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Electric mobility promoted in Rwanda, environmental and economic impact on Kigali city

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Abstract
Kigali city is one of smart cities in Africa, guiding citizens to a clean orientation with low pollution emissions is a target of the city. Rwanda has intention to reduce the emissions through promoting E-mobility. This paper was intended to assess how ICE-users can shift to e-mobility, they understand the cost of a city to be smart, 64.5 % of respondents agreed to drive e-vehicles, 39.9 % of respondents interested to buy e-car but recommend that E-Mobility infrastructures such faster chargers should be available at low cost, 65% of respondents agreed that E-Mobility enable air quality improvement, 68% suggested on station allocation and 69% agreed that the system contribute to energy saving and noise reductions. Chi-square results indicated ICE – vehicle users will shift to electric cars.

Keywords: E-mobility, urban mobility, environment and economic sustainability

1. Introduction
Rwanda is depending on imports where 100% of fuel used in Rwanda is imported and transport cost is high due to fuel imported. Today Rwanda is promoting E-Mobility where electrical motorcycles, vehicles and bikes are in manufacturing in Rwanda to reduce the emissions and quantity of fuel consumptions (Sweco, 2019) [5].
The E-mobility avoids the use of fuel and promotes the decrease of carbon emissions in environment. Average price of fuel in Rwanda is 1.09 $ and the average vehicles in Kigali city was about 30,000 in 2018. Three companies Ampersand, Safi and Rwanda Electric mobility are targeting to contribute in implementation of this new system of E-Mobility.
Development of urban transport is increasing due to high increase of population in the Cities. Rwanda is targeting 35% of Rwandans to be in cities by 2030. Use of E-vehicles does not need any toxic materials to be manipulated (Gardiner, 2017). E-Mobility optimizes the consumption of fuel (Johnson, 2017). The city can be cooled down by 2oC due to a use of E-Mobility (Zielinski, 2015). The E-System contributes on city cleanness and quit (Gardiner, 2017), innovation in technology should be applied for the system to perform in relation with battery life span and cost (Köhler *et al*., 2009) [3]. The Charging infrastructures and their performance for battery electric vehicles should be provided around the city to meet the economy of scale (van Bree *et al*., 2010). The electric vehicles contribute on reduction of CO2-emissions only when the source of energy does not depend on combustion coals (Zimmer *et al*., 2011) [4]. The city of Kigali to be carbon neutral, the e-vehicles, moto, scooters and bikes have been manufactured and started to operate in the city (Ruud, 2019), Electric cars require few parts compared to combustion engine cars (Barthel *et al*. 2010). The study conducted in 2006 indicated that more that 20% of Co2 emissions produced in urban zones was from urban mobility (Schoemaker *et al*., 2006); the mileage consumed by combustion engine vehicles will be substituted by electrical and the government of Rwanda has targeted electric access at 100% by 2024 (Usaid, 2020).

2. Materials and Methodology
The materials in this paper are electrical vehicles, E-bikes and E-motors in Kigali city. The methodology used to collect data is on site observation and survey applied in different points of the city. The sample size was calculated based on city population with confidence level and tolerance amount to be 95% and 0.005 respectively. The population in Kigali city is 1,132,000 and the research decided to apply the survey to 1,132 persons grouped into three

groups: group of Combustion Engine vehicles (377 persons), group of motor taxis operators (377 persons) and group of bicycle riders (378 persons). During the evaluation of survey, SPSS and chi-square test was used with reliability rate of 0.001.

3. Research findings

Below research findings are based on site observations and survey study made at Kigali city on different points.

Fig 1: Road in Kigali (Original 2021)

Fig 2: Motorcycles in Kigali (Original 2021)

Fig 3: First e-vehicles in Rwanda (E-Golf)

Fig 4: Electric motorcycles (Ampersand)

3.1 Site observation

During observations, people of different ages were riding for fun in weekends, to works and to school in non-weekend days, most of bicycles in use were tradition bicycles and mount bikes, this indicated that once the manufactured E-Bikes increased to operate, the city will be smarter and quality of air will be high. There are more motorbikes in the city where in 15 minutes you count more than 400 motors at different position, this indicating that the use of E-motors will reduce the fuel used and emissions in air. Some stations for vehicles charging are in implementation so that vehicles will spend at least 30 minutes on charge to be full.

3.2 Survey findings

In order to prove how Rwandans in the city are intend to shift from old system of using combustions engine vehicles and motors to electric vehicles, some questions were prepared and answered, below are the tables indicating the results starting from E-bikes, E-Motors and E- vehicles.

3.2.1 Electric vehicles

Below analysis is based on how vehicle drivers intend to drive Electrical vehicles, 64.5 % of respondents were interested to drive electrical vehicles for business, 46.4% for work trips and 41.1% for other purpose. 58.9% of respondents were not interested for the use of E-vehicles. The City of Kigali should provide incentives for Electric vehicle drivers like free parking to increase the level of being chosen. Most of drivers who were not interested for e-vehicles driving were wondering on performance of battery for long distance and time taken waiting the car to be full charged, some charging stations should be provided around the city with less time for charging.

Table 1: Analysis based on car drivers' perception towards E-vehicles

Value	The city of Kigali is promoting E-mobility where E-cars are in operation in Kigali city, 2. How do you will to drive Electric cars?					
	Interested		Not Interested		Total	
	%	Quantity	%	Quantity	%	Quantity
Business	64.5	243	35.5	134	100.0	377
To work	46.4	186	53.6	215	100.0	401
Others	41.1	86	58.9	123	100.0	209

Below analysis is based on vehicle owners to shift from their habitually combustion engine vehicles toward electrical vehicles. The respondents interested for E-vehicles for business, to work and for other purpose were 37.9%, 23.6%and 11.4% respectively. On other hand the respondents not interested for business, to work and other purpose were 62.1%, 76.4% and 88.6% respectively. The level of shifting to a new system is low due to high cost of such vehicles (Lithium iron battery is very expensive), it will be hard for government to reduce taxes on such vehicles while on other side their use will decrease the fuel tax revenues more than 6 billion Rwandan Francs and electric tariff is high were the cost per Kilowatt-hour is about 27.7$ (Byiringiro 2020) [1]. A great number of respondents interested for business use; this is due to low travel consumption cost per km compared to fuel consumptions engines.

Table 2: Analysis based on vehicle owners to shift to e-cars

Value	The city of Kigali is promoting E-mobility where E-cars are in operation in Kigali city, 3. How do you will to buy an Electric car?					
	Interested		Not Interested		Total	
	%	Quantity	%	Quantity	%	Quantity
Business	37.9	143	62.1	234	100.0	377
To work	23.6	89	76.4	288	100.0	377
Others	11.4	43	88.6	334	100.0	377

3.2.2 Electric motors

Below results are based on Electric motors, all respondents on this issue is motor taxis operators in Kigali City, 62.3 % of respondents are frequently interested to use E-motors for business, 37.7 respondents are sometimes interested to use e-motors for other purpose and 37% will never interested. The operators willing to use e-motors for business purpose as they understand their use is economical. Ampersand reported that 100 Rwf currently is spend for 5km but on e-motors 100 Rwf is spend for 11km, this indicates that the use of e-motor generated more than double benefits compared to Ice–motors (ampersand, 2020). Battery swap station should be around the city so that no time to lose, in ampersand report, they stated that battery swap generates additional benefits to e-motor operators of 500$ yearly and the time taken for swap is less that time of fuel filling.

More than 30,000 Ice –motors are in operation in Kigali city, to achieve the green mobility, those motors should be converted to electric motors, and some incentives should be provided so that the action can be speeded up.

Table 3: Analysis based on electric motor

Value	The city of Kigali is promoting E-mobility where E-vehicles are in operation in the city, 4. For what purpose do you intend to use E- motors?							
	Frequently		Sometimes		Never		Total	
	%	Quantity	%	Quantity	%	Quantity	%	Quantity
Business	62.3	235	29.7	112	8.0	30	100.0	377
others	52.5	198	37.7	142	9.8	37	100.0	377

3.2.3 Electric Bikes

The analysis indicated that the purpose of traveling with Electric bikes is: 56.1% of the students frequently ride to school, 73.5 % ride for business purpose and 25.9% never ride to work. The culture of Rwanda gives a favor to cycle as bicycle sometimes is a tool not to miss in wedding arrangements, this make most Rwandans to know how to rise as most of every home has a bicycle. Business comes first with 73.5% as a bicycle is a tool for goods transport for short distance. The city is characterized by mountains; this will promote the use of e-bike as some times no energy required to move from one place to another place, even old people can enjoy the riding. There some research which indicated that riding a bicycle brought a happiness and on other hand fitness of people increases.

Table 4: Analysis based on trip purpose

Value	The city of Kigali is promoting E-mobility where E-bike are in operation in Kigali city, 1. For what purpose do you intend to ride E-Bike to contribute to the smartest of the City?							
	Frequently		Sometimes		Never		Total	
	%	Quantity	%	Quantity	%	Quantity	%	Quantity
Business	19.3	73	73.5	278	7.1	27	100.0	378
Shopping	22.0	83	66.9	253	11.1	42	100.0	378
Education	56.1	212	29.6	112	14.3	54	100.0	378
To work	17.2	65	56.9	215	25.9	98	100.0	378
Others	57.9	219	32.5	123	9.5	36	100.0	378

In city might be a decrease in use of ICE-mobility as the use of e-mobility is increasing in the same time charging infrastructures and e-mobility policies are in implimentation. The comparative analysis between e-mobility users and ICE-Users table below shows a strong significant relationship between e-mobility users and fuel users. The chi square results are x2 (1, N=4560) = 7.547 at p=0.001<0.05. E-mobility will cause ICE vehicles to decrease.

4. Conclusion and recommendation

For E-Mobility to be sustainable, some measures and

policies should be adopted. Some carrying capacity buses should be recommended for public operators and the city should dedicate the bus lane, some incentive should be provided to those interested for e-vehicles adopters like free parking and low tariff for vehicle charging. The battery is the one which make e-vehicles to be expensive, subsidies should be applied for a period of one year, vehicles importers should be recommended a percentage of e-vehicles to be imported at a specific period. Faster charging system should be provided so that time taken for charging should be optimized.

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