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ASSESSMENT OF CO_2 EMISSION DUE TO SPEED BUMPS ON SELECTED HIGHWAYS IN BAUCHI STATE

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ABSTRACT

One industry that will emit carbon dioxide (CO_2) that is dependent on the production of fossil fuels is transportation. Even though cars emit carbon dioxide (CO_2), which contributes to air pollution, fossil fuel-powered vehicles nevertheless require widespread use. Traffic-calming devices act as tools to reduce the rapidity of automobiles. They make a major contribution to road protection; however, air contamination is more likely to arise due to the fact that motor vehicles use brakes and accelerate more regularly. This study examines the impact of speed bumps brought on by elevated carbon dioxide (CO_2) levels on selected commercial vehicles, including Vectra, Volkswagon, Peugeot, Ford Galaxy, and Toyota Hiace buses, traveling on highways from Bauchi to Jos, Bauchi to Azare, Bauchi to Gombe, and Bauchi to Kano. To estimate the CO_2 emissions of each kind of specified commercial vehicle, the fuel consumption of the vehicles before and after the installation of bumps was gathered using a questionnaire model and examined using a mathematical model using a macro-scale approach. The result shows that there is an increase of 21% in CO_2 emissions on the Bauchi to Jos Highway, 15% in CO_2 emissions on Bauchi to Azare, 24% in CO_2 emissions on Bauchi to Gombe, and 40% in CO_2 emissions on Bauchi to Kano. The study concludes that transport-related pollution on Bauchi Highway has indeed significantly increased with the installation of calming traffic devices, which is dangerous to human health and vegetation near these highways.

Keywords: Fossil fuel, Carbon dioxide (CO_2), Emissions, Traffic-calming, Vehicles, Highways

INTRODUCTION

Many changes have occurred on our world recently, starting with the way the earth is arranged or the creatures that live there. The biosphere is another place where human involvement is evident. The environment that humans live in has changed. That is not as natural as usual because it includes a greater variety of pollutants that are common in today's planet in addition to the temperature that is continually changing due to numerous inspirations. There are many sectors that cause global carbon dioxide (CO_2) emissions, including residential, commercial, and public services; electricity and heat production sectors; other energy industries' use; manufacturing and construction industries; and also the transportation sector (Yunita & Atika, 2019). Vehicle-related pollution continues to pose a risk to environmental health issues, which should logically rise as the number of motor vehicles increases. According to (Ikechukwu and Timi,2019), evaluated the diurnal and spatial variation of CO_2 emissions from road transportation in a large tropical city and established that the ambient level of CO_2, a primary greenhouse gas, is approximately five times higher than the internationally accepted safe limit of 350ppm in Benin City.

Also, (Enemari, 2001 & National Bureau of Statistics, 2009), In a study of vehicular pollution in Benin City, it was shown that in May and June 2008, about 22 deaths from CO poisoning were reported in Nigeria. The study also showed that at all the sampling stations and at different times of the day, Nigeria Federal Ministry of Environment Statutory limit for CO which is 10.0 ppm (11.4mgm-3) was violated. Carbon monoxide - alongside other vehicular emission constituent gases like ammonia (NH3), sulfur dioxide (SO2), nitrogen dioxide (NO_2), carbon dioxide (CO_2), hydrogen sulfide (H_2S), and chlorine gas (Cl_2) – are considered very inimical to the health of man and other living creatures especially when in concentrations above their safe limits. As a result of emerging nations like Nigeria gradually seeing a rise in their car population.

And according to the International Energy Agency (IEA), (2022), global CO2 emissions increased from 20.5 billion tonnes to 31.5 billion tonnes during the years 1991 to 2020. The amount of CO2 emitted globally was estimated to be 33 billion tonnes in 2021, and the power industry remains the largest contributor to these emissions by sector. The transportation and industrial sectors also contribute significant amounts. The transportation sector represents 28.9% of the total final energy consumption across the world and 21.9% (7.245 Gt CO2) of the global CO_2 emissions. In a study (Hanse, 2008) had proposed, using paleoclimate evidence, that global atmospheric CO_2 concentration will need to be reduced from this current level to at most 350 ppm. This has become the internationally accepted target that may be required to stabilize global average temperatures within a likely range of 0.6–1.4°C above pre-industrial values and preserve the state on which civilization developed and to which life on Earth is adapted. (Julio César Pérez-Sansalvador, 2020) findings reveal that for roads with a low number of vehicles, speed humps highly increase CO_2, NOx and PM emissions. Moreover, their overuse has a dramatic impact on the generation of those pollutants. Urban planners and traffic managers can use our results to evaluate the feasibility of speed humps deployment (quantity) since the determined pollution effect has considered both velocity bounds and fluctuations, involved in acceleration and deceleration dynamics.

Recent research has demonstrated that transportation plays a significant role in the production of carbon dioxide (CO2), the primary greenhouse gas, whose concentration rises have been linked to global warming. According to Environment Canada (2010), transportation was responsible for 27% of the total GHG emissions in 2007, and 69% of this was accounted for by road transportation. Furthermore, compared with the 1990, emissions level in 2007 had gone up to 35% for private vehicles, almost doubling the growth rate of Canada's population during the same period. More so, according to (Okhimamhe & Okelola, 2013), The results established that the emission levels in these three cities (Suleja, Minna and Abida) was approximately eight times more than the internationally accepted safe limits of 350ppm for atmospheric CO2, but less than the Occupational Safety and Health Administration (OSHA) permissible exposure limits of 5,000ppm which has adverse health effects, and may contribute to climate change, in the long term, if unmitigated. According to Federal Republic of Nigeria (2006), throughout the two and a half decades (1980–2005), CO2 emissions in Nigeria rose by almost 54% (from 68.5 million metric tons to 105.2 million metric tons), with a consistent increase observed since 1997. They attributed this constant increase to the consumption of fossil fuel in the transport sector, notably because of the importation of old and fairly used vehicles ('tokunbo') and the increasing use of motorbikes ('okada') for public transportation. In this study, different between the speed bump road and non-speed bump road in terms of carbon dioxide emission was investigated. On average, the levels of increase in CO2 emissions calculated at the highways in Bauchi to Jos, Bauchi to Azare, Bauchi to Gombe, and Bauchi to Kano were 0.24 tons, 0.17 tons, 0.27 tons, and 0.45 tons, respectively. The results established that the emission levels in these four highways was approximately more than the internationally accepted safe limits of 0.000318ton for atmospheric CO_2, and Occupational Safety and Health Administration (OSHA) permissible exposure limits of 0.000455ton which has adverse health effects, and may contribute to climate change, in the long term, if unrelieved. Bauchi state is situated at 10.31° North latitude, 10.00° East longitude, and 616 meters beyond sea level. It occupies an overall land area of 49119 km2 (18965 sq mi), representing about 5.3% of Nigeria's total land mass. What is now known as Bauchi was, until 1976, a province in the then-North-Eastern State of Nigeria, bordered by Jigawa to the north, Yobe to the northeast, Gombe to the east, Taraba and Plateau to the south, Kaduna to the west and Kano to the northwest. According to the 2006 census, the state has a population of 4,676,465. It's estimated population as of 2016 is 6,537314, and as a major agriculture-based state, the Bauchi state economy partially relies on livestock and crops, such as cotton, groundnuts, millets, tomatoes, and yams, with an innovative irrigation system increasing agricultural production since statehood and transportation business ((The World Gazetteer TWG, 2007).

MATERIALS AND METHODS

The commercial drivers (employees of the National Road Transport Workers Union of Bauchi chapter) who drove on the designated routes completed questionnaires that provided the data utilized in this study. In order to compute the amount of carbon dioxide (CO_2) released on the sample routes both before and after speed bump installation, the method of data collection was utilized to get an accurate fuel consumption of each sample vehicle. The selected commercial vehicles and Bauchi highways with their distance are (vetra, sharon, Ford galaxy, Peugeot and lite hiace bus) and (Bauchi to Jos with a distance of 120 km, Bauchi to Azare with a distance of 190 km, Bauchi to Gombe with a distance of 160 km, and Bauchi to Kano with a distance of 350 km) respectively. To determine the carbon dioxide (CO_2) emissions produced by each vehicle, a mathematical model with a micro-scale approach was applied. In the model, the average consumption of all of the vehicles has been taken into account. It was also needed to have the average run in kilometers to calculate the total fuel consumption (liter) and the total CO_2 emission (EM). Other required data, such as Specific Gravity of the fuel (SG_F), Calorific Power of the fuel (CP_F), and Emission Factor of the fuel (EF_F), is also needed to calculate the amount of CO_2 emissions in the atmosphere. Briefly, the model is specified as follows (Aliakbar Kakouei, Ali Vatani, and Ahmed Kamal Bin Idris, 2012).

$$F_C = A_C \times V \times R_D \quad (1)$$

Where

F_C = fuel consumption (diesel or petrol) (L)

A_C = Average fuel consumption by each type of vehicle per kilometer (L/km)

V = Number of each type of vehicle

RD = Amount of running per day by the vehicle (km)

$$EM(CO_2) = F_C \times SG_F \times CP_F \times EF_F \quad (2)$$

Where:

SG_F = Specific gravity of the used fuel (kg/m3) = 737 kg/m^3.

CP_F = Calorific power of the fuel (kcal/kg) = 11464 kcal/kg = 4.7 x 10^{-5}TJ/kg

EF_F = Emission factor of the fuel (tco2/TJ) = 69.3 tCO_2/TJ.

Speed humps and speed cushions

A speed hump is a raised portion of a road that creates a vertical motion for vehicles and discomfort that leads the driver to slow down. Its length is greater than the wheelbase2 of vehicles and the slope is gradual. These characteristics distinguish it from the speed bump which is more aggressive and not recommended for public roads. The centre portion of a speed hump can be rounded or flat. Speed humps are one of the most effective and most widely used traffic calming measures in Québec. Many have also been implemented in North America and in Europe in the last decades. They have been in place long enough to establish a fairly precise definition of the conditions in which these measures can reduce speed while minimizing potential disadvantages. Distinctive features specific to Québec were also identified in a survey conducted with approximately 50 municipalities in fall 2009 as well as several follow-up consultations.

Traffic-Calming and Emissions

In general, motorists speed up when a traffic signal turns green, when they pass a bump, or when there is room in front of them on the highway. Drivers, on the other hand, slow down to prevent crashes with other cars, to stop at traffic signals, to adhere to speed limits, to navigate speed bumps, and to cross pedestrian paths. Unfortunately, these changes in speeds due to acceleration and deceleration are the main sources of vehicles emissions [(Baltr˙enas et al., 2017), (Januševicˇius et al., 2019), (Ghafghazi et al., 2015)]. Also, in congested traffic, higher emissions are produced at low speeds [(Zhang et al., 2011), (Zhang et al., 2013), Pan et al., 2018)].

Carbon *dioxide*

After petroleum-based fuels (such as gasoline, diesel, natural gas, etc.) are used, the main exhaust byproducts that engines release are CO_2 and water vapour. By mass, CO_2 makes up more than 99% of all the gaseous exhaust components (CO_2, CO, HC, NOx, etc.). A significant portion of the carbon monoxide (CO) and hydrocarbons (HC) are oxidized to CO_2 and H_2O by catalytic and other exhaust systems. Because of this, CO_2 is thought to be the main type of pollution released by internal combustion engines.

RESULTS AND DISCUSSION

Table 1: Showing the carbon dioxide emissions on the Bauchi to Jos Highway

Vehicle types	quantity of automobiles daily	Road distance (km)	A_C (l/km) before bumps	A_C (l/km) after bumps	F_C before bumps(m^3)	F_C after bumps(m^3)	EM CO_2 before bumps (tons)	EM CO_2 after bumps (tons)	Increase in EM CO_2 per day (tons)	EM CO_2 per month (tons)	EM CO_2 per year (tons)
Vectra	10	120	0.125	0.166	0.150	0.199	0.3600	0.4776	0.1176	3.5280	42.9240
Volkswagen	5	120	0.250	0.291	0.150	0.174	0.3600	0.4176	0.0576	1.7280	21.0240
Peugeot	4	120	0.250	0.291	0.120	0.139	0.2880	0.3336	0.0456	1.3680	16.6440
Ford galaxy	4	120	0.266	0.300	0.127	0.144	0.3048	0.3456	0.0408	1.2240	16.6440
Toyota Hiace Bus	2	120	0.291	0.333	0.069	0.079	0.1656	0.1896	0.0240	0.7200	8.7600

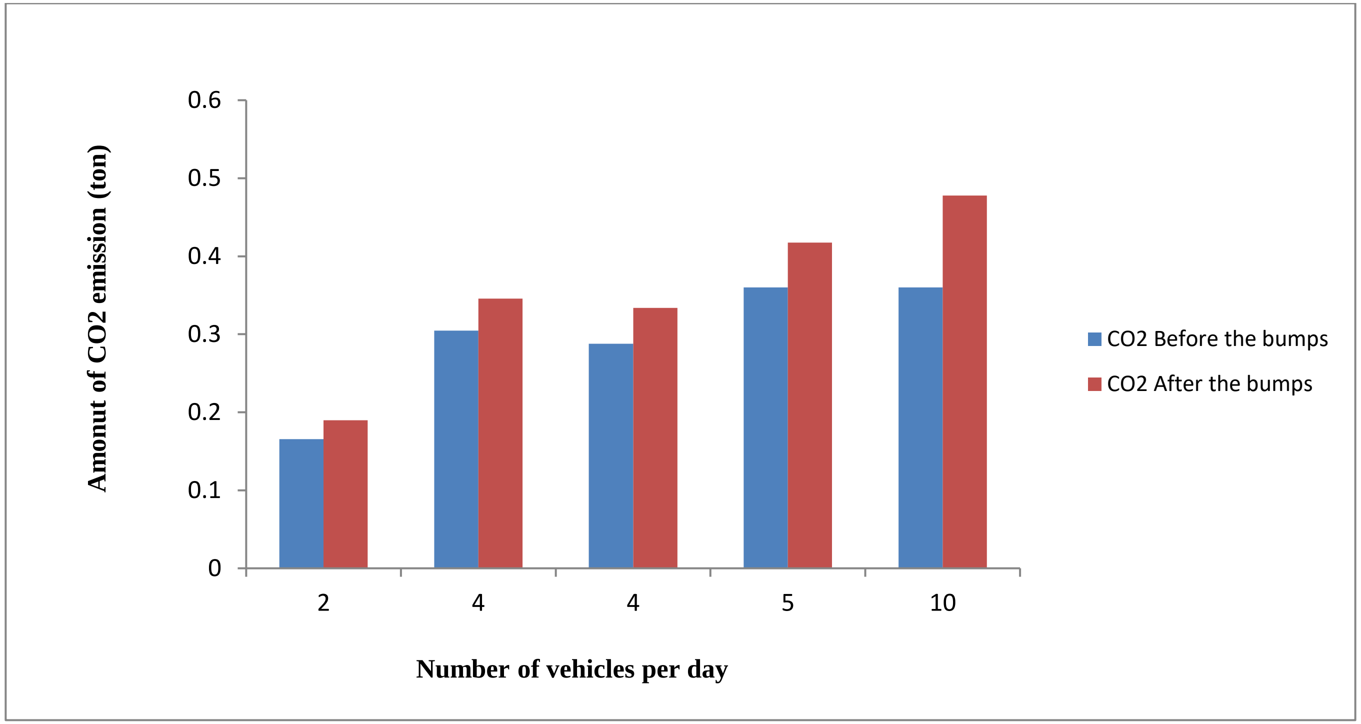

Figure 1: comparison of CO_2 emitted before and after installation of speed on the Bauchi-Jos highway

Table 2: Showing the carbon dioxide emissions on the Bauchi to Azare Highway

Vehicle types	quantity of automobiles daily	Road distance (km)	Ac (l/km) before bumps	Ac (l/km) after bumps	Fc before bumps(m^3)	Fc after bumps(m^3)	EM CO_2 before bumps (tons)	EM CO_2 after bumps (tons)	Increase in EMCO_2 per day (tons)	EM CO_2 per month (tons)	EM CO_2 per year (tons)
Vectra	7	190	0.131	0.157	0.174	0.208	0.4176	0.4993	0.0817	2.4510	29.8205
Volkswagen	3	190	0.289	0.315	0.164	0.179	0.3936	0.4296	0.0360	1.0800	13.1400
Peugeot	1	190	0.289	0.315	0.054	0.059	0.1296	0.1416	0.0120	0.3600	4.3800
Ford galaxy	2	190	0.294	0.326	0.111	0.123	0.2664	0.2952	0.0288	0.8640	10.5120
Toyota Hiace Bus	1	190	0.315	0.342	0.059	0.064	0.1416	0.1536	0.0120	0.3600	4.3800

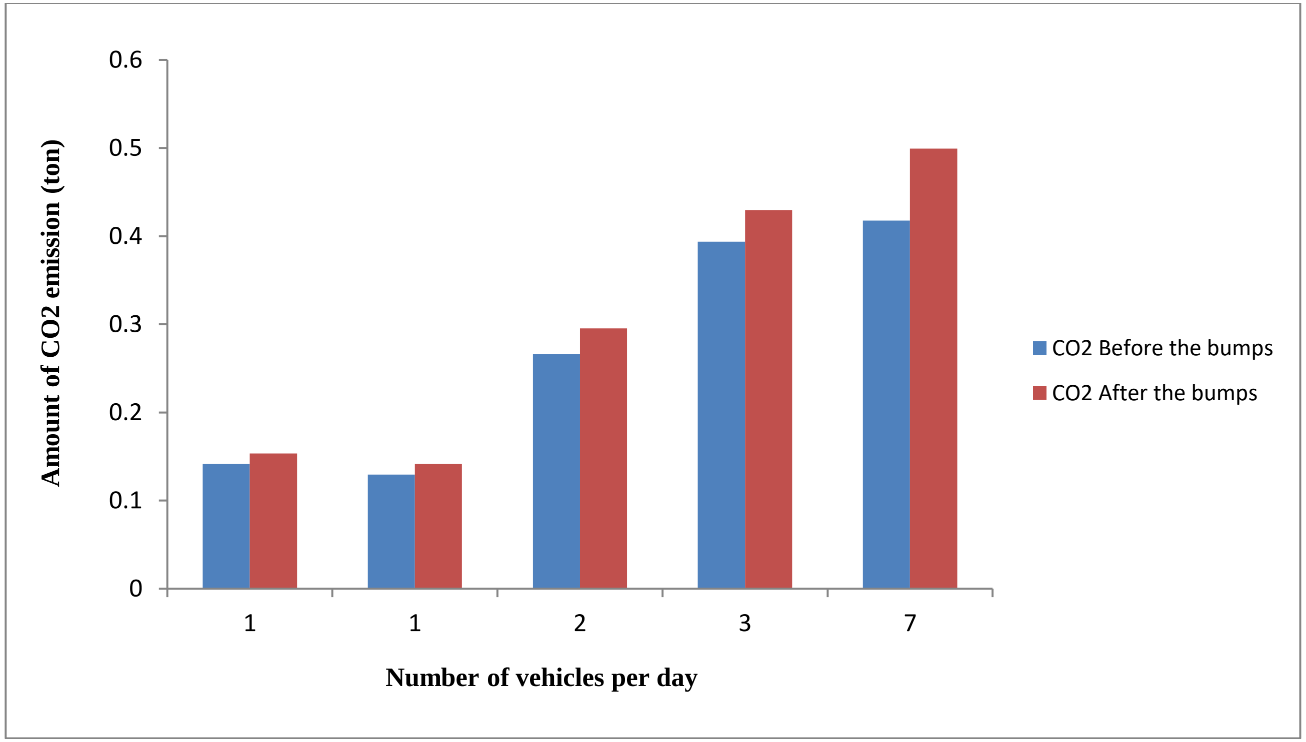

Figure 2: comparison of CO_2 emitted before and after installation of speed on the Bauchi-Azare highway

Table 3: Showing the carbon dioxide emissions on the Bauchi to Gombe Highway

Vehicle type	quantity of automobiles daily	Road distance (km)	A_C before bumps (l/km)	A_C after bumps (l/km)	F_C before bumps (l/km)	F_C after bumps (l/km)	EM CO_2 before bumps (tons)	EM CO_2 after bumps (tons)	Increase in EM CO_2 per day	EM CO_2 per month	EM CO_2 per year
Vectra	10	160	0.093	0.125	0.148	0.200	0.355	0.480	0.124	3.744	45.552
Volk wagen	5	160	0.312	0.343	0.249	0.274	0.597	0.657	0.060	1.800	21.900
Peugeot	4	160	0.337	0.356	0.215	0.227	0.516	0.544	0.028	0.864	10.512
Ford galaxy	3	160	0.343	0.362	0.164	0.173	0.393	0.415	0.021	0.480	7.884
Toyota Hiace bus	3	160	0.281	0.312	0.134	0.149	0.321	0.357	0.036	1.080	13.140

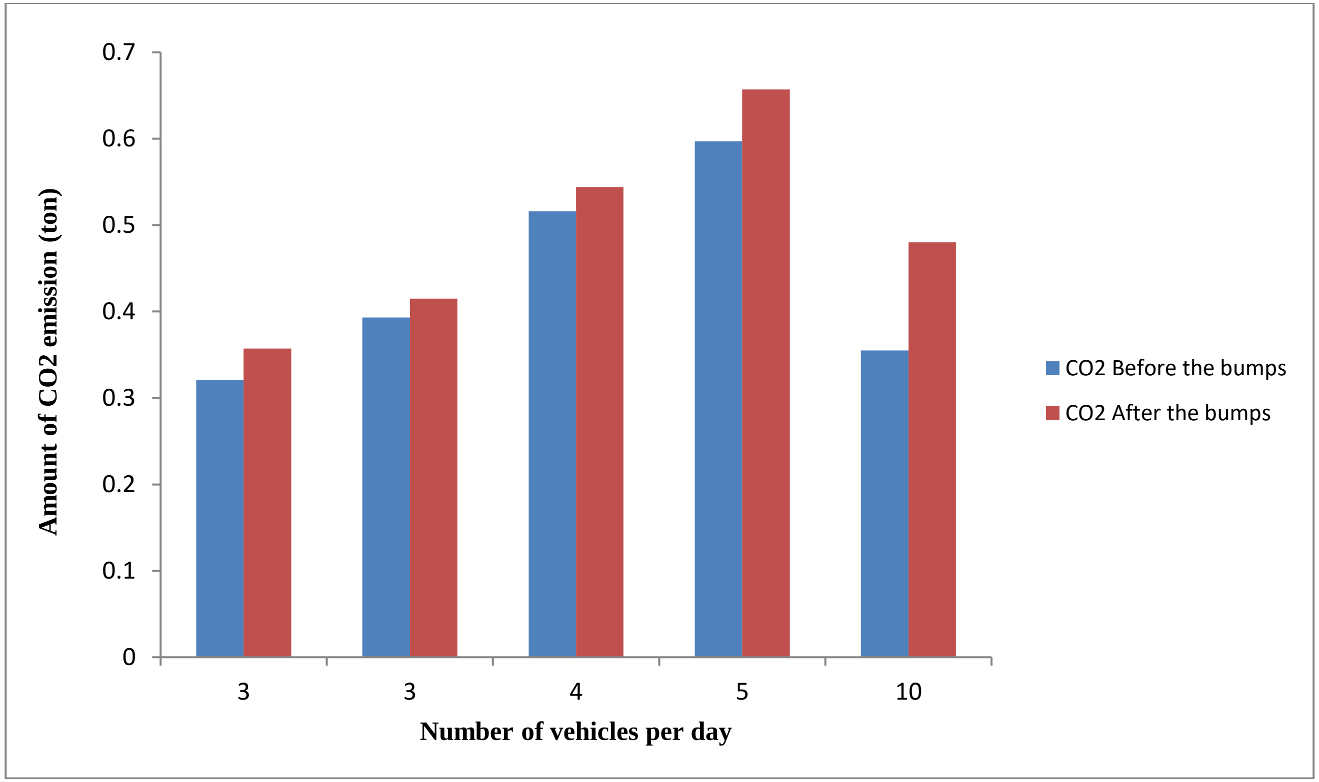

Figure 3: Comparison of CO_2 emitted before and after installation of speed on the Bauchi-Gombe highway

Table 4: Showing the carbon dioxide emissions on the Bauchi to Kano Highway

Vehicle Type	quantity of automobiles daily	Road distance (km)	AC before bumps (l/km)	AC after bumps (l/km)	FC before bumps (l/km)	FC after bumps (l/km)	EM CO_2 before bumps (tons)	EM CO_2 after bumps (tons)	Increase in EM CO_2 per day	EM CO_2 per month	EM CO_2 per year
Vectra	10	350	0.171	0.188	0.598	0.658	1.4354	1.5795	0.1441	4.3230	52.5965
Volk wagen	6	350	0.160	0.182	0.336	0.382	0.8065	0.9169	0.1104	3.3120	40.2960
Peugeot	4	350	0.157	0.188	0.219	0.263	0.5257	0.6313	0.1056	3.1680	38.5440
Ford galaxy	4	350	0.168	0.182	0.235	0.254	0.5641	0.6097	0.0456	1.3680	16.6440
Toyota Hiace bus	3	350	0.342	0.360	0.359	0.378	0.8617	0.9073	0.0456	1.3680	16.6440

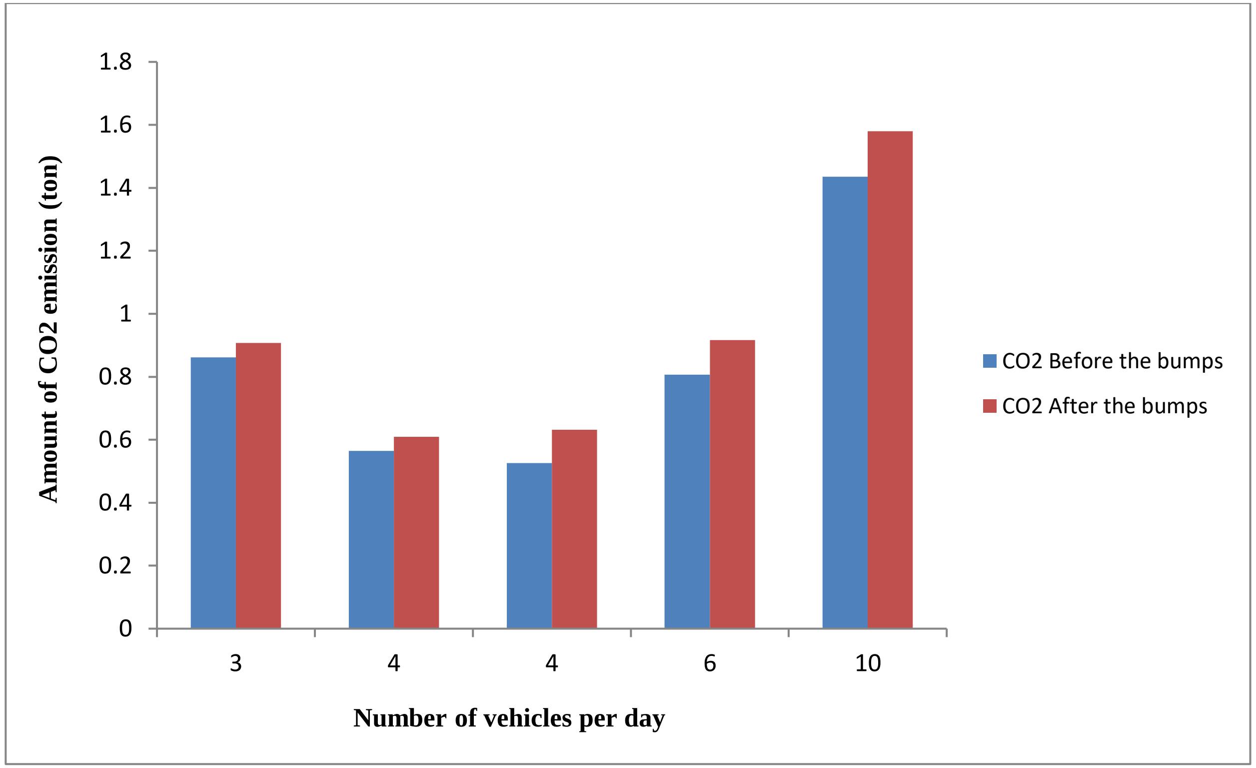

Figure 4: Comparison of CO_2 emitted before and after installation of speed on the Bauchi-Kano highway

Table 5: Showing the increase in CO_2 emission per day on Bauchi Highways

Vehicle Type	Bauchi to Jos (CO_2 tons)	Bauchi to Azare (CO_2 tons)	Bauchi to Gombe (CO_2 tons)	Bauchi to Kano (CO_2 tons)
Vectra	0.1176	0.0817	0.1248	0.1441
Volkagon	0.0576	0.0360	0.0600	0.1104
Peugeot	0.0456	0.0120	0.0288	0.1056
Ford galaxy	0.0408	0.0288	0.0216	0.0456
Lite Hiace Bu	0.0240	0.0120	0.0360	0.0456
TOTAL CO_2	**0.24**	**0.1705**	**0.2712**	**0.4513**

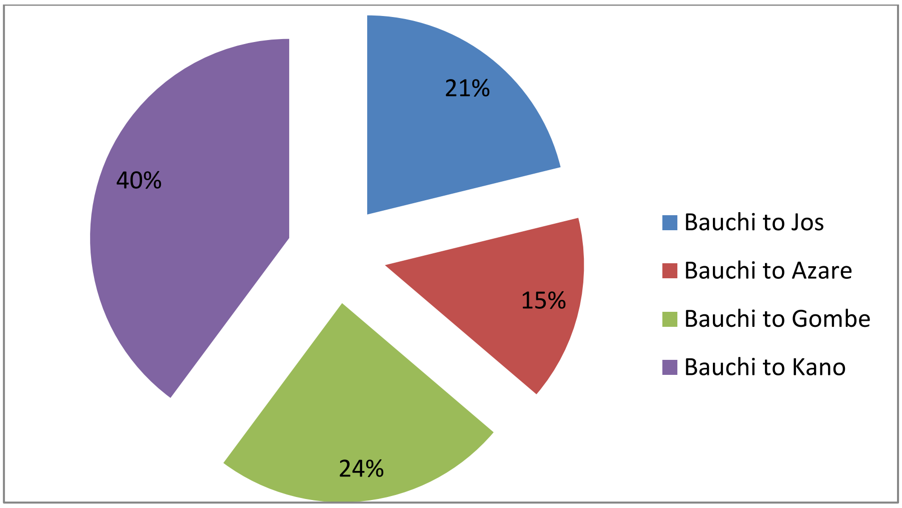

Figure 5: Percentage different of CO2 emission of the highways

Discussion

This methodology for gathering data is unique. The format of the tables includes the kind of vehicle, number of cars driven per day, road distance (km), average fuel consumption (AC), fuel consumption (FC), and computed carbon dioxide emissions (EM CO2 ton). The differences in fuel consumption and the number of cars driven each day on the chosen highways were represented in the table, which also contributed to the variations in carbon dioxide emissions. Since federal highways connect the state capital to Jos, Gombe, and Kano, a large number of cars travel these routes every day. However, Kano Highway holds the greatest ranking due to its constant patronage as a commercialized and industrialized state.

The daily, monthly, and annual variations in CO2 emissions between speed bump roads and non-speed bump roads are displayed in Figure 1-4. With 1.579 tons of carbon dioxide emissions on a speed bump road (Figure 5), Vectra had the highest emissions, compared to 0.1441 tons when there were no bumps.

The CO2 emissions in percentage between the two roadway conditions are compared in Figure 5. According to the Occupational Safety and Health Administration's (OSHA) allowed limit of 0.5%, it was found that the four highways—Buchi to Jos (21%), Bauchi to Azare (15%), Bauchi to Gombe (24%), and Bauchi to Kano (40%)—had significant increases in carbon dioxide emissions. Harmful air pollutant and greenhouse gas emissions are lowest when a vehicle is travelling at steady speed, and emissions are increased when the amount of acceleration and deceleration is increased (Jayne, 2023).

CONCLUSION

In this work, the values of fuel consumption by the selected commercial vehicles on Bauchi highways are correlated with the calculated carbon dioxide emissions that are presented. The results showed that fuel consumption is directly proportional to the carbon dioxide emissions produced; that is, the higher the fuel consumed, the higher the CO2 emissions produced. In addition, the percentage difference in CO2 emissions was compared to the results previously obtained in EURO 1-4, UK. The percentage of carbon dioxide emissions obtained in this study was found to be lower than that of already established and published references that used different techniques (Basil et al., 2005).

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