehicles attempt to avoid stationary buses, thus disrupting traffic patterns and leading to non-contact conflicts. Similarly, pedestrian crossings, especially in high-traffic zones, lack adequate protective measures, resulting in frequent conflicts between pedestrians and vehicles as drivers struggle to adjust to sudden pedestrian movements (Bichi, *et al*., 2020).

Moreover, the composition of traffic in Kano adds to the complexity of vehicular traffic conflicts. The roads host a mix of vehicles, motorcycles, tricycles, buses, and pedestrians, all competing for limited space, often leading to erratic traffic behavior and unpredictable patterns. Tricycles and motorcycles, in particular, tend to disregard traffic regulations, further exacerbating the congestion and traffic conflicts at key nodes, especially intersections and junctions (Bichi, *et al.*, 2020). At these critical nodes, traffic from multiple directions converges, often without adequate traffic control systems such as synchronized traffic lights or clear signage, leading to chaotic and hazardous driving conditions.

Thus, this study seeks to fill these critical gaps by providing a detailed analysis of the level of connectivity in Kano's Road network, exploring the nature and distribution of traffic nodes, and examining the vehicular traffic patterns that define daily road use. It also investigates how ancillary road infrastructure such as bus stops, pedestrian crossings, and speed bumps influence the aggravation/worsening of traffic conflicts, particularly non-contact conflicts, which disrupt traffic flow without resulting in collisions. The aim is to offer an in-depth understanding of how the current road transport infrastructure contributes to vehicular traffic conflicts in Kano Metropolis and to propose evidence-based solutions that can enhance road safety, improve traffic flow, and reduce congestion.

LITERATURE REVIEW

Pawinee, Emese, and Sararad (2023) investigated driver behaviors contributing to road safety among different modes at road junctions, Peri-Urban Areas, Thailand. The study focused on 4 points of road junctions of multi-lane highways and to observe their longitudinal differences with their speeds. The CCTV technology prototype was applied as a tool for collecting traffic data in the pilot area. The data was analyzed in terms of creating safety to be used in the assessment of the road safety information management index. Data analysis was applied to intersections using the road safety indices Time-to-Collision (TTC) and Speed. The results showed that traffic volume has a major impact on accident risk, especially at higher traffic volumes and in mixed-traffic situations.

Swanson, *et al*. (2022) observed pedestrian-vehicle traffic conflicts in school zones to evaluate the effectiveness of road safety interventions and reduce injuries in Ghana, Vietnam, and Mexico, 2019 - 2021. Three non-governmental organizations in Ghana, Vietnam, and Mexico applied three TCTs from the TCT Toolkit to collect traffic conflict data before (pre-intervention) and after (post-intervention) road safety intervention implementation. As the number of traffic conflicts was often less than 100, confidence intervals (CIs) based on gamma distributions were calculated for the traffic conflict rate. Using the calculated traffic conflict rate, the difference between pre- and post-intervention rates was assessed by determining overlap of the CIs. When CIs did not overlap, the difference was said to be statistically significant at the 0.05 level. Results indicated a decrease in traffic conflicts between pre- and post-intervention data collection periods. Pre- and post-intervention traffic conflict rates with non-overlapping CIs demonstrated the results were statistically significant, providing evidence that the road safety interventions were effective.

Nopadon (2021) investigated intersection safety assessment using video-based traffic conflict analysis: The case study of Thailand. The study developed a risk-based approach that incorporates video-based traffic conflict analysis to investigate vehicle conflicts under mixed traffic conditions including motorcycles and cars in Thailand. The study applied such conflict data to assess the risk of intersections in terms of time-to-collision and conflict speed. Five functional classes of intersections were investigated. The results showed that intersection classes, characteristics, and control affect the behavior of motorists and the safety of intersections. The results found that the low-order intersections with stop/no control are high risks due to the short time-to-collision of motorcycle-related conflicts. They generate frequent conflicts with low chance of injury. The high-order intersections with signal control are high risks due to high conflicting speeds of motorcycle–car conflicts. They generate few conflicts but at a high chance of injury.

Formosa (2022) developed Vehicle-based Traffic Conflict Prediction Algorithms Using Deep Learning. Automated video analysis method was developed by which traffic conflicts were identified using a faster Regional Convolution Neural Network (RCNN). The data was then integrated with highly disaggregated microscopic traffic data and in-vehicle sensors data collected from a section of the UK M1 motorway using an instrumented vehicle. It was found that DNNs outperform other techniques in predicting conflicts. Such promising results reflect that DNNs can be further applied to deepen our understanding in predicting traffic conflicts in order to design more reliable primary safety systems for intelligent vehicles. Results also showed that by adding multiple factors a significant difference (64.5%) in sensitivity was observed than when adopting TTC only for a 10% false alarm rate. Additionally, when considering uncertainty, a consistently higher sensitivity value and a 5% increase in AUC value was observed when compared to traditional estimation. This extends the systems' application for a wider spectrum of traffic scenarios.

Daniel and Xavier (2021) empirically examined the relationship between traffic congestion and road safety in cities. The study used panel data from 129 large cities in Europe for the period 2008–2017. It was found that the strong evidence of a quadratic relationship between congestion and deaths in accidents, using both parametric and non-parametric econometric techniques. The threshold points at which the relationship between congestion and deaths in accidents is reversed and becomes positive occur when congestion results in about a 30 per cent increase in travel time compared to a free flow situation. For most congested cities, any effective measure to contain congestion may also lead to better safety outcomes.

Mahssn. *et al.* (2024) conducted a study on non-signalised junctions and their effect on traffic flow and safety: A case study along Parit Raja main road. The study evaluated the effects of intersections on traffic flow and safety. The assessment was based on data collected at three unsignalized intersections on Jalan Kluang. Data on traffic volume, traffic conflicts, and delays were collected using a video camera and stopwatch during the start of monitoring in the morning rush hour and evening rush hour. Data collected included traffic volume, traffic conflicts, and delays. The developed model showed that the incremental increase in traffic conflicts can be represented by a negative exponential trend concerning the volume of approaching traffic. This negative exponential model showed a better explanation than other models. Therefore, the study was able to correlate the parameters that were determined by the characteristics of the studied non-signal intersections.

Abdurahman (2021) examined road user awareness and traffic safety issues, using Shashemene Town, Ethiopia, as a case study. Both descriptive and analytical methodologies were used in the investigation. Purposive sampling was the method of choice for the study, and the population under examination was chosen at random. The study found that some of the factors contributing to traffic accidents include drivers' lack of awareness of pedestrian traffic laws, their skill, their poor enforcement of the law, their lack of a speed breaker, the width of the roadway, the width of the bridge, their poor roadside furniture, excessive speed, failure to give priority to pedestrians, risky overtaking, following of one another too closely, and disregard for the right of way.

Fulu (2020) examined the variables that influence collisions between motorized and non-motorized vehicles in the turning lanes of intersections with signals. The field data were gathered using an unmanned aerial vehicle (UAV). And a variety of techniques, including manual statistics, video detection, and deep learning, were used to evaluate the data in order to determine the volume of traffic as well as the paths taken by cars and people. Various techniques, such as Pearson correlation analysis and the 2-tailed significance test, were employed to investigate the impact of traffic volume, speed, and traffic control elements on traffic conflicts. According to the study, there is a significant relationship between the frequency of conflict and the volume of non-motor vehicles (MNV) traffic; the speed at which right-turning vehicles at intersections have no significant effect on the frequency of conflict ($P = 0.071 > 0.05$); the setting of traffic markings is a significant factor ($P = 0.000 > 0.05$), which can be seen in the volume of non-motor vehicles (MNV) traffic at intersections (not controlled by signals); and the enhancement of traffic control elements can effectively reduce the frequency of conflict between motor and non-motor vehicles (MNV).

Matilda, John, and Dauh (2016) investigated the safety of signalized crossings in Baghdad, Iraq, by conducting a study on the geographical analysis of traffic conflicts. The ratio of the number of conflict events that occur within the identified hazard locations (hotspots within intersections) to the area covered was represented by the Intersection Prediction Conflict Index (IPCI), which was calculated using kernel density estimation, a spatial analysis tool in ArcGIS software, to estimate conflict intensity at each location. The study revealed that the developed method is effective and dependable in detecting possible hot spots and rating locations in relation to observed crash frequency because it is based on the spatial characteristics of traffic conflict occurrences.

Bassey, Ofem, and Edim (2019) examined the problems of vehicular traffic and its implications on the economy in a study of Calabar metropolis. The study used both primary and secondary sources of data. The sampling technique used in the study was stratified random sampling, where the population was divided into sections based on three locations, so chosen junctions, streets, and roundabouts. Descriptive analysis was used in the study. The descriptive statistics made use of tables, charts, simple percentages, and the one-way Analysis of variance (ANOVA) to determine the significant difference in spatial distribution of traffic congestion among traffic points used in the study. ANOVA was used to test this hypothesis on the influence of vehicular traffic problems on human health conditions.

The study findings; there is a massive failure of motorists to obey traffic rules, high rate of illegal street trading, there are few and inadequacy of alternative routes, insufficient presence of regulators and control of checkpoints by law enforcement officers near and/or at junctions, inadequate transportation infrastructure, services and technology, large number of vehicles has been introduced into the streets of Calabar with no official upgrading of the existing infrastructure, air pollution and various forms of heart diseases and reduction in marginal labor productivity as a result of carbon emission, traffic congestion causes pollution which invariably affects human, plants and animals.

Suleiman, *et al*. (2024) conducted a study on the analysis of the road transport infrastructure in Wudi town, Kano State, Nigeria. The study used both primary and secondary data. The primary data source involved the use of ARCGIS 10.1 software to map out the roads and potholes in the study area. The coordinates of locations of potholes were obtained using a handheld Geographical Position System (GPS). The secondary data source involved obtaining information about the existing number of roads from the Kano State Ministry of Transport. Descriptive statistics such as cross-tabulation, percentages, and mean were used to analyze the data collected for the study. The study revealed that road transport infrastructures in the study area are grossly inadequate, and the few that are available are completely in a state of despair, calling for urgent attention.

Wada (2023). empirically studied traffic congestion and delays at urban intersections, using Abuja, Nigeria's Federal Capital Territory, as a case study. A delay count at the intersection was used to collect the data, using data representation and a simple descriptive technique to analyze the associated data sets. The study revealed that intersections cause serious traffic issues that hinder travel times and economic activity within the study area.

Adepoju (2021) conducted a study on the analysis of road transportation infrastructure construction and maintenance for sustainable development in southern Nigeria. Principal component analysis was used to identify the various factors that are responsible for the inability of the government to construct and repair roads. Descriptive analysis was used to explain the challenges of construction companies and also the effects of bad roads on national development. The study revealed that there are factors that should be observed if the construction and maintenance of roads are to achieve sustainable development in south-western Nigeria. Apart from these factors, construction companies also have their challenges. The challenges of the construction companies and the funding, especially from the government, must be examined before embarking on any construction project.

Suleman and James (2020) carried out a study on Nigerian transportation safety concerns using a relative risk approach. Both primary and secondary data were used, and the analysis method was the multinomial logistic regression model, specifically using the relative risk ratio approach. The study found that each of the six geopolitical zones has a different level of risk exposure and that the risk differences between the exposed and unexposed groups were significant in the North-West, North-Central, and South-West zones due to risk factors like poor road conditions, road blockages or obstructions, kidnapping, poorly maintained vehicles, overloading, speeding, and other reckless road usage.

METHODOLOGY, RESULTS, AND DISCUSSIONS

Road characteristics in Kano Metropolis are shown in Table 1.

<u>Road Network Connectivity in Kano Metropolis</u>

The road network in Figure 1 displayed a clear hierarchical structure. At the top of this hierarchy are the primary roads, with the A2 highway and other major radial routes forming the backbone of the city's transportation system. These primary roads serve as vital arteries, connecting the city center to peripheral areas and extending to surrounding regions. The primary roads are essential not only for local traffic but also for facilitating long-distance travel, underlining their critical role in both intra-city and inter-regional movement.

Beneath the primary roads, there is an extensive network of secondary roads that branch off from the main arteries, effectively linking key districts such as Gwale, Fagge, Nasarawa, and Tarauni. These secondary roads enhance the overall accessibility within Kano Metropolis, ensuring that various neighborhoods are well connected to the primary road network. This network configuration is crucial for dispersing traffic across the city and reducing reliance on the main roads.

Table 1: Road Characteristics in Kano Metropolis.

LGA	S/No	Road Name	Road Length (metres)	Nature of Carriage way	Carriage way Width (metres)
Dala	1	Kurna Babban pLayi	4365	Dual	9.0
	2	Hospital road	2003	Dual	6.5
Fagge	3	BATA	2180	Dual	6.75
	4	France road	1942	Dual	9.50
Gwale	5	Kabuga road	1740	Dual	10
	6	Gwarzo road	3992	Dual	10
Ungogo	7	Kanar Ungogo	4955	Dual	7.5
	8	Zoo Road	2380	Dual	9.0
Kumbostso	9	Zaria Road	3515	Dual	9.5
	10	Ibrahim Bello Road	1425	Dual	8.85
KMC	11	BUK Road	1575	Dual	10.0
	12	Post office Road	792	Dual	7.0
Nasarawa	13	Hadejia	2890	Dual	11.0
	14	Club Road	850	Dual	13.0
Tarauni	15	Maiduguri Road	3435	Dual	7.5
	16	Zaria Road	3290	Dual	9.5

Sources: Kano State Ministry of Transport/Author's Fieldwork, 2023.

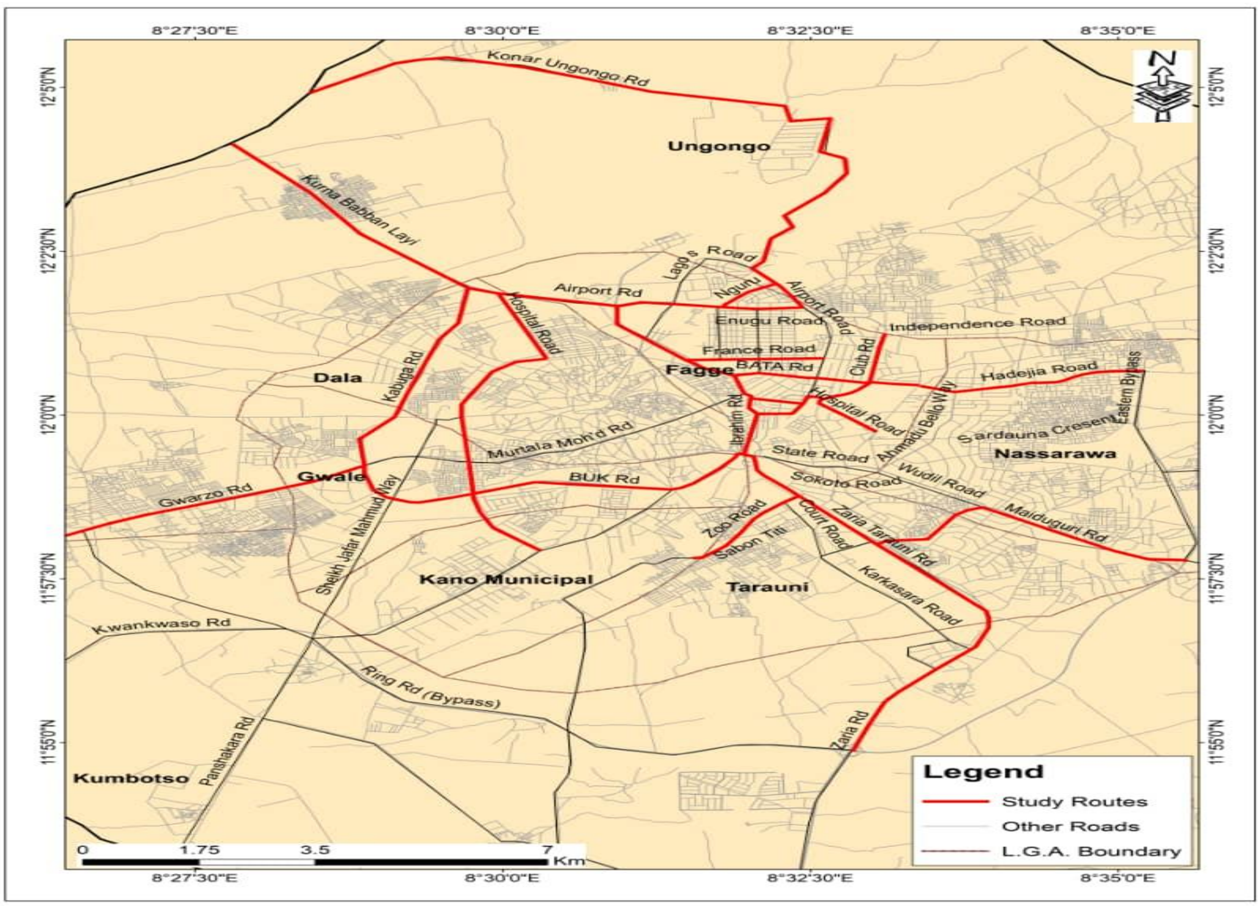

Figure 1: Connectivity of the Road Network in Kano Metropolis.
Source: Author's Fieldwork, 2023

At the local level, districts such as Gwale, Kano municipal, and Fagge benefit from a dense network of smaller roads, which serve to further improve connectivity and accessibility within these areas. The local roads enable ease of movement within neighborhoods and contribute to reducing travel time for residents accessing local services and amenities. This hierarchical structure, with primary, secondary, and local roads, underscores the layered nature of Kano's road network and its importance in facilitating efficient traffic flow.

The road network of Kano Metropolis also exhibits a radial and ring-road configuration. The Ring Road Bypass, in particular, plays a pivotal role in improving connectivity for the peripheral areas of the city. By diverting traffic away from the congested inner-city core, the ring road mitigates bottlenecks in the city center and ensures smoother traffic flow for vehicles that do not require entry into central Kano. This structure not only enhances connectivity between distant neighborhoods but also reduces the strain on radial roads leading into the city. The radial roads, which radiate outward from the city center, ensure that both the core and outer areas of Kano, such as Kumbotso, Ungogo, and Kano South, are well connected to the central business district. This design provides efficient access from various parts of the city to key economic and administrative hubs.

In terms of cross-district connectivity, districts such as Dala, Gwale, and Tarauni benefit from major roads that facilitate easy movement between them. This cross-district connectivity is vital for promoting intra-city mobility, enabling commuters to traverse between neighborhoods efficiently and reducing overall travel times. The smooth flow of traffic between districts is crucial for the city's economic productivity and the accessibility of public services.

The road network of Kano also demonstrates strong peripheral and regional access, as evidenced by the presence of major highways such as the A2 a 718-kilometre road that connects Kano to Port Harcourt city in south central Nigeria. These highways ensure that Kano is well-connected not only within its urban boundaries but also to other regions of Nigeria, playing a vital role in integrating regional traffic with the city's road system. This linkage between the urban core and peripheral areas supports Kano's role as a major commercial and logistical hub in Northern Nigeria, facilitating the flow of goods and people between the city and the surrounding regions.

However, despite the overall effectiveness of Kano's road network, there are potential bottlenecks that may arise, particularly due to the heavy reliance on a few major radial roads leading into the city center. The concentration of traffic on these roads, especially during peak periods, can lead to congestion. Roads such as France Road are likely to experience significant traffic volumes, as they serve as primary entry points into the central urban area. This highlighted the need for strategic traffic management solutions to mitigate congestion and ensure that the road network continues to function efficiently, particularly as the city grows and urban traffic increases.

Distribution and Clustering of Road Intersection in Kano Metropolis

Figure 2 showed the result of GIS mapping of the connectivity of road junctions in Kano Metropolis. The “nodal area" are central or focal point within a broader system, which often functions as a hub of activity, resource distribution, or connectivity. Nodal areas for distribution of road junctions are critical in understanding how this infrastructure is concentrated and dispersed within a region.

The nodal areas have been classified across five categories that range from "Very Low" to "Very High." These classifications provide a visual understanding of how the variable in question is distributed spatially across the metropolis. The attribute could represent any measurable phenomenon, such as population density, infrastructure development, pollution levels, economic activity, or accessibility, making this analysis a critical tool for urban planning and resource management.

The central region of the map, depicted in red, signifies areas of the highest concentration or intensity of the mapped road junctions. These areas are potential hotspots for vehicular traffic conflict and congestion in the metropolitan area of Kano. The high concentration in this central area is indicative of its critical importance in resolving traffic conflict and congestion within the Kano Metropolis.

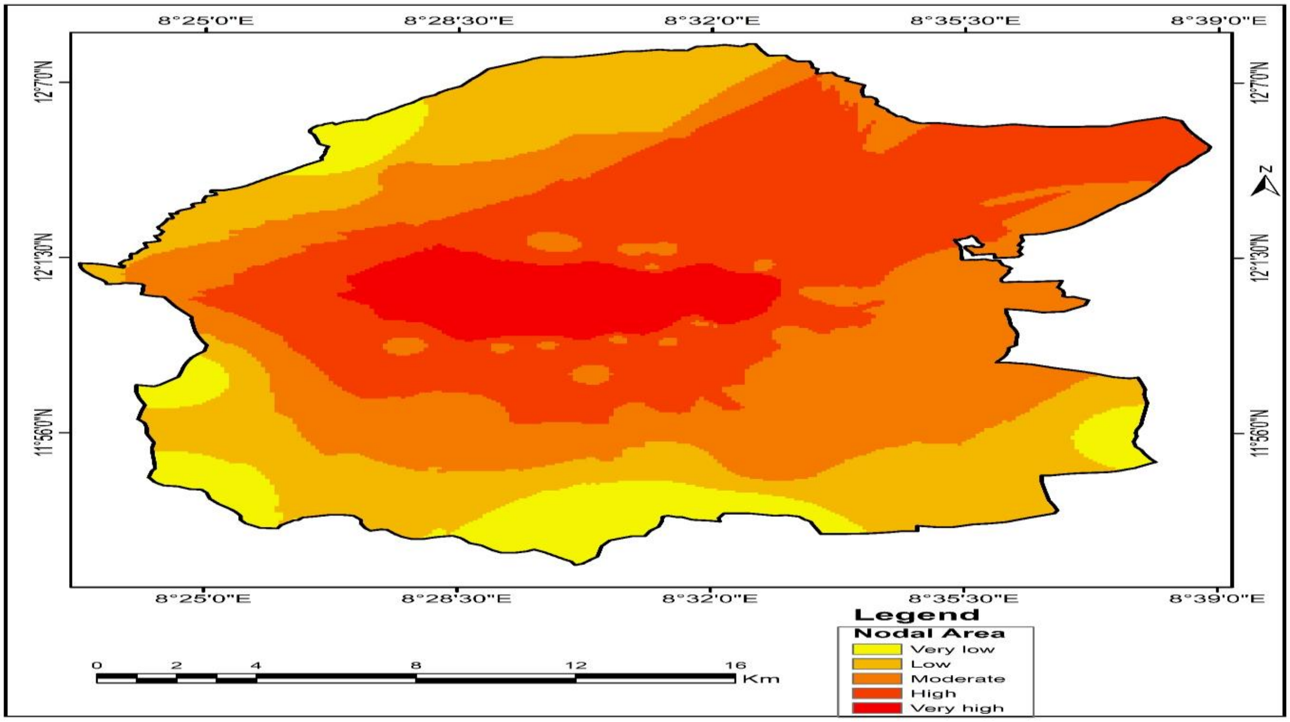

Figure 2: The Density of Road Network Connectivity in the Kano Metropolis.
Source: Author's Fieldwork, 2023

The orange zone, which encircles the red core, signifies areas of high but slightly lower intensity in the distribution of road intersections. These regions often serve as transitional or buffer zones around the central hub. In an urban setting, this zone could represent highly active districts that support the central area, such as densely populated residential areas or significant commercial zones. While these areas may not experience the same peak intensity as the core in terms of traffic conflict, they remain highly influential and contribute to the overall system dynamics.

Regions classified under the yellow zone exhibit moderate levels of the cluster of junctions. These areas can be seen as intermediary zones, balancing between the high-intensity core and the more peripheral areas. In terms of road infrastructure, these represent suburban districts intersections or mixed-use areas that serve as connectors between the highly concentrated urban core and the lower-intensity outer regions. The moderate concentration of junctions suggests that these areas may either benefit from or contribute to the adjacent zones of higher intensity, playing a stabilizing role within the urban system.

Areas classified as "Low" exhibit a lower concentration of road intersections in Kano Metropolis. These regions are less directly influenced by or contribute to the core activities or resources, suggesting that they may be more peripheral or less developed. The lower levels of intensity suggest these areas could be less affected by the dynamics occurring in the core and transitional zones.

The outermost areas, classified as "Very Low" and depicted in white, represent the least concentration of the road junctions. These peripheral regions are the least connected to or influenced by the central dynamics. In urban and regional studies, this might represent rural or underdeveloped areas with sparse population, limited infrastructure, or low economic activity. These regions may play a minimal role in the broader traffic system, either due to their geographical isolation or limited capacity to contribute to or benefit from the central zones.

The overall pattern of road distribution suggests a core-periphery model, where the intensity of the road network decreases as one moves away from the central areas. This spatial configuration is characteristic of many urban regions where resources, activities, or population densities are concentrated in a central hub and gradually diminish towards the outskirts. The gradation from "Very High" to "Very Low" highlighted a centralized phenomenon, whether population, economic activity, or infrastructure development that shapes the spatial dynamics of the Kano Metropolis. The observed distribution also implies a spatial hierarchy where the central zones are pivotal, potentially driving the socio-economic or environmental trends across the metropolis.

Nodal Area Analysis

The Nodal Area analysis result from the GIS tool provided a detailed spatial analysis of road intersections in Kano Metropolis. The result of the analysis revealed a pattern of nodal centralization with a clear gradient from traversing from high to low intensity. This spatial arrangement is crucial for understanding the distribution of various urban vehicular traffic zones and conflict areas that are concerned for traffic conflict, which may require focused attention for analysis or for development, infrastructure investment, or environmental mitigation.

The map under examination in Figure 3 below presents an analysis of road intersection density within the Kano Metropolitan area. The output utilized varying shades to depict different levels of road network concentration in the study area. The color gradient that ranges from light beige to dark orange provides a clear visual representation of the distribution and intensity of road infrastructure across the metropolis.

Foremost attention goes to the central portion of the map which was characterized by a prominent dark orange that signifies areas of high road density as shown in Figure 3. This dense road network is indicative of an urban core area within the metropolis. The Western part of the core is the traditional central area hosting the palace of the Emir and market area while the east of the area is the modern central business area with modern administrative activities such as the Governor's office as well as key state government ministries. This in other words functions as form of central business area that encompasses administrative, commercial, and transportation hub within the Kano Metropolis. The concentration of roads in this region is a combination of ancient city settlement and modern administrative and business with developed infrastructure attracting a potential high volume of vehicular traffic, commercial activities, and high population density. The road configuration in these areas included both major arterial roads and a complex network of secondary and tertiary roads that cater for intra-city mobility, facilitating accessibility to key services and institutions located in the city's core are major areas of vehicular traffic conflict with attendant issues of traffic congestion.

Away from the central area, the result as depicted in the map revealed a gradual transition to medium orange zones, representing areas of moderate road density. These regions may correspond to residential, semi-urban, or mixed-use zones where the road network remains significant but is not as intricate or congested as in the core. In these zones, the road network still serves important transportation needs, possibly connecting outlying districts with the central business area, but the infrastructure is comparatively less dense. The moderate road density in these areas likely reflects a balance between urban expansion and infrastructure development, where road networks are primarily designed to serve local populations and connect peripheral regions with major arterial routes.

Towards the outskirts of Kano Metropolis, the map displayed lighter beige regions, indicating low road density. These areas are typically peripheral, with less developed infrastructure and fewer roads relative to the central and mid-density areas. Low road density in these zones suggested rural or less urbanized areas, where the need for an extensive road network may be reduced due to lower population densities, limited economic activities, or less demand for frequent transportation. In many cases, these outer regions may rely on a few major roads or highways for access to the city center, with minimal local road infrastructure serving scattered settlements or agricultural areas

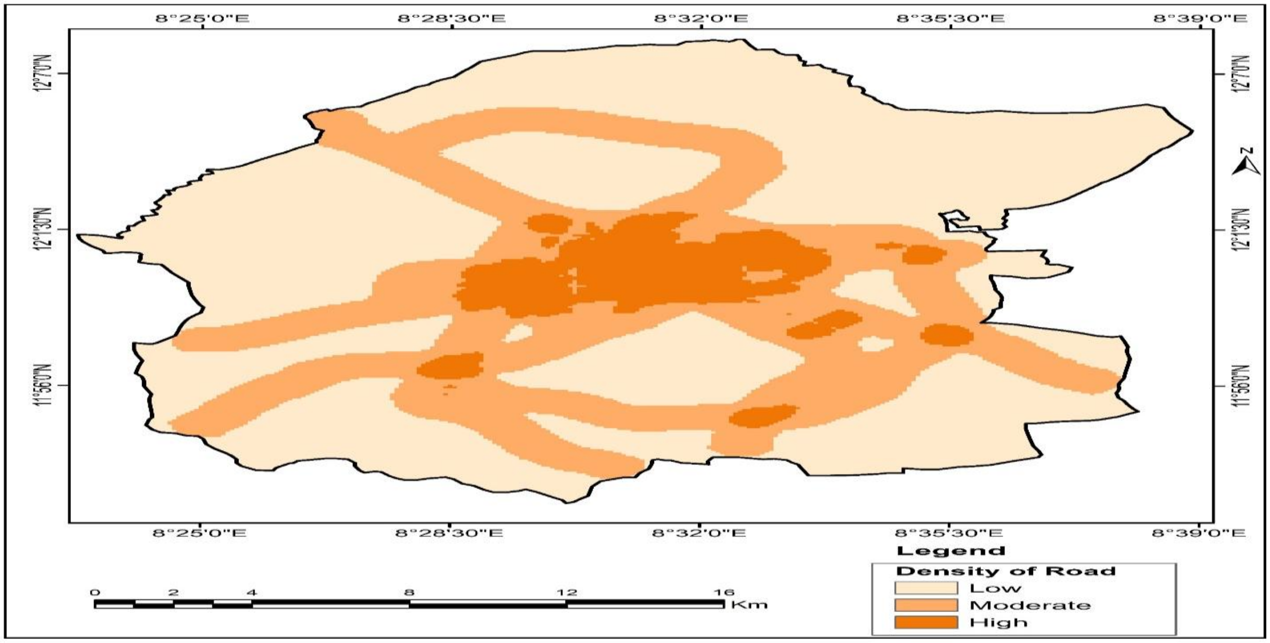

Figure 3: The Density of Nodal Point in the Kano Metropolis.
Source: Author's Fieldwork, 2023

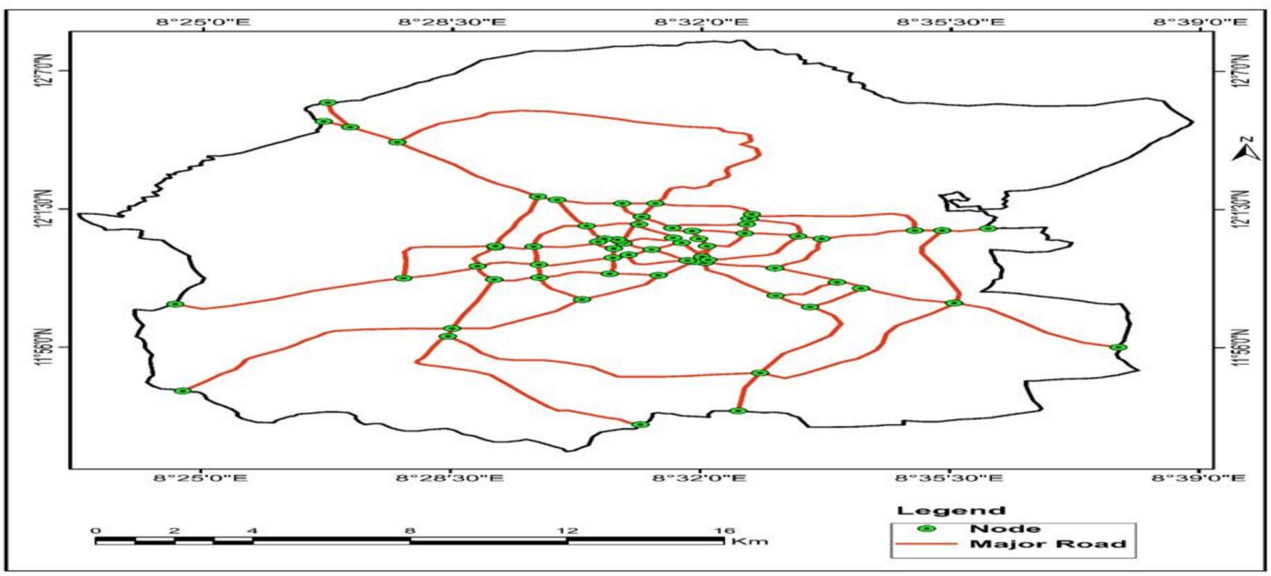

Figure 4: The Critical Nodes and Major Roads in Kano Metropolis.

Critical Nodes Areas within the Road Network of Kano Metropolis

An understanding road traffic conflict and resolving any inefficiency arising from the nature of infrastructure outlay within the Kano metropolitan area requires a detailed understanding of the connectivity of the road network within the study area. The connectivity level of a road network is a critical indicator of how efficiently different parts of an urban area like Kano Metropolis are linked. Such a level of linkage could directly influence travel time, accessibility, and overall traffic flow in the study area. The result in the case of Kano Metropolis, several important observations can be made regarding the road network's connectivity based on the map provided.

The connectivity of the road network was evaluated by investigating network centrality measures of existing road network such as betweenness centrality, degree centrality, and closeness centrality for each node or intersection. These measures help identify key intersections that serve as traffic hubs and potential conflict points. Using the Network Dataset tool in GIS, an analysis of the accessibility of nodes was conducted, and the results were mapped to show areas of high and low connectivity.

These nodes are essential for managing the influx of vehicles entering Kano from surrounding states and regions. By strategically positioning these nodes along key arterial routes, the city can better control the flow of external traffic, ensuring that vehicles destined for peripheral areas are efficiently routed away from congested inner-city roads. This type of connectivity helps maintain the flow of goods and services into the city while minimizing disruptions to local traffic.

CONCLUSION

This research has comprehensively examined the relationship between road infrastructure and vehicular traffic conflict in Kano Metropolis, providing valuable insights into the patterns of road network connectivity, vehicular traffic distribution, and the influence of ancillary road infrastructure on traffic performance. The findings revealed a hierarchical road network, with a central clustering of road intersections contributing to high vehicular traffic conflicts, particularly in densely populated and commercially active areas.

The analysis also underscores the significant role of tricycles and the need for better traffic management at critical nodes, especially along major radial roads like France Road. Moreover, the regression analysis highlighted the positive impact of pedestrian bridges on travel times, while identifying deficiencies in road signs, traffic lights, and bus stops as contributors to congestion and traffic inefficiencies.

RECOMMENDATIONS

The existing reliance on T-junctions and roundabouts in the Metropolitan’s Road design contributes significantly to vehicular traffic conflicts. It is recommended that these intersections be gradually replaced with fly-overs, which can better handle high vehicular volumes and reduce conflict points. Furthermore, road signage should be improved by using clear, legible signs inscribed in Hausa and placed at visible locations to enhance compliance and safety for all road users.

The clustering of road intersections in central areas, which often leads to increased traffic conflicts, requires targeted traffic management solutions. More efficient traffic lights, improved roundabouts, and intelligent traffic control systems should be deployed to regulate vehicular movements. Moreover, traffic personnel should be assigned during peak hours to assist in managing traffic flow at these high-conflict intersections.

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