CO_2 Emission Assessment of Tricycles in Damaturu Metropolis: A Middle Approach Perspective and Strategies for Sustainable Transport

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Abstract

Through a middle approach perspective, this research evaluates the carbon dioxide (CO2) emissions produced by tricycles in Damaturu Metropolis and puts forward recommendations for sustainable transportation. Tricycle traffic volumes were monitored for 7 hours each week on specific roads, identifying peak hours and examining the influence of road length on emissions. The outcomes indicated that Gashua Road, characterised by the longest distance and the highest tricycle count, was the primary contributor to emissions. In contrast, the Maiduguri-Gashua Bypass had the least impact. Despite lower tricycle volumes, the hourly CO_2 emissions peaked between 12-1 PM, underscoring the significant impact of road length. Regression models were established for each road, illustrating a robust positive relationship (R=1) between tricycle volume and CO2 emissions, and accounting for 100% of sample variability (R^2=1). The survey reveals a notable necessity for improved emission control regulations and heightened climate consciousness among tricycle operators in Damaturu, given that many remain uninformed about their contribution to climate change despite the consistent upkeep of their vehicles. The results recommend emphasising road length more than traffic volume in emission reduction strategies. This study offers valuable insights for urban planners and policymakers seeking to enhance environmental sustainability within urban transportation systems.

Keywords: *CO_2 Emissions, Sustainable Transport and Tricycles*

1.0 Introduction

According to Ulrich et al. (2023), the transport industry is among the major emitters of greenhouse gases (GHGs) that have not seen a decline in emissions over the preceding decades. The need for transport will increase, therefore even with worldwide efforts to speed up decarbonisation, this sector's CO_2 emission will rise (Kurisu et al., 2023). According to Yaacob et al. (2020), this industry is the main source of CO_2 emissions that cause global warming.

The increase in extreme weather events and natural disasters is proof that vehicle emissions are detrimental to the environment as stated by Usman et al. (2017). In recent years, global warming has presented a serious threat to human life and advancement (Guo et al., 2022). Human health depends on the evaluation of air quality concerning traffic emissions and the application of suitable control measures (Al-Jeelani, 2013). Road transport is the human activity that contributes most to airborne pollution, according to Usman et al. (2017).

Various methodologies are accessible for the quantification of CO_2 emissions, such as calculation techniques, portable emission measurement, and developed models. The utilization of top-down, middle, and bottom-up models is common for quantification objectives. Nevertheless, discrepancies in the results of CO_2 emission quantification arise due to the integration of diverse factors into these models, specifically demand, supply, and environment (Zavala-Reyes et al., 2019).

Saharidis and Konstantzos (2018) have categorised the models employed in estimating vehicular CO_2 emissions into five groups: average speed models, aggregated emission factor models, multi-linear regression models, traffic situation models and modal models. Nonetheless, each of these methodologies presents specific limitations concerning the variables permissible for inclusion in the models.

Numerous scholars employ models (He et al., 2020), GIS technology (Cong et al., 2018), and IPCC guidelines (Isik et al., 2021) for the quantification of CO_2 emissions. Nevertheless, each of these approaches is not devoid of limitations. According to Li et al. (2022), the existing models and techniques for quantifying CO_2 emissions heavily rely on the well-established data and statistical systems accumulated in developed nations. Consequently, measuring CO_2 emissions in developing countries using these models by international standards remains challenging.

The quantification of CO_2 emissions is complex due to its reliance on various factors, including road characteristics, speed and acceleration, fuel variety, vehicle manufacturer and model, driving circumstances, and weather conditions (Chandrashekar et al., 2022). Despite these obstacles, numerous research studies have indicated that road transportation is a significant source of CO_2 emissions in both developed and developing nations (Assomadi et al., 2019, Karunathilaka et al., 2018). As reported by Adhi (2018), 45% of Jakarta's total CO_2 emissions, totalling 19.61 million tons, originated from the transportation sector in 2015.

While the quantity of vehicular emissions in low-income cities remains insufficiently documented, understanding this information is crucial for comprehending the extent of the problem. Globally and domestically, it is widely acknowledged through various studies that vehicles play a substantial role in CO_2 emissions. Recent research by Li et al. (2022) revealed that the road transport sector in Qingdao, China, alone emitted 8.15 million tons of CO_2 in 2020, with 84.31% of the emissions attributed to private car usage. Similarly, Su et al. (2022) demonstrated that in 2018, vehicles in 36 mainland Chinese cities emitted 1076 Mtc of CO_2, with private cars contributing significantly to the emissions.

In Africa, the current number of operational vehicles stands at a minimum of 72 million, with the rate of motorisation of 95 vehicles per 1000 residents. This surge has led to a 7% annual increase in CO_2 emissions, with a projected doubling rate by 2030. In 2015, Nigeria recorded 35,239 Gg of CO_2 emissions. Seven countries including Egypt, Algeria, Ethiopia, Libya, Morocco, Nigeria, and Ghana contribute to 70% of Africa's CO_2 emissions (Ayetor et al., 2021).

Known by various names such as auto-rickshaws, Napep or tuk-tuks, tricycles are a common form of transportation in many developing nations, especially in Nigeria. These three-wheeled vehicles are popular for the delivery of goods and public transit because of their flexibility, affordability, and ability to manoeuvre in crowded metropolitan areas (Bamidele, 2016). But given how common tricycles are, there are worries about how they may affect the environment, especially in terms of CO_2 emission. Though they produce less carbon dioxide, petrol-powered tricycles in Nigeria release more hydrocarbons and carbon monoxide than motorcycles and vehicles (Odunlami and Alaba, 2021).

Although there have been various global and Nigerian research studies concentrating on sustainable transportation systems, only a few have endeavoured to measure CO_2 emissions produced by tricycle in low-income urban areas and assess their impacts on public health and the ecosystem. There is a noticeable absence of literature specifically addressing this issue in the North-eastern region of Nigeria. Therefore, this study aims to fill this gap by quantifying the CO_2 emissions resulting from the current utilization of tricycles as public transport and proposing sustainable urban mobility solutions, with a specific focus on pedestrianism, cycling, urban planning, and mass transit systems.

2.0 Methodology

This study used a mixed-method approach to research design, combining quantitative and qualitative techniques. Primary and secondary data were used in the investigation. The methodology flow chart is presented in Figure 1.

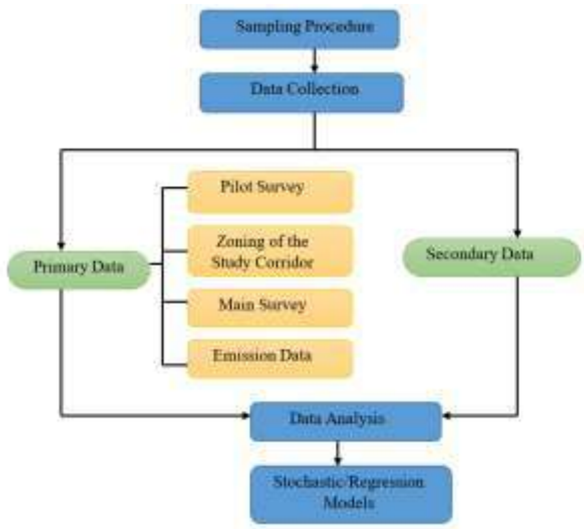

Figure 1: Methodology Flowchart

The investigation was carried out in the urban centre of Damaturu; initially, a preliminary survey was undertaken to assess the current status of tricycle attributes and accessibility. During this phase, the proposed segmentation of the study route was executed. Various bustling thoroughfares within the urban centre, such as the four bypasses and the Maiduguri, Gujba, Potiskum, Gujba, One Million, and Gwange roads, were chosen for examination. These selected routes were divided into four zones, with the city centroid at the town Centre (central roundabout).

Similarly, field investigations were conducted and questionnaires were distributed using a random sampling technique. During seven hours spread across seven days, the tricycle on every one of the selected routes was counted using the manual classified counting technique. The findings were then averaged to show the daily mean traffic volume of tricycles on the designated routes.

The tricycles' distance travelled, fuel efficiency, emission rate per litre of fuel, and expected daily traffic volume were all taken into account when calculating CO_2 emissions using the Middle approach. Assuming that every vehicle seen on a given route had driven the whole length of the road segment, the length of each relevant route was measured.

Two approaches were used to determine the tricycles' fuel efficiency. Most of the fuel usage information per given distance came from driver responses to questionnaires that were sent out. Then, utilising a stratified random sampling procedure, a representative subset of tricycles was chosen. After that, the fuel economy was calculated by dividing the total fuel used by all vehicle categories over a certain distance. Equation 3 was incorporated into the methodology that was described by (Usman et al., 2017)

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Where:

TE = Total CO_2 emission measured in grams per kilometre.

AVA = Average amount of vehicle types per hour.

FCA = Fuel consumption for a vehicle of class A measured in kilometres per litre.

RL = Road length in kilometres.

Ef = Emission factor measured in grams per litre.

The results were then analysed using descriptive statistics and regression models were generated for each of the selected roads to predict future emissions on these roads.

3.0 Results

Table 1 illustrates the tricycle traffic volume on the designated routes during an average weekly counting period lasting 7 hours. Among the total of 34,482 tricycles observed, the highest proportion of 15.63% was noted between 5 to 6 PM. Conversely, the lowest percentage of 10.09% was documented between 7 to 8 AM. Moreover, tricycle traffic distribution indicated that 15.43%, 15.35%, 15.01%, 14.22%, and 14.22% of the tricycles were seen during the time intervals of 12 to 1 PM, 9 to 10 AM, 1 to 2 PM, 8 to 9 AM, and 2 to 3 PM, respectively. These findings suggest that the peak hour for tricycle traffic occurs between 5 to 6 PM.

Table 1: Hourly Tricycle Volume on the Selected Roads

Road Name	Tricycle volume count Vehicle/Hour						
	7-8 am	8-9 am	9-10 am	12-1 pm	1-2 pm	2-3 pm	5-6pm
Maiduguri Road	551	977	704	925	1001	865	923
Potiskum Road	624	790	863	853	913	997	1185
Gasua Road	605	992	1196	1197	897	854	1064
Gujba Road	545	877	1151	973	875	783	1016
Maiduguri- Gashua Byepass	126	135	189	151	163	194	28
Gashua Byepass	128	146	167	157	193	167	145
Potiskum-Gujba Byepass Roa	149	165	171	178	211	175	137
Gujba-Maiduguri Byepass Ro	133	173	186	198	209	153	141
One Million Road	311	332	342	352	360	367	378
Gwange Junction	308	330	336	341	357	352	375

Figure 2 demonstrates the total contribution of each thoroughfare to the overall 34,482 tricycles recorded during a 7-hour timeframe. The data shows that Gashua Road boasts the highest share of tricycle traffic at 19.73%, whereas the Maiduguri-Gashua Bypass registers the lowest at 2.86%. The distributions from the remaining paths are as follows: Maiduguri Road (17.24%), Potiskum Road (18.05%), Gujba Road (18.03%), Maiduguri-Gashua Bypass (3.18%), Gashua Bypass (3.43%), Potiskum-Gujba Bypass (7.08%), Gujba-Maiduguri Bypass (6.96%), One Million Road, and Gwange Junction Road. These results suggest that in terms of alleviating the situation, precedence should be accorded to Gashua Road.

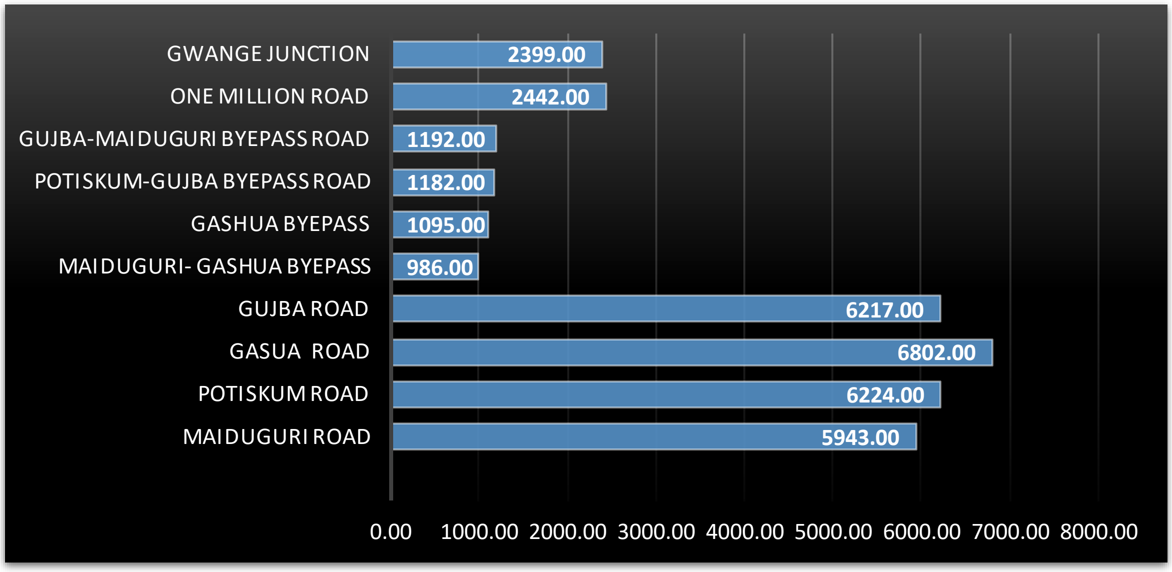

Figure 2: Average Daily7 Hours Cumulative Roads Tricycle Volume

Tables 2 present the computed CO_2 emissions stemming from tricycles traversing the designated routes. The data indicates a noteworthy correlation between road length and the emission of CO_2. Despite the lower presence of tricycles during the time frame of 12-1 PM in comparison to 5-6 PM, a notable 15.46% of the total 10,229.99 kg of CO_2 emissions occurred during this particular hour. This phenomenon can be attributed to the higher tricycle density and the extended distance of Gashua Road.

The allocation of emissions per hour is as follows: 7-8 am (10.24%), 8-9 am (14.26%), 9-10 am (15.43%), 12-1 pm (15.46%), 1-2 pm (15.3%), 2-3 pm (14.44%), and 5-6 pm (14.87%).

Table 2: Hourly CO2 emission in kg/h

Road Name	Tricycle Houly CO_2 Emission in KG						
	7-8 am	8-9 am	9-10 am	12-1 pm	1 to 2 pm	2-3 pm	5-6 pm
Maiduguri Road	155.8	276.4	199.1	261.7	283.8	245.2	261.1
Potiskum Road	170.9	216.3	235.7	233.0	249.4	272.9	323.7
Gasua Road	176.9	290.3	350.1	350.4	263.1	249.9	312.0
Gujba Road	122.6	196.7	258.3	218.3	196.7	175.6	228.0
Maiduguri- Gashua Byepass	83.0	91.6	124.8	99.6	107.6	129.5	18.6
Gashua Byepass	80.6	92.0	103.5	99.0	121.9	106.6	91.4
Potiskum-Gujba Byepass Roa	49.5	54.4	56.4	59.4	69.7	57.8	45.2
Gujba-Maiduguri Byepass Ro	77.9	101.9	108.4	114.8	123.0	89.1	83.2
One Million Road	60.9	65.0	66.4	68.9	70.1	71.5	74.0
Gwange Junction	69.4	73.9	75.7	76.6	80.0	78.8	84.4

From Figure 3, out of the cumulative CO_2 emission of 10,229.99 kg (equivalent to 10.23 tonnes) emitted, Gashua Road accounted for 19.48% of the emissions, while Potiskum-Gujba Bypass contributed merely 3.84%. The allocation of discharges from alternate pathways is as such: Maiduguri Road (17.24%), Potiskum Road (16.64%), Gujba Road (19.48%), Maiduguri-Gashua Bypass (6.4%), Gashua Bypass (6.79%), Potiskum-Gujba Bypass (7.08%), Gujba-Maiduguri Bypass (6.83%), One Million Road (4.66%), and Gwange Junction Road (5.27%).

These outcomes signify that in the realm of CO_2 emission reduction through sustainable methodologies, the emphasis should be placed on road length rather than traffic volume, as indicated by the findings of this study.

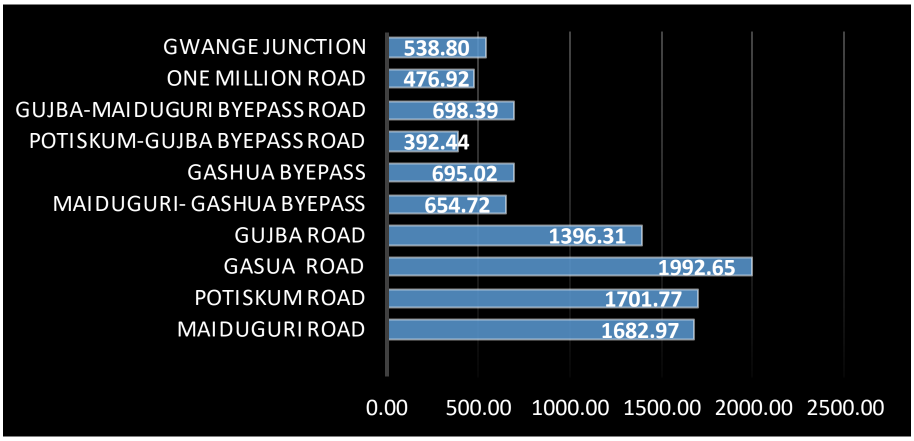

Figure 3: 7 Hours Cumulative CO2 emissions in kg/h

Table 3 illustrates the estimated regression models for CO_2. A unique model was constructed for each specified road to aid authorities in further research and planning related to the estimation of CO2 emissions. The model operates by taking into account the quantity of tricycles observed on each road and generating the resultant CO_2 emissions.

An R-value of 1 denotes a robust positive relationship between the tricycle volume and the corresponding emissions. The R-squared value indicates that the model accounts for 100% of the variation in the sample, showcasing its precision.

Table 3: CO_2 Estimation Models

Road Name	Tricycle CO_2 emission Developed Model	R	R^2
Maiduguri Road	$CO_2\ Emission = 0.0057 + 0.28T$	1.0	1.0
Potiskum Road	$CO_2\ Emission = 0.00 29 + 0.27T$	1.0	1.0
Gasua Road	$CO_2\ Emission = 0.0057 + 0.293V$	1.0	1.0
Gujba Road	$CO_2\ Emission = 0.0029 + 0.23T$	1.0	1.0
Maiduguri- Gashua Byepass	$CO_2\ Emission = 0.00141 + 0.66T$	1.0	1.0
Gashua Byepass	$CO_2\ Emission = 0.0029 + 0.64T$	1.0	1.0
Potiskum-Gujba Byepass Roa	$CO_2\ Emission = 0.0008 + 0.33T$	1.0	1.0
Gujba-Maiduguri Byepass Ro	$CO_2\ Emission = 0.0002 + 0.59T$	1.0	1.0
One Million Road	$CO_2\ Emission = 0.0003 + 0.2T$	1.0	1.0
Gwange Junction	$CO_2\ Emission = -0.0015 + 0.23T$	1.0	1.0

A total of 312 surveys were distributed, resulting in a 70% response rate. The participants were divided into categories such as public servants (37%), students (30%), and entrepreneurs (33%). The age distribution was segmented into the following groups: 18-22 years (17%), 23-28 years (33%), 30-45 years (33%), and over 45 years (17%). In terms of ownership of tricycles, 40% of the respondents possessed one, while 60% did not.

The age of a tricycle has an influence on its fuel efficiency. As reported by the participants, tricycle age distribution in Damaturu city was as follows: 1-2 years (54%), 3-4 years (33%), and 5 years or older (13%). Furthermore, the study disclosed that 50% of tricycles consumed 5-6 liters of fuel daily, 33% consumed 7-8 liters, and 17% consumed 8-9 liters per day. This information showcases the daily petrol consumption and consequent CO_2 emissions by these vehicles.

The upkeep practices are essential in regulating the emissions of these vehicles in the long term. The findings from the survey displayed that 97% of tricycle owners maintained their vehicles regularly, while 7% did not. Nevertheless, a troubling discovery was that 47% of respondents were unconcerned about the impact of tricycle emissions on global warming, compared to 53% who expressed worry. This underlines a lack of awareness regarding climate change.

In response to inquiries about the influence of tricycle emissions on climate change, 53% of respondents agreed that they do have an impact, 33% disagreed, and 14% were uncertain. Concerning emission control strategies, 53% of participants mentioned the absence of such policies or mechanisms, while 27% believed they were in place, and 20% were unsure.

Moreover, 60% of respondents indicated a readiness to adhere to any newly implemented emission control strategies, while 27% displayed no interest. Additionally, 67% of participants were willing to transition to a more sustainable mode of transportation if one were introduced, in contrast to 33% who were not.

4.0 Conclusions

Based on this research outcome it could be concluded that

a) The research revealed a significant association between road length and CO_2 emissions, particularly emphasizing the substantial contribution of elongated routes such as Gashua Road to the overall emission levels.

b) The emissions of CO_2 peaked during the hours of 12-1 PM, despite the relatively lower presence of tricycles, suggesting that emission levels are influenced by variables beyond mere vehicle counts.

c) Through regression analysis, a robust positive relationship (R=1) was established between tricycle volume and CO_2 emissions, showcasing the models' adeptness in capturing the entirety of sample variations (R^2=1).

d) To effectively reduce CO_2 emissions, it is imperative to prioritize road length over traffic volume. The implementation of sustainable transportation solutions, such as fuel-efficient tricycles and optimized traffic management, is strongly advised.

e) The survey reveals a notable necessity for improved emission control regulations and heightened climate consciousness among tricycle operators in Damaturu, given that a considerable number remain uninformed about their contribution to climate change despite the consistent upkeep of their vehicles.

f) The possibility for embracing sustainable transportation appears robust, as most participants show readiness to make the transition; however, the current policies are inadequate or inadequately disseminated, emphasizing the requirement for strengthened regulatory structures and increased public engagement.

The following are recommended:

a. Backing the promotion of fuel-efficient or electric tricycles is advised to lower CO_2 emissions. The acceleration of this transition can be facilitated through the implementation of subsidies or incentives aimed at encouraging drivers to switch to more environmentally friendly options.

b. The adoption of traffic management techniques, such as the synchronisation of traffic lights and the establishment of exclusive tricycle lanes, is proposed to alleviate congestion and reduce idle time, consequently leading to a decrease in emissions.

c. It is advised to prioritize mitigation endeavours on roads characterised by substantial emissions, such as Gashua Road. These efforts may encompass the enhancement of road infrastructure, the promotion of alternative routes, and the elevation of public awareness regarding the environmental repercussions of tricycles operating on these particular roads.

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