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A Preliminary Study of Greenhouse Gases Emissions of Lagos Commercial Vehicles: the Intergovernmental Panel on Climate Change Guidelines at Work

*Michael Adetunji AHOVE[1], Chinenye Lilian OKAFOR[2], and Samuel G. ODEWUMI[3]
Lagos State University/Centre for Environmental Studies and Sustainable Development, Ojo Lagos, Nigeria [1, 2]
Lagos State University/School of Transport, Ojo Lagos, Nigeria[3]

[Corresponding Author indicated by an asterisk *]

***Abstract*—Nigeria deployed Intergovernmental Panel on Climate Change (IPCC) top-down approach which generalizes transport emissions, is not detailed to localize solutions based on sectors. This identified gap was filled using IPCC's Bottom-Up approach. Quantitative research design was employed using a descriptive survey to determine fuel consumption, vehicle and drivers characteristics through the use of a 30-item instrument named GHG emission estimation instrument (GHGEEI) to estimate the quantity of GHGs from vehicular emissions of commercial road passenger transport activities within the selected routes in Iyana-ipaja, differentiate emission estimates by vehicle categories (Tricycle referred to as 'Keke', Shuttle,'Danfo'14, 18 and 22-seaters) and determine the relative contribution of each commercial road passenger vehicle type according to its age, fuel type, number of engine plugs, and frequency of service. Quota sampling technique was used to identify the strata and their frequency in the population and then convenience sampling was used to select 15% of the quota population for each stratum. Results from the study showed that 10,259.88kg/CO_2e, of Carbon dioxide (CO_2), 3.65kg/CO_2e of Methane (CH_4), and 0.58kg/CO_2e of Nitrous Oxide (N_2O) was emitted daily on the selected areas.**

***Index Terms*—Climate Change, Greenhouse Gases, IPCC Guidelines, Vehicular Emissions.**

1. Introduction

Our contemporary World has become a fast-growing global vehicle fleet, responsible for about 25% of energy-related global greenhouse gas emissions and propelling the consequences of climate change [United Nations Environment Program, (UNEP) 2020a]. Transportation has become an important part of the modern life without which development cannot occur and remain effective (Rodrigue, 2016). Road transport as opined by Maciulis, Vasiliauskas & Jakubauskas (2009) has greatly contributed to the development of the world and the economies of entire nations depend on easy access to people and goods. The use of transportation system around the World would continue to rise by the day especially as the global population continues to increase, more emissions are expected as several studies indicate vehicular emissions is a cardinal cause of Greenhouse Gases (GHGs), influencing air pollution and human health (Gireesh, Lekhana, Tejaswi, & Chandrakala, 2021). Thus a quick fix may not be at sight as a consequence of increase in global population especially in poor economies with low literacy, poor technological capacities and climate adaptation techniques. Nevertheless the transport system is an important part of human existence and a major driving force to development. As one of the major consumers of petroleum in the world, transportation systems produces emissions/air pollutants which have being a vital contributor to global warming and climate change (Warner, Lamm & Rumble, 2018). In OECD (Organization for Economic Co-operation and Development) countries, road transport accounts for about 50% of the cost of air pollutant emissions [Environmental protection agency, (EPA) 2017]. The authors of the Intergovernmental Panel on Climate Change 2013 assessment report indicated that, transportation emissions are on track to double by 2050. On the current trajectory, GHGs emissions from cars, trains, ships and airplanes may become one of the greatest drivers of human-induced climate change, according to a draft of the forthcoming United Nation (UN) fifth assessment report on mitigation of climate change [Intergovernmental Panel on Climate Change, (IPCC) 2015]. Thus impact of used polluting vehicles is quite obvious now than ever, and may not become significantly tackled within a short period. About 7 Million poor quality Light Duty Vehicles (LDV) flooded Africa between 2015 and 2018, contributing significantly to air pollution and hindering efforts to mitigate GHGs and the effects of climate change (UNEP, 2020a). The United Nations Environment Program (UNEP) reported that this data is set to at least double by 2050 (UNEP, 2020b). If this data becomes a reality by 2050, then we should be expecting a more pathetic case scenario with more GHGs emissions in our African cities especially in Nigeria being the most populous and largest importer in Africa of these vehicles from the three major exporters (EU, USA and Japan) with a total importation of 238,760 Light Duty Vehicles (LDVs) in 2018 (UNEP, 2020b); may have to bear most of the broth that comes with the challenges of GHGs emissions especially in urban cities with higher population density. According to records from the Emission Database for Global Atmospheric Research

(EDGAR) (2017), the total GHG emissions (kt of CO_2 equivalent) in Nigeria were 301,010ktCO_2e as at 2012. Between 1970 and 2012, the total GHG emission was highest in 2005 with a value 374,422ktCO_2e and lowest in 1970 with a value of 74,940 ktCO_2e. This value placed Nigeria at the 35th position on the ranking for total GHGs emissions in 2012 with China, USA, and India taking the first, second and third positions, respectively. In other cities, power plants, factories, and other stationary sources still constitute the greatest threat to air quality and MacCracken (2010) pointed out that the concentration of CO_2 and other GHGs are very key factor to the state of the global climate. However, assuming fossil fuels remain the source of energy for the transport sector, the share of emissions from the transport sector in developing countries is expected to rise in the future because of the growing sizes of motor vehicle fleets and the failure to upgrade to the cleanest fuel-burning technologies (Giwa, Sulaiman & Nwaokocha, 2017).

According to Sim, Oh & Jeong (2015) and Yaacob, Yazid, Abdul-Maulud, & Basri (2020), the need to measure transportation emissions cannot be taken for granted because what cannot be measured cannot be managed and transportation appears to be the fastest growing CO_2 emitter. For the most accurate analysis, the impacts of a vehicle trip can be quantified in a rigorous way by doing on-road measurements using a Portable Emission Monitoring System (PEMS) to collect vehicle dynamics, engine data, and road topography as well as tailpipe gas concentration of pollutants during operation. Such monitoring equipment is used to measure the emission concentrations in ambient air, and then using a pump to sample the ambient air and collect samples of Particulate Matter (PM) or hydrocarbon)HC emissions that can be analyzed in a laboratory. PEMS can also be used in tunnel studies, where this equipment is placed inside the tunnel in order to measure the emissions factors for CO, CO_2, NO_x, and HC (Weeberb, Petros & Henrique, 2015). The impacts of a vehicle trip can also be quantified by On-road remote sensing; here some tools are set up on a roadside to measure the emissions from a single car when it passes. However, because it is not feasible to measure every vehicle technologies performing selected driving cycles, various data sources are often used in different estimations. Using a combination of the two approaches can make it possible to identify worst and best scenarios in relation to uncertainties in estimating vehicle emissions. Quantification of transport-related emissions and their impacts is always the first step in clean transport policy decision-making. World Resource Institute (2019) reported that although monitoring GHG emission is critical at both state and national levels, they are not necessarily very consistent and faces the challenge of data gathering at the Government department of climate change, Sustainable Development Goals (SDGs) and Green growth Agenda.

According to Okafor, Ahove & Odewumi (2021), it was the need for appropriate measurement and quantification of Greenhouse gases by all the countries in the world that the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) in 1988 set up the Intergovernmental panel on Climate change (IPCC). In order for IPCC to achieve one of its set objectives, it provided the 1996 and 2006 guidelines for estimating greenhouse gas emissions from various sectors. These guidelines have also been refined recently in 2019. At the moment, the guideline uses two approaches (top-down and bottom-up) and three tiers (1, 2 and 3) for its estimation. In order to challenge governments of developing nations to take this step, this study applies the IPCC guidelines to estimate GHG from commercial road passenger transport activities in Lagos through a Bottom-up Approach as opposed to the Top-down Approach used by the Department of Climate change (DCC) under the Ministry of Environment in Nigeria (DCC, 2018). The DCC's Top-down Approach generalizes transport emissions and as such cannot be used to localize solutions to State/ Local Government/Route/Vehicle category transport emissions. This top-down approach most times uses a less accurate secondary data from Nigerian National Petroleum Corporation (NNPC) and energy balances as fuel consumption estimates while the Bottom-up Approach that will be employed by this study will be using a more accurate end-user fuel consumption data for its emission estimations and reduction suggestions/recommendations. This appears to be a trail blazer in Nigeria. The following research questions were raised in other to achieve the objectives of this study:

1. What quantity of GHGs (CO_2, CH_4 and N_2O) will be generated in the study area?
2. What quantity of GHGs (CO_2, CH_4 and N_2O) will be generated in each of the selected routes and which vehicle category plying the same route contributes more GHGs?
3. What relationships will exist among the contributions of each commercial road passenger vehicle type and age, fuel type, number of engine plugs, and service frequency?

2. Review of Related Literature

The quest for Industrialization and urbanization in many developing countries has heightened the use of fossil fuel and consequently has led to many air pollution problems due to the amount of greenhouse gases released [UNEP (2020b) and Xu, Liu, Chang, & Huang (2021)]. According to Roman-Cuesta *et al*. (2016) & Agarana, Bishop & Agboola (2017), Africa has the lowest historical GHGs emissions when compared to other continents but its emissions are now growing rapidly driven by an increase in the use of fossils fuels. Vehicular emissions are packaged in a cocktail of pollutants not without significant quantities of nitrogen oxides, sulphur oxides, particles, carbon monoxide and hydrocarbon. These pollutants are responsible for strokes, chronic respiratory diseases, lung cancer, ischemic heart disease, diabetes, and other non-communicable diseases (HEI & IHEM [Health effects institute & the Institute for health metrics and evaluation], 2020). Just like He *et al*. (2005) and Otene, Murray & Enongene (2016) pointed out, transportation is highly dependent on fossil fuels and CO_2 emissions from these fuels have been on a progressive rise and Nigeria is not an exception. With a population of over 158 million persons depending heavily on fossil fuel based transport in Nigeria, it becomes vital to understand the environmental impacts of the present road passenger transport sector as well as how these may change in the future as the sector continues to develop in its role in fostering development [Gujba, Mulugetta & Azapagic (2013); Rodrigue (2016) and Usman (2017)]. According to Okoli, Achebe & Anosike (2017) and Aminu & Asikhia (2019), a vehicle's emission is directly proportional to its fuel consumption. For example, a diesel car emitting 95g CO_2 per kilometer consumes around 3.7litres of fuel per 100km, while a gasoline car consumes around 4litres/100km for the same CO_2 emissions. They also noted that fuel efficiency/economy directly relates the distance travelled with the fuel consumed. The impact of transportation on the environment (air pollution, global warming, climate change and so on) therefore calls for a serious concern [Maciulis *et al*., (2009) and Vyas & Amin (2016)].

Over the years, climate change has been described by various scholars as a variation in the statistical distribution of weather patterns over an extended period (i.e., decades to millions of years) (Akpodiogaga & Odjugo, 2017). Climate change may refer to a change in average weather conditions, or in the time variation of weather around longer-term average conditions (i.e., more or fewer extreme weather events). According to Adeniyi (2017) scientists have long been aware of the planetary impacts of carbon dioxide (CO_2) and other greenhouse gases in the atmosphere. In recent decades however, concern has grown over the issue of global climate change caused by increased accumulations of these gases. In Nigeria, Adeniyi (2017) highlighted some peculiar effects of climate change to be the nearness of the Lagos bar-beach to Ahmadu Bello Way unlike in the 1980s when the beach could only be assessed after a few meters walk. He also pointed out the pronounced reduction in the size of the Lake Chad and the overflow in Rivers Niger and Benue causing significant flooding of farmlands. Climate change has therefore become an existing menace to human race irrespective of place. The 2^0C global temperature target set by the Paris Agreement to address the problem of climate change poses as a significant challenge for most countries especially the developing ones Cheewaphongphan, Chatani & Saigusa (2019). The need to keep inventories of emission sources and sinks also became pertinent as a means of meeting the global target. However, Cheewaphongphan *et a*l. (2019) pointed out that the accuracy and ease of compiling emission inventories is very important. Uncertainty analysis estimation thus became an element of a complete emission inventory because it is conducted to describe the accuracy, precision, and variability of emission estimation. To ensure accuracy from different countries, the Intergovernmental Panel on Climate Change (IPCC) developed the methodologies/guidelines to estimate greenhouse gases from the most important anthropogenic sources of greenhouse gases within the categories of energy, industrial processes and product use, agriculture, forestry and other land use, and waste [Vuuren *et al*., (2009) and IPCC (2019)]. The Nigerian Government is not left out in making efforts towards reducing the menace of climate change especially from road transportation [Atubi, (2015) and Agarana, Bishop & Agboola (2017)].

According to Maduekwe, Akpan, & Isihak (2020), several studies have been carried out over the years to estimate GHG emission in the transport industry. These studies however have used various methods to achieve their objectives. Some have used models while others have used portable emission monitoring devices. Emodi, Emodi, Murthy, & Emodi (2017); Shabbir & Ahmad (2010) and Maduekwe *et al*. (2020) used the Long Range Energy Alternative Planning (LEAP) model to project future energy demand and GHG emissions in various cities while Uhuegbu (2013) and Nkwocha *et al.* (2017) used portable emission monitoring devices to estimate emissions in various cities as well. In applying the IPCC guidelines for GHGs estimation, a typical bottom-up Tier 1 approach estimates emission from the consumer up to the producers while a typical top-down Tier 1 approach focuses on the economy as a whole and estimates from producers down to consumers. According to Weitz, Coburn & Salinas (2008), the potential to reduce greenhouse gas emissions locally can be determined in a bottom-up approach by introducing different GHG emission reduction strategies in the order of their costs (cheapest measure first). There has been a considerable increase in research on the use of portable emission monitoring equipment to profile the emission of a particular area and this appears to need further analysis to enable a researcher isolate the different sources of emission vis-à-vis residential, transportation, industrial and even fugitive emissions. The IPCC model on the other hand is able to go beyond this limitation by estimating emission from road transportation through the activity data (fuel consumption) and the quantity of a particular pollutant in each fuel (emission factor) through an end-user (bottom-up) approach.

All the literature reviewed pointed out the various approach and methodologies seen in previous studies. It gave a justification for the present study to take the following approach and methodology which is a bit different in order for it to achieve its aims and objectives and subsequently make proposed contributions to the problems at hand.

1. Estimations will be made using the Tier 1 Approach and a bottom-up sectoral approach with recommendations towards a Tier 2 approach of estimation by comparing the carbon content of petrol and diesel with the default carbon contents provided by IPCC. The 2018 Nigerian Biennial Update Report 1 submitted to the UNFCCC used ONLY Tier 1 approaches for the 3 GHGs emission estimation and a Top-Down Reference Approach.

2. Estimations will be made using both vehicle sub category and route differentiation while the Biennial Update Report 1 used only vehicle sub category

3. Estimations will be made using real time direct fuel consumption data from surveys which basically translates to actual fuel consumption statistics while Biennial Update Report 1 used fuel data from the Energy Balance which attributes fuel consumption to fuel sales.

This study filled the gap created by the Top-down estimation approach as a basis for climate action. This Bottom-Up approach used in this study employed a more accurate end-user fuel consumption data for its emission estimation thereby creating a data estimation template for further studies. This study provided details on emissions by locality, subsector, transportation mode, and route and vehicle category. The findings from this study are also significant to the business development in manufacturing, maintaining and sales of alternative sources of energy. Finally, the need for a comprehensive and accurate quantification of GHGs by road transport is very essential in Nigeria as a trail blazer, apparently the first in this sector and a base line data gathering mechanism. This study is significant in providing data that will help environmental, climate scientists and policy makers to set feasible emission reduction targets on specific vehicle types at the state and local communities' levels this is an essential step towards climate action plans.

3. Methodology

The study adopted both qualitative and quantitative research designs involving descriptive survey and focus group discussion. The descriptive survey was chosen because it gave the opportunity to determine the average quantity of fuel consumed by each vehicle, the vehicle characteristics and driver characteristics through the use of an instrument. The focus group discussion was chosen because it created the opportunity to elicit some information which may not reside in one person, through collective reasoning (Warner et al., 2018).

***Study Area*:** Alimosho is a Local Government Area (LGA) in the Ikeja Division of Lagos State, Nigeria. It is the largest local government in Lagos state and in Nigeria, with about 5,700,714 inhabitants. It is subdivided into several Local Community Development Areas (LCDA) which include; Alimosho, Agbado/Oke-odo, Ayobo-Ipaja, Igando-Ikotun, Egbe-Idimu and Mosan-Okunola. According to the hierarchy of roads, the two road categories selected for this study in respect to their functions and capacities are the arterial and the collector/distributor roads because they have the highest traffic volume in the study area and also the proposed parameters will be easier to track considering that they are intra-city roads. The three road types were included in this study. First is Primary Arterial which provides access route(s) between LGAs and LCDAs and it carries more traffic load and speed. Then the Secondary collector which forms a key access from the primary arterial roads to the central areas and distributes traffic to other communities and it carries less traffic volume and speed than the primary arterial. Finally, the Tertiary /Local Street which provides access route for door-to-door transport services and other properties.

***Population for the Study*:** The study population comprised of commercial road passenger vehicles that ply selected routes in Alimosho area of Lagos state. Statistics of motor vehicle registration in Lagos state indicates only the number of vehicles for commercial and not the exact location/routes they operate (Lagos Bureau of Statistics, LBS, 2016). The National Union of Road Transport Workers (NURTW) is structured to operate various offices to take charge of the different loading points. Selected locations within Alimosho L.G.A include: Igando for Igando-Ikotun LCDA; Ayobo for Ayobo-ipaja LCDA and Egbeda for Mosan-Okunola LCDA covering the three out of the six LCDAs in Alimosho LGA selected randomly. Iyana-ipaja bus-stop was also purposefully selected as it forms a hub in the LGA with feeder roads from within and outside the LGA.

The vehicle categories selected for the study include: Tricycle (Keke), Mini bus (Shuttle) and Commercial bus (Danfo) (14, 18 and 22-seaters). Three routes were selected; each of them starts and ends within the same local government area (Alimosho). The routes include: 1). Iyana-Ipaja to Igando 2). Iyana-Ipaja to Ikotun 3). Iyana-Ipaja to Ayobo.

***Sample and Sampling Techniques*:** A combination of sampling techniques was employed in this study. First was the quota sampling technique (Tyrer & Heyman, 2016).This is a non-probability equivalent of stratified sampling as the researchers first identified the strata and their frequency within the population. Convenience sampling was further used to select the required number of participants from each stratum. The population was first divided into five sub-groups (quotas) which fully represented the various vehicle categories. They include: Tricycle (Keke), Mini bus (Shuttle) and Commercial bus (Danfo) (14, 18 and 22-seaters), see figures 1, 2 & 3. Convenience sampling was then used to select 15% of the quota population which was obtained from Transport Union Unit Statistics to form each quota sample size. Only vehicles duly registered with the Road Transport Employers Association of Nigeria (RTEAN) or NURTW at some stage during the survey period were selected. Secondly, purposive sampling technique was employed for the focus group discussion as the most appropriate way to engage the audience given that random sampling was inappropriate and not possible within the context of this study (Warner et al., 2018).

Fig 1: Keke

Fig 2: Shuttle

Fig 3: Danfo 14, 18 and 22-seaters

***Instrument Development*:** The instrument used for this study is called the GHG Emission Estimation Instrument (GHGEEI) and was adapted from various instruments like the Modified Manchester Driver Behaviour Questionnaire, the Driving Knowledge Questionnaire and the Driver Demographics Questionnaire (Eichelberger, Stulce, McGraw, Perez & Stowe, 2014). GHGEEI was designed to interview the respondents (drivers) on issues concerning fuel consumption, vehicle characteristics and usage. It is divided into four parts:

- Part A: Background/Driver Information: This section covered items regarding the socio-demographic characteristics of the respondents.
- Part B: Vehicle Characteristics: This section elicited information on the vehicle technology irrespective of usage such as vehicle type, number of engine plugs and type of fuel used amongst other.
- Part C: Vehicle Usage: This section elicited information on how the vehicle was operated on a daily basis.
- Part D: Vehicle Maintenance: This section extracted information on the frequency of service and routine checks done on the vehicle.

A total of thirty items was structured to provide the number of trips each vehicle undertakes in a day, daily fuel consumption data (in liters and by fuel type), routes taken, vehicle age, maintenance schedule, vehicle technology and few other parameters.

Data Collection procedure: The procedure for data collection in this study was done in two major dimensions, first is the primary data and second is the secondary data. Primary data was gathered using the questionnaire which was administered to the drivers of the selected vehicles and route categories. The questionnaire was distributed across the recognized bus stations in the selected areas while vehicles queue awaiting passengers to board. Focus was on drivers that had many vehicles ahead of them on the queue, this created enough time for them to be interviewed. This enables the drivers to patiently respond adequately to the questionnaire. They were expected to respond to the interview based on their present situation. A one-on-one administration to the respondents was employed to ensure that the detailed information was recorded.

Secondary data used are; default emission factors of CO_2, CH_4 and N_2O as provided by the IPCC; Net Calorific Values of CO_2, CH_4 and N_2O provided by (Badmus, Fagbenle, & Oyewola, 2013) as 44.0MJ/KG for gasoline and 42.7MJ/KG for diesel. The total number of commercial road transport operators in the study area was gathered from the National Union of Road Transport Workers (NURTW). Secondary data was gathered from transport agencies in Lagos state; National Union of Road Transport Workers (NURTW) and The National Association of Privately Owned Commercial Vehicles, provided statistics on registered commercial vehicles operating in Ikeja Lagos. The Lagos Metropolitan Area Transport Authority (LAMATA): a state agency in charge of its urban transportation projects and policies provide statistics on the different road networks and their lengths. The study was carried out over 3 weeks during the month of August 2018. All the days of the week was represented except Sunday.

METHOD OF ESTIMATION EMISSION USING IPCC TIER 1 APPROACH

CO_2 FROM ROAD TRANSPORT:

$$\text{Emission} = \text{Summation} \sum [\text{Fuel}_a * \text{EF}_a]. \quad (1)$$

Where: Emission = Emissions of CO_2 (kg).
Fuel_a =Fuel consumption (TJ).
EF_a= emission factor (kg/TJ).
$_a$= type of fuel (e.g. gasoline or diesel)

CH_4 AND N_2O FROM ROAD TRANSPORT:

$$\text{Emission} = \text{Summation} \sum [\text{Fuel}_a, * \text{EF}_a]. \quad (2)$$

Where: Emission = emission in kg.
EF_a= emission factors of CH_4 and N_2O (kg/TJ).
Fuel_a = fuel consumed (TJ) (as represented by fuel used).
$_a$ = fuel type (e.g., diesel, gasoline, natural gas, LPG)

Equation for the Tier 1 method implies the following steps:

- Step 1: Determine the amount of fuel consumed by fuel type for road transportation.
- Step 2: For each fuel type, convert to the original units (litres) to common energy unit (terajoules) for consistency purpose using the Net Calorific Values (NCV).
- Step 3: For each fuel type, multiply the amount of fuel consumed by the appropriate CO_2, CH_4 and N_2O default emission factors.
- Step 4: Emissions of each pollutant are summed across all fuel types.

Emission Factors: This research used the IPCC default emission factor to estimate CO_2 emissions. The CO_2 default emission factor for road transportation for gasoline is 69,300kg/TJ and 74,100kg/TJ for diesel (IPCC, 2019).

Net Calorific Values (NCVs): The NCVs used in this study were obtained from Badmus et al. (2013). They are 44.0MJ/KG for Gasoline and 42.7MJ/KG for Diesel.

Data Analysis

Analysis of collected data was done using IBM-Statistical Package for Social Sciences (SPSS version 24.0). Percentages, Mean and Standard Deviation were the descriptive statistics used. They were used to organize and describe the variables collected (Warner et al., 2018). This was done after the standardized guidelines (IPCC inventory software) have been used to get the GHGs estimates. To determine the relationships that may exist among levels of GHGs emission and other parameters identified in the objectives, a Chi-square test of independence analysis was used. To achieve the first objective of the study which assessed the quantity of GHGs emission from commercial road passenger transport activities within the selected routes and the second objective differentiated emission estimates of vehicle category, the fuel consumption values (in litres) was substituted in the Tier 1 equation using the IPCC inventory software. The third objective focused on the relative contribution of each commercial road passenger vehicle type according to its age, fuel type, the number of engine plugs and frequency of service, a cross tabulation relating the quantity of GHGs emissions and the aforementioned parameters was done using chi-square. A p-value of less than 0.05 indicated a statistical significant difference between the quantity of GHGs emissions and the parameters. The methodology developed and used in this research is outlined in Figure 4. This methodology is built on

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two clusters of primary and secondary data sources. The primary data sources were derived basically from the 2006 IPCC guidelines, fuel type and from commercial road transport. The secondary data sources were gleaned from the study area and local transport organisations which include; NURTW, LAMATA and MVAA. The data properly gleaned and scientifically applied both qualitatively and quantitatively were deployed to provide answers to the research questions articulated in this article.

One limitation encountered in this study centered on the fluctuations on the pump price of fuel at different fueling stations. For instance, gasoline price varied between 143-145 naira per liter but the diesel remained constant. Another limitation lies in the accuracy of their metering systems; some drivers reported that most times they pay for the value of four liters but end up having about 3.75 liters in reality. These limitations are a justification for uncertainty analysis carried out for the estimates.

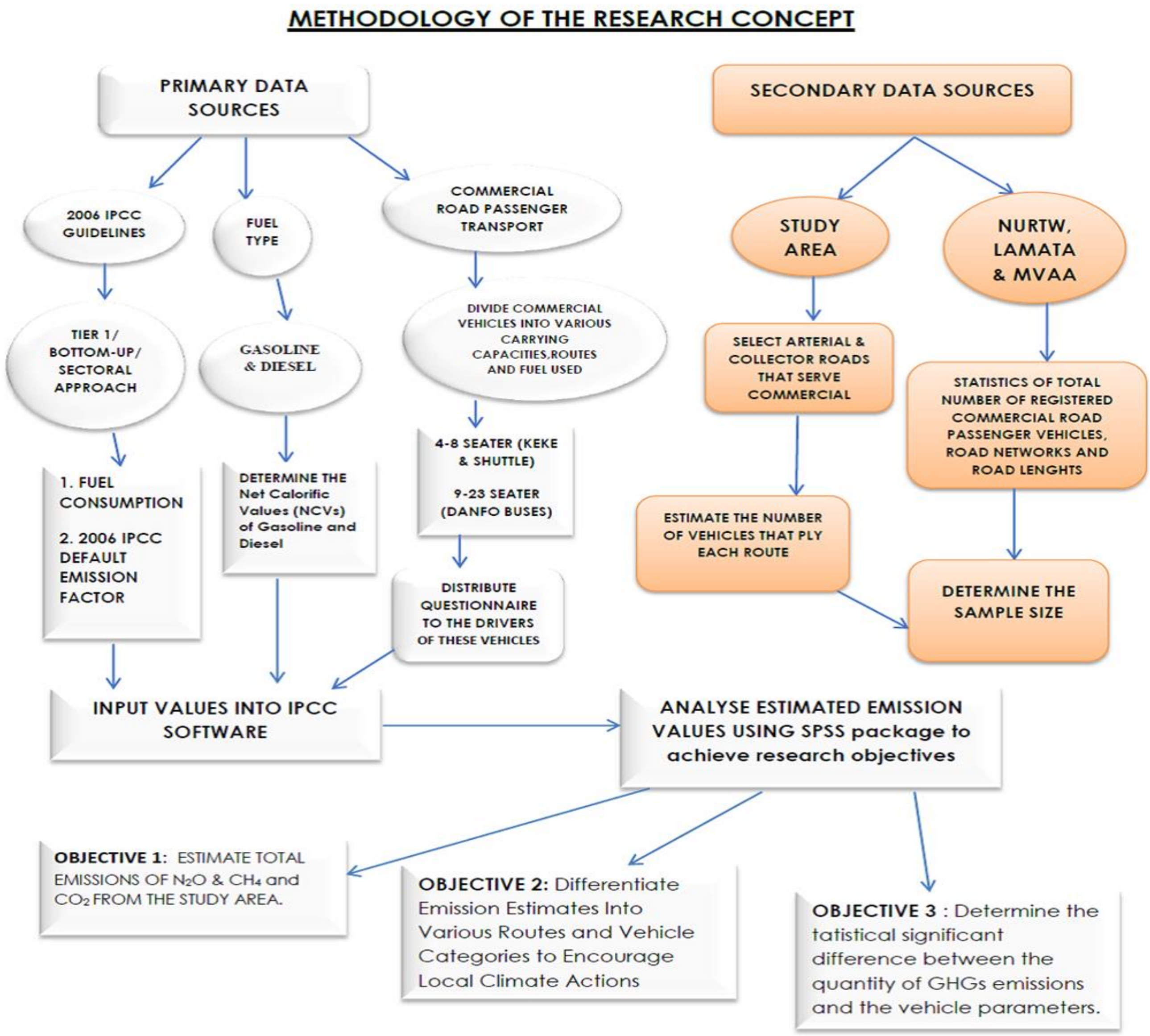

Fig 4: Methodology developed for the study

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4. RESULTS AND DISCUSSION

Table 1 presents the selected sample size for the vehicle categories and routes. It shows here that the 14-seater vehicle (Danfo-14) plies all the three routes in the study area indicating the bus popularity among the commercial drivers in the communities. The route between Iyana-Ipaja and Ikotun had the highest number of 14-seater buses (39) while the route between Iyana-Ipaja and Ayobo has the least among the three routes. The researchers observed that the Iyana-Ipaja and Ikotun route (11 kms) had more passengers, higher bus fare and apparently more economic gain for the transporter but more traffic to contend. 14-seater buses are the only once that plies the Iyana-Ipaja and Ikotun route. The Iyana-Ipaja to Igando route (12.1 kms) had 14, 18 and 22 seater buses competing for passengers. We observed that the 14 seaters appears to cover more trips in a day than the two other seater buses, perhaps because they have fewer passengers to deal with during the boarding and disembarking process at the various bus-stops along the route. The Iyana-Ipaja to Ayobo route (6.4kms) is obviously dominate by the Keke (40), as indicated in table 1, carries four passengers, three at the back and one person hazardously tucked-in beside the tricycle driver. This vehicle is swift on the road relative to the others as it can navigate along a congested road. Since it has the benefit of carrying fewer passengers the time of boarding and disembarking is shorter and several trips are made in day. Iyana-Ipaja to Ayobo is the only route that the Keke vehicle plies. The reason for this could be based on the observations made by two authors of this article and experience acquired haven lived within this Local Government for over 20 years, shows that this route has the least, among the three routes, heavy duty vehicular movement, better road networks and many short distance bus stops apparently convenient for such a vehicle. It should be mentioned that the several trips made by Keke would obviously result in emissions of more GHGs.

Table 1: Selected sample size for each route and vehicle category

VEHICLE CATEGORY & ROUTES	SELECTED SAMPLE SIZE
IYANA-IPAJA TO IYANA- IBA	
14-Seater	12
18-Seater	8
22-Seater	10
IYANA-IPAJA TO IKOTUN	
14-Seater	39
IYANA-IPAJA TO AYOBO	
Keke	40
Shuttle	13
14-Seater	8
18-Seater	6
TOTAL	136

Table 2 presents the results from fuel consumption. The total quantity of fuel consumed per day by the respondents was divided by the cost of a liter in naira, which for gasoline was 143 naira and 220 naira for diesel, these gives the total quantity of fuel in liters consumed by every commercial vehicle involved in this study. Considering the Iyana-Ipaja to Igando route, the buses displayed interesting consumption patterns. Based on fuel type, there were 6 number of 14-seater buses on each of the divide plying the same route. But the gasoline buses consume more liters (244.76) of fuel than their diesel counterpart (163.64) by a difference of 81.12 liters as indicated in table 2. However on the average each gasoline 14-seater consumes 40.19 liters while the diesel buses consumes 27.27 liters. Each 18-seater bus in this route consumes 27.97 liters of gasoline while the diesel bus consumes 24.32 liters a day all on the average. The 22-seater had only diesel buses and consumes 27.96 Liters on the average for each bus.

The Iyana-Ipaja to Ayobo route has four categories of buses. The 14-seater buses consumed 129.37 liters of gasoline and the diesel counterpart consumed 121.58. But each bus consumes about 25.87 Liters of gasoline while the diesel buses consume about 20.45 liters each. There was only one gasoline 18-seater bus in this route and it consumed 27.97 liters, but the diesel counterparts were 5 consuming 91.14 liters. On the average each 18-seater gasoline and diesel bus consumes 27.97 and 18.23 liters a day respectively. There were a total of 12 gasoline and one diesel shuttle buses involved in this study, consuming 246.50 and 15.91 liters as well as 20.54 and 15.91 liters on each shuttle bus of gasoline and diesel shuttle respectively. There were 40 Keke within this route with gasoline (38) and diesel (2) engines consuming a total of 455.94 and 25.91 liters of fuel; while each bus consumes 12.00 and 12.96 liters of fuel respectively.

The Iyana-Ipaja to Ikotun route had only the popular 14-seater buses within this route with gasoline (30) and diesel (9) engines consuming a total of 1208.74 and 227.27 liters of fuel; while each bus consumes 40.29 and 25.25 liters of fuel respectively. There appears to be some form of relation in the consumption pattern in the 14-seater buses in the Iyana-Ipaja to Iyana- Iba route and the Iyana-Ipaja to Ikotun route. These buses were consuming on the average 40.79 and 40.29 liters of gasoline and 27.27 and 25.25 liters of diesel a day, but with the Iyana-Ipaja to Ayobo route it was about 25.87 liters of gasoline and 20.45 of diesel respectively. Interestingly, 18-seater buses irrespective of the route, this implies comparing the Iyana-Ipaja to Igando route of 12.1 kms with the Iyana-Ipaja to Ayobo route of 6.4kms, which shows almost equal amount of gasoline consumption where the distance of the former is almost double the later as indicated in table 2. However factual this data appears, the number of trips covered by buses in these two routes may vary substantially, especially considering the difference road quality and traffic networks discussed earlier as a possible variation and reason for this difference. On a general note, it is important to mention that gasoline fuel burns faster than diesel, hence the later has more hydrocarbons showing the propensity of more carbon emissions (HEI & IHEM, 2020).

Table 2: Fuel consumption computations

	FUEL- GASOLINE			FUEL- DIESEL		
VEHICLE CATEGORY & ROUTE	NUMBER OF VEH	AMT IN NAIRA	QTY IN LTRS	NO OF VEH	AMT IN NAIRA	QTY IN LTRS
IYANA-IPAJA TO IGANDO						
14-SEATER BUS	6	35,000	**244.76**	6	36,000	**163.64**
18-SEATER BUS	1	4,000	**27.97**	5	26,750	**121.59**
22-SEATER BUS	0	0	**0**	10	61,500	**279.55**
IYANA-IPAJA TO AYOBO						
14-SEATER BUS	5	18,500	**129.37**	3	13,500	**61.36**
18-SEATER BUS	1	4,000	**27.97**	5	20,050	**91.14**
SHUTTLE	12	35,250	**246.50**	1	3,500	**15.91**
KEKE	38	65,200	**455.94**	2	5,700	**25.91**
IYANA-IPAJA TO IKOTUN						
14-SEATER BUS	30	172,850	**1208.74**	9	50,000	**227.27**
TOTAL	95	**334,800**	**2341.26**	**41**	**217,000**	**986.36**

To achieve the first and second objectives of the study, the fuel consumption values (in litres) was substituted in the Tier 1 equation using the IPCC inventory software. The results are seen as in Table 3, showing the GHGs emitted from each of the routes based on vehicle fuel type and capacity. Thus the total quantity of GHGs emitted in the study area shows, 7138.97kg/CO_2e, of carbon dioxide, 3.40kg/CO_2e of methane and 0.33kg/CO_2e of nitrous oxide, emitted daily from gasoline use. While 3,120.91kg/CO_2e, of carbon dioxide, 0.25kg/CO_2e of methane and 0.25kg/CO_2e of nitrous oxide were emitted daily from diesel use. In this study area gasoline fired vehicles emitted more GHGs than diesel vehicles, although it is important to mention that the former were more than double in number than the later (see table 2). The fact that gasoline fuel commercial vehicles in this study contributed significantly higher to GHGs emissions than diesel vehicles aligns with the UNEP report (UNEP, 2020b). The report also confirms that most of the LDVs imported to Nigeria from the three major global exporters (EU, USA and Japan) are classified as Euro 3 standard or below. Also 25% of LDVs exported to Nigeria from EU between 2015 and 2018 were reported to be about 19.6 years old on the average with mileage of about 200,000. A juxtaposition of the UNEP report UNEP (2020b) as highlighted in the earlier arguments with the results obtained from this study shows an alignment, confirmation and justification for the high levels of GHGs emissions obtained from the commercial vehicles in Lagos. The commercial drivers in these study locations possess and perhaps have preference for gasoline vehicles, which is a general observation in the streets of Lagos. In view of this result, it may be a good idea to deploy more resources to commercial drivers with gasoline fired vehicles if the challenge of GHGs emissions reduction in the commercial transport sector of the local governments involved in this study and by extension Ikeja the state capital, if it has to be tackled with gravity.

To achieve the third objective which determined the relative contribution of each commercial road passenger vehicle according to its number of engine plugs, age (name and model year), fuel type, route taken, tire pressure value, vehicle weight and vehicle type; a cross tabulation relating the quantity of GHGs emissions and these parameters was done using chi-square. A p-value of less than 0.05 indicated a statistical significant difference between the quantity of GHGs emissions and the parameters. The Chi-square significant values suggest that the parameters were significantly associated with the quantity of fuel consumed and subsequently the quantity of GHGs emissions. Table 4 shows that a direct relationship exists between the route taken and the amount of fuel used per day, and it also exists between other vehicle parameters like the number of engine plugs, vehicle age and type of fuel used.

Table 3: GHGs estimations for vehicle categories and routes

	FUEL- GASOLINE			**FUEL- DIESEL**		
VEHICLE	**FUEL**	**NCV**	**EMISSION FACTORS AND TOTAL**	**FUEL**	**NCV**	**EMISSION FACTORS AND TOTAL**

CATEGORY & ROUTE	QTY		EMISSIONS			QTY		EMISSIONS		
			CO_2(69,300 kg/TJ)	CH_4(33 kg/TJ)	N_2O(3.2kg/TJ)			CO_2(74,100 kg/TJ)	CH_4(3.9kg/TJ)	N_2O(3.9 kg/TJ)
IYANA-IPAJA TO IGANDO										
14-SEATER	244.76	44.0	746.32	0.36	0.03	163.64	42.7	517.77	0.03	0.03
18-SEATER	27.97	44.0	85.29	0.04	0.00	121.59	42.7	384.72	0.02	0.02
22-SEATER	0	-	-	-	-	279.55	42.7	884.52	0.05	0.05
IYANA-IPAJA TO AYOBO										
14-SEATER	129.37	44.0	394.48	0.19	0.02	61.36	42.7	194.15	0.01	0.01
18-SEATER	27.97	44.0	85.29	0.04	0.00	91.14	42.7	288.37	0.02	0.02
SHUTTLE	246.50	44.0	751.63	0.36	0.03	15.91	42.7	50.34	0.00	0.00
KEKE	455.94	44.0	1390.25	0.20	0.06	25.91	42.7	81.98	0.00	0.00
IYANA-IPAJA TO IKOTUN										
14-SEATER	1208.74	44.0	3685.69	1.76	0.17	227.27	42.7	719.10	0.12	0.12
TOTAL	**2341.26**		**7138.97**	**3.40**	**0.33**	**986.36**		**3120.91**	**0.25**	**0.25**

NCV: Net Calorific Value (Nigerian values); Emission Factors (IPCC Default)

Table 4: Relationship between vehicle parameters and quantity of fuel per day

FUEL QUANTITY PER DAY Vs.	Cases					
	Valid		Missing		Relationship	
	N	Percent	N	Percent	P-value	Chi-square
NUMBER OF ENGINE PLUGS	136	100.0%	0	0.0%	123.335	0.000
VEHICLE AGE/MODEL YEAR	133	97.8%	3	2.2%	85.728	0.000
FUEL TYPE	136	100%	0	0.0%	30.763	0.000
ROUTE TAKEN	136	100%	0	0.0%	107.027	0.000
VEHICLE TYPE	136	100.0%	0	0.0%	124.775	0.000

Figure 5 shows that the Keke vehicles were the least fuel consuming vehicles (between N1, 000-N3, 000) but because they outnumber the other vehicle types wherever they exist, their GHGs emissions contributions are outrageous. Their large number in a particular route comes mostly because they are low capacity carrying vehicle and the waiting line to board the bus is usually short, thus reducing the waiting time for commuters. Danfo-14 vehicle types consumes more fuel than the Keke and Shuttle but one advantage it has over the previous lies in the carrying capacity.

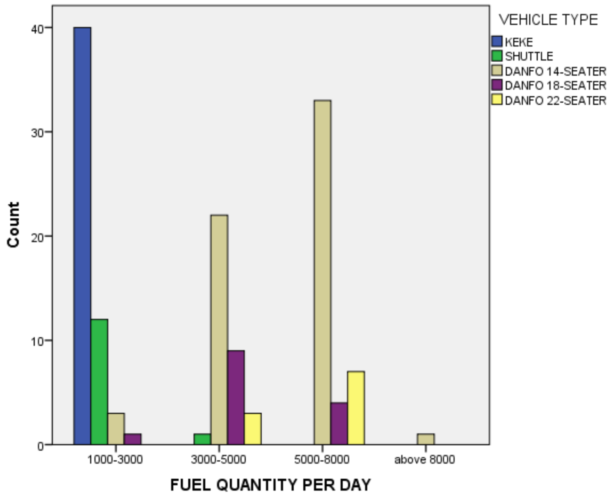

Fig. 5: Showing relationships between the Vehicle type and Quantity of fuel per day

Figure 6 shows that gasoline fired vehicles are more in number than the diesel fired vehicles hence they have larger quantity. This outcome supports the report of UNEP (2020b) that most vehicles exported to West Africa and Nigeria in particular are gasoline fired engines. This also reflects the preference of the drivers of these vehicles, a triangulation interview conducted post-research among 25 drivers found that, most Lagos commercial drivers prefer gasoline engine buses because of the following: 1. The vehicle moves faster 2.Cheaper to service the engine (cost of the lubricating oil and manpower) 3. Auto-mechanics for this engine are easily accessible.

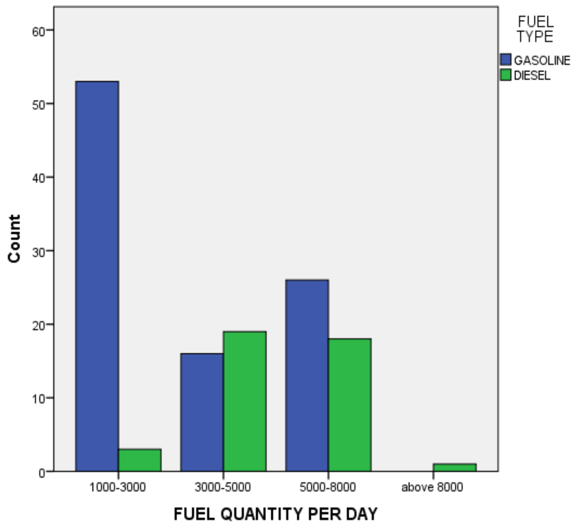

Fig. 6: Showing relationships between the Fuel type and Quantity of fuel per day

Figure 7 indicates the relationship among the number of engine plugs and quantity of fuel. The figure did not depict and relationship in quantity of fuel with number of engine plugs. Thus number of engine plugs does not appear to influence the quantity of fuel consumed on a general note in this study.

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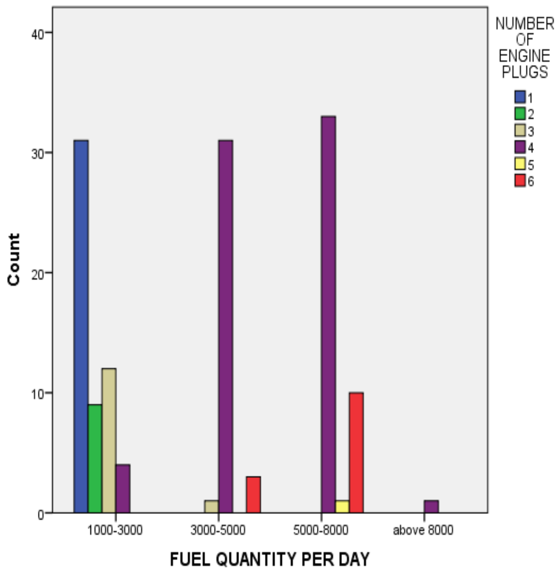

Fig. 7: Showing relationships among the number of engine plugs and quantity of fuel per day

In figure 8, the three different routes are dipicted along with the quantity of fuel. There is a similar relationship among the three routes based on the quantity of fuel between 3,000 and 5,000 naira per day. This may be the reflection of the amount of fuel most of the buses on the average consumes in a day.

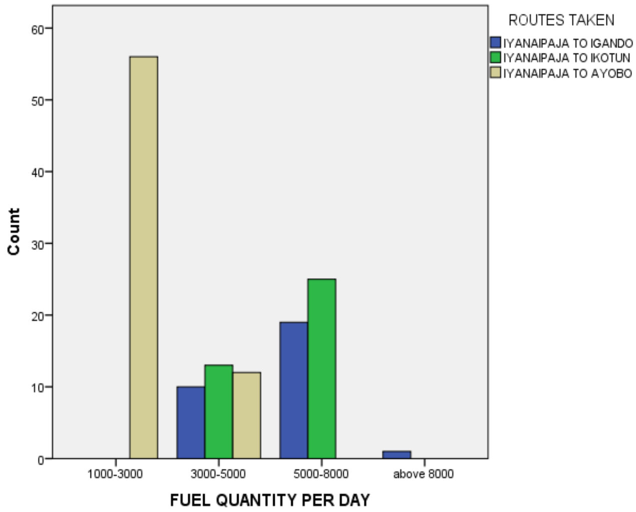

Fig. 8: Showing relationships among the route taken and quantity of fuel per day

Figure 9 shows the relationship among vehicle age and quantity of fuel per day. Vehicle age appears does not seem to have a meaning difference in fuel quantity per day as viewed in this study holistically. However, 2011 model buses demanded for more quantity of fuel per day, and these are the Keke buses as a result of their frequency of trips per day.

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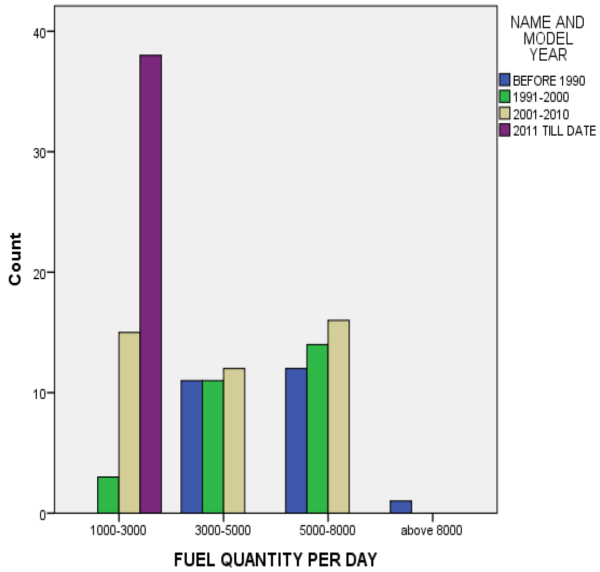

Fig. 9: Showing relationships between the Vehicle Age/Model year and Quantity of fuel per day

Uncertainty analysis

Uncertainties were analyzed for: emission factors and activity data (fuel consumption). A 95% confidence interval encloses the true value of an unknown fixed quantity with a specified confidence (probability). Giwa *et al*. (2017) specifies that a 95% confidence interval is used in greenhouse gas inventories and also from a statistical perspective because it is the range that maybe declared to be consistent with any observed data or information. The estimated uncertainties for CO_2 emissions from both gasoline and diesel of this study are seen in table 5. The result shows that the certainty ranking for the estimated was high which implies that the level of accuracy and precision met required standards.

Table 5: Uncertainty Analysis

	Step 1 + 2						**Step 3**			
Description	A	B	C	D	E	F	G	H	I	J
Fuel type, Route and vehicle category	**Activity Data (e.g. Quantity of fuel used)**	**Unit of Activity Data**	**Uncertainty of activity data (a) (Confidence interval expressed in ± %)**	**GHG emission factor (EF)**	**Unit of GHG EF (for kg CO_2)**	**Uncertainty of EF (Confidence interval expressed in ± %)**	**CO_2 emissions in kg A * D**	**CO_2 emissions in metric tonnes G/1000**	**Uncertainty of calculated emissions** $I = \sqrt{C^2 + F^2}$	**Certainty Ranking**
Gasoline Iyana-iba 14-seater	**10769.44**	**TJ**	**+/- 2.0%**	**69,300.00**	**kg CO_2 / GJ**	**+/- 5.0%**	**746,322,192.00**	**746,322.19**	**+/- 5.4%**	**Good**
Gasoline Iyana-iba 18-seater	**1230.68**	**TJ**	**+/- 2.0%**	**69,300.00**	**kg CO_2 / GJ**	**+/- 5.0%**	**85,286,124.00**	**85,286.12**	**+/- 5.4%**	**Good**
Gasoline Iyana-iba 22-seater	**0.00**	**TJ**	**+/- 2.0%**	**69,300.00**	**kg CO_2 / GJ**	**+/- 5.0%**	**0.00**	**0.00**	**+/- 5.4%**	**Good**
Gasoline Ayobo 14-seater	**5692.28**	**TJ**	**+/- 2.0%**	**69,300.00**	**kg CO_2 / GJ**	**+/- 5.0%**	**394,475,004.00**	**394,475.00**	**+/- 5.4%**	**Good**
Gasoline Ayobo 18-seater	**1230.68**	**TJ**	**+/- 2.0%**	**69,300.00**	**kg CO_2 / GJ**	**+/- 5.0%**	**85,286,124.00**	**85,286.12**	**+/- 5.4%**	**Good**
Gasoline Ayobo shuttle	**10846.00**	**TJ**	**+/- 2.0%**	**69,300.00**	**kg CO_2 / GJ**	**+/- 5.0%**	**751,627,800.00**	**751,627.80**	**+/- 5.4%**	**Good**
Gasoline	**20061.36**	**TJ**	**+/- 2.0%**	**69,300.00**	**kg CO_2 /**	**+/- 5.0%**	**1,390,252,248.00**	**1,390,252.25**	**+/- 5.4%**	**Good**

Ayobo keke					**GJ**					
Gasoline Ikotun 14-seater	**53184.56**	**TJ**	**+/- 2.0%**	**69,300.00**	**kg CO_2 / GJ**	**+/- 5.0%**	**3,685,690,008.00**	**3,685,690.01**	**+/- 5.4%**	**Good**
Diesel Iyana-iba 14-seater	**6987.43**	**TJ**	**+/- 2.0%**	**74,100.00**	**kg CO_2 / GJ**	**+/- 5.0%**	**517,768,563.00**	**517,768.56**	**+/- 5.4%**	**Good**
Diesel Iyana-iba 18-seater	**5191.89**	**TJ**	**+/- 2.0%**	**74,100.00**	**kg CO_2 / GJ**	**+/- 5.0%**	**384,719,049.00**	**384,719.05**	**+/- 5.4%**	**Good**
Diesel Iyana-iba 22-seater	**11936.79**	**TJ**	**+/- 2.0%**	**74,100.00**	**kg CO_2 / GJ**	**+/- 5.0%**	**884,516,139.00**	**884,516.14**	**+/- 5.4%**	**Good**
Diesel Ayobo 14-seater	**2620.07**	**TJ**	**+/- 2.0%**	**74,100.00**	**kg CO_2 / GJ**	**+/- 5.0%**	**194,147,187.00**	**194,147.19**	**+/- 5.4%**	**Good**
Diesel Ayobo 18-seater	**3891.68**	**TJ**	**+/- 2.0%**	**74,100.00**	**kg CO_2 / GJ**	**+/- 5.0%**	**288,373,488.00**	**288,373.49**	**+/- 5.4%**	**Good**
Diesel Ayobo shuttle	**679.36**	**TJ**	**+/- 2.0%**	**74,100.00**	**kg CO_2 / GJ**	**+/- 5.0%**	**50,340,576.00**	**50,340.58**	**+/- 5.4%**	**Good**
Diesel Ayobo keke	**1106.36**	**TJ**	**+/- 2.0%**	**74,100.00**	**kg CO_2 / GJ**	**+/- 5.0%**	**81,981,276.00**	**81,981.28**	**+/- 5.4%**	**Good**
Diesel Ikotun 14-seater	**9704.43**	**TJ**	**+/- 2.0%**	**74,100.00**	**kg CO_2 / GJ**	**+/- 5.0%**	**719,098,263.00**	**719,098.26**	**+/- 5.4%**	**Good**

Sum CO_2 emissions (M):	**10,259,884,041.00**	**10,259,884.04**	
			Aggregated Certainty Ranking
Step 4: Cumulated Uncertainty: $\pm u = \pm \frac{\sqrt{\sum_{i=1}^{n}(H_i * I_i)^2}}{M}$		**+/- 2.3%**	**High**

5. Conclusion And Recommendations

One of the most fundamental steps African nations must take for the commencement of climate action is data gathering especially from the grassroots or local communities who are the primary consumers of fuel. It is only when data is obtained from the primary consumers of fuel that anyone can scientifically deduce the quantity of GHGs emissions from such sector. Sector's emissions ranking can therefore be developed to form a bases for decision making in tackling emissions reduction. This is a crucial step to building adaptive and mitigative strategies for Climate Change. The formulation of localized policies and effective management practices of climate action should be based on data gleaned from research such as this study. This study found that 10,259.88kg/CO_2e, of Carbon dioxide (CO_2), 3.65kg/CO_2e of Methane (CH_4), and 0.58kg/CO_2e of Nitrous Oxide (N_2O) was emitted daily on the selected areas. About 2,341.26ltrs of petrol and 986.36ltrs of diesel was consumed daily within the study area and this indicates that petrol is frequently consumed relative to diesel. Data from this study also shows a high concentration of a particular vehicular type 'Keke' leading to high rate of fuel consumption. This can be mitigated by the introduction of a higher carrying capacity vehicle which will reduce the amount of fuel consumed by these 'Keke' or introduction of climate friendly vehicle. Reducing GHGs emissions from vehicles requires the use of clean vehicles technologies as well as the effective deployment of catalytic converters that filter exhaust gases from petrol vehicles. HEI & IHEM (2020) mentioned that some catalytic converters may reduce pollutants by 90 per cent or more as well as diesel particulate filters effective as much as 99% of small particulates emitted by diesel vehicles.

This study when scaled up do seem plausible to be used in estimating the total concentration of GHGs contributed by commercial road passenger transport activities in Lagos state and Nigeria as a whole. Furthermore, this study serves as a detailed template for end use data gathering (bottom-up) instead of statistics on production, import, export and stock exchanges of fuel from NNPC considering that there are many other uses of fuel in Nigeria (electricity generation).

The bottom-up method used in this research was based on the fuel consumption within the study area and the emission estimates can be differentiated by fuel, vehicle categories, routes, vehicle age and a few others. It is also a less expensive way to estimate emissions and therefore can be used frequently to monitor emission reductions when targets are set.

Targets like supporting and patronizing locally made solar powered Keke (tricycles) and shuttle (mini-buses) can be set for a start. Ongoing research, training and development on the use of Compressed Natural Gas (CNG) over petroleum based fuel for Danfo buses can be strengthened. Government of Nigeria must place a total ban and enforce same on the importation of used vehicles more than 5 years and ensure that they have high emissions standards not less than EU 6. This will promote significant reduction in the GHGs emitted on the streets of Lagos. Road worthiness must be effectively conducted on all transport vehicles periodically not the current lip service.

Government should incentivise commercial transport driver that comply with low GHGs Local and state transport and environmental policies as well as individuals should be involved in addressing the contribution of road transport to climate change if they can estimate their contributions at micro levels leading to a better climate action.

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References

Adeniyi, A. (2017, August). Adaptation to climate change vulnerabilities. *African Journal of Environmental Health Sciences*. 4(2017), 87-92. Retrieved August 21, 2018, from AJEHS database on the World Wide Web: http://www.ajehs.com

Agarana, M., Bishop, S. & Agboola, O. (2017). Minimizing carbon emissions from transportation projects in Sub-Saharan African cities using mathematical mode: a focus on Lagos, Nigeria. ScienceDirect Procedia Manufacturing. 7(2017), 596-601. DOI: 10.1016/j.promfg.2016.12.089.

Akpodiogaga, P. & Odjugo, O. (2017). General overview of climate change impacts in Nigeria. *Journal of Human Ecology*. 29(1), 47-55. DOI: 10.1080/09709274.2010.11906248.

Aminu, S. & Asikhia, O. (2019, June). Fuel-efficient vehicles and petrol consumption in the transportation sector of Lagos State, Nigeria. *Governance and Management Review (GMR)*. 4(1), 1-17. Retrieved July, 12, 2021, from Punjab University database on the World Wide Web: http:// www.pu.edu.pk

Atubi, A. (2015). Transport and the environment: towards reducing road traffic emissions in Nigeria. *International Journal of Science and Technology.* 4(1), 58-78. DOI: 10.4314/stech.v4i1.6.

Badmus, I., Fagbenle, R. & Oyewola, M. (2013). Fuel-mix and energy utilization analysis of Kaduna refining and petrochemical company, Nigeria. *International Journal of Energy Engineering*. 3(3), 190-199. DOI: 10.5923/j.ijee.20130303.10.

Cheewaphongphan, P., Chatani, S. & Saigusa, N. (2019). Exploring gaps between bottom-up and top-down emission estimates based on uncertainties in multiple emission inventories: a case study on CH_4 emissions in China. *Sustainability*. 11(7), 1-18. DOI: 10.3390/su11072054.

Department of Climate Change. (2018). *First biennial update report (BUR1) of the federal republic of Nigeria under the United Nations framework convention on climate change (UNFCCC)*. Abuja, Nigeria. Federal Ministry of Environment.

EDGAR (Emission database for global atmospheric research). (2017). *Global greenhouse gas emissions*. Netherlands. EDGAR. 4(2).

Eichelberger, L., Stulce, K., McGraw, D., Perez, M. & Stowe, L. (2014). Naturalistic driving study: technical coordination and quality control. *National Academies of Sciences, Engineering, and Medicine.* 1:151-153, 198-199 & 350-356, DOI: 10.17226/22362.

Emodi, N., Emodi, C., Murthy, G. & Emodi, S. (2017). Energy policy for low carbon development in Nigeria: a LEAP model application. *Renewable and Sustainable Energy Reviews, Elsevier.* 68(1), 247–261. DOI: 10.1016/j.res.2016.09.118.

EPA (Environmental protection agency) (2017). *Global atmospheric concentrations of CO_2, CH_4, N_2O and other halogenated gases over time.* Retrieved April 19, 2018, from EPA database on the World Wide Web: http://www.epa.gov

Gireesh, K., Lekhana, P., Tejaswi, M., & Chandrakala, S. (2021). Effects of vehicular emissions on the urban environment- a state of the Art. *Materials Today: Proceedings*. 45, 6314–6320. DOI: 10.1016/j.matpr.2020.10.739.

Giwa, S., Sulaiman, M. & Nwaokocha, C. (2017). Inventory of greenhouse gases emissions from gasoline and diesel consumption in Nigeria. *Nigeria Journal of Technological Development*. 14(1), DOI: 10.4314/njtd.v14i1.1.03.12.

Gujba, H., Mulugetta, Y. & Azapagic, A. (2013). Passenger transport in Nigeria: environmental and economic analysis with policy recommendations. *Energy Policy*. 5(2013), 353-361. DOI: 10.1016/j.enpol.2012.12.017.

He, K., Huo, H., Zhang, Q., He, D., An, F. & Wang, M., et al. (2005). Oil consumption and CO_2 emissions in China's road transport: current status, future trends, and policy implications. *Energy Policy.* 33(12), 1499–1507. DOI: 10.1016/j.enpol.2004.01.007.

HEI & IHEM (Health effects institute & the Institute for health metrics and evaluation) (2020, January). *State of Global Air 2020. Special Report*. Boston, MA: Health Effects Institute.

IPCC (Intergovernmental Panel on Climate Change). (2015). *The fifth assessment report of IPCC 2013*. IPCC. Retrieved March 1, 2017 from http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_chapter8.

IPCC (Intergovernmental Panel on Climate Change). *The 2019 refinement of the 2006 IPCC guidelines for national greenhouse gas inventories.* IPCC. Retrieved January 23, 2021 from www.ipcc-nggip.iges.org

Lagos Bureau of Statistics (LBS). (2016). *Motor vehicle statistics in Lagos state, Nigeria*. Nigeria. Lagos Bureau of Statistics.

MacCracken, M. (2010, February). *Beyond mitigation: potential options for counter-balancing the climatic and environmental consequences of the rising concentration of greenhouse gases*. Retrieved April 12, 2018, from open knowledge database on the World Wide Web http://www.openknowledge.worldbank.org

Maciulis, A., Vasiliauskas, A. & Jakubauskas, G. (2009). The impact of transport on the competitiveness of national economy. *Transport*. 24(2), 93-99. DOI: 10.3846/1648-4142.2009.24.93-99.

Maduekwe, M., Akpan, U. & Isihak, S. (2020). Road transport energy consumption and vehicular emissions in Lagos, Nigeria: an application of the LEAP model. *Transportation Research Interdisciplinary Perspectives*. 6(100172). DOI: 10.1016/j.trip.2020.100172.

Nkwocha, A., Ekeke, I., Kamalu, C., Kamen, F., Uzondu, F. & Dadet, W. et al., (2017). Environmental assessment of vehicular emission in Port-harcourt city, Nigeria. *International Journal of Environment, Agriculture and Biotechnology.* 2(2), 906-911. DOI: 10.22161/ijeab/2.2.44.

Okafor, C., Ahove, M. & Odewumi, S. (2021). Intergovernmental panel on climate change guidelines for emissions estimation among Lagos commercial vehicles. In: F. W. Leal, J. Luetz & D. Ayal (Eds.), *Handbook of climate change management.* (pp. 1-24). Switzerland. Springer, Cham.

Okoli, O., Achebe, H. & Anosike, N. (2017, November). Comparative emission study on petrol vehicles. *International Journal of scientific Research, Engineering*. 7(4), 1-5. Retrieved June 30, 2018, from IOSRJEN database on the World Wide Web http://www.iosrjen.org

Otene, I., Murray, P. & Enongene, K. (2016). The potential reduction of CO_2 emissions from gas flaring in Nigeria's oil & gas industry through alternative productive use. *Environments*. 3(4), 31. DOI: 10.3390/environments3040031.

Rodrigue, J.-P. (2016). The role of transport and communication infrastructure in realising development outcomes. In J. Grugel & D. Hammett (Eds.), *The palgrave handbook of international development* (pp. 595-614). London: Palgrave Macmillan.

Roman-Cuesta, R., Rufino, M., Herold, M., Butterbach-Bahl, K., Rosenstock, T. & Herrero, M. et al., (2016). Hotspots of gross emissions from the land use sector: patterns, uncertainties and leading emission sources for the period 2000-2005 in the tropics. *Journal of Biogeosciences*. 13(4253-4269). DOI: 10.5194/bg-13-4253-2016.

Shabbir, R. & Ahmad, S. (2010). Monitoring urban transport air pollution and energy demand in Rawalpindi and Islamabad using LEAP model. *Energy.* 35(5), 2323–2332. DOI: 10.1016/j.energy.2010.02.05.

Sim, S., Oh, J. & Jeong, G. (2015). Measuring greenhouse gas emissions for the transportation sector in Korea. *Annals of Operations Research*. 230, 129-151. DOI: 10.1007/s10479-013-1452-y.

Tyrer, S. & Heyman, B. (2016). Sampling in epidemiological Research: Issues, hazards and pitfalls*. BJPsych Bulletin*. 40(1), 57-60. DOI: 10.1192/pb.bp.114.050203.

UNEP (United Nations Environment Program) (2020a, April). *New UN report details environmental impacts of exports of used vehicles to developing world.* Retrieved September, 7, 2021 from: https://www.unep.org/news-and-stories/press-release/new-un-report-details-environmental-impacts-export-used-vehicles

UNEP (United Nations Environment Program) (2020b, April). *Used vehicles and the environment- a global overview of used light duty vehicles*: flow, scale and regulations. Retrieved September, 7, 2021 from https://wedocs.unep.org/bitstream/handle/20.500.11822/34175/UVE.pdf?sequence=1&isAllowed=y

Uhuegbu, C. (2013). Measurement of carbon monoxide emissions in some selected area in Lagos State. *Journal of Scientific Research & Reports* 2(2), 536-543. DOI: 10.9734/JSRR/2013/3223.

Usman, S., Abdulhamid, A., Gwadabe, S., Usman, A., Isah, B. & Mallam, I. (2017). Urbanization and climate change: the role of road transport carbon dioxide emission in Kano Metropolis, Nigeria*. Bayero journal of Pure & Applied sciences*. 10(1), 536-540. DOI: 10.4314/bajopas.v10i1.101S.

Vuuren, D., Hoogwijk, M., Barker, T., Riahi, K., Boeters, S. & Cjateau, J. et al., (2009). Comparison of top-down and bottom-up estimates of sectoral and regional greenhouse gas emission reduction potentials. *Energy Policy.* 37 (2009), 5125–5139. DOI: 10.1016/j.enpol.2009.07.024.

Vyas, S. & Amin, S (2016). Effects of transportation on environment. *International Journal of Advanced Research.* 4(11), 212-225. DOI: 10.21474/IJAR01/2073.

Warner, A., Lamm, A. & Rumble, J. (2018). Can videos play a role in promoting good landscape management behaviors? *Applied Environmental Education & Communication.* 7(3), 187-197. DOI: 10.1080/1533015X.2017.1388199.

Weeberb, R., Petros, K. & Henrique, R. (2015). Spatial distribution of vehicular emissions in the federal district of Brazil. *Journal of Atmospheric Environment.* 112: (32-39). DOI: 10.1016/j.atmoenv.2015.04.029 10.09.2017.

Weitz, M., Coburn, J. & Salinas, E. (2008). Estimating national landfill methane emissions: an application of the 2006 intergovernmental panel on climate change waste model in Panama. *Journal of Air & Waste Management Association.* 58:636–640. DOI: 10.3155/1047-3289.58.5.636.

World Resource Institute (2019, December). *Driving equitable climate transitions: governance frameworks for the climate change, SDGs and green growth agendas.* Retrieved February 2, 2019, from www.wri.org/events/events/2019/01/greeninig-governance-seminar-seris-driving-equitable-climate-transitions

Xu, Y., Liu, Y., Chang, X. & Huang, W. (2021). How does air pollution affect travel behaviour? a big data field study. *Transportation Research Part D: Transport and Environment*. 99 (2021). DOI: 10.1016/j.trd.2021.103007.

Yaacob, N., Yazid, M., Abdul-Maulud, K. & Basri, N. (2020). A review of the measurement method, analysis and implementation policy of carbon dioxide emission from transportation. *Sustainability.* (12)5873. DOI: 10.3390/su12145873.

AUTHORS

Michael A. Ahove, Ph.D., is an Associate Research Professor of climate change and environmental education at the Centre for Environmental Studies and Sustainable Development, Lagos State University, Ojo, Lagos Nigeria (e-mail: tjahove@gmail.com).

Chinenye L. Okafor, Ph.D., is an Adjunct Research Fellow at the Centre for Environmental Studies and Sustainable Development, Lagos State University, Ojo, Lagos Nigeria (e-mail: chinenyeokafor2017@yahoo.com).

Samuel G. Odewumi, Ph.D., is a Professor of Transportation and the Dean of the School of Transport, Lagos State University, Ojo, Lagos, Nigeria (e-mail: eesgee@yahoo.com).

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