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Full Length Research Paper

Energy Assessment of e-Motorcycles as a Clean Transport Mode for Passenger Mobility: A Case of Ilala District, Dar es Salaam

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ABSTRACT

Electric motorcycles or e-motorcycles is a clean mode of road transport that present a prominent solution toward decarbonizing cities. Despite of e-motorcycles being cleaner than gasoline ones, at the moment, there is missing information whether it is feasible to replace gasoline motorcycles with e-motorcycles used for business transport purposes. This paper, therefore, presents the results comparing energy usage when using e-motorcycles and when using the gasoline motorcycles. The energy demand for driving passengers using an e-motorcycle in the precarious routes originated from Gongo la Mboto bus stop to Segerea bus stop, Buguruni Malapa, Gerezani bus stop, Kivukoni bus stop, and Buza bus stop has been estimated. In each route, the energy has been estimated in one and four round-trips. The results reveal that the brushless direct current motor (BLDC) rated 2.5 kW is suitable for driving two passengers while consuming about 0.05 kWh/km at 50 km/h for the distance of 36 km. Increase in route length exhibit the uptrend in total energy required (E_{total}). The maximum E_{total} for one and four round-trips are 2.5 kWh and 10.0 kWh, respectively, for a route of 36 km length. Considering the energy demand of 2.5 kWh for one round-trip of 36 km, a battery pack of 45 Ah 60 V is found suitable to power the e-motorcycle per charge without compromising the design in terms of weight and size. Consequently, this yields to a saving of about 6.4 kWh, which is around 72 % of the energy that could be used by its gasoline counterpart. This means an e-motorcycle of this power rating could save 0.18 kWh/km, equivalent to 0.02 L/km. Moreover, e-motorcycle could cost 24.3 Tsh/km compared to 754.8 Tsh/km for its gasoline counterpart, and save around 97 % of the fuel cost. These results indicate that an e-motorcycle can outperform its gasoline counterpart. These findings play vital roles in designing energy storage systems and charging infrastructure that could offer a reliable service to end-users and assist to accelerate e-motorcycle adoption.

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INTRODUCTION

Traditional motorcycles are the common mode of passenger mobility in many of the world cities that operates as a low-cost transport and fills an important niche in the public transportation system (Koossalapeerom et al., 2019). On the other hand, traditional motorcycles play a vital role on roads where public transport finds it difficult to reach by providing first and last-mile connectivity to public transport such as suburban and metro railways and regional bus services as affordable and time-saving mobility options (Greyson et al., 2021a). However, the growing concerns over urban air pollution (Borén, 2020; Gerutu et al., 2021), world mega cities have introduced electric vehicles (Mohamed et al., 2021; Chombo et al., 2021) especially electric motorcycles (e-motorcycles) (Koossalapeerom et al., 2019) owing to no tailpipe emissions during driving, less noise (Borén, 2020) and smooth driving. However, for the e-motorcycle to successfully operate in the city, an accurate energy demand needs to be estimated.

A few years ago, efforts have been made to accurately estimate energy demand for powering e-motorcycles plying under varied conditions. Koossalapeerom et al. (2019) compared the energy consumption of a 1 kW e-motorcycle and 108 cc gasoline motorcycle under real-world driving condition in Khon Kaen city, Thailand. Their findings showed an energy consumption of 35.96 km/kWh and 4.38 km/kWh for electric and gasoline motorcycle, respectively. Tuayharn et al. (2015) conducted a chassis dynamometer test with a simulated load in the laboratory found that the energy consumption of electric and gasoline motorcycles is 2.5 kWh/100 km and 18 kWh/100 km, respectively. Xuan, et al., (2013) compared an energy consumption of conventional internal combustion engine (ICE) sports motorcycle Honda CBR400RR and converted battery-powered electric one. Their results showed a life cycle energy reduction of 72 % for the converted battery-powered electric one. Kammuang-lue, Pattana, and Wiratkasem, (2020) tested 37 e-motorcycles having maximum propulsion power ranging from 0.24 to 7.0 kW at the maximum speed ranging from 20 to 120 km/h using chassis dynamometer by following the ECE R47 and World Harmonized Motorcycle Test Cycle (WMTC). They revealed an energy performance standard ranging between 0.020 to 0.057 kWh/km. Asaei and Habibidoost (2013) converted a 125 cc ICE motorcycle to hybrid e-motorcycle by using a brushless direct current motor in the front wheel as an auxiliary propellant. With nominal powers of 6.6 kW and 500 W for the ICE and BLDC respectively, the fuel consumption was decreased by 22%. Farzaneh and Farjah (2018) reported a reduction in energy consumption from 0.038 to 0.012 kWh when using an e-motorcycle. Despite the fact that e-motorcycle could have a great energy saving but most of those studied were designed for private use such as office or sport uses. The energy saving of e-motorcycles used for passenger mobility is rarely studied. Thus, for widespread adoption of passenger carrying e-motorcycle, estimation of energy demand become crucial.

Therefore, the main goal of this study is to assess the energy demand of an e-motorcycle used for passenger mobility in Ilala district, Dar es Salaam region. The focus is on sizing an appropriate e-motorcycle motor and battery pack with extensive assessments on energy consumption, total energy, and energy saving. The findings are expected to contribute more knowledge on the energy demand required for the adoption of e-motorcycle for passenger mobility in Tanzania as compared to the use of gasoline motorcycles.

METHODS AND MATERIALS

Description of study Area

The study is performed in Dar es Salaam city. This city has been selected as one of the country's areas having high demand in road transportation. For the purpose of assessing the energy demand for passenger mobility, the study was conducted in some selected routes in Gongo la Mboto area, located within Ilala district. The reason of choosing Gongo la Mboto area at Ilala district for performing this study is due to the ample of residential areas and passengers plying to the city center, shopping malls, offices, schools, markets and regional bus terminals via interconnection with city buses, bus rapid transit, metropolitan railway and regional bus services. The energy requirement for passenger mobility at the targeted area is estimated from Gongo la Mboto bus stop to Segerea bus stop, Buguruni Malapa, Gerezani bus stop, Kivukoni bus stop, and Buza bus stop. The referred bus stops can be seen on google map as presented in Fig. 1 and their average mileages are indicated in Table 1. The estimated one-way distance in each route were used in sizing and analyzing the performance of the e-motorcycle.

Table 1: One-way average distance of routes in the study area

Route description	Route name	One-way distance (km)
Gongo la Mboto to Segerea bus stop	Route 1	15.8
Gongo la Mboto to Buguruni Malapa bus stop	Route 2	13.0
Gongo la Mboto to Gerezani bus stop	Route 3	15.0
Gongo la Mboto to Kivukoni bus stop	Route 4	18.0
Gongo la Mboto to Buza bus stop	Route 5	13.0

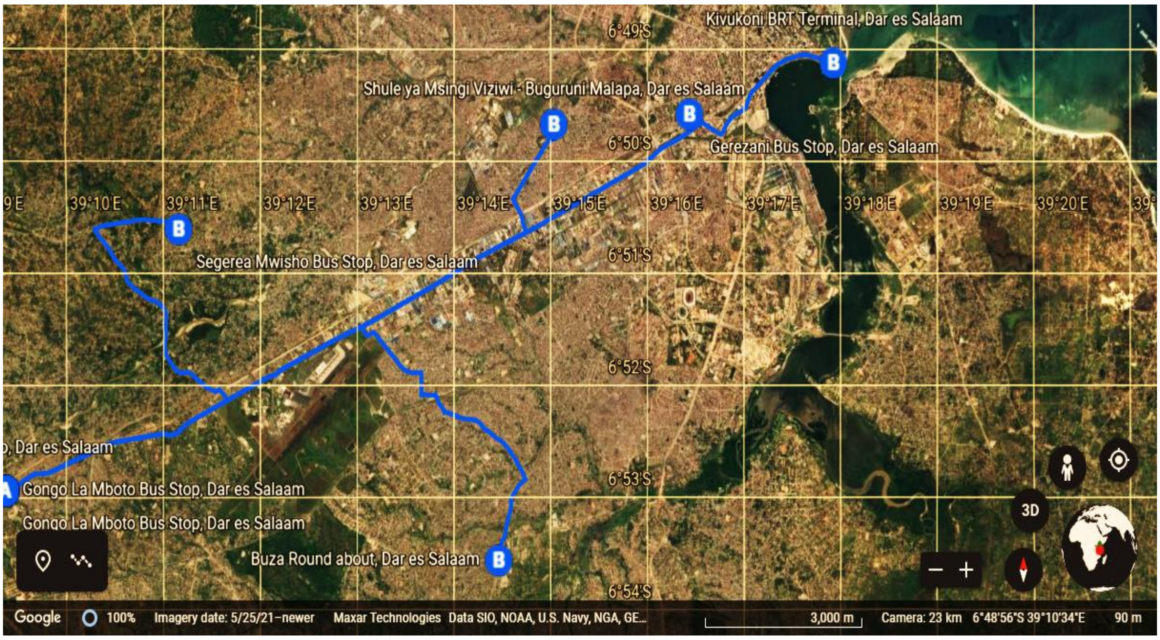

Figure 1: The routes under the study area of Gongo la Mboto, Ilala district, Dar es Salaam region.

Power Requirement of the e-motorcycle

The power required to move the e-motorcycle needs to overcome all the resisting forces acting on it. The resisting forces include aerodynamic force (F_{aero}), inertial force (F_g) and frictional force (F_{RR}) as shown in Fig. 2. F_{aero} accounts the resistance due to the wind as shown in Eqn. (1), F_g for the total weight (dead weight and payload weight) as shown in Eqn. (2), and F_{RR} for the friction between wheels and road as shown in Eqn. (3). The tractive force (F_{tr}) is a resultant force that overcomes all the resisting forces and move the e-motorcycle, and is expressed in Eqn. (4). The resultant mechanical power (P) and torque (T) are given in Eqns. (5) and (6) (Greyson et al., 2021b), respectively.

$$F_{aero} = \frac{1}{2} A_f C_D \rho_{air} \left(V_d - V_w\right)^2 \tag{1}$$

$$F_g = (m_d + m_p) g \sin\left(\theta\right) = Mg \sin\left(\theta\right) \tag{2}$$

$$F_{RR} = (m_d + m_p) g C_{RR} \cos\left(\theta\right) = Mg C_{RR} \cos\left(\theta\right) \tag{3}$$

$$F_{tr} = F_{aero} + F_g + F_{RR} \tag{4}$$

$$P = F_{tr} \times V_d \tag{5}$$

$$T = \frac{P}{\omega} = \frac{60 \times P}{2\pi N} \tag{6}$$

where A_f is the front area of the e-motorcycle (m^2), C_D is the drag coefficient due to air, ρ is the density of air (kg/m^3), V_d is the longitudinal velocity of the e-motorcycle (m/s), V_w is the mean wind velocity (m/s), M is the of sum of dead weight and payload weight of the e-motorcycle (kg), g is the force of gravity (m/s^2), θ is the road angle (degree), C_{RR} is the frictional coefficient between tires of the e-motorcycle and road, and N is the maximum powertrain speed (rpm).

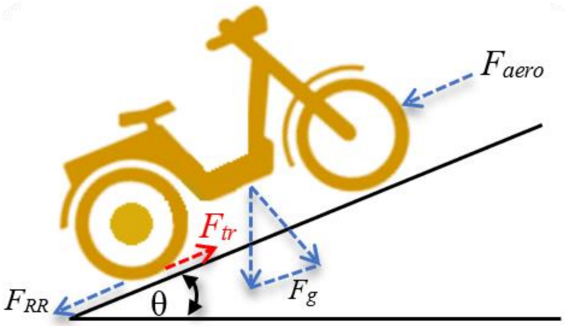

Figure 2: Resisting forces acting on an e-motorcycle.

Table 2 shows the maximum values used in the computation of power required to propel the e-motorcycle. The energy consumed per kilometre, usable energy required to cover only the distance of route i, and total energy required to cover the distance of route i plus the small portion of energy remained in the battery of the e-motorcycle are expressed in Eqns. (7) – (10) (Greyson et al., 2021b).

Table 2: Maximum values of system parameters

Parameters	Abbreviation	Unit	Values	Ref
Dead weight	m_d	kg	60.00 [a]	Greyson et al. (2021b)
Payload weight	m_p	kg	240.0 [b]	This study
Total weight	M	kg	300.0 [c]	This study
Road angle	θ	º	3.40	This study
Air density	ρ	kg/m^3	1.29	Greyson et al. (2021b)
Drag coefficient	C_D	-	0.60	
Frontal area	A_f	m^2	0.50	
Gravitational force	g	m/s^2	9.81	Greyson et al. (2021b)
Driving velocity	V_d	km/h	50.0	
Coefficient of friction	C_R	-	0.48	

[a] The dry weight of a motorcycle without an engine, but including an electric motor and battery
[b] An average weight of two passengers and driver, each having 80 kg
[c] A sum of dead weight and payload weight

$$E_{cons} = \frac{P}{V_d} \quad (7)$$

$$E_{usable} = E_{cons} \times d \quad (8)$$

$$E_{total} = E_{usable} \times DoD \quad (9)$$

where E_{cons} is the energy consumption of the motor (kWh/km), E_{usable} is the usable energy required to cover only the distance of route *i*, (kWh), E_{total} is the total energy required for plying in a route *i* plus the energy remained in the storage system to account for its safety (kWh), *DoD* is the depth of discharge of the energy storage system (typically 20% state of charge or 1.25).

Energy Saving

The energy saving is considered as a difference in energy when using an e-motorcycle and a gasoline motorcycle plying in the same distance as shown in Eqn. (10). For this case, the energy content of gasoline fuel used in a traditional motorcycle is converted to its electricity equivalent before computation. The conversion factor for a liter of gasoline to electricity is considered to 8.9 kWh/L (Natural Resource Canada, 2022). The obtained difference is considered as an energy that could be saved by using an e-motorcycle.

$$e_{sav.} = e_{e-mot.} - e_{trad-m.} \quad (10)$$

where e_{sav} is the energy saving when shifting from using a gasoline motorcycle to an e-motorcycle (kWh), e_{e-mot} is the energy used when plying using an e-motorcycle (kWh) and e_{trad-m} is the energy used when plying using a traditional motorcycle (kWh).

RESULTS AND DISCUSSIONS

Power Requirement

From Eqn. (5), the computed tractive power (P) required to carry the payload (two passengers of 80 kg each) of 160 kg is about 2.48 kW. In the advancement of technologies, various kinds of the electric motor are available in the market such as direct current (DC) series motor, permanent magnet synchronous motor (PMSM), three phase induction motor (IM), switched reluctance, and brushless direct current motor (BLDC). Hence, choosing an appropriate electric motor to meet the drive requirement of a particular vehicle becomes prominent. A DC series motor produces high starting torque but draws less current and power (Gupta, 2014). However, challenges such as poor speed regulation, reduced lifespan, high electric noise and loading before operation make it not fit for EV propulsion. Three phase IM particularly squirrel cage type has simple construction, self-starting, robust, low maintenance cost and can operate in dirty environments (Gupta, 2014). Their main weaknesses include serious lagging power factor, increased losses, low efficiency, invariable speed and difficult to control (Chan & Wong, 2004). The PMSM has high efficiency, torque, precision, small size, and low losses, but they are costlier compared to other types (Gupta, 2014). BLDC is attributed by long life, high starting torque, no-load speed, efficiency and volume to weight ratio, low loss, less space, and compact size (Greyson et al., 2021b; Mhaske & Dhande, 2015; Boccaletti et al., 2008; Texas Instruments, 2014). In this work, a three-phase BLDC motor known as rear wheel hub motor was found appropriate for the e-motorcycle applications. From the calculated tractive power of 2.48 kW, the standard value of 2.5 kW is chosen for further energy analyses.

Energy Demand of an e-motorcycle

The energy demand is estimated based on the selected standard motor size of an e-motorcycle and route distances presented in Table 1. To further understand the consumption characteristics of an e-motorcycle, two scenarios were made: i) energy consumed in one round-trip, and ii) energy consumed in four round-trip. These scenarios were made to understand their implications on the battery size to be incorporated in the e-motorcycle.

The E_{cons}, E_{usable}, and E_{total} were computed based on Eqns. (7) to (9). Table 3 shows the summary of daily energy demand of an e-motorcycle. It is shown that the BLDC of 2.5 kW consumes almost 0.05 kWh/km when driven at a speed of 50 km/h, regardless of the route length and number of trips per day. In case of E_{usable}, the maximum of 2.0 kWh and 8.0 kWh for one and four round-trips, respectively, per day can be used. The obtained maximum values are based on the maximum route length of 18.0 km (from Gongo la Mboto to Kivukoni), indicating that more energy is required in longer routes than shorter ones.

This signifies that route length is the main factor that affects the energy requirement of an e-motorcycle. The E_{usable} can satisfy the energy demand for driving in a certain route. However, it ends on no energy remained in the battery, which in-turn can damage cells and shorten the lifespan of the battery. Thus, it is necessary to rely on the E_{total} which accounts for the allowable *DoD* for achieving two-fold advantages: satisfying end-users and sustaining the battery life. From Table 3, the maximum E_{total} for one and four round-trip are 2.5 kWh and 10.0 kWh for a route length of 36 km. The comparison of energy demand for driving the e-motorcycle at different routes for one and four round-trips is shown in Fig. 3. Note that, the round-trip distance shown on the secondary y-axis of Fig. 3 is for one round-trip. In case of four round-trip, it should be multiplied by four.

Table 3: Daily energy demand of a passenger e-motorcycle in one and four round-trips

Route name	One round-trip			Four round-trip		
	E_{cons} (kWh/km)	E_{usable} (kWh)	E_{total} (kWh)	E_{cons} (kWh/km)	E_{usable} (kWh)	E_{total} (kWh)
Route 1	0.05	1.76	2.20	0.05	7.04	8.80
Route 2	0.05	1.44	1.80	0.05	5.76	7.20
Route 3	0.05	1.67	2.09	0.05	6.68	8.33
Route 4	0.05	2.00	2.50	0.05	8.00	10.0
Route 5	0.05	1.44	1.80	0.05	5.67	7.22

A round-trip distance for each route is considered to compute E_{cons}
The DoD of 20% or 1.25 is considered in E_{total}

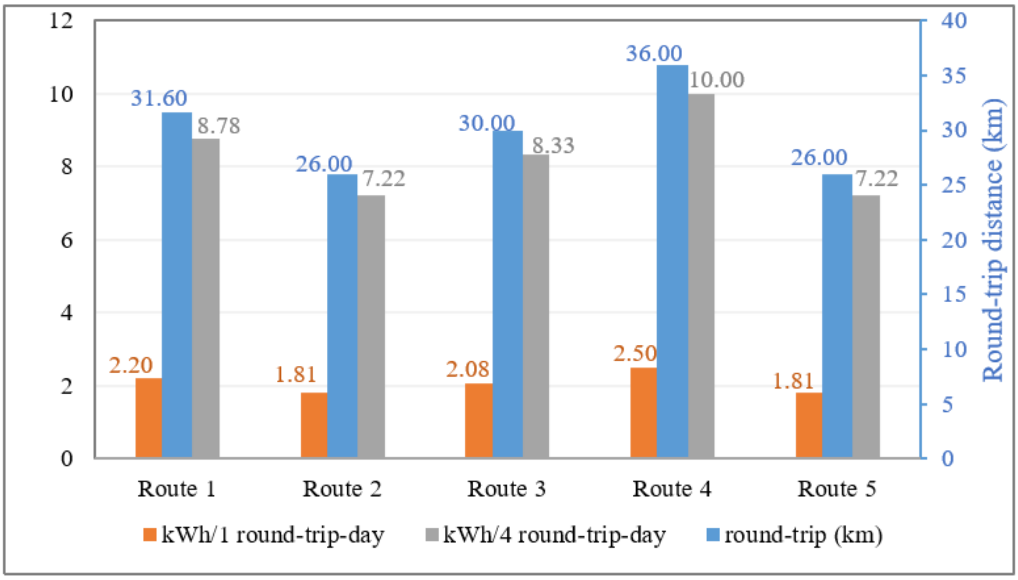

Figure 3: Comparison of energy demand for one and four round-trips at different routes.

Sizing a Battery for an e-motorcycle

The E_{total} accounts for the *DoD* required to maintain the safety of the battery. Therefore, E_{total} of 10 kWh could allow plying almost 144 km (four round-trips from Gongo la Mboto bus stop to Kivukoni bus stop) per day. With a motor working voltage of 60 V, the battery capacity of 10 kWh/60 V = 166.67 Ah could be able to drive the e-motorcycle in four round-trips a day. This battery capacity is equivalent to two 100 Ah $LiFePO_4$ Lithium-ion batteries having 40 kg each and size of about 420×360×195mm (AliExpress, 2022a). When opting for Lead acid battery, the weight could be slightly lower but larger in size. In this case, plying four round-trips for one charge could lead to the complicated design on the battery pack.

By considering charging in every one round-trip, a maximum E_{total} of 2.5 kWh would be required to drive the e-motor cycle from Gongo la Mboto to Kivukoni. With a motor working voltage of 60 V, the battery capacity of 2.5 kWh/60 V = 41.67 Ah could be able to drive the e-motor cycle for 36 km. This capacity is equivalent to one 45 Ah 60 V Lithium-ion battery having 11.5 kg and size of 146×165×254 mm (AliExpress, 2022b).

When opting for Lead acid battery, five N50 12 V batteries would be required to deliver a working voltage of 60 V, which in-turn increases weight and size. To date, Lithium-ion batteries have become the most popular source of energy in electric vehicle owing to the superior attributes such as higher current, voltage, power and energy density (Mohamed et al., 2022; Chombo & Laoonual, 2020; Peng et al., 2020), reduced cost, weight, excellent stability, low self-discharge rate and prolonged life cycle (Peng et al., 2020; Chombo & Laoonual, 2020; Chombo & Laoonual, 2022a; Quintiere, 2020; Chombo & Laoonual, 2022b). These attributes make Lithium-ion battery useful in propelling electric vehicles. Therefore, a 45 Ah 60 V Lithium-ion battery could be the right choice.

Energy Saving

When comparing with the traditional motorcycle having 125 cc (commonly used in the streets of Dar es Salaam), the fuel of 1 litre could be used for plying approximately (say 35 km/L x 1 L) 35 km. This distance is equivalent to one round-trip (Gongo la Mboto to Kivukoni and back) on e-motorcycle. This 1 L of gasoline fuel is equivalent to (1 L x 8.9 kWh/L) of electricity. Alternatively, the traditional motorcycle can consume about (8.9 kWh/36 km) 0.25 kWh/km. This amount is cross to that reported by Ruensumruay et al. (2016) of which a 5-year-old 125 cc gasoline motorcycle was consuming around 0.32 kWh/km. From Table 3, route 4 has a round-trip distance of 36 km and requires an Etotal of 2.5 kWh. Comparatively, e-motorcycle would save approximately 6.4 kWh. The energy saving is about 2.56 times the energy used in one round-trip with an e-motorcycle. This means that, the energy saved could to ply more two round-trips.

In the other words, plying with e-motorcycle could save around 72 % of the energy that could be used by the traditional motorcycle instead. Similar results were obtained by Ruensumruay et al. (2016) where the energy saving of an e-motorcycle reached 90 %. This is to say, the-motorcycle of this power rating (2.5 kW) could save around (6.4 kWh/36 km) 0.18 kWh/km, equivalent to (0.18 kWh/km ÷ 8.9 kWh/L) 0.02 L/km or 0.72 L/36 km which indicates a huge potential on energy saving when adopting in a large scale (in a large number of e-motorcycles).

Table 4 shows the summary of energy and fuel cost saved by plying with e-motorcycle. As shown in Table 4, the fuel costs are of October 24, 2022 with reference in Dar es Salaam region. The Table displays that e-motorcycle would cost around 24.3 Tsh per kilometer compared to 754.8 Tsh per kilometer for its gasoline counterpart. The fuel cost saving reaches to 97 %, indicating a huge potential on benefiting e-motorcycle users.

Table 4: Summary of energy and cost savings of an e-motorcycle

Type of motorcycle	e-motorcycle	gasoline powered motorcycle
Fuel used	electricity	gasoline
Measuring unit	kWh	L
Unit equivalence	Energy content: 1 kWh	Energy content: 8.9 kWh/L
	For 35 km: 2.5 kWh	~ 1 L × 8.9 kWh/L = 8.9 kWh
Fuel cost (Tsh per unit)	350 Tsh/kWh[a]	3,019 Tsh/L[b]
Mileage (km/unit of fuel)	36 km / 2.5 kWh = 14.4 km/kWh	35 km / 8.9 kWh = 4.0 km/kWh
Operating cost per km (Tsh/km)	350 Tsh/kWh / 14.4 km/kWh = 24.3 Tsh/km	3,019 Tsh/L / 4.0 km/kWh = 754.8 Tsh/km
Energy saving for 35 km	8.9 kWh - 2.5 kWh = 6.4 kWh	
Energy saving per km	6.4 kWh / 36 km = 0.18 kWh	
Fuel cost saving (Tsh/km)	754.8 – 24.3 = 730.5 Tsh/km	
Percentage of energy saving (%)	(6.4 / 8.9) × 100 = 72%	
Percentage of fuel cost saving (%)	(730.5 / 754.8) × 100 = 97%	

[a]The unit cost of electricity is as of October 2022 (TANESCO, 2022).
[b]The gasoline price per litre in Dar-es-Salaam as on 5 October 2022 (EWURA, 2022).

CONCLUSION

In this work, energy demand for driving passengers using an electric motorcycle (e-motorcycle) from Gongo la Mboto bus stop to Segerea bus stop (15.8 km), Buguruni Malapa (13.0 km), Gerezani bus stop (15.0 km), Kivukoni bus stop (18.0 km), and Buza bus stop (13.0 km) is estimated. The results showed that the brushless direct current motor (BLDC) rated 2.5 kW is suitable for driving two passengers while consuming about 0.05 kWh/km when driven at a speed of 50 km/h. The maximum total energy (E_{total}) for one and four round-trip are 2.5 kWh and 10.0 kWh, respectively, which depends on route length. For the case of energy storage, a battery pack of 45 Ah 60 V is found to be able to power the e-motorcycle for one round-trip of 36 km per charge without compromising the design in terms of weight and size. As a result, an e-motorcycle could ply about 36 km with 2.5 kWh and save approximately 6.4 kWh, which is around 72 % of the energy that could be used by the traditional motorcycle instead. On the other side, e-motorcycle is found to save around 24.3 Tsh per kilometer compared to 754.8 Tsh/km for its gasoline counterpart. The fuel cost saving reaches to 97 %, indicating a huge potential on benefiting e-motorcycle users. The findings of this work can be used on understanding the energy demand required for mobility, developing charging infrastructure and offering reliable service to end-users, which can assist to accelerate e-motorcycle adoption.

DECLARATION OF COMPETING INTEREST

The authors declared that there have no any relations that appeared to the inspiration of this work.

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REFERENCES

AliExpress. (2022a). LiFePO$_4$ battery. https://www.aliexpress.com/item/1005001600630907.html [Accessed on 1 October 2022]

AliExpress. (2022b). 60 V 45 Ah 50 Ah battery. https://www.aliexpress.com/item/4000299023463 .html [Accessed on 1 October 2022]

Boccaletti, C., Duni, G., Petrucci, P., & Santini, E. (2008). **6**: 349-353. DOI: 10.24084/repqj06.296

Borén, S. (2020). Electric buses' sustainability effects, noise, energy use, and costs. *International Journal of Sustainable Transportation*, **14**(12): 956-971.

Chan, C.C. & Wong, Y. S. (2004). The state of the art of electric vehicles technology. The 4th International Power Electronics and Motion Control Conference, IPEMC 2004., 2004, pp. 46-57.

Chombo, P. V., & Laoonual, Y. (2020). A review of safety strategies of a Li-ion battery. Journal of Power Sources, 478, 228649.

Chombo, P. V., & Laoonual, Y. (2022a). Quantification of heat energy leading to failure of 18650 lithium-ion battery abused by external heating. *Journal of Loss Prevention in the Process Industries*, *79*, 104855.

Chombo, P. V., & Laoonual, Y. (2022b). Prediction of the onset of thermal runaway and its thermal hazards in 18650 lithium-ion battery abused by external heating. *Fire Safety Journal*, **129:** 103560.

Chombo, P.V., Laoonual, Y., & Wongwises, S. (2021). Lessons from the electric vehicle crashworthiness leading to battery fire. *Energies*, **14**(16): 4802.

EWURA. (2022). https://www.ewura.go.tz/wp-content/uploads/2022/10/Cap-Prices-for-Petroleum-Products-wef-5-October-2022-Kiswahili.pdf [accessed on 24 October 2022]

Farzaneh, A., Farjah, E. (2018). Analysis of Road Curvature's Effects on Electric Motorcycle Energy Consumption. Energy **151:** 160–166

Gerutu, G.B., Mohamed, C.H., & Chombo, P.V. (2021). Transition to Compressed Natural Gas Rickshaws for Urban Mobility: a case of Dar es Salaam city. *Journal of Logistics, Management and Engineering Sciences*, **3**(2): 81-87.

Greyson, K.A., Gerutu, G.B., Bobi, S. & Chombo, P.V (2021a). Exploring the potential of compressed natural gas as a sustainable fuel for rickshaw: A case study of Dar es Salaam. *Journal of Natural Gas Science and Engineering*, **96**: 104273.

Greyson KA, Gerutu GB, Mohamed C.H., & Chombo PV. (2021b). Exploring the adoption of e-bicycle for student mobility in rural and urban areas of Tanzania. *Sustainable Energy Technologies Assessment*, **45**: 101206.

Gupta, J.B. "Theory and Performance of Electrical Machines", S.K. Kataria and sons, 2014.

Kammuang-lue, N., Pattana, S., and Wiratkasem, K. (2020). Draft of the MEPS and HEPS for two-wheel electric motorcycles in Thailand. Energy Reports, 6, 851-855.

Koossalapeerom, T., Satiennam, T., Satiennam, W., Leelapatra, W., Seedam, A. & Rakpukdee, T. (2019). Comparative study of real-world driving cycles, energy consumption, and CO_2 emissions of electric and gasoline motorcycles driving in a congested urban corridor. *Sustainable cities and society*, **45:** 619-627.

Mhaske, V. A. and Dhande, K. K. (2015). Design of electric drive for one-wheeled motorcycle. *International Engineering Research Journal*, 545-548: http://www.ierjournal.org/pupload/mitpgcon/MD2-106.pdf

Mohamed, C.H., Chombo, P. V., Laoonual, Y., & Wongwises, S. (2022). An Electrothermal Model to Predict Thermal Characteristics of Lithium-Ion Battery under Overcharge Condition. *Energies*, **15**(6): 2284.

Mohamed, C.H., Gerutu, G.B., & Chombo, P.V. (2021). Risk assessment for battery electric vehicles' occupants during fire accident. *Journal of Logistics, Management and Engineering Sciences*, **3**(2): 1-10.

Natural Resource Canada. (2022). Understanding the tables. https://www.nrcan.gc.ca/energy-efficiency/transportation-alternative-fuels/personal-vehicles/choosing-right-vehicle/buying-electric-vehicle/understanding-the-tables/21383 [accessed on 24 October 2022]

Peng, Y., Yang, L., Ju, X., Liao, B., Ye, K., Li, L., Cao, B., & Ni, Y. (2020). A comprehensive investigation on the thermal and toxic hazards of large format lithium-ion batteries with LiFePO4 cathode. *Journal of hazardous materials*, **381**: 120916.

Quintiere, J.G. (2020). On methods to measure the energetics of a lithium-ion battery in thermal runaway, *Fire Safety Journal*, **111:** 102911.

Ruensumruay, S., Pattaraprakorn, W., Chutiprapat V., and Bhasaputra, P. (2016). The study on the effect of electric motorcycle to energy consumption in Thailand, 13th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), pp. 1-4, doi: 10.1109/ECTICon.2016.7561407.

TANESCO. (2022). Tariffs. https://tanesco.co.tz/index.php/media1/downloads/tariffs/7-bei-za-umeme-zilizoidhinishwa [accessed on 24 October 2022]

Texas Instruments. Hardware Design Considerations for an Electric Bicycle Using a BLDC Motor, A*pplication Repor*t, pp. 3, 2014.

Tuayharn, K., Kaewtatip, P., Ruangjirakit, K., & Limthongkul, P. (2015). ICE Motorcycle and Electric Motorcycle: Environmental and Economic Analysis, SAE Technical Paper 2015-01-0100, 109-114.

Xuan, P. Y., Henz, M., & Weigl, J. D. (2013). Environmental impact of converted electrical motorcycle. *World Electric Vehicle Journal*, **6**(4), 1136-1143