Motorized urban transport and CO_2 emission in African metropolises: The case of the city of Yaoundé, Cameroon

Transport urbain motorisé et émission des CO_2 dans les métropoles Africaine : Le cas de la ville de Yaoundé, Cameroun

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Abstract: This study appraises the relationship between motorized urban transport mode and CO_2 emission in the city of Yaoundé using data from the 2020 urban displacement plan. Adopting a behavioral model's framework, results indicate that: (a) urban motorized transport modes increase CO_2 emissions with minibuses/buses having

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the highest effects and (2) we observe an inverted U-shaped between the number of travels per day-a proxy for distance and CO_2 emissions on one hand, and a U-shaped relationship for the joint effect of motorized urban transport and number of travels per day and carbon dioxide emissions on the other hand. As policy suggestion, in order to build sustainable urban cities, the issue of urban transport modes should be at the forefront of policies and especially, government should curb the importation of very old vehicles that do not have technologies that reduce emissions through a malus and bonus framework for less polluting cars.

Keywords: Motorized urban transport, CO_2 emission, urbanization, Yaoundé.

Résumé : *Cette étude analyse la relation entre le transport urbain motorisé et l'émission des CO_2 dans la ville de Yaoundé en utilisant les données du Plan de Déplacement Urbain 2020. Adoptant un cadre d'analyse base sur le modèle de comportement, les résultants indique que : (a) les modes motorisés des transports augment les émissions de CO_2 avec les minibus/veilles bus ayant le niveau le plus élevé ; et (b) non observons une relation d'un U-inversé entre le nombre des voyages par jour-un proxy indiquant la distance parcouru et les émissions de CO_2 d'une part, et une relation en U pour l'effet conjoint transport urbain motorisé et le nombre des voyages et l'émission des CO_2 d'autre part. Comme politique de recommandation, pour bâtir des citées urbaines durables, la question du mode des transports devrait être au centre des politiques avec un accent mis sur la réduction des vielle véhicules polluantes n'ayant pas des technologies qui diminuent les émissions, à travers un cadre de malus bonus qui encourage l'importation des véhicules moins polluants.*

Mots Clés : *Transport urbain motorisé, émission du CO_2, urbanisation, Yaoundé.*

***JEL code**: R40; R49.*

1. INTRODUCTION

Building sustainable urban transport infrastructures and inclusive urban mobility schemes are essential to advancements towards realizing the 2030 agenda for sustainable development. This is because mobility is at core of urbanization and subsequent negative externalities on the climate like pollution. In metropoles of developed countries, urban mobility is an important concern with one of the principal challenges being the reduction of greenhouse gas emissions (Bertaud et al., 2011). Nonetheless, the main solution to urban mobility in sub-Saharan Africa (SSA) cities has been to develop adequate public transportation after the collapse of transport infrastructures following the economic crisis of the 1980s. These cities have been characterized by unplanned urbanization which has caused the growth of uncontrolled shantytowns. Some examples include Dakar and Abidjan (Antoine, 1996), Bamako (Kouma, 1993), Ouagadougou (Jaglin et al., 1992), Dar es Salam (Calas and Bart, 1997) or Yaoundé (Ongolo and Epo, 2015). In 2014, about 55% of SSA urban population lived in slums (Saghir and Santoro, 2015).

Unfortunately, the failure of governments and local city authorities in several countries in SSA to meet transport demands has led to the significant present of informal transport offers driven by high urbanization rates (Pendakur, 2005). In particular, cities like Yaoundé have failed to mitigate negative externalities of a dysfunctional transport sector, leading to an atomized market of small private operators. They principally operate in the informal transport sector. A direct consequence for these cities in SSA, including Yaoundé, has been the increase of carbon dioxide emissions from motorized urban transport modes (Rodes et al., 2014; Sietchiping et. al., 2012).

In African cities, the average number of trips per inhabitant is between three to four and a half travels per day (Centre d'Etudes sur les Réseaux, les Transports, l'Urbanisme et les Constructions Publiques (CERTU), 2008), characterized by high shares of artisanal transport modes. Traditional transport modes largely account for transport offer in African cities like Abidjan, Nairobi, Dakar, Dar es Salam and Yaoundé (Mfoulou, 2017). Increasing income levels, insufficient supply of public transport and non-motorized transport amenities in developing cities is pushing people to opt to use private modes of transport.

City dwellers in African cities indicated that between 42% and 75% of their commuting is done using one of the motorized urban modes of transport; 42% in Niamey, 58% in Ouagadougou and 75% in Douala (Sahabana, 2006). In cities in SSA, public transport is predominantly provided by poorly endowed state-owned companies and a large number of smaller privately owned buses. For instance, the share of public transport is about 35% for Addis Ababa, 30% for motorized trips in Dakar, 63% of public transport shares for Dar es Salam of which about 90% is largely privately owned and artisanal, 60 % for Accra with more than two-third constituted of informal minibus taxis and 43% of commuter trips in Lagos are undertaken using privately operated, and largely unregulated, minibus vehicles (Infrastructure Commission of Africa [ICA], 2016). In Yaoundé, motorized trips are about 60% of daily travels with only about 3-5% of displacements being done using the sole public transport operator. A large portion of travelers use old-aged yellow taxis to commute (Yaoundé Urban Council [YUC], 2020). For all these cities, these transport services are overcrowded, operated in congested mixed traffic, and make use of old, unreliable and inefficient vehicles (ICA, 2016; Stucki, 2015; Pendakur, 2005).

A direct consequence of high rates of artisanal transport modes and a high frequency of displacement has been the rapid increase in motorized urban transport modes which don't have technologies that reduce emissions due to their old age. For instance, more than 65% of the vehicles (excluding motorcycles and tricycles) during their first matriculation in the city of Yaoundé are older than 10 years (Ministry of Transport, 2018). These vehicles are used by operators in the informal transport sector to service urban transportation supply deficiency (Yaoundé Urban Council (YUC), 2010). On average, about 40% of minibuses in Yaoundé are aged 20 years and above. Kumar and Barret (2008) also find a similar tendency in other cities in Africa where the average age of mini-buses, widely used for commuting, was between 15-to-20 years (Abidjan, Accra, Dakar, Douala, Kinshasa, Lagos, Nairobi) and 10-to-15 years (Conakry, Kampala, Dar es Salam).

The International Energy Agency (2014) reports that 23% of total energy-related CO_2 emissions was produced by the transport sector, with Africa experiencing a strong increase in CO_2 emissions. Growing at a quicker rate than any other energy end-use, global Greenhouse Gas Emissions from the transport sector doubled since 1970 to reach 7 gigatons of CO_2 emissions in 2010 (Intergovernmental Panel on Climate Change [IPCC], 2014). The report also specified that the final energy Consumption for transport reached 27.4 % of total end-use energy, of which a large share was urban. If no substantial efforts are assumed, transport emissions may well rise at a faster rate than emissions from other energy end-use sectors and reach about 12 gigatons of CO_2 a year by 2050[4]. Current estimates for Yaoundé suggest that the actual level of household gas emission is 664 800 tons, about 212 kg per inhabitant. This amount is expected to reach 2 054 600 tons in 2035, representing 368 kg per inhabitant (YUC, 2020).

Stucki (2015) and Nducol et al. (2020) appraised the rate of concentration of particulate matter or particle pollution with a diameter of ten microns or less, for different cities in SSA and Yaoundé. Their results indicate that the rate of concentration ranged between 20-25 for Port Louis, 30-35 (Yaoundé, Morogoro and Cape town), 50-70 (Pretoria, Buchanan), 90-100 (Accra, Johannesburg) and 170-180 for Dakar. For particles less than 2.5 microns, the concentration fluctuated between 11 to 51 with Accra, Dakar and Johannesburg reporting figures greater than 40. Only Yaoundé and Buchanan reported concentration values of 9. These concentration rates which monitor air pollution were above the levels recommended by the World Health Organization.

In furtherance, a study by the Sub-Saharan Africa Transport Policy Program (SSATP) evaluated key urban transport issues associated with environmental quality and resources for twenty cities in SSA (Cairo, Tunis, Sfax, Rabat-Salé, Casablanca, Dakar, Ouagadougou, Abidjan, Bouaké, Accra, Kumasi, Lagos, Kinshasa, Addis Ababa, Nairobi, Dar Es Salam, Maputo, Kampala, Gauteng, Cape Town). The author finds: (a) either significant or strong concerns with no registered improvements for all the cities and (b) none of the cities showed any improvements and about half reporting either no change or a deteriorating

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[4]Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Chapter 8, Transport).

situation (Stucki, 2015). Godard (2002) corroborates the idea that CO_2 emissions rates for some cities in Africa, albeit being low, have recorded strong increases overtime with environmental governance efforts lagging behind.

Two main observations can be inferred from the above remarks. First the growing utilization of urban motorized transport modes to resolve mobility issues is largely driven by urbanization. Second, an increase in urban pollution is at least driven in part by urban transportation, especially motorized urban transport modes. These have consequences related to air pollutions, exacerbated by the age of high particulate-emitting vehicles (CERTU, 2008; Duprez, 2002). Furthermore, in lower and middle-income cities in SSA like in Nairobi (Salon and Aligula 2012), Kampala, Uganda and Harare (Bryceson et al., 2003), Cairo (Kalthier 2002) the poorer segments of the population rely heavily on informal public transport and are excessively affected by negative externalities created by transport like air pollution (Vasconcellos, 1997; Drabo, 2013).

Indeed, several differences in terms of urban transport emissions exist between cities with similar levels of development and urbanization trends. Nonetheless, two main factors explain urban carbon intensity: (a) the overall distance required to travel using urban motorized modes and (b) the carbon intensity of these motorized urban transport modes (Rodes et. al., 2014). It is therefore important that urban transport and ways to ameliorate travel needs in cities in general, and those in SSA like Yaoundé, should contribute towards achieving carbon reduction targets (Hickman and Banister, 2015). Thus, actions associated with motorized urban transport in cities like Yaoundé, needs' new thinking and approaches in terms of reducing urban CO_2 pollution.

This study therefore questions the consequences of motorized urban transport mode on carbon dioxide emissions. The main objective of this paper is to evaluate the effects of motorized urban transport mode on carbon dioxide emission in the city of Yaoundé using data on travel behaviors gotten from the 2020 Yaoundé Urban Displacement Plan. Specifically, we investigate the joint effect of motorized urban transport and distance travelled-proxied by the daily number of travels of a given individual to gauge the role of urbanization (urban sprawl). We also appraise the joint effect of motorized urban transport and frequency of travels. The nature of these relationships should help in policy design. This is because a non-linear relationship indicates the possible presence of thresholds, and thus policy targeting motorized urban transport-CO_2 linkages should be adequately crafted not produce adverse effects.

2. DEMOGRAPHIC GROWTH AND MOTORIZED URBAN TRANSPORT

In October 2015, the Africa Sustainable Transport Forum (ASTF) outlined a harmonized roadmap to achieve sustainable transport in Africa. In this framework, vehicle emissions and energy efficiency are among some of the priority areas. Nevertheless, efficiently implementing this roadmap for cities in SSA like Yaoundé will need a rethink of her urban context. This context is driven by uncontrolled urban sprawl and negative externalities from motorized urban transport setups that ought to be mitigated. In this section, we first analyze the urban context of the city of Yaoundé and secondly explore urban motorized modes and mobility behaviors.

2.1. Demographic and population growth in the city of Yaoundé

Despite the sub-Saharan Africa region experiencing an economic contraction between 1970 and 2000, urbanization appears to have rather increased (Satterthwaite, 2010; United Nations, 2013). This has been caused by growth in urban population and urban sprawl. The combined effect of these two factors have had huge implications for transport provision in African metropoles like the city of Yaoundé.

Demographics is one of the main factors explaining observed urbanization in sub-Saharan African cities in general (Dyson, 2011). SSA is the world's fastest urbanizing region with about 472 million people living in urban areas, and this expected to double over the next 25 years (Saghir and Santoro, 2018). In 2011, about ten million Cameroonians lived in urban areas with an average urban growth rate estimated at 3.2% between 2010 and 2015 (UN-World Statistics Pocket Book, 2013). UN-Habitat (2005) reports that urban growth rate for Nairobi, Dar es Salam and Harare were 7.7%, 6.6% and 5.9%, respectively.

Urban population increase in African cities is characterized by rural-urban migration in search of jobs and better socioeconomic infrastructure offer. Given the limited housing capabilities registered in the urban areas, they tend to settle in slumps situated at the peripheries that are not adequately serviced in terms of transport infrastructures and use old vehicles for movements towards the city center. For instance, in cities like Addis-Ababa and Mogadishu, about 80-85% of her populations live in informal peripheries less endowed with infrastructure and equipment's, as well as low employment opportunities. This value was between 70-

60% for the cities of Luanda, Dar es Salam and Ouagadougou (Simons, 1992; Sahabana, 2006).

Yaoundé like most metropolis in Africa have been witnessing high urban growth rates. In 2018, the city of Yaoundé had an estimate of 3,2 million inhabitants, with projections indicating 4,02 million inhabitants in 2025 and 5,5 million in 2035 (YUC, 2020). The main consequence of this upsurge of the population of Yaoundé is an increase in the city's outward sprawl, encouraging motorization and negative externalities like pollution.

2.2. Urban sprawl in the city of Yaoundé

Recently, governmental authorities recognized the city of Yaoundé face uncontrolled urban sprawl (Government of Cameroon, 2009). The urban fabric has grown about ten times fold from 38km^2 in 1980, 160km^2 in 2002 to 348 km^2 in 2020. It projected that in 2025, this fabric on the metropolitan areas will increase to 442 km^2 and 559 km^2 in 2035. The geographic extension of cities of the Yaoundé is observed on three fronts: the North/North-Eastern front, the Eastern front and the Southern front (YUC, 2020). This urbanization setting follows the principal roads exiting the city and thereon progressively densifies.

The process of urban sprawl has been principally driven by an increase in urban population which has led to the development of uncontrolled monofunctional peripheries. These peripheries are situated away from the city center endowed with socioeconomic infrastructure (hospitals, markets, administrative units, among others) thereby increasing need for urban motorization. This observation for the city of Yaoundé is similar to other African cities where uncontrolled urbanization has created functional differences between an underpopulated center business district and peripheries that are overpopulated but lack economic and social infrastructures.

2.3. Urbanized motorized modes and mobility behaviors in Yaoundé

According to the 2001 World Business Council for Sustainable Development report, the growth in motor fleet vehicles has outpaced urban infrastructural development and institutional structures in cities in the developing world, causing sociocultural and environmental imbalances and inequalities like pollution. The observation is relevant for the most SSA cities including the city of Yaoundé.

Looking at data for 28 African countries between 2000 and 2009, urban households reported a motorization rate of 10% for 17 countries, and about 25% overall (Diaz et al., 2010). Urban household motorization rates, in cities like Alger (15%), Cairo (23%) and Yaoundé (25%) have witness rapid increases over time (Etende and Etoundi, 2014). Three main takeaways are observed when appraising motorization rates in Yaoundé: (a) owning a vehicle is highly correlated with the households' income levels with more 50% of rich households possessing at least a vehicle; (b) 75% of the vehicles owned by households are for private use and (c) among these motorized households 81% of their annual mileage is less than twenty thousand kilometers (YUC, 2020).

Despite the growing rate of motorization reported for the city of Yaoundé (Ministry of Transport, 2018), urban road network development in the city of Yaoundé stalled because resources to develop urban roads were significantly reduced after the structural adjustment program (SAP). In spite of attaining the Heavily Indebted poor Country Initiative (HIPC) in 2006, public spending to meet the required level of urban transport infrastructure have not followed the pace of urban sprawl and demand for motorized transport offers. Consequently, the differences observed between the slow growth in the road transport network and high growth in vehicle fleet can also explain the motorization pattern of the city of Yaoundé.

Concerning urban motorized transport modes, the 2020 urban displacement Plan survey indicated that the four-wheel vehicles (taxis, private cars minibuses and buses) accounted for a significant share of transport modes used by urban residents in Yaoundé. Taxis account for over 40 percent of total number of commuting in Yaoundé followed by motorcycles. Regarding informal minibuses, they service the peri urban localities of the city from about seven main bus stations. Considering the different road networks of the city, minibuses transport between 2000 to 60000 people per day (YUC, 2020).

3. RELATED LITERATURE REVIEW

Since the publication by Newman and Kenworthy (1989), empirically analyses on the link between urban structure and mobility as well as how this relates to energy consumption have been densely researched for cities in developed countries. For cities in SSA, we observe that research carried out is very limited. The literature on possible policy scenarios that aim at diminishing the effect of transport on the environment can be grouped into push and pull interventions (Cools et al., 2009; Kamruzzaman et al., 2013; Yigitcanlar and Kamruzzaman, 2014), which can further be casted into psychological or structural interventions (Graham-Rowe et al., 2011). In this regard, the main orientation has been to incorporate environmental concerns into the standard land use and transport interaction models (Gu and Young, 1998). Several authors have suggested different models to gauge the effect of environmental concerns in transportation models (Moore-Li and Kim, 1995; Van Wee et al., 1998; Hensher and Tu, 2002; Zhao et al., 2013; Oxley et al., 2012).

Overall, the literature has revolved around the following. Firstly, investigating policy interventions that evaluate how technological efficiency versus behavioral changes affect CO_2 emissions (Perez-Lopez et al., 2013; Creutzig et al., 2011; and Anable et al., 2012). Secondly, appreciating policy interventions that highlight co-benefits of climate policies associated with transportation through efficient and effective allocation of resources to solve multiple environmental problems (Haines et al.2007; Woodcock et al., 2007). Third, exploring the interaction between transport and the environment through the lens of environmental management (Khanna and Speir, 2013; Comoglio and Botta, 2012).

Reviewing the literature on the effect of mobility on climate, Marsden et al. (2015) indicates that this relationship can be group into studies that explore questions on policy perspective (Marsden and Rye, 2010), behavioral perspectives (Howarth and Ryley, 2015; Ryley, 2006) and mobility perspectives (Doi and Kii, 2015; Kii et al., 2005). Concerning behavioral perspectives, Howarth and Ryley (2015), Lucas and Jones (2009) and Ryley (2006) indicate that individual behavior associated with car preference usage has produced both benefits and disbenefits like climate change. Cao and Mokhatarian (2003) show that policies aimed at reducing traffic congestion sometimes fail because they do not adequately factor-in variables which influence traveler's preferences, subjective perceptions, desires and preferences in travelling. Gross et al. (2009) argue that efforts or campaigns that change the behavior of car users reduce CO_2 emissions. Anable et al. (2006) suggest that measures associated with "Smarter Choices" could affect behavior patterns of individuals which could affect mobility and emission reduction outcomes.

Despite the effect of transport on climate being largely explored in developed countries, in developing countries like Cameroon we observe very limited literature. In Cameroon, only few studies on mobility exist (Ongolo and Epo, 2015; Mfoulou, 2017; Kemajou et al., 2019) with none looking at motorized urban transport modes and CO_2 emissions from a behavioral perspective.

4. MODEL SPECIFICATION AND DATA

4.1. Model specification

Several modelling approaches that investigate how transport activities relate with emissions have been analyzed at the local and at global scales (Linton et al., 2015). At a global or international level, the energy systems models deliver evidence on effects of emissions on the transport sector (Kim et al., 2012). At the local level, we identify the traffic network models and the behavioral models (Stern and Richardson, 2005). For the former, these models use predicted traffic flows and travel decision making to offer planners with information about the emissions impacts of infrastructure (Gudmundsson, 2011). Concerning the latter, they can make available further insight on travel behavior (Hensher et al., 2013) and the impact of emissions on the existing infrastructure resulting from changes in driving habits (Shafiei et al., 2012).

In this paper, the empirically model is an adaptation of the behavioral model constructed from the Stern and Richardson (2005) process-oriented framework. Linton et al. (2015), indicates that one of the goalmouths of behavioral research in transport is to comprehend how commuters use the transport infrastructure to forecast needs and improve decision-making (Davidson et al., 2007). These models hinge on social psychology and behavioral economics to establish their frameworks (Schaap and van de Riet, 2012). This framework demonstrates how other factors outside the need to travel from an origin to a destination can be evaluated in understanding travel behavior. In this paper, we consider that choosing one of the urban motorized modes constitutes a decision-making travel choice. A direct consequence is emissions of rate of CO_2 associated with the travel needs of the commuters who use these urbanized transport modes. We then appreciate the causal relationship that indicates how a change in demand for the different motorized transport modes relate to carbon dioxide emissions as reported in equation 1 below.

$$LnCO_2 = \alpha_0 + \sum_{k=1}^{K} \alpha_k V_k + \sum_{j=1}^{2} \eta_j Z_j + \sum_{j=1}^{2} \lambda_j \left(D_j \times Z_j\right) + \sum_{j=1}^{2} \delta_j \left(T_j \times Z_j\right) + \varepsilon \quad (1)$$

where, $LnCO_2$ represent log of carbon dioxide emissions from urban travels in g/km and Z the two main four-wheel urban motorized modes of transport (taxis and buses/minibuses) which travelers use to commute in the city of Yaoundé. $V_k$is a vector of K exogenous covariates associated to commuters decision to travel defined in Table 1; $\left(D_j \times Z_j\right)$ the interaction between the different urban motorized modes of transport and the distance-proxied by the daily number of travels of a given commuter; $\left(T_j \times Z_j\right)$the interaction between the different urban motorized modes of transport and the variable intensity-proxied by the frequency of using a given transport mode to cover the distance travelled by a commuter; α_k is a vector of K parameters for the explanatory variables; η_j (j=1,2) are the parameters of the different urban motorized modes of transport; ε is the error term under the assumption that $E(\varepsilon) = 0$; and $\alpha, \eta\ , \lambda, \delta\ and\ \xi$are parameters to be estimated.

4.2. Data

This study uses data from the 2020 Urban Displacement Strategy for Yaoundé collected in 2018. The objective of this survey was to collect information on travelers' behaviors related to traffic and commuting in the city of Yaoundé. Fifty-four out of one hundred principal sites were identified as counting points. About 1500 households and 5664 individuals above the age of six were interviewed. The origin-destination survey was conducted between the months of April and May 2018, with over 12 436 observations counted. For household's travel behaviors, the data was collected in the month of July 2018 (Yaoundé Urban council, 2020). The goal of carrying out surveys for households and individuals was to investigate socioeconomic dimensions associated with trips as well as cost analysis appended to the travel's modes and choices.

Table 1 outlines descriptive statistics for the different variables considered in this study. CO_2 emissions associated with trip-making decisions information is computed from the 2020 Yaoundé Urban Displacement Plan. To compute these values, the methodology adopted was defined using a bottom-top approach which combines the distance covered by the vehicle, the amount of fuel consumption based of factors like age, vehicle models, etc. and the emission levels of the type of fuel used by the vehicle (see Maatchebou (2014) and *Mobilise Your City* (2018) for detailed explanations).

Other covariates include the time spent by an individual to reach their destination, the average transport fare for travels, the number of travels per day of a given individual (daily trips), the frequency of using a given transport mode to travel, the different modal choices (walking, motorcycles, taxis, buses and other modes of transport) of travelers, the motives that instigate a commuter to effectuate a travel. To capture joint effects, we interact motorized urban modes with number of travels per day and the frequency of travels with the different urban transport modes urban dwellers use to commute.

Descriptive statistics suggest that average CO_2 emissions is 129 grams per kilometer. On average, a commuter spends about 25 minutes to get to their destination with the maximum duration being about 60 minutes. Commuters spend about 205 FCFA (0,37 US dollars) per travels. The average number of travels per day of a given urban dweller was about 1.2 trips per day. 26% of commuters used one of the modes of transport every day. Appraising the different motorized modes of transport, commuting by taxis reported the highest proportion (43%), followed by two-wheel vehicles and buses/minibuses. Regarding travel motives, 42% of households indicated the travel principally to return home with these households situated at the peripheries. 38% travel for economic motives and 18% for social motives.

Table 1: *Descriptive statistics for variables considered in this study*

Variables	N	Mean	Sd.	Min.	Max.
Carbon dioxide emissions for urban transport modes (in grams/km-annual average)	12,436	129.3	52.61	23.9	494.3
Log of Carbon dioxide emissions (in grams/km)	12,436	4.79	0.37	3.17	6.20
Time spent to get destination (in minutes)	12,436	24.17	15.78	0.00	59.00

Transport fares (in FCFA)	12,436	204.9	337.3	0.00	10,000
Number of travels per day	12,436	1.189	1.572	0.02	20.63
Number of travels per day squared	12,436	3.889	19.65	0.0003	425.6
High frequency use of an urbanized transport modes (1=daily and 0=otherwise)	12,436	0.26	0.44	0.00	1.00
Modal choices of urban travel					
Commuting by walking (1=yes and 0=otherwise)	12,436	0.28	0.45	0.00	1.00
Commuting by motorcycle (1=yes and 0=otherwise)	12,436	0.14	0.35	0.00	1.00
Commuting by taxi (1=yes and 0=otherwise)	12,436	0.43	0.49	0.00	1.00
Commuting by bus/minibus (1=yes and 0=otherwise)	12,436	0.05	0.21	0.00	1.00
Commuting by other modes (1=yes and 0=otherwise)	12,436	0.10	0.30	0.00	1.00
Motives for travelling/commuting					
Travels for economic motives (1=yes and 0=otherwise)	12,436	0.39	0.49	0.00	1.00
Travels for social motives (1=yes and 0=otherwise)	12,436	0.18	0.39	0.00	1.00
Travels-returning home (1=yes and 0=otherwise)	12,436	0.42	0.49	0.00	1.00
Interacting transport modes with number of travels-a proxy for distance					
Commuting by walking times number of travels per day	12,436	0.338	0.987	0.00	20.63

Commuting by motorcycle times number of travels per day	12,436	0.163	0.652	0.00	13.99
Commuting by taxi times number of travels per day	12,436	0.507	1.211	0.00	20.63
Commuting by bus/minibus times number of travels per day	12,436	0.058	0.500	0.00	20.63
Commuting by other modes times number of travels per day	12,436	0.121	0.594	0.00	20.63
Commuting by taxi times number of travels per day squared	12,436	1.725	13.87	0.00	425.6
Commuting by bus/minibus times number of travels per day squared	12,436	0.253	6.709	0.00	425.6
Interacting urbanized transport modes with frequency-use					
High frequency use of an urbanized transport modes times using a motorcycle to commute (1=yes and 0=otherwise)	12,436	0.03	0.17	0.00	1.00
High frequency use of an urbanized transport modes times using a taxi to commute (1=yes and 0=otherwise)	12,436	0.11	0.31	0.00	1.00
High frequency use of an urbanized transport modes times using a bus/minibus to commute (1=yes and 0=otherwise)	12,436	0.01	0.08	0.00	1.00

Source: *Computed by authors using data from the 2020 Yaoundé Urban Displacement Plan. Nota Bene: Sd.: standard deviation, Min.: minimum values, Max.: maximum values, Mean: averages for continuous variables and proportions for binary variables.*

5. EMPIRICAL RESULTS

Robust estimates of determinants of carbon dioxide emissions are reported in Table 2. Results show that the adjusted coefficient of determination was 0.74 and the model globally significant at a percentage point. We find a non-linear inverted U-shaped relationship between distance-proxied by the daily number of travels of a given urban dweller with CO_2 emissions.

By differentiating equation 1 with respect to daily trips, we obtain that the threshold number of trips is 10 travels per day. Thus, before this threshold pollution associated to daily trips increase albeit at a decreasing rate and vice versal beyond. Urban sprawl in the city of Yaoundé, reflected by distance travelled, has caused the development of poorly endowed (in terms of social and economic infrastructures) peripheries. This highlights that possible factors such a relatively high cost associated to average transport fares, when comparing average household revenues, may compel commuters undertaking more than ten trips to adopt fewer polluting modes like motorbikes/walking beyond a certain number of daily trips. Another possible observation is the change of modal choices during several trips where urban commuters opt to use more than one transport mode when undertaking a high number of daily travels for different motives.

***Table 2:** Determinants of Carbon dioxide emissions in the city of Yaoundé: Dependent Variable-Carbon dioxide emissions in grams per km*

Variables	Robust Ordinary Least Square estimates
Time spent to get destination (in minutes)	-0.0001
	(0.0001)
Transport fares (in FCFA) *10^2	0.004
	(0.005)
Daily number of travels of an urban dweller	0.380***
	(0.003)
Daily number of travels of an urban dweller squared	-0.019***
	(0.000)
High frequency use of an urbanized transport modes (1=daily and 0=otherwise)	0.012**
	(0.005)
Reference variable: Commuting by motorcycle or other modes of transport	
Commuting by taxi (1=yes and 0=otherwise)	0.033***
	(0.006)
Commuting by bus/minibus (1=yes and 0=otherwise)	0.059***
	(0.013)
Reference variable: Returning home	
Travels for economic or social motives (1=yes and 0=otherwise)	-0.004
	(0.003)

Interacting urban transport modes with number of travels-a proxy for distance	
Commuting by taxi times number of travels per day	-0.037***
	(0.005)
Commuting by taxi times number of travels per day squared	0.004***
	(0.000)
Commuting by bus/minibus times number of travels per day	-0.059***
	(0.010)
Commuting by bus/minibus times number of travels per day squared	0.006***
	(0.001)
Interacting urban transport modes with frequency-use	
High frequency use of an urbanized transport modes times commuting by taxi (1=yes and 0=otherwise)	-0.015*
	(0.008)
High frequency use of an urbanized transport modes times commuting by bus/minibus (1=yes and 0=otherwise)	0.005
	(0.024)
Constant	4.414***
	(0.005)
R-squared/ Adjusted R-squared	0.743/0.742
Fisher (k, n-k) [df.]	2560.24[0.000]
Number of observations	12,436

Source: *Computed by authors using data from the 2020 Yaoundé Urban Displacement Plan. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.*

The variable associated with the frequency of using one of the different urban modes of transport related positively and significantly with CO_2 emissions. These results are similar to Rodes et. al., (2014). Peng (1997) indicates that good equilibrium between inclusive urban infrastructure and adequate habitation for individuals living these areas, generates fewer polluting modes of transportation.

Considering urbanized transport modes, commuting by taxi and minibuses both significantly and positively relate to carbon dioxide emissions. The semi-elasticity of the CO_2-motorized modes relationship was two times higher for buses/minibuses when compared to taxis. This finding purport that while the modal share for taxi was about 40%, a percentage increase in CO_2 emissions associated with this urban transport mode was relatively lower than buses/minibuses. These findings are similar to studies by Howarth and Ryley (2015), and Ryley (2006) who indicate that behaviors associated with using a motorized mode of transports as preferred means of transport affect climate change.

Considering joint effect of motorized urban transport and daily trips, we observe a U-shaped relationship with CO_2 emissions. The threshold level for choosing to use a taxi or a bus/minibus to effectuate daily travels was four and a half trips for the former and five trips for the latter, respectively. Before, these thresholds, daily urban commuting related negatively with CO_2 emissions and vice versal. This suggest that above these number of trips, urban motorize modes increase carbon dioxide emissions for an additional daily trip. This non-linear relationship points to the need to appropriately define policies to mitigated the negative effect of the motorized urban modes dynamics-one of the main outcomes of urbanization, on climate change.

6. CONCLUSION AND POLICY RECOMMENDATION

This paper evaluated the effects of motorized urban transport mode on the production of CO_2 emission in Yaoundé. Results indicated the travel behavior of urban dwellers via the use of urban motorized transport modes associated to taxi and minibuses/buses increase CO_2 emissions with the latter having a higher effect that the former due to their old age and poor pollution reducing technologies. Furthermore, we find an inverted U-shaped relationship between distance covered by commuter-proxied by daily number of travels and CO_2 emissions on hand. On the other hand, this associated posted a U-shaped relationship for the joint effect of motorized urban transport and distance-proxied by the number of daily trips.

As policy suggestion, government should enact strategies that aim at decarbonizing urban motorized transports modes in the city of Yaoundé by: (1) encouraging the importation of newer vehicles that have technologies that reduce emissions through a malus and bonus framework for less polluting cars-especially old minibuses and taxis that cover highly solicited travels from the CBD to peripheries at peak commuting hours and (2) enforcing alternative mobility modes that have low carbon print like walking and cycling.

Regarding the set-up for less polluting car, governmental actions could be established on two fronts. First, the "car spare part sector" needs to be further regulated and curtailed because this sector perpetuates the usage of old vehicles because they don't buy new modern spare parts but rather disassemble old vehicles and sell their different parts, thereby perpetuating the use of these old vehicles. This, may stiffen upstream effort to encourage the importation of newer and less polluting vehicles. Secondly, government should identify an adequate incentivizing mechanism, especially on the financial front, by taxing polluting sectors of the economy to finance the malus and bonus framework-especially for old minibuses that commute from the CBD to urban peripheries at peak hours and also face traffic congestions in several urban routes. Simultaneously, enterprises that transform old vehicle scraps and use them as raw material for other activities should be incentivized.

Concerning, policies that encourage mobility modes that have low carbon, the principal focus at the level of urban governance should be to redesign of urban infrastructure to encore actives like walking and cycling. Urban amenities light street lighting, materializing cycling lanes, organize road pavements, among others, should be developed and dilapidated structures rehabilitated. To finance these actives, one of the main tools could be optimizing fees gotten from public parking spaces.

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