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Road Transport Infrastructure and Traffic Density in Kano Metropolis, Nigeria

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Abstract. A major Nigerian urban centre, Kano Metropolis, deals with serious road traffic problems that lead to frequent congestion and delays. Although most research focusses on traffic flow and volume problems, it rarely addresses the role that vehicle noncontact conflicts play in traffic flow, given the type of infrastructure. The purpose of this study was to find whether road infrastructure affected vehicular traffic conflicts in Kano Metropolis, Nigeria. To meet its objectives, the study used statistical modelling. This research assessed how different ancillary road infrastructures affected travel time and traffic patterns using linear regression models. Primary sources provided data; these included traffic counts, road network maps, and field observations on sixteen main highways. The average travel time on roads served as the dependent variable, and evaluated traffic node clustering using node distribution and traffic volume analysis. The results of the study showed that Kano Metropolis's Road network connection was usually inadequate, with notable gaps between main routes. The model only explained 23.5% of the variance in average travel time on the Kano metropolitan road network, according to the regression study. It also indicated the existence of bus stops statistically influencing average travel time and pedestrian bridges ($p = 0.037$). Other factors, such as traffic lights ($p = 0.208$), overhead bridges ($p = 0.656$), laybys ($p = 0.087$), and speed bumps ($p = 0.296$), did not significantly influence travel time on the main Kano highways. 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 prioritise building traffic lights at important intersections for the development of pedestrian bridges and overhead bridges, thereby enhancing connectivity.

Keywords: Infrastructure, Road network connectivity, Traffic conflict, Traffic congestion, Travel time

1. Introduction

Globally, transport systems are the backbone of urban and rural development, supporting environmental sustainability, social advancement, and economic prosperity. Whether through roads, railways, airways, or waterways, efficient transportation systems which link people, goods, and services across various regions, thus supporting trade and economic activities by means of their fundamental connectivity (Usman & Sani, 2022). Vinod *et al*. (2003) claim that the effectiveness of transportation systems directly affects the rate and extent of urbanisation and industrialisation, thereby determining the spatial and economic landscape of cities. According to Ademiluyi & Solanke (2007) transport is the foundation of city operation. Consequently, since it promotes regional and worldwide trade and integration, transportation is not just a basic utility but also a major driver of globalisation. Particularly in developed countries, the ongoing worldwide investment in transportation networks emphasises their non-negotiable nature in preserving competitiveness in the global economy (Solanke, 2013; Rodrigue *et al*., 2020).

In industrialised nations, robust transport systems are closely associated with sustainable urban development, improved living standards, and reduced access inequality. As countries develop, the need for modern and effective transport networks becomes increasingly evident. Modern transport systems lower travel time, increase general quality of living, and boost productivity. Similarly, we cannot emphasise how important transportation infrastructure is to underdeveloped nations, such as Nigeria. Expanding urban centres and fast-rising populations create demand for transportation systems that can manage the complexity of urban mobility while promoting economic development and integration. In order to close the rural-urban divide and guarantee inclusive access to markets, goods, and services, transport networks in these areas are absolutely essential (Dam *et al*., 2021).

The social development of developing nations depends critically on transport systems that provide required linkages for trade, mobility, and regional integration. In Nigeria, several forms of transportation, including rail, water, air, and road have various functions in both national and local development. Although historically rail transport was important for delivering bulk products over long distances, the sector has suffered from decades of neglect and under investment, reducing its current efficiency. Because of poor infrastructure and navigational difficulties, water transportation, which is beneficial throughout Nigeria's rivers and coastal areas for goods, particularly agricultural products, remains underdeveloped.

Conversely, air transport is a vital link between regions and, globally, offers a rapid substitute for long-distance travel. However, air transport mostly manages passenger travel and high-value products, thereby providing little help for daily urban mobility (Ibrahim & Bello, 2022). In Nigeria, road transport still dominates all other modes of transportation, notwithstanding these alternatives.

Nigeria, being the most populated country in Africa depends mostly on its transportation system to connect its several regions. The transport system, which consists of roads, rail, air, and waterways, is essential in allowing the flow of goods and services throughout the country. Among these modes, road transport dominates, it accounts for more than 90% of both passenger and freight movements (National Bureau of Statistics, 2022). With almost 200,000 kilometres, the vast Nigerian road network is absolutely essential for regional trade, national cohesion, and economic integration. Routes are like critical arteries linking metropolitan centres with rural areas, therefore enabling necessary connections between production and consuming centres. Nevertheless, the condition and capacity of the road network significantly influence its effectiveness and ability to promote economic development.

Road transport, which facilitates the movement of people and goods across diverse geographic landscapes, is a major component of global transportation systems. Road transport, the most commonly used form of mobility, facilitates regional integration and development, provides access to basic amenities, and stimulates economic activity. Globally, road connections are quite important for the functioning of economies since they are main commerce routes between cities as well as countryside parts and help to link them. Countries all over the world invest heavily in building, developing, as well as maintaining their road systems, demonstrating the significance of road transport. Roads enable nearly 80% of world passenger and goods movement, according to the World Bank (2021), therefore highlighting the sector's importance in the global economy.

National road transport infrastructure plays a crucial role in linking many areas, encouraging domestic trade, and enabling people's mobility. Road travel is especially important in many developing nations due to the underdevelopment of other modes of transportation, such as rail and air. For both intra as well as inter-state journeys in Nigeria, road transport is the most often used form of mobility. It provides access to basic goods and serves as a trading hub between Nigerian states and surrounding nations. By guaranteeing the movement of goods and people, road transport promotes trade, increases production, and enables social contact. However, the state of road infrastructure directly impacts the quality and efficiency of transport services, thereby significantly influencing their efficacy. Although road networks in cities like Lagos, Kano, and Port Harcourt are vital for economic development, the infrastructure supporting them sometimes remains insufficient, which results in congestion, road vehicular traffic conflicts, and inefficiencies.

Though it presents many difficulties, Nigerian road infrastructure is absolutely vital for the country's GDP. Roads, bridges, and highways, among other aspects of transportation infrastructure, build the basis of social and economic growth. By allowing seamless transit and thereby lowering travel time, well-maintained road networks greatly support regional integration, urban growth, and economic development (Takyi, Kofi, & Anin, 2013).

A major problem with broad consequences for road safety in Nigeria and transportation efficiency is road traffic conflict. Traffic conflicts occur when the actions of road users whether drivers, cyclists, or pedestrians intersect in a way that could result in a collision if no changes are made to their movements (Adegboye & Olanrewaju, 2023). These conflicts, which are common in crowded metropolitan contexts, can include merging conflicts, rear-end conflicts, crossing conflicts, and lane-change conflicts.

According to the World Health Organization (2022), traffic accidents, which mostly affect low- and middle-income nations like Nigeria and Ghana, are among the top causes of death worldwide; road traffic conflicts are thus a major factor causing traffic accidents.

According to Ghazali *et al*. (2021), the degree of congestion and the effectiveness of traffic management strategies, such as traffic lights, signage, and road markings, primarily influence urban road traffic conflicts. Many Nigerian cities have had regular accidents, traffic congestion, and a high frequency of road user deaths from inadequate road traffic system management.

2. Literature Review

Sheykhfard *et al*. (2023) conducted a traffic conflict analysis that included right-turning vehicles at unsignalised junctions in suburban settings. An instrumental vehicle study gathered driving behaviour data to offer a comprehensive analysis of the elements controlling the safety of right-turn manoeuvres. The researchers used this data to identify the parameters influencing the risk of vehicle-vehicle (V-V) and vehicle-pedestrian (V-P) conflicts during right-turn stage movements at six suburban crossroads in Babol, Iran. The data analysis revealed a total of 1,456 VV and VP disputes. Linking vehicle speed, the distance between road users, and driver and pedestrian delays, the logistic regression model identified higher danger in vehicle-to-vehicle or vehicle-to-pedestrian confrontations. Researchers developed a linear regression model to forecast, during several phases of the right turn, including the commencement, along with completion of the movement, the safe right-turn speeds drivers should utilise. The results showed that drivers adjusted their behaviour in the same manner against pedestrians as they did toward cars.

Jiawei, Essan, & Hatem (2021) used microsimulation to investigate the analysis of pedestrian-vehicle conflict at signalised junctions. The purpose of the study was to determine whether the Surrogate Safety Assessment Model (SSAM) and the VISSIM simulation model could produce reasonable forecasts for pedestrian-vehicle collisions along signalized intersections. The study covered two types of pedestrian-vehicle conflicts: pedestrian-yielding vehicle and vehicle-yielding pedestrian. They gathered field data using seven signalised junctions and recorded 42 hours. Researchers generated pedestrian-vehicle conflicts using the calibrated and verified VISSIM model, then extracted these conflicts from the vehicle trajectory file using the SSAM program. Using the mean absolute percent error (MAPE), they established the maximum TTC and PET thresholds for pedestrian-vehicle interactions. The study found that setting the maximum TTC threshold to 2.7 and the maximum PET threshold to 8 produced the best goodness-of-fit between generated and actual conflicts. Using a linear regression, they looked at the relationship between the simulated conflicts from the micro-simulation and the real-world conflicts seen on the field. The study turned up a clear statistical association between the simulated and real conflicts. The VISSIM model, the researchers also discovered, understated the count of pedestrian-vehicle incidents. One reasonable theory for this could be the VISSIM simulation's incapacity to create real-world pedestrian-vehicle conflicts involving illegal pedestrian actions, including red-light violations.

Using UAV video data, Lu *et al*. (2023) investigated the lane-change conflict between vehicles and trucks in the merging sector. Analysing conflicts between several vehicle kinds in the portion of the highway merging was the primary aim of the study. An unmanned aerial vehicle (UAV) gathered field data in Shanghai, China's merging zones. The vehicle extraction technique is used to derive the vehicle trajectories. The surrogate safety measure was time-to-collision (TTC). TTC of truck-truck clashes was the highest; TTC of car-car conflicts was the smallest. Traffic issues often arise at the on-ramp and acceleration lane. The data showed a notable variation in the spatial distribution of lane-change conflicts between various vehicle types, suggesting that drivers especially those in cars should keep a reasonable distance. Moreover, traffic management authorities should think about modifying the dotted line to a solid lane at the beginning of the accelerating lane in order to lower lane-change problems in the merging region.

Under diverse and weak lane-discipline traffic, Heral *et al*. (2023) investigated a new traffic conflict-based paradigm for real-time traffic safety evaluation. The work suggested a macroscopic flow-variable real-time traffic safety evaluation system. They used extended vehicle trajectories under open access. They produced macroscopic traffic flow characteristics and rear-end traffic conflicts from the trajectory data and then incorporated them for a real-time safety evaluation. Since the proportion of stopping distance (PSD) considers all kinds of contacts - both safe and dangerous - in the traffic flow, researchers used it to investigate rear-end traffic conflicts. To assess the rear-end traffic disputes, a macroscopic indicator named "time spent in conflict (TSC)" was developed. They utilized machine learning techniques, particularly random forests (RF). Researchers projected TSCs using macroscopic traffic flow variables using Support Vector Machines (SVM) and Extreme Gradient Boosting (XGB). The results demonstrated a consistent and reasonable relationship between the TSC calculated based on PSD and the macroscopic traffic flow characteristics. The TSC computation based on PSD revealed that safety depends much on the somewhat crowded traffic flow conditions. Complicated traffic phenomena, including traffic hysteresis, traffic oscillations, and additional speed changes, produce these situations. Moreover, the study indicated a consistent link between traffic flow and safety for different threshold values.

Mesenbet *et al*. (2024) conducted a community-based cross-sectional study examining road traffic accidents and the contributing reasons among public transport users in Mizan Aman town, Ethiopia. The study aimed to assess drivers of public transport in Mizan Aman town's frequency of road traffic accidents and their respective contributing factors. Researchers carried out a grassroots longitudinal study among 376 public transport pilots. They selected each study using a simple random selection technique. Semi-structured, open-ended questionnaires provided data on demographic characteristics, risky personal behaviours and lifestyles, driving factors, vehicle condition, and environmental conditions. The interviewer then compiled the information using KoBo Collect tools. Following data modification and cleaning in the Kobo Collect toolkit. Descriptive data were presented using figures, tables, and words. In search of the influential factors, researchers looked at binary logistic regression. The statistics show that public transport drivers in Mizan Aman town had a 17% incidence of road traffic accidents. The study revealed a number of elements influencing traffic accidents on the road: marital status (single), employment status (permanent), monthly income (1001–2500 Ethiopian Birr), alcohol use, car maintenance (none), road type (not asphalt), and weather conditions (being windy).

Using the Traffic Conflict Parameter Technique, Muhammad *et al*. (2022) investigated the traffic performance study on unmarked crossings. The purpose of this study is to examine at an unmarked intersection the degree of service, the kind of conflict, and the traffic complexity. Researchers gathered primary information on the conflict strategy and traffic volume using the field survey approach. With a DS value of 1.06 and LOS F, the research revealed that 3,810 passenger automobiles per hour accounted for the maximum traffic volume. During the peak one-hour observation period, 420 disagreements occurred. In 138 cases, the majority of the confrontations resulted in straight-right turn motions.

Using a broad approach, Lizarazo (2020) examined tracking system failure-caused traffic conflict identification. This effort primarily focused on developing a general case framework for traffic conflict identification. Researchers tested and assessed this framework to show its relevance in developing tracking technologies using area-wide detection systems and in-vehicle sensors. When comparing the observed crashes with the expected number of crashes, they found that the controlled environments from naturalistic driving studies offered a unique opportunity to evaluate the discovered conflicts. Moreover, researchers projected the potential crash intensity depending on a given conflict using statistical methods. This paradigm offers a potential approach to optimize current data sources and assess road safety based on traffic conflicts rather than collisions.

Using a new Baneshwor intersection as a case study, Abhash & Ani (2020) investigated traffic conflict prediction at signalized crossings. The work showed how to use VISSIM and SSAM to project vehicle interactions at the New Baneshwar Intersection. They calculated the projected daily counts of probable lane changes, rear-end crashes, and crossings as 1, 9, and 945, respectively. With R-squared values of 0.8545, 0.7474, 0.88677, and 0.99138 for crossing, lane-changing, rear-end, and overall conflicts, respectively, the simulated and observed conflicts displayed a statistically significant association. They observed that designing traffic signals based on changing traffic volume rather than applying a fixed-time traffic signal can significantly reduce the frequency of crossings, lane changes, and rear-end incidents by a maximum of 88%, 40%, and 39%, respectively.

Ram (2020) looked at significant elements of human behaviour in road traffic accidents. The study sought to pinpoint more general human activities as well as socio-demographic and environmental elements linked to road traffic accident risk. The study revealed a close correlation between a risk of road traffic accidents and elements including young age, male gender, speed, influence of drugs, use of mobile phones, driving experience, temperament, attitude, aggression, stress, anxiety, emotional expression, tiredness, lack of sleep, and road conditions. Professional drivers, such as bus and taxi drivers, are particularly vulnerable to road traffic accidents, despite possessing significant driving instruction and the necessary skills to operate motor vehicles.

Ebiai & Mgbeanuli (2023) examined driving behaviour and workplace stress as indicators of road traffic accidents in Borno State, Nigeria. The study took a cross-sectional survey approach. They gathered information for this study using records and questionnaire distribution. The study involved a total of 87 participants. Based on documents from the police departments, hospitals, Federal Road Safety Commission, and National Union of Road Transport Workers, researchers purposefully sampled accident victims within the state. The analysis revealed that road traffic accidents in Borno State have no appreciable correlation with number of accidents (r =.03, M = 19.3 p.05) or age (r =.03, M = 8.3 p.05). Among Borno State drivers, work stress (r =.24, M = 8.3, $p < 0.05$), and driving behavior (r =.49, M = 8.5, p).

In Jalingo Metropolitan, Taraba State, Nigeria, Muhammad & Shamshudeen (2022) looked at risky behaviour in road traffic accidents among commercial vehicle drivers. The study applied a model of descriptive survey research. The population consisted of two thousand commercial vehicle drivers enrolled with the National Union of Road Transport Workers (NURTW). Researchers examined the null hypotheses under a 0.05 level of significance. The study advised the government and other pertinent organizations, including the Federal Road Safety Corps and Vehicle Inspection Officials (VIO), to plan regular seminars and enlightenment campaigns to inform commercial vehicle drivers about actions that might lead to road accidents. In addition, owners of commercial vehicles should not only select competent drivers but also ensure they refrain from engaging in dangerous activities that could potentially cause traffic accidents.

Ajiboye *et al*. (2020) investigated road traffic conflicts using the main gate T-junction at university of Benin. The study employed a survey approach to identify and classify traffic conflict and volume data at the intersection. The study employed one-way ANOVA to examine traffic volume variations, observing no significant change until the holiday season, when a distinct one emerged. The study's constructed model demonstrates that linear relations, with a coefficient of determination ranging from 0.47 to 0.76, significantly explain the relationship between traffic conflict and traffic volume. The study also revealed that temporal drum placement at the intersection helped to lower cross-merge and merge-merge-activated problems by preventing commercial drivers from cramming at the intersection. The study suggests appropriate countermeasures to improve traffic safety: zebra crossing, effective control over commercial drivers, identifying the minor road, giving signs and signals legible enough for operators, and so on.

Olaifa (2020) investigated the assessment of road network accessibility and traffic indexes using a case study of Ondo State. He performed the road network analysis with the ArcGIS Network Analyst extension. In this study, researchers used a manual traffic count system, reporting counts on the count sheet, doing physical inspections, and counting the cars at the chosen centroids. The analysis revealed that the high road density of the studied area results in a significant degree of connectedness and an outstanding state of the road network.

Chinebuli, Samantha, & Lai (2019) carried out an observational study on dangerous behavior in Nigerian traffic conflicts. The study applied the TCT, or traffic conflict approach. At three separate sites in the eastern part of Nigeria, they compiled information by roadside observation. They used this approach to get over Nigeria's inherent problems with accessible, inadequate, and consistent crash data. Researchers documented 946 traffic conflicts overall, and statistical analysis revealed that the drivers had at least one risky action before the confrontations. Road user type, location, and time of day statistically linked with passenger scouting and other risky activities, while improper indication use (13.3%) and tailgating (11.3%) emerged as the most common risky actions. Tricycle operators were significantly more likely to engage in dangerous behaviour compared to drivers in other vehicles. Drivers on straight roads also have a higher tendency to act in a dangerous way. Moreover, they found a higher frequency of this dangerous behaviour during the busiest traffic times. To help improve traffic safety, experts suggest better regulations and enforcement, Nigerian road infrastructure improvements, and suitable road safety education.

3. Research Methodology

3.1 The Study Area

With a projected population of 4,490,734 million (NPC, 2024), Kano Metropolis, the major urban centre and business hub in Northern Nigeria, ranks second among all the cities in Nigeria after Lagos. Roads connect Kano to most surrounding states and African cities. Roads connect Kano with other communities in the Republic of Chad and Niger, facilitating the movement of large trucks, buses, and other vehicles (Bichi, 2018).

Kano City has a longitudinal coordinate between 8033´19.69 and 8031´59.690 E and an equatorial latitude between 11059´59.57 and 12002´39.570 N. Kano City is located on the north-central border of Nigeria, 1,140 miles from the Atlantic Ocean and 840 kilometres from the Sahara. Comprising eight Local

Government Areas (LGAs), the 499 square kilometre (193 square mile) city spans Dala, Kano Municipal, Fagge, Gwale, Nasarawa, Tarauni, Ungogo, and Kumbotso (Bichi, 2018). From the Kano urban region to the southwest, Madobi and Tofa's LGAs encircle Dawakin Kudu to the southeast, Gezawa to the east, and Minjibir to the north (see figure 1).

Kano, located in the northernmost region of the nation, is the capital of Kano State and a major centre of political, business, and cultural activity. With centuries of rich history, the city is currently well-known for its active economy, busy markets, and large road network linking it to other regions of Nigeria and surrounding nations. Comprising the metropolitan area of Kano, the study area offers a special mix of conventional and modern urban features that affect its road system and traffic flow.

The city's mostly flat top makes it ideal for building highways and other kinds of transportation systems. But Kano's Road system has been under great strain over the years from its rapid urbanization, population increase, and economic growth. With densely populated districts such as Dala, Fagge, Gwale, and the Sabon Gari neighbourhood, the city has developed into a vast metropolis. These districts, marked by small roads, informal settlements, and heavy pedestrian and vehicle traffic, stand in stark contrast to more recent, more ordered projects, like Nasarawa GRA and other affluent neighbourhoods, where road infrastructure is generally more developed.

Kano's strategic location as a commercial centre, especially for textiles and agricultural products has drawn local and foreign traders in great numbers. Particularly as heavy-duty vehicles, commercial buses, and informal transportation systems (such as motorcycles and tricycles) converge in these areas to serve both traders and consumers, the city's vast market network - including Kurmi Market and Sabon Gari Market helps greatly to contribute to traffic congestion. Concentrating intercity and regional traffic, the Kano motor parks, Yankaba, Naibawa, and Kofar Ruwa also form vital nodes in the city's transportation infrastructure. Especially during peak hours and market days, these car parks provide notable traffic inflows and outflows that help explain the traffic complexity of the city.

Though somewhat vast, Kano Metropolis's Road system is quite diverse in quality. Relatively well-developed major arterial routes include Zaria Road, Airport Road, and Katsina Road, which have several lanes and improved traffic control systems. For the metropolis as well as for other areas of northern Nigeria, these highways are vital linkers. However, the interior roads, particularly in the older sections of the city, suffer from poor maintenance, inadequate signage, and a significant amount of traffic congestion. Furthermore, the high population density and business activity have outpaced the development of road infrastructure, leading to frequent traffic congestion and confrontations at intersections, particularly where roads intersect without proper traffic control systems.

Kano's environment affects traffic flow as well. The area has a clear wet and dry season; the rainy season (from June to September) usually results in road degradation, particularly in places lacking drainage systems. Particularly in low-lying parts of the city, flooding during the rainy season can seriously disturb traffic flow. By contrast, the dry season brings more dust and visibility problems that could compromise road safety.

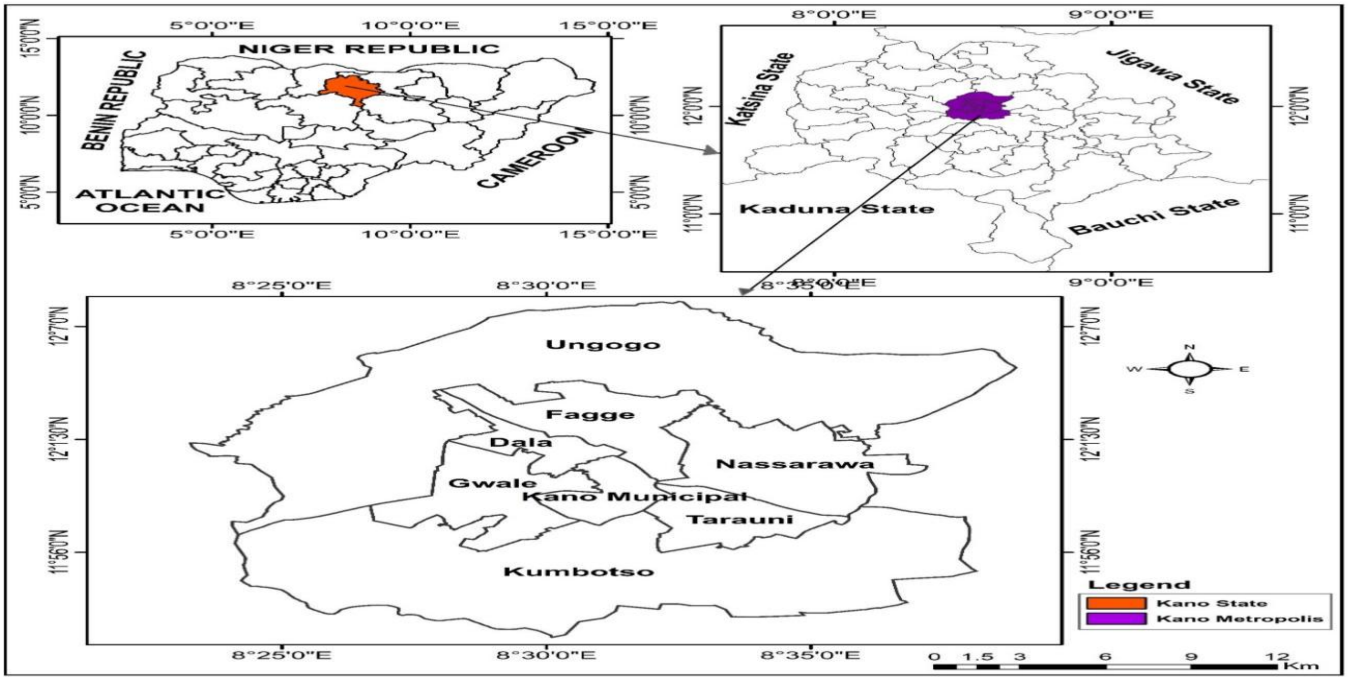

Figure 1: *Kano Metropolis Nigeria*
Source: *Author's Fieldwork, 2023*

4. Results And Discussion

Table 1: Road Transport Infrastructure Characteristics and Traffic Density on Kano Roads

VEHICULAR TRAFFIC CHARACTERISTICS ON MAJOR METROPILITAN ROADS IN KANO						
	ROAD FEATURE		INFLOW		OUTFLOW	
ROAD	Average Travel time(m)	Road Length (m)	AVG. VEH.TRAFFIC	VEH. DENSITY/KM	AVG. VEH.TRAFFIC	VEH. DENSITY/KM
Kurna Babban Layi	10	4365	908	208	863	198
Hospital road	8	2023	302	149	289	143
BATA	9	2180	1210	555	1149	527
France road	13	1942	946	487	898	462
Kabuga road	13	1740	872	501	829	476
Gwarzo road	16	3992	608	152	577	145
Kanar Ungogo	19	4955	365	737	347	70
Zoo Road	6	2380	1092	459	1038	436
Zaria Road	9	3515	981	279	921	262
Ibrahim Road	8	1425	1152	804	1094	768
BUK Road	10	1575	849	539	808	513
Post office Road	33	792	667	842	633	799
Hadejia	32	2990	969	324	921	308
Club Road	39	850	715	841	680	80
Maiduguri Road	29	3435	1071	312	1018	296
Zaria Road	39	3292	1019	310	968	294

Table 2 shows the results of the regression model. With an R-value of 0.769 overall, the model shows a rather acceptable correlation between the chosen infrastructure factors and average travel time along the 16 main roadways in Kano. But the R-squared value of 0.592 showed that these building components accounted for about 59.2% of the variance in average journey time. Notwithstanding this, the modified R-squared is much lower at 0.235, suggesting that, considering the model's number of predictors, the independent variables' explanatory power is 23.5%. This implies that the model ignores 76.5% of the influencing elements.

The constant term (B = 10.500) reflects the baseline travel time on Kano's metropolitan roadways, while all other factors remain constant. The presence of pedestrian bridges as a variable has a significant negative coefficient (B = -27.714, p = 0.037), meaning that their presence often greatly lowers travel time. The negative indicator suggests that pedestrian bridges could potentially alleviate traffic congestion by reducing pedestrian interference with vehicle traffic, thereby enhancing traffic flow and reducing conflicts at road crossings.

Conversely, the impact of traffic signs appears to be quite minimal, with an unstandardized coefficient of B = -2.286 and a p-value of 0.769. This insignificance suggests that road signs, despite their intended use in traffic direction, have no effect on travel times or on vehicle traffic conflicts on the Kano metropolitan road system. Either poor signage placement or a lack of road users' adherence could help explain the result.

The results also indicate a positive correlation (B = 11.643, p = 0.208) between the presence of traffic signals and longer travel times. However, note that this result is a chance occurrence rather than a certainty. The good connection could point to functional problems with this collection of city auxiliary facilities. Structure inside the city. Though the outcome is not statistically significant, the existence of overhead bridges also has a positive coefficient (B = 3.786, p = 0.656). This effect is therefore once more a chance occurrence. The lack of statistical significance for both traffic lights and overhead bridges suggests that both systems, although meant to improve road safety and lower conflicts, may need more research on their likely impact.

The presence of road lay-bys, while not statistically significant at traditional thresholds, exhibits a positive coefficient (B = 16.214) with a p-value of 0.087, suggesting a slight effect on travel time.

Although the p-value (0.296) indicates that their impact on traffic performance is a chance event, not statistically significant, the data also show a notable positive effect of speed breakers (B = 21.929). The high coefficient of the variable indicated that speed breakers, meant to slow down traffic and a main cause of induced conflict, might drastically slow down movement and thereby increase the journey time. Nonetheless, as shown by the non-significant p-value, their uneven distribution throughout important road networks could have a considerable impact over the sampled locations.
Finally, we found that the presence of bus stops and ancillary road infrastructure significantly reduces travel time (B = -30.357, p = 0.051), almost reaching statistical significance. The results showed a significant negative coefficient, suggesting that bus stops on Kano Metropolitan roads exacerbate traffic congestion and delays.

With a p-value of 0.247 and an overall F-value of 1.656, the ANOVA test for the model indicated that it is not statistically significant at the traditional 5% level. This outcome revealed that although individual infrastructure elements like pedestrian bridges and bus stops appear to influence travel time, the collective model does not provide sufficient data to indicate that these varied effects have a statistically significant impact on the average travel time on the 16 main roads of Kano Metropolis. This regression study revealed some significant variations in the way road infrastructure influences traffic performance, which arise from traffic congestion on the principal roadways of Kano Metropolis.

Table 2: Regression Result on Influence of Road Infrastructure on Traffic Performance

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	10.500	8.143		1.290	0.233
	Pedestrian bridge	-27.714	11.097	-0.798	-2.498	0.037
	Road signs	-2.286	7.539	-0.092	-0.303	0.769
	Traffic Light	11.643	8.498	0.470	1.370	0.208
	Overhead bridge	3.786	8.322	0.163	0.455	0.661
	Lay-bye	16.214	8.322	0.700	1.948	0.087
	Speed breaker	21.929	19.616	0.462	1.118	0.296
	Bus stop	-30.357	13.260	-0.874	-2.289	0.051
	Model Summary	R=0.769	R^2=0.592	Adjusted R^2 = 0.235		
	ANOVA	F=1.657	P=0.247			
Dependent Variable: Average Travel time on kano roads Bus stop, Pedestrian bridge, Road signs, Traffic Light, Lay-bye, Overhead bridge, Speed breaker						

Source: *Author's Fieldwork, 2023*

The Pearson correlation results reveal a weak correlation between the average travel time along roads within Kano Metropolis and any ancillary infrastructure. The overhead bridge, for instance, has a moderately negative correlation with travel time (r = -0.489, p = 0.051), suggesting that its presence might be associated with reduced travel time slightly, though this result is on the border of statistical significance. This indicates that overhead bridges could facilitate smoother vehicular traffic flow by reducing points of pedestrian-vehicle interaction, thereby reducing delays.

Interestingly, the presence of pedestrian bridges, traffic lights, speed breakers, bus stops, and roundabouts on selected roads within Kano Metropolis all exhibit weak to negligible correlations with travel time, none of which are statistically significant, except for one notable case. The presence of traffic lights exhibits a weak negative correlation (r = -0.122, p = 0.652), which suggests no substantial impact on travel time. Similarly, pedestrian bridges (r = -0.329, p = 0.213) also demonstrate a weak, non-significant correlation. These results imply that, in the context of Kano's metropolitan roads, pedestrian bridges and traffic lights may not substantially contribute to reducing travel time, perhaps due to their operational inefficiencies or because they are located on less congested roads where their impact is minimal.

Notably, the speed breaker shows a very weak correlation with travel time (r = -0.052, p = 0.848), indicating almost no relationship between their presence and travel time in this study. However, speed breakers demonstrate a significant positive correlation with bus stops (r = 0.681, p = 0.005), suggesting that roads with more speed breakers also tend to have more bus stops. Most often than not, speed breakers are placed near bus stops to reduce the risk of physical conflict between vehicles and enhance road safety, which makes sense for this pattern. There is also a positive correlation between the number of bus stops and roundabouts (r = 0.567, p = 0.027), which suggests that these two types of roadside infrastructure often coexist. This is especially true in areas with a lot of traffic, where both roundabouts and bus stops are necessary to control traffic and make room for public transportation.

On a more significant note, traffic lights and roundabouts show a moderate positive correlation (r = 0.526, p = 0.036), suggesting that roads with more traffic lights also tend to have more roundabouts. Areas with higher traffic density or intersections that require both types of infrastructure to manage vehicle flow may be the source of this correlation. Overall, the results suggest that while certain ancillary infrastructures like overhead bridges may slightly improve travel times, others like pedestrian bridges, traffic lights, and speed breakers do not exhibit a strong impact on average travel time. The findings point to the complex interplay between road design, infrastructure placement, and their functional effectiveness in mitigating traffic conflict and congestion on Kano's roads.

Table 3: Association Between Average Travel Time and Road Ancillary infrastructure

		Av. Travel Time	Pedestrian Bridge	Traffic Light	Overhead Bridge	Speed Breaker	Bus Stop	Round about
Av. Travel Time	Pearson Correlation	1	-0.329	-0.122	-0.489	-0.052	-0.191	0.193
	Sig. (2-tailed)		0.213	0.652	0.054	0.848	0.496	0.475
	N		16	16	16	16	15	16
Pedestrian Bridge	Pearson Correlation		1	-0.246	0.235	-0.113	-0.178	-0.350
	Sig. (2-tailed)			0.359	0.382	0.677	0.525	0.183
	N			16	16	16	15	16
Traffic Light	Pearson Correlation			1	0.124	-0.206	0.021	.526*
	Sig. (2-tailed)				0.648	0.444	0.940	0.036
	N				16	16	15	16
Overhead Bridge	Pearson Correlation				1	-0.305	0.219	0.120
	Sig. (2-tailed)					0.252	0.432	0.658
	N					16	15	16
Speed Breaker	Pearson Correlation					1	.681**	0.207
	Sig. (2-tailed)						0.005	0.442
	N						15	16
Bus Stop	Pearson Correlation						1	.567*
	Sig. (2-tailed)							0.027
	N							15
Roundabout	Pearson Correlation							1
	Sig. (2-tailed)							
	N							16

Source: *Author's Fieldwork, 2023*

5. Conclusion

In conclusion, addressing the challenges of road congestion and traffic conflicts in Kano Metropolis requires a multi-faceted approach that includes enhancing road connectivity, upgrading ancillary infrastructure, and improving traffic management systems. By implementing targeted interventions, such as expanding road networks, modernising traffic lights, and promoting public transport, Kano can improve urban mobility, reduce traffic delays, and foster sustainable development. This study provides a foundation for future research on transport infrastructure in urban centres, emphasising the importance of integrated planning and infrastructure investment to ensure efficient, conflict-free transportation networks.

6. Recommendations

The Kano State government has taken strong steps in the construction and maintenance of road transport infrastructure through direct investment and the creation of a Kano State traffic management agency to ensure the free flow of traffic. However, the metropolis still faces challenges related to vehicular traffic conflict, necessitating further action. Based on the study's findings, the researcher recommends the following measures for effective and efficient management of traffic conflict:

The rapid expansion of Kano Metropolis necessitates closer coordination between urban planning and road infrastructure development. The study recommends that future city planning incorporate transportation frameworks that accommodate growing residential areas and commercial hubs. By integrating new developments with appropriate road networks, we can minimise traffic congestion and vehicular traffic conflicts.

The state must systematically upgrade traffic light systems, particularly at key intersections, to ensure their functionality and efficiency. Introducing smart traffic light systems capable of adjusting to real-time traffic conditions would significantly reduce delays and improve the flow of vehicles. Kano State government should institutionalise regular maintenance and performance evaluations to prevent malfunctions that worsen traffic congestion.

Major arterial roads like France Road experience considerable bottlenecks, especially during peak hours. The study recommends the expansion of these key corridors to ease vehicular congestion. The state should also develop alternative routes or bypasses to distribute traffic more evenly across the city.

The state should revisit the design of bus stops. Constructing well-designed lay-byes and off-road bus stops, particularly on major roads like BATA and Ibrahim Road, can improve the current configuration that frequently leads to traffic obstructions.

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