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Benefits of Electric Motorcycle in Improving Personal Sustainable Economy: A View from Indonesia Online Ride-Hailing Rider

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Abstract. The energy cost of electric vehicles is reportedly less than its internal combustion engine counterpart due to using technologies to boost efficiency through regenerative braking. Based on this condition, a possibility of its implementation as vehicles in ride-sharing applications is observed. Therefore, this study aims to analyze the benefits of electric vehicle implementation to ride-sharing platforms in Indonesia. An electric motorcycle was used in this study as a vehicle for daily ride-sharing activities. In addition, the rider often used an internal combustion engine motorcycle. The study focused on the economic benefits obtained by the rider through swapping the ICE motorcycle with an electric scooter. Also, it used observation data for two months by utilizing electric motorcycles. Before using this vehicle, a comparison was additionally conducted based on the amount of money received by the rider. Furthermore, potential drawbacks were considered, such as battery charging durations and range of travel per day. The questions in this study included the following, "Are there any compromises that should be conducted by the rider to use the electric motorcycle for ride-hailing purposes?". Therefore, the results obtained in this study are expected to provide answers to these questions. Based on the data comparisons, a rider saved up to 68% of their income by using an electric motorcycle, compared to an ICE vehicle. It was also found to be similarly practical as the ICE counterpart for ride-hailing. Moreover, the electric motorcycle effectively served the customers' requirements as conducted by the ICE vehicle regarding orders and trips traveled. To further enhance the benefits of economic riders, a battery swap station should be readily available to prevent charging for 3-4 hours. By utilizing this station, the personal productivity of the electric motorcycle increased to 100%. Therefore, electric motorcycles successfully met the expected standards by creating substantial unique economic benefits and providing a more environmentally friendly vehicle without any losses. Th study was used as evidence for those interested in adopting the electric motorcycle to improve personal economic benefits. The government also used it to set up momentum to accelerate electric motorcycle adoption in Indonesia.

Keywords: Electric motorcycles; Electric vehicles; Environmentally friendly; Ride-hailing applications; Sustainable economic development

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1. Introduction

Motorcycle ride-sharing is gaining more popularity in Indonesia due to being a significant innovation in the transport sector. The companies that own the applications has also successfully become the first Indonesian unicorn organization, with an estimated $10 billion in 2020 (KrASIA, 2020). The reason is raid-hailing companies have attracted more than 2 million drivers/riders across the country (Setiawan, 2019). The company's contribution to the Indonesian economy is a staggering IDR 104.6 trillion (CNN Indonesia, 2020), 1% of the country's gross domestic income. A survey conducted by the University of Indonesia showed that the company's impacts on the economic benefits of its drivers/riders were significant (Lembaga Demografi, 2018). The survey was based on improving their quality of life through a substantial increase in income. Although ride-hailing created positive benefits for the involved parties, it also caused several environmental hazards (Anair *et al.,* 2020) due to mileage and air pollution created by its internal combustion engine. Based on the report of the company in 2018 (Kumparan, 2018), the total distance covered by its drivers/riders in Indonesia was 4.4 billion km. When converted to carbon equivalent pollution according to carbonfootprint.com (Carbon Footprint Calculator, 2021), its footprint was estimated to be 365,464 metric tons of CO_2-equivalent, which was terrible for the environment. Furthermore, several studies have also been conducted to reduce the air pollution caused by the ride-sharing/hailing scheme (Thaithatkul *et al.,* 2021; Sheth and Sarkar, 2019; Zulkarnain *et al.,* 2012).

Anair *et al.* (2020) elaborated that the ride-hailing industry was one of the concerns regarding climate change risk. This organization is presently responsible for 69% of the increase in air pollution within the U.S. Based on this condition, suggestions state that the U.S. ride-hailing industries should implement electric vehicles (electric passenger cars) in the future. Furthermore, Hall *et al.* suggested a framework for cities interested in implementing electric vehicles, with the configuration of the ride-hailing sector being prioritized (Bernar, Hall, and Nicholas, 2021). Although this reduces the current Green House Gas (GHG) emission, it also promotes the global acceleration of adopting E.V.s in the cities. The study by Hunt and McKearnan (2020) also outlined the challenges, benefits, and options to be considered by any state in the U.S. to accelerate the adoption of E.V.s in the ride-hailing industries. This study explained that one of the several benefits of the adoption was the improvement of mobility solutions in low-income communities and drivers' earnings. The elaboration of the survey by Paundra *et al.* (2020) was further based on the economic impact of the ride-sharing platform in Indonesia. This study focused more on the motorcycle services within the country and its neighbors (Vietnam and Thailand). The results showed that ride-sharing platforms were slightly inconsistent in creating positive environmental impacts, with the services not reducing the ownership of vehicles. The result also reveals that a ride-sharing platform only increases the mobility of people and vehicle ownership. Therefore, a new directive from policymakers should be introduced for the positive materialization impact of the services. The expected directive was in accordance with the previous study by Suatmadi, Creutzig, and Otto (2019), which showed an interesting fact about motorcycle ride-sharing platforms in Indonesia. The results indicated that the services only increased mobility within the country, not sustainability. Also, it increased carbon emissions due to the internal combustion engine used in Indonesian motorcycles. Based on these conditions, suggestions stated that adopting the electric motorcycle was viable for the country. Electric motorcycles could increase mobility and improve the sustainability of the cities. In addition, electric vehicles and motorcycles were the keys to reducing GHG emissions in the ride-sharing/hailing industry, according to several studies (Hu and Creutzig, 2021; Sanguinetti and Kurani, 2021; Flämig *et al.,* 2020;

McQueen, MacArthur, and Cherry, 2020; Ambrose *et al.,* 2020; Jenn, 2020; Tirachini, 2020; Xu and Meng, 2019; Burghard and Dütschke, 2019; Pavlenko, Slowik, and Lutse, 2019; Sopjani *et al.,* 2019; Sykes and Axsen, 2017; Wappelhorst *et al.,* 2014).

This present study did not intrinsically analyze the ride-sharing effects of Indonesian motorcycles on the environment. As suggested by previous studies, an electric motorcycle is a focal point in this research. Electric motorcycles are provided to a selected rider whose income from the ride-sharing platform is minimal, with operations being carried out daily. Several data from these operations are collected, such as travel range, energy consumption, money generated from the electric motorcycle, and charging frequencies during the day. In this study, the ride-sharing test aims to answer several questions: (1) Does the charging time of the motorcycle hinder the ride-sharing application? (2) Are the trips/orders compromised by the reduced work durations due to charging? (3) Does the electric motorcycle create a personal benefit for the rider? (4) What income level is generated by the driver based on switching from a conventional vehicle to an electric motorcycle?

All data to be collected, except charging time, are realistically provided by the ride-sharing applications during the test period of three months. The rider manually records this excluded parameter (charging time). Furthermore, the data obtained will be analyzed and compared with the rider's experiences before using the electric motorcycle. This empirical research should be used as a case study and lesson for those interested in the platform. Based on the need for empirical research, the involvement of users was suggested by Sopjani *et al.* (2019), as the theory of sustainable development is still conceptual and abstract to practitioners.

The electric motorcycle is also tipped as a game-changer, reducing the negative effect of land transportation on the environment in developing countries. However, its adoption to replace the internal combustion engine motorcycle is confronted with several barriers (Huu and Ngoc, 2021; Satiennam *et al.,* 2014). The study by Eccarius and Lu (2020) also conducted a comprehensive review of the customer adoption of an electric motorcycle. The decision to use electric motorcycles is complex and intertwined due to the involvement of several factors. Furthermore, the barriers involved in adopting this mechanism include the acquisition and maintenance costs, limited range, fear of dead battery, the safety of the electric motorcycles (from flood and heavy rain), and resale value. The acquisition cost of this motorcycle is also higher than the conventional types because its battery is accountable for over 40% of its total valuation. Based on energy consumption, electric motorcycles are eight times lower than conventional ones (Koossalapeerom *et al.,* 2019). Although they offer several benefits and advantages, the people of Indonesia are still skeptical about their adoption as a mode of daily transportation as well as the report of Huu and Ngoc (2021), which further suggested that more practical and empirical research involving motorcycle users should be conducted. Therefore, this study aims to analyze how an electric motorcycle improves the personal economic development of a ride-sharing rider in Indonesia.

2. Research Methodologies

It is an experimental methodology. The experiment subject must perform a specified and controlled hailing operation per their daily routines. The method was chosen as it is believed to be more suitable and more reliable in terms of data gathered. It reflects the actual and real-life operation of the riders' hailing.

2.1. Electric Motorcycle Selections

Several available electric motorcycles were distributed across all Indonesian markets due to the gradual increase and popularity in their utilization. The criteria for selecting these motorcycles for use were based on the power and torque, which should be comparable with conventional types. Most ride-sharing riders use traditional motorcycles with power and torque of approximately 8 hp and 9 N·m. However, the maximum torque at their wheels is found to be 100 N·m. This power and torque helped carry either passenger or a payload of approximately 100 kg. With such a load, conventional motorcycles could still reach an average speed of 25 km/h.

According to Table 1, GESITS was the selected motorcycle used in this study. It has wheel torque more or less similar to most the conventional motorcycles used in the ride-sharing application. Furthermore, two scenarios were used based on the field test, with the first and second stages using single and double battery packs at 1.5 and 3 kWh, respectively. Figures 1(a) and 1(b), the utilized electric and comparable conventional motorcycles are further illustrated in the figures.

Table 1 Electric motorcycle candidates available in Indonesia for the study in this paper

Brand Electric Motorcycle	Power (W)	Torque (N·m)	Wheel Torque (N·m)	Battery Capacity (kWh)
Viar Q1	800	30	30	1.38
GESITS	5.000	30	150	1.5 (single battery) 3 (double battery)
United T1800	1.800	27	27	1.68
Niu NQ Sport	1.800	27	27	2.1

(a) (b)

Figure 1 The electric motorcycle (GESITS) (a) and its conventional motorcycle counterpart (b)

2.2. Ride-Sharing Platform and Rider Selections

There were several ride-sharing motorcycles in Indonesia, the two notable types being GOJEK and Grab, respectively. According to a survey, the study was conducted in Surabaya, Indonesia, with the GOJEK model being selected (Lembaga Demografi, 2021). This selection was based on the motorcycle model being the most popular ride-sharing application in the study location. After this, the next step was to select the rider. The rider is determined based on several criteria, such as driver rating point, average daily mileage, and the numerous services offered, as shown in Table 2.

According to the minimum value of each criterion, complete and comprehensive results were expected. This research measured several factors such as the practicality level of the electric motorcycle, rate of money generated, charging frequency, and time effects on rider activities.

2.3. Field Testing Scenario

Field testing is required as the authors believed this is a more suitable and reliable data gathering methodology. It is based on the real-life performance of the rider's online hailing experiences. By selecting the field testing, it is expected that the data are accurate and reflect actual riders' journeys daily.

The two scenarios were chosen since the electric motorcycle in this study provides two options in terms of its battery pack. The first one is the electric motorcycle was sold with only 1 battery pack at 1.5 kWh. The second option was to purchase the electric motorcycle with two battery pack options at 3 kWh. The difference between the two options is in their cost and their range of travel. The scenarios were chosen to evaluate which options are better and preferable from the online hailing riders' point of view. The results analysis will be helpful for any riders who want to switch to an electric motorcycle or for the manufacturer of the electric motorcycle. Based on the results presented in this paper, they can select their best option. Moreover, manufacturers can use it as decision support data to develop suitable marketing and costing for the electric motorcycle under investigation.

The selected rider used the GESITS model as its ride-sharing motorcycle for 65 days (continuously) based on the field test. Before beginning the process, the rider should provide the ride-sharing performance data for the previous 65 days.

Table 2 Electric motorcycle candidates available in Indonesia for the study in this paper

No	Criteria	Minimum value	Note
1	Rider rating	4.5 stars	A star rating is to measure the service performance of a rider. The maximum score is five stars.
2	Average daily rider mileage	100 kilometers	The charging frequency and time are the main focus of this study, with minimum mileage requirements. Average daily rider mileage is to reflect a rider services performance. Approximately 100 kilometers is the minimum value, as the study aims to also learn the practicality of an electric motorcycle compared to the conventional type.
3	Number of services offered by the rider	Two services	Services offered by GOJEK riders are Go-Ride, Go-Food, Go-Send, Go-Mart, and Go-Shop.

2.3.1. Scenario 1

According to the manufacturer's data, this scenario showed that the rider used a single battery pack GESITS, which had a capacity of 1.5 kWh. The estimated driving range of this capacity is 50 km, based on the calculation of GESITS apps, as shown in Figure 2.

In scenario 1, the rider traveled on a 40-50 km per charge, with the scenario's objective based on determining the effectiveness and efficiency of the 1.5 kWh battery energy. The process was conducted for a minimum of 15 days, with the rider ordered to report any problem encountered, such as charging difficulties and their effect on ride-sharing performances. In addition, the data obtained were the daily rider mileage, energy consumption, and cost.

2.3.2. Scenario 2

In this scenario, the electric motorcycle used two battery packs, with energy capacity and an estimated trip range of approximately 3 kWh and 100 km, respectively. The estimated mileage of this capacity is shown in Figure 3.

The results of the two-battery pack electric motorcycle were compared to the single type to determine the best practicality. The data obtained were the daily rider mileage and energy consumption, and the cost of the electric motorcycle model. The range mileage was also the main focus of the comparisons, with the operations of a two-battery pack tested for a minimum of 15 days.

3. Field Testing Data Analysis

3.1. Daily Trip

The most frequently asked questions on electric motorcycles are based on the charging mileage per battery pack, also known as range anxiety. Range anxiety often prevented people from using the vehicles due to the identification by Pevec *et al.* (2019) and Chen *et al.* (2020). Furthermore, there was no exception in the electric motorcycle used in the ride-sharing application, as the first raised concern was based on the potential compromise of income by the vehicle. Therefore, the field test employed two scenarios to evaluate the effect of battery capacity on the riders' performances. The rider's performance data was also observed during the ride-sharing daily trip. Subsequently, the data from the rider was selected as the baseline of performance when using the conventional motorcycle, as shown in Figure 4.

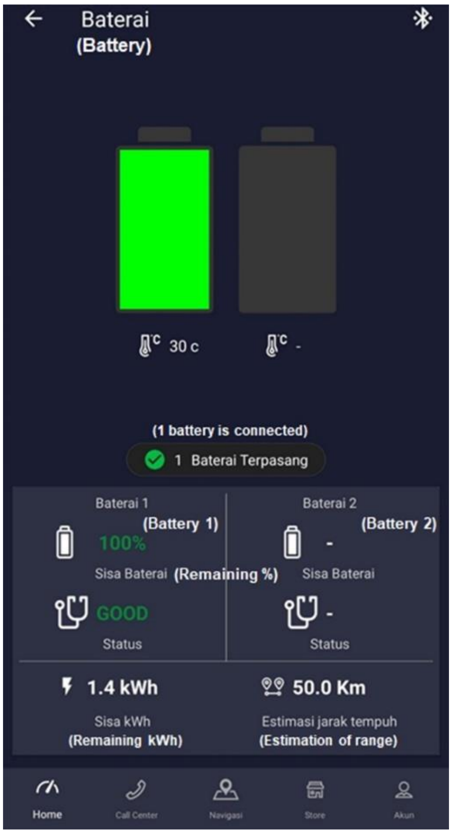


Figure 2 The dashboard snapshot of the single battery pack estimated range

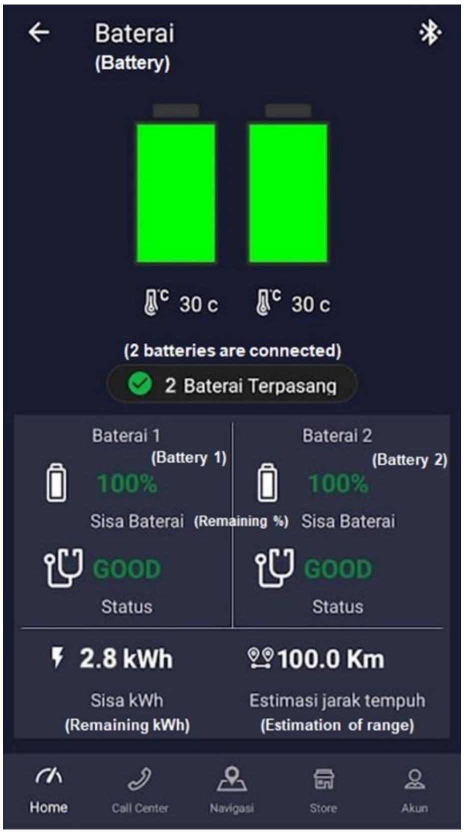


Figure 3 The dashboard snapshot of the two-battery pack estimated range

Based on Figure 4, the average daily trip of the rider was 87 km, as the total estimation after 65 days provided 5.715 km. The data on using electric motorcycles were further compared with those obtained by riders for 65 days. The data obtained in scenarios 1 and 2 for the electric motorcycle trips are further shown in Figures 5a and 5b, respectively.

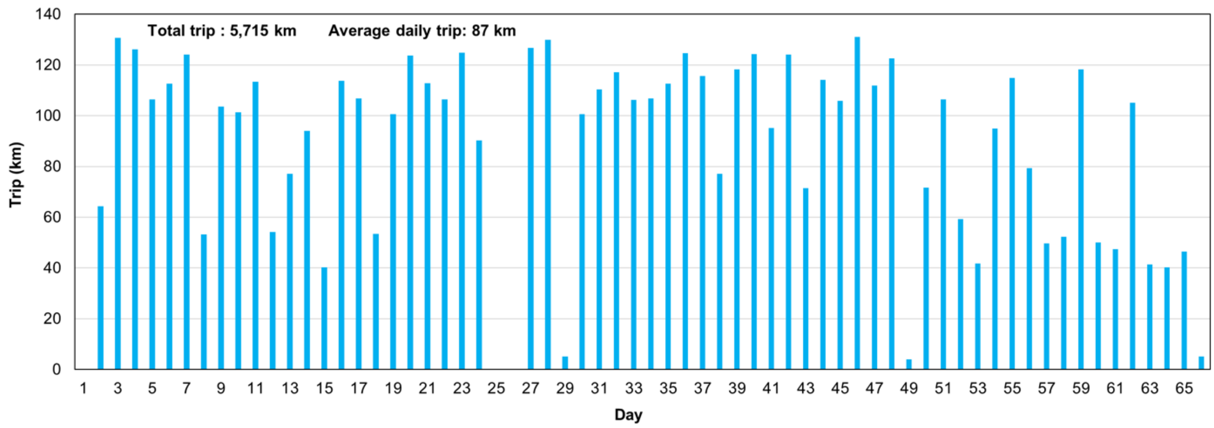


Figure 4 Baseline daily trip used conventional motorcycle

Scenario 1 evaluated electric motorcycle performance through a 1.5 kWh battery pack. Based on Figure 5a, the rider's total trip traveled was 1.007 km in 20 days, equal to an average of 48 km daily. According to Figure 5b, a 3 kWh battery pack was used, with the total trip traveled observed at 5.458 km. This scenario 2 was carried out for 45 days, with an average daily trip of 121 km. Furthermore, scenario one was only carried out for 20 days, and the required minimum daily trip was half the 100 km target, at 48 km. The required minimum daily trip of 48 km was due to the electric motorcycle battery pack needed to be charged at a maximum trip distance of 50 km. It also required four hours of charging to achieve total capacity. Therefore, the charging duration of the battery compromised the available time for the rider to carry out the ride-sharing process. Meanwhile, different results were entirely obtained using a 3 kWh battery pack. For a minimum target trip of 100 km, the electric motor did not require charging during the ride-sharing activities. Figures 5(a) and 5(b) show that the ride-sharing activities were not compromised by the 3 kWh battery pack, as its average daily trip achieved 121 km. This was the farthest distance observed in this study compared to scenario one or the conventional motorcycle.

3.2. Energy Consumption Cost

The following data to be evaluated and compared was the energy consumption cost of each scenario, based on the daily trip data shown in Figures 4, 5(a), and 5(b). In addition, the energy consumption cost of the conventional motorcycle was used as the baseline.

3.2.1. Conventional motorcycle

The total energy consumption cost for 65 days is depicted in Figure 6. The data was based on the rider's actual amount paid for daily energy (gasoline) usage, with the estimated value per liter at IDR 9,950. Furthermore, the total energy cost for the conventional motorcycle was IDR 1,624,590 for 65 days.

This cost was further used to obtain a distance of 5,715 km (Figure 4). Therefore, the calculation for the total cost of energy per kilometer of travel is shown as follows,

$$Total\ cost\ of\ energy\ per\ kilometer\ travelled = \frac{Total\ cost\ energy}{Total\ distance\ trip} \quad (1)$$

$$Total\ cost\ of\ energy\ per\ kilometer\ travelled = \frac{\text{IDR 1,624,590}}{\text{5,725 km}} = 284\ \frac{\text{IDR}}{\text{km}}$$

Thus the average daily energy cost on a conventional motorcycle is IDR 24,615.

3.2.2. Scenario 1 – Electric motorcycle

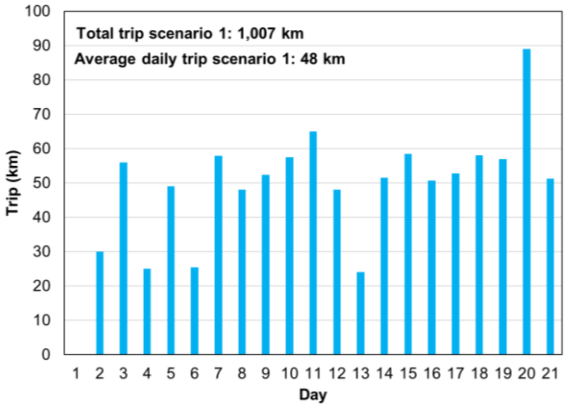
The energy consumption cost for the 20 days field test of the electric motorcycle is shown in Figure 7. The data was based on the rider's amount paid for daily charging, with the estimated value per kWh of electric energy at IDR 1,100.

According to Figure 7, the owner of the electric motorcycle paid a total of IDR 31,016 or IDR 1,477 for energy costs on a daily average. Equation (1) states that when added to the whole distance of scenario 1 (Figure 5a), the energy cost per kilometer travel is as follows:

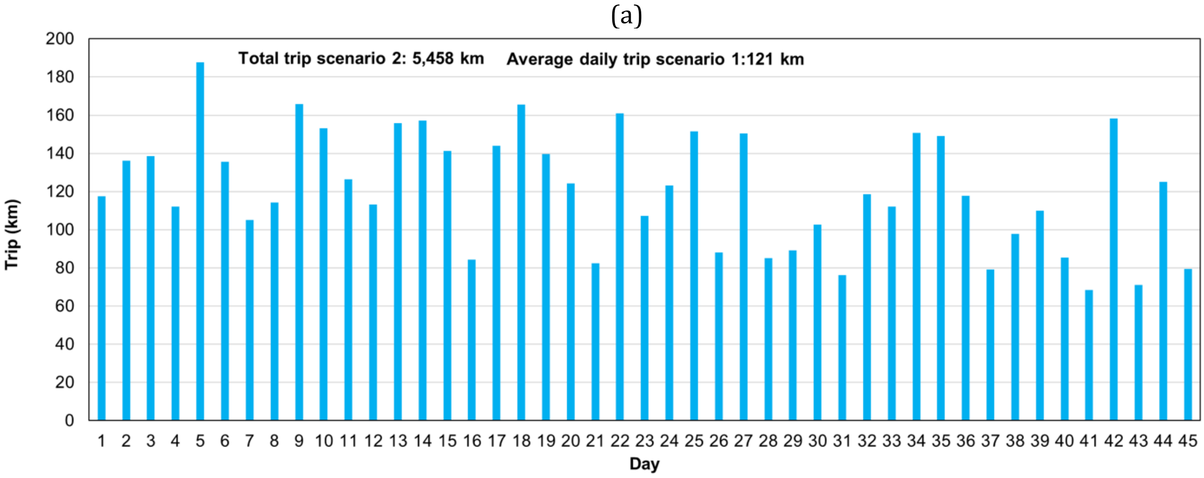
$$Total\ cost\ of\ energy\ per\ kilometer\ travelled = \frac{\text{IDR } 31{,}016}{1{,}007 \text{ km}} = 30.8\ \frac{\text{IDR}}{\text{km}}$$

3.2.3. Scenario 2 – Electric motorcycle

The energy consumption cost for the 20 days field test of the electric motorcycle is shown in Figure 7. The data was based on the data was based on the rider's real daily billing fee, with an estimated value of IDR 1,100 per kWh of electric energy.



(a)



(b)

Figure 5 Ride-sharing trip data (a) scenario 1 electric motorcycle (b) scenario 2 electric motorcycle

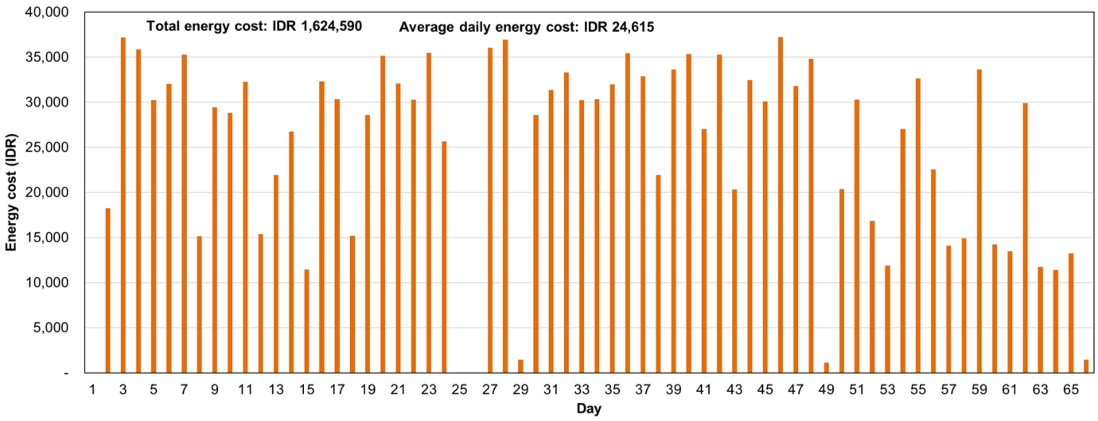


Figure 6 The conventional motorcycle energy cost

Scenario 2 employed a 3 kWh battery pack, with its energy cost shown in Figure 8. To determine the comparable measure of charge, the total expenses of energy per kilometer traveled are calculated according to Equation (1), as follows,

$$Total\ cost\ of\ energy\ per\ kilometer\ travelled = \frac{\text{IDR } 168{,}116}{5{,}458 \text{ km}} = 31\ \frac{\text{IDR}}{\text{km}}$$

As a result, no difference was observed between both scenarios. In addition, the energy costs per kilometer were 30.8 and 31 IDR/km for scenarios 1 and 2, respectively.

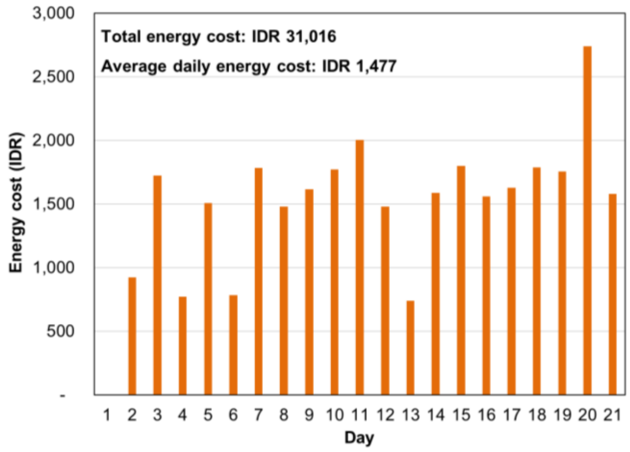


Figure 7 The energy cost for the electric motorcycle ride-sharing testing – scenario 1

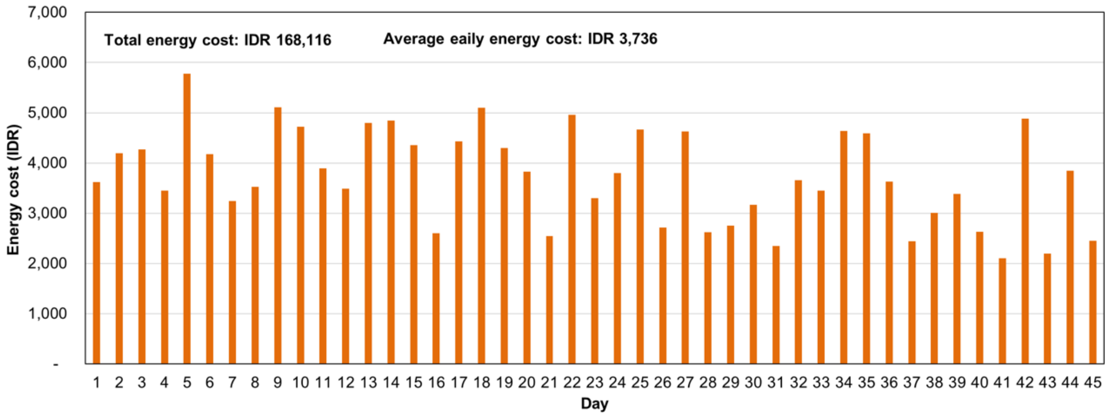


Figure 8 The energy cost for the electric motorcycle ride-sharing testing – scenario 2

3.3. *Maintenance Cost*

The maintenance cost for both conventional and electric motorcycles was virtually nothing due to both vehicles being brand new. Therefore, the electric and conventional motorcycles required zero maintenance costs and a one-time oil replacement. The cost to replace the engine oil of this conventional vehicle was IDR 65,000, which occurred when a distance of 2,000 km had been achieved. The replacement indicated that the average daily maintenance cost for the motorcycle was IDR 1,000 for 65 days.

3.4. *Rider's Income*

Following the type of services offered, riders were paid by the ride-sharing company (in this case, GOJEK). GOJEK was further found to provide several benefits, as shown in Table 2. In the field test process, the rider offered Go-Ride, Go-Food, Go-Mart, Go-Shop, and Go-Send (passenger, food, shopping, and goods and document deliveries). The services provided by GOJEK are shown in Figure 9.

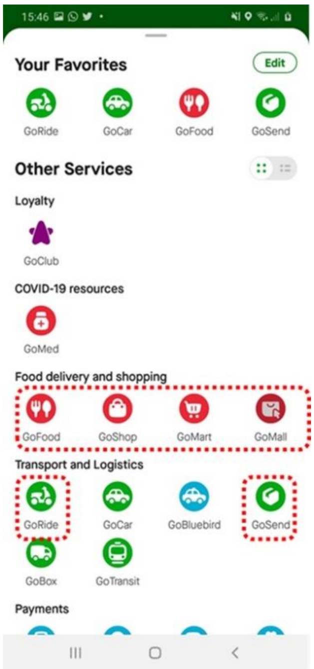


Figure 9 The ride-sharing services offered by the testing rider (red dotted line)

Those services describe the rider's income, as seen in Figure 10 – 12. Figure 10 shows the rider's income when the conventional motorcycle is employed, while Figure 11 and 12 indicate similar situations when testing the electric vehicles in scenarios 1 and 2, respectively.

3.4.1. Conventional motorcycle

According to Figure 10, the total and average daily earnings were IDR 10,724,130 and IDR 162,487, respectively, through the utilization of the conventional motorcycle. Based on this condition, the average daily net income of the rider was calculated as follows:

$$\begin{aligned} Average\ daily\ net\ income\ &= Average\ daily\ income\ -\ Average\ energy\ cost \\ &\quad -Average\ daily\ maintenance\ cost \end{aligned} \tag{2}$$

Therefore, the average daily net income baseline is,

$Average\ daily\ net\ income$ = IDR 162,487 – IDR 24,615 – IDR 1,000

$Average\ daily\ net\ income$ = IDR 132,872

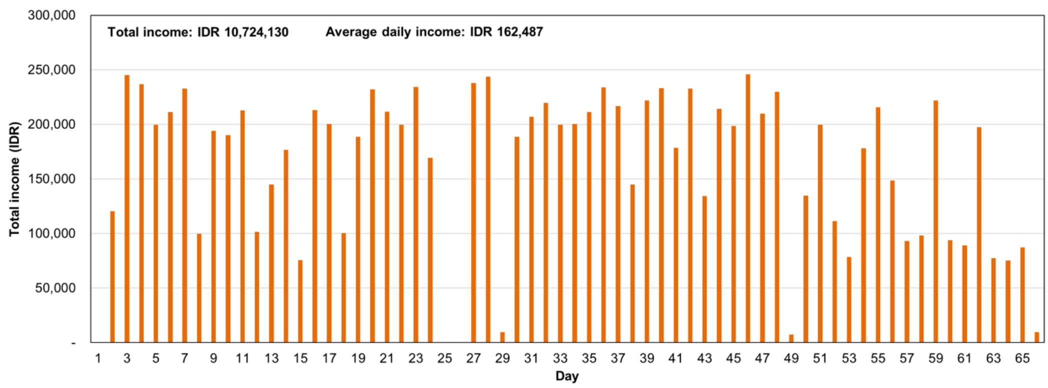


Figure 10 Rider income from the ride-sharing – baseline conventional motorcycle

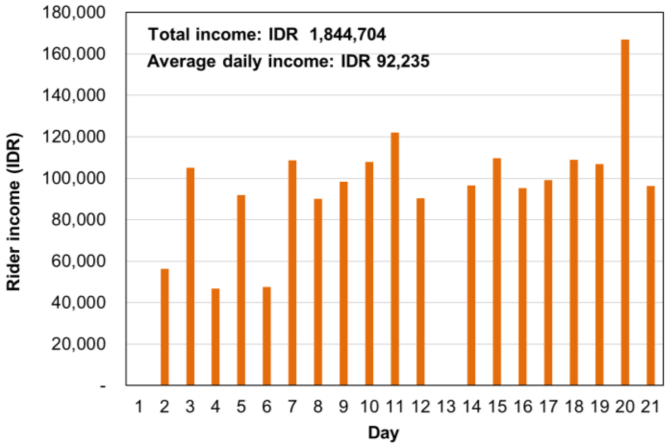


Figure 11 Rider income from the ride-sharing – Scenario 1 electric motorcycle

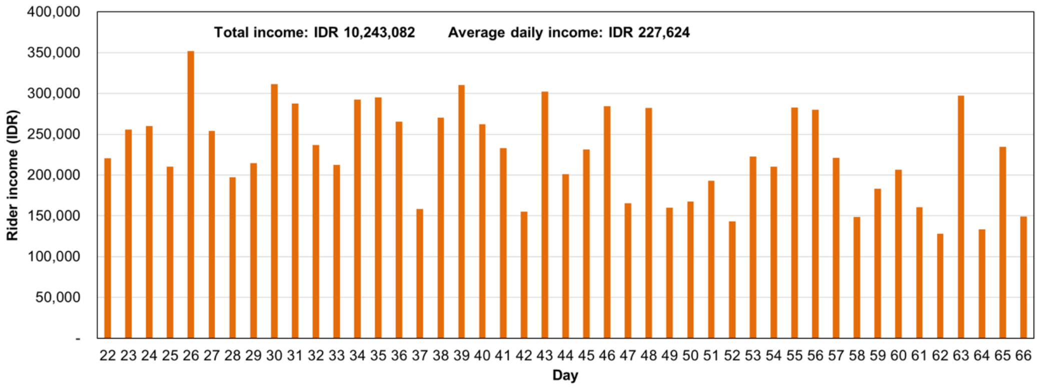


Figure 12 Rider income from the ride-sharing – Scenario 2 electric motorcycle

3.4.2. Scenario 1 (electric motorcycle)

Based on scenario 1, the rider's income is presented in Figure 11. It is shown that the rider's total and average daily incomes during the 21 days of ride-sharing were IDR 1,844,704 and IDR 92,235, respectively, due to using an electric motorcycle with a 1.5 kWh battery pack. To better understand this income level, an average daily net income using the 1.5 kWh vehicle is as follows,

Using Equation (2), the average daily net income is,

$$Average\ daily\ net\ income = \text{IDR } 92{,}235 - \text{IDR } 1{,}447 - \text{IDR } 0$$
$$Average\ daily\ net\ income = \text{IDR } 90{,}778$$

3.4.3. Scenario 2 (electric motorcycle)

The result in scenario two is shown in Figure 12, which indicates that the rider obtained total and average daily incomes of IDR 10,243,082 and IDR 227,624, respectively, during the 45 days of the ride-sharing test.

When the rider's income was expressed in terms of average daily net income, the calculations according to Equation 2 are as follows,

$$Average\ daily\ net\ income = \text{IDR } 227{,}624 - \text{IDR } 3{,}736 - \text{IDR } 0$$
$$Average\ daily\ net\ income = \text{IDR } 223{,}888$$

3.5. CO_2-equivalent Emission

Although the CO_2-equivalent in this study is measured from Tank to Wheel (TTW) emissions, it is still known as direct emission in other terms, with the calculations applying to both conventional and electric motorcycles. As suggested by Hass *et al.* (2014), the electric motorcycle had zero CO_2-equivalent emissions, while that of the conventional vehicle was approached by a tool of carbonfootprint.com (Carbon Footprint Calculator, 2021). This conventional motorcycle had an engine capacity of 125 cc and an average value of CO_2-equivalent emission factor of 83.06 gram/km. For the 65 days of ride-sharing, it managed to achieve a distance of 5.715 km, with CO_2-equivalent emission at 0.48 metric tons of CO_2-equivalent. Therefore, electric motorcycles were better and greener than their conventional counterparts.

4. Ride-sharing Testing Results Comparisons and Discussions

The data obtained in the field testing previously are then compared with the baseline data. As previously stated, the study's objective is to determine whether the electric motorcycle performance is better compared to the conventional motorcycle. The conventional motorcycle performances in the online ride-sharing platform are then used as baseline data. The performance indicators metric to be compared are as follows: average daily trip, total energy cost, average daily maintenance cost, average daily income, average net daily income, and Tank to Wheel CO_2 emission from both motorcycles.

The average daily trip is the most essential performance indicator to be included in this comparison. The average daily trip is to answer the most crucial question about the electric motorcycle, i.e. its range of travel and its practicality with the lack of charging/battery swap stations. Without the charging/battery swap stations, the electric motorcycle will depend only on a home charging point. Therefore, the usage of home charging point becomes the minimum requirement. Suppose the electric motorcycle can perform better with a lack of support. In that case, it can be expected once the charging/battery swap stations are available, then it will only yield better performance.

The second question related to the electric motorcycle is, is it true that it offers better efficiency? This question needs to be addressed. That is why the second and third performance indicators are compared and analyzed. If it is true that the electric motorcycle has better efficiency than the conventional motorcycle, then the value of each performance indicator should be lower than its baseline. The total energy cost per kilometer performance indicator measured the total energy cost spent by online ride-sharing riders in their daily work. The average daily maintenance cost estimates the total cost of maintenance paid to do the maintenance on an electric and conventional motorcycle. It is expected that the total cost of maintenance of an electric motorcycle should be lower than the baseline as an electric motorcycle has a small number of moving/mechanical components compared to a conventional motorcycle. The lower the number of the mechanical element, the better will be its reliability. The complete comparison of the field testing results is shown in Table 3.

Table 3 The ride-sharing testing results for the conventional and electric motorcycle

No	Parameter	Baseline	Scenario 1		Scenario 2	
			Value	Diff. to Baseline	Value	Diff. to Baseline
1	Average Daily Trip (km)	87	48	-45%	121	39%
2	Total energy cost per kilometer (IDR/km)	284	30.80	-89%	31	-89%
3	Average Daily Maintenance Cost (IDR)	1,000	0	-100%	0	-100%
4	Average Daily Income (IDR)	162,487	92,235	-43%	227,624	40%
5	Average Daily Net Income (IDR)	132,872	90,778	-32%	223,888	68%
6	TTW CO_2-equivalent Emission (Metric tons of CO-equivalent)	0.48	0.00	-100%	0.00	-100%

The fourth and fifth performance indicators reflect the practicality of the electric motorcycle. If it is deemed as practical as a conventional motorcycle, then the value of average daily income and its net average daily income will be similar or better.

The last performance indicator is about CO_2 emission. It is also important to be compared as the electric motorcycle, in theory, should have better emissions. Or in some cases, the electric motorcycles are tagged to have zero-emission from TTW.

4.1. Scenario 1 vs Baseline

The limitation of scenario 1 was the electric motorcycle battery pack capacity, which was only 1.5 kWh. The travel range of this vehicle per charge was also an average of 40 km (GESITS, 2021). As shown in the Table 3, 1.5 kWh battery pack performances were below the baseline values of ride-sharing activities. Regarding the average daily trip, the electric motorcycle only managed to achieve a distance of 48 km per charge. The distance was due to charging requirements per 40-50 km of the trip. Using its onboard charger, approximately 3–4 h was required to achieve a fully charged capacity. Based on this condition, the available time remaining for ride-sharing was limited. Therefore, the electric motorcycle can only accomplish a daily average of 48 km. According to the rider's feedback, the use of this vehicle was quite troublesome when its range was limited. However, this trouble is likely to be eliminated with the availability of a battery swap station, which should be an exciting subject to be explored in future research. In addition, future studies should be conducted to evaluate whether battery swap station positively impacts electric motorcycle ride-sharing operations.

The rider's income was the other limitation of the utilized 1.5 kWh battery pack motorcycle. Due to the lack of kilometer trips paid for ride-sharing, the rider's personal and average daily net incomes were 43 and 32% downwards, respectively, compared to the baseline. The electric motorcycle, on the other hand, was greener and more environmentally friendly due to the absence of CO_2 emissions. Moreover, the vehicle required zero maintenance costs during the test. The total energy cost needed to run the electric motorcycle per kilometer was also substantially reduced by 89%.

4.2. Scenario 2 vs Baseline

Based on scenario 2, the battery pack capacity was doubled to 3 kWh, with the electric motorcycle requiring no charging during the ride-sharing period. It was also capable of achieving a distance of 100 km. Regarding the ride-sharing average daily trip, the 3 kWh motorcycle obtained a daily average of 121 km, which was an increase of 39% compared to the baseline. Also, the total energy cost per kilometer trip was IDR 31, indicating a decrease of 89%. Furthermore, the rider's income increased by 40%, with the daily income observed at IDR 227,624.00. Based on the zero-maintenance cost during the test period, the net personal income was IDR 223,888.00 per day, an increase of 68% compared to the baseline.

Based on these data, the 3 kWh electric motorcycle only positively impacted the rider, increasing personal income, reducing energy costs, and emitting no CO_2 pollution. However, the rider stated that the revenue obtained should be more than 68% with the availability of a battery swap station. In addition, charging was not required during the ride-sharing period.

5. Conclusions

This study aimed to evaluate the impacts of the electric motorcycle on ride-sharing applications in Indonesia. According to the results and comparisons, the electric motorcycle with a 3 kWh battery positively impacted the rider. Compared to the conventional counterpart, the net personal income also increased. Furthermore, it emitted no environmental pollution and offered positive benefits to the rider, especially in Indonesia. Even for heavy applications such as ride-sharing, electric motorcycles were superior to conventional ones. The range anxiety of this vehicle was also eliminated by installing the second battery. As evident in the results, the electric motorcycle with only 1 battery pack at the moment is not suitable for online ride-sharing activities due to a lack of charging/battery swap stations. It will be an exciting topic for future research to design, evaluate and validate (field testing) public charging and/or battery swap stations for the electric motorcycle. Future research can also optimize the placement of such stations to improve electric motorcycle usage for everyday activities.

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