

# Comparing Total Cost of Ownership of Electric and Conventional Motorcycles in Indonesia

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## ABSTRACT

The adoption of Electric Vehicles (EV) is one of the solutions to reduce emission problems. In Indonesia, the government targets 2.1 million Electric Motorcycles (EM) ownership in 2025. One of the keys to encouraging the EV Indonesian market is vehicle cost analysis, like Total Cost of Ownership (TCO). This study developed a TCO model to compare EM with Conventional Motorcycles (CM) in Indonesia. Data were collected from surveys and information from stakeholders. The proposed TCO model considered a battery replacement cost, which influenced the resale value of the vehicle. As a result, the TCO of EM had a more economical value than CM of 12% (IDR 3 million) on low mobility, 16% (IDR 4 million) on medium mobility, and 18% (IDR 5.5 million) on high mobility. In addition, several scenarios were also analyzed as a study to consider providing subsidies ownership motorcycles in Indonesia.



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## 1. Introduction

Currently, various problems related to energy scarcity, air pollution, and greenhouse gas emissions are sweeping the world [1]. One of the most significant contributors that trigger this problem is energy consumption from vehicles' petroleum fuel, which increases CO<sub>2</sub> emissions [2]. In 2018, the development of fueled vehicles in Indonesia increased rapidly to reach 126.5 million, consisting of 11.7% passenger cars, 0.2% bus cars, 3.8% freight cars, and 84.3% motorcycles [3]. This problem raised concerns, especially related to environmental problems. From these problems, an environmentally friendly and energy-efficient transportation solution is needed to reduce existing emissions, such as electric vehicle technology innovation and battery technology innovation [4]. In Indonesia, the existence of Presidential Regulation Number 55 of 2019 strengthens this solution concerning the Acceleration of the Battery-based Electric Motor Vehicle Program for Road Transportation as one of the government's efforts to reduce the disposal of GHG or Greenhouse Gas. Through this regulation, the government also socializes motorcycles and electric cars, followed by the issuance of 17 incentives for electric cars. In 2025, the government is also targeting as many as 2.1 million units of EMs and 2.2 thousand units of electric cars.



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Unfortunately, the population of EMs until the end of August 2020 has not reached 2,000 units, which suggested that the market share was only 0.095% of the government's target [5]. This fact indicates that the adoption of EMs in Indonesia is still very low. The low adoption rate of EMs is due to the high purchase price compared to the CMs [6]. More than half of consumers only consider purchase price when making decisions in purchasing and underestimate the sizeable cost advantage of the other costs in a period of ownership [7-9]. In addition, many factors play roles in consumer decisions in purchasing electric vehicles [10-13]. There are two classifications of these factors, namely monetary and non-monetary. Some research usually approaches the monetary group using the Total Cost of Ownership (TCO) model. TCO is a philosophy intended to calculate the actual cost of buying a product such as a motorcycle [14]. The main objective of this TCO is to make better purchasing decisions by considering the issue of costs beyond price [15] and comparing all costs associated with owning a product over its economic life [16].

Some studies discussed the application of the TCO model for comparisons between electric and conventional vehicles. Comparing the TCO between conventional and electric cars or trucks to assess the existence of Corporate Average Fuel Economy standards [17]. Then, [18] compared the TCO of 17 car brands consisting of conventional and electric to create new business models promoting EV adoption in Singapore. [19] investigated the TCO between passenger and private cars in Belgium to maximize the RES (Renewable Energy Sources) used and cost guarantee status. One application of this TCO model is the consumer-oriented approach (TCOc), which considers all actual costs received and borne directly by consumers when using the product [15]. This TCOc consists of two types of costs, namely Capital Expenditure and Operational Expenditure. Capital Expenditure is a component of capital cost, which includes the purchase and the resale price. Meanwhile, Operational Expenditure is a cost component related to operational ownership, including taxes, insurance, maintenance, energy consumption, and discount rates [20]. Some previous research ignored several cost components in calculating the TCO value and explained in Table 1.

Table 1. State of The Art of This Research

No	Reference	Capital Expenditure				Operational Expenditure					Other
		Purchasing Price Vehicle	Purchasing Price Battery	Resale Value Battery	Resale Value Vehicle	Energy Consumption	Maintenance & Repair	Insurance	Vehicle Tax	Discount Factor	Battery Replacement Cost
1	Mitropoulos, et al. [21], Hagman, et al. [22]	X	-	X	-	X	X	X	X	-	-
2	Bubeck, et al. [23]	X	X	X	-	X	X	X	X	X	-
3	Kerdlap and Gheewala [24]	X	-	X	X	X	X	-	-	X	-
4	Babin, et al. [25]	X	X	X	X	X	X	-	-	-	-
5	Letmathe and Soares [20]	X	X	X	X	X	X	X	X	X	-
6	Palmer, et al. [26], Sherrington and Moran [27], Danielis, et al. [28]	X	-	X	-	X	X	X	X	X	-
7	Millard-Ball [17]	X	-	X	-	X	X	X	X	X	-
8	Pavan, et al. [29]	X	-	X	-	X	X	X	X	-	-
9	Riyanto, et al. [30]	X	-	X	-	X	X	X	X	X	-
10	Kumar and Chakrabarty [31]	X	-	X	-	X	X	-	-	X	-
11	This Research	X	X	X	X	X	X	X	X	X	X

From **Table 1**, the findings of this research consisted of two points. First, this study added complete components of consumer-oriented and the cost of replacing the battery taking into account the user's charging behavior. When the battery exceeds the economic life of the charging cycle, its capacity will decrease to 70% [32]. Several previous studies in this cost component only considered the length of time as a determinant of the economic life of the battery [24, 29, 33]. However, most batteries were equipped with a battery management system to see the number of charge cycles to determine the economic life, which was very dependent on the user's behavior [34]. Second, this research was considered necessary since the output could be a beneficial study for the users. The benefit covered the description in detail. In addition, the purchase included the vehicle's price, considering the total cost during the ownership period [35].

This research was a study on EVs in Indonesia, especially focusing on Ems. Motorcycles are the main transportation in Indonesia [34]. Some previous researches developed an adoption intention model from independent and dependent factors. In contrast, this research was intended to develop a total cost of ownership model focusing on the monetary factors. This study also aimed to develop a consumer-oriented TCO model and compare EM and CM's TCO value. The urgency of this research was to help accelerate the adoption of EM in the Indonesian market to achieve the government's target in 2025 of 2.1 million motorcycles. In addition, this research was an effort to conserve the dwindling fuel oil and reduce the high carbon emissions in big cities in Indonesia.

## 2. Methods

The research procedure of this research is presented in **Fig. 1**. The research's five (5) main stages included object definition, data collection (primary and secondary data), TCO Model Development, TCO Value Calculation, and Sensitivity Analysis. In addition, a complete description of the Research Procedure is presented in the following sub-section.

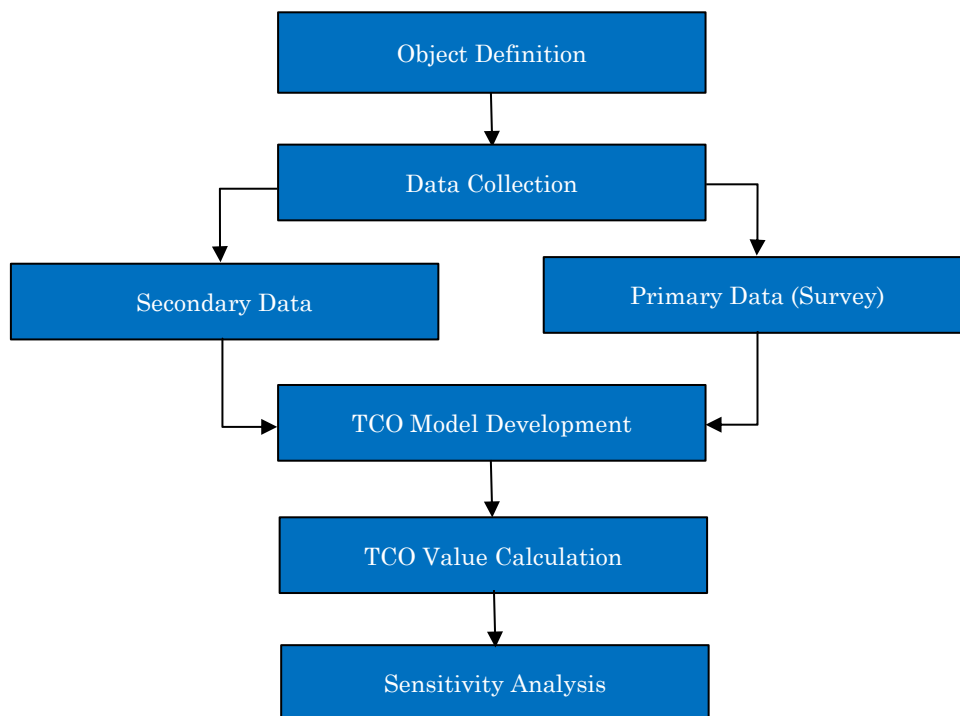


Fig. 1. TCO Research Procedure

## 2.1 Object Definition

This research selected the motorcycles vehicle based on the best Conventional Motorcycles (CM) brands performance based on Top Brand Award [36]. The determined Electric Motorcycle (EM) brands had similar body shapes, motorcycle, foot, and tire sizes. In this study, the samples were obtained from the automotive website. It is used to compare the TCO of the CM and EM. Each attribute type was grouped into primary data directly influenced by users and required a survey as the study tool. The secondary data were taken from the government regulations.

## 2.2 Data Collection

Primary data were obtained from survey results for attributes user behavior to get an accurate result of TCO [37]. This research collected data using questionnaires from the CM and EM users. The priority of respondents consists of respondents with the province domiciled with the highest level of motorcycle sales in Indonesia. This data collection divided the survey into three sections with the attributes of the questions described in Table 2. If a user did not meet one or more of the screening criteria, then the data from that user were not considered valid. The result of the survey was then processed using analytical methods with statistical analysis. This research also grouped the respondent into three types of mobility (low, medium, and high mobility) based on the daily mileage, according to Bubeck, et al. [23].

Secondary data were collected from stakeholders' documents, namely the government, manufacturers, distributors, motorcycle agents, and previous studies. The secondary data are shown in Table 3. The total responses matched with the requirements for processing data consisted of 118 CMs respondents and 74 EMs respondents.

Table 2. Attribute of Survey

Screening [38]	Socio-demographic [38]	User behavior [20, 23, 24, 30, 39]
People who are $\geq$ 17 years old	Domicile	Vehicle brand
Having a SIM C	Age	Payment system
One of the decision-makers	Gender	Period of ownership
to replace or buy motorcycles	Marital Status	Performance
CM or EM User	Occupation	Mileage
	Last Education-al Level	Fuel type (for CM) and Charging place (for EM)
	Monthly Income Level	Energy charging frequency (for EM)
		Type of parts serviced
		Service cost
		Parking cost
		Insurance cost

## 2.3 TCO Model Development

This study developed the model proposed by [30] by adding the Battery Replacement Cost (BR) component as suggested in [40]. The formula for Consumer-Oriented TCO (TCOc) is shown in Equation (1). Resale Value (RV), Operating Expenditure (Copex), and Battery Replacement Cost (BR) models are presented in Equations (2), (3), and (4), respectively. Details of the TCOc, RV, Copex, and BR models are described in the following sub-section.

Table 3. Assumptions from Secondary Data used in this study

Assumption	Value	Unit	Assumption	Value	Unit
Battery life	1,000	Charge cycle	Vehicle depreciation	7.08%/year	Processings data result
Discount rate	12.78	Sum of inflation and consumption rate (%)	Fuel Cost	7,650	IDR/liters
Interest Charged	0.65%	Loans to banks (purchases on credit)	Percentage increase in energy consumption	2% (for CM)	per years
Tenor payment	36 month		Electricity Cost	0.03% (for EM)	per charging
Battery depreciation	8%/year 11%/year 14%/year	Low mobility Moderate mobility High mobility		1,650	IDR/kWh

$$TCO_C = PP + \sum_{t=1}^j \frac{C_{opex}}{(1+r)^t} - RV (1+r)^{-j} + BR \tag{1}$$

$$RV = (1 - d_V)^n \times PP + C_B \tag{2}$$

$$C_{opex} = C_{EC} + C_{MR} + C_{IN} + C_{TA} + C_{OF} + C_{IP} \tag{3}$$

$$BR = \sum_{t=i}^{f_i < j} \frac{(BP - C_B)}{(1+r)^t} \tag{4}$$

### 2.3.1 TCO Consumer-Oriented (TCOc)

The Purchased Price (PP) is the OTR (on the road) price, which includes the net price of the purchase of a vehicle, including tax and other administrative costs. This price also decreases over time, such as the effect of the age of a motorcycle. The purchase price data are based on the official automotive website. Then, a discount rate (r) is an essential component in the calculation because it affects the fluctuation of prices. Thus, the results of calculating costs at a certain time can be converted to the present value.

### 2.3.2 Resale Value (RV)

In this research, TOC calculation research also implemented a resale value formula [41]. It was affected by the depreciation value (DV) during the ownership period (n). Then, the calculation of the resale value of EMs was calculated separately between the battery and the vehicle. Meanwhile, the calculation of the battery resale price (CB) was similar to RV. However, the value depreciation of the battery was according to the type of vehicle mobility.

### 2.3.3 Operating Expenditure (Copex)

The cost of annual operating expenditure (Copex) consists of the sum of all cash payments, such as cost of energy consumption (CEC), cost of maintenance and repair (CMR), cost of insurance (CIN), cost of tax vehicle (CTA), other fixed cost or parking cost (COF), and cost of interest payment (CIP). CEC and CMR were the cost variables as they were affected by Annual Kilometers Travelled (AKT), using the Equations (5) and (6), respectively.

$$C_{EC} = (100\% + k_{CM} (t - 1))x \frac{AKT \times C_E}{EC} \quad (5)$$

$$C_{MR} = C_R + (C_M \times AKT) \quad (6)$$

Where,

$k_{CM}$  : Percentage increase in energy consumption

$t$  : Year,  $t \in \{1, \dots, \text{period of ownership}\}$

$EC$  : Energy Consumption Needs

$C_E$  : Energy Cost

$C_R$  : Repair Cost

$C_M$  : Maintenance Cost

### 2.3.4 Battery Replacement Cost (BR)

The economic life of the battery in this study was 1000 cycles. Then the battery capacity decreased to 70% and required replacement. The difference of BR between the purchase price ( $BP$ ) and the battery's resale price ( $CB$ ) was relevant to the discount rate in the year of replacement. The higher the charging frequency, the faster the economic life of the battery ran out. The battery replacement period ( $i$ ) was obtained by dividing the economic life of the battery ( $b$ ) by the frequency of charging ( $fF$ ). Meanwhile, the battery replacement sequence ( $f$ ) was obtained by dividing the length of ownership ( $n$ ) by the battery replacement period ( $i$ ).

### 2.4 TCO Value Calculation

Primary and secondary data were used as input values in the TCO model that was developed. Based on the calculation results, it could be shown that the comparison of TCO EM and CM values was superior and could be used as a basis for consideration.

### 2.5 Sensitivity Analysis

The sensitivity analysis of the TCO model was selected to see the model's sensitivity to changes in existing parameters. It was acted as the basis for determining policy recommendations. The model developed in this study also could be used to see the effect of fiscal and non-fiscal policies that were possible. For example, to look at the impact of decreasing the annual tax or parking fee, this study provided the option to give subsidies in decreasing or erasing tax, parking fee, or the other subsidy. With that, the effect of policy on TCO was perceived.

The data input used in this analysis was the type of user with low mobility, with a defined work period of 6, 9, and 12 years based on a survey of respondents where 14% of the battery has a service life of  $\geq 7$  years.

## 3. Results and Discussion

### 3.1 Results of Survey

The social factors based on the survey results showed that most CMs respondents had one unit of motorcycles with a level of environmental awareness in the very caring category. Meanwhile, most of the respondents of EMs owned more than one unit of motorcycles with a level of environmental awareness in the very caring category. Therefore, based on the survey results, the respondent profile is described in [Table 4](#).



**Table 4. Respondent Profile based on the survey**

Attribute	Value	Attribute	Value
Daily travel distance	Low mobility (14km per day)	Daily parking fee	Low Mobility (IDR 2,000.00)
	Medium mobility (28km per day)		Medium Mobility (IDR 2,000.00)
	High mobility (56km per day)		High Mobility (IDR 4,000.00 for CM; IDR 2,000.00 for EM)
Frequency of charging energy (for EM)	Low mobility (104 cycles)	Maintenance Cost	EM: IDR 70,000.00 per service
	Medium mobility (156 cycles)		CM: IDR 119,000.00 per service
	High mobility (208 cycles)		
Ownership period	Six years	Repair Cost	EM: IDR 7.34 / km
Insurance premium	1.5%		CM: IDR 12.5 / km

### 3.2 TCOc Value Calculation Results

Based on [Table 5](#), the purchase price and resale value of CM were lower than EM, while CM's operating costs were higher than EM. Through calculations using the formulation model 1, the TCOc value in [Table 1](#) showed that EM TCOc was more efficient than CM. These results are consistent with similar research in Indonesia, which compares the cost of owning an electric car, where the value of EV (Electric Vehicle) is proven to be more efficient than CV. Based on [Table 5](#), the CM value also suggested a value that tended to be higher than the EM value for all types of mobility. So, the higher the distance traveled in every type of mobility, the higher the cost savings in EM, increasing significantly.

**Table 5. TCOc Value Calculation Results**

Item	Low Mobility (IDR '000)		Moderate Mobility (IDR '000)		High Mobility (IDR '000)	
	CM	EM	CM	EM	CM	EM
Purchase Price	17,650.00	18,990.00	17,650.00	18,990.00	17,650.00	18,990.00
Operational Price	10,732.82	8,642.44	13,702.18	10,194.77	19,428.81	13,266.25
Resale Value	5,520.87	7,708.03	5,520.87	7,389.12	5,520.87	8,447.61
Battery Replacement	-	-	-	-	-	2,203.26
TCO - Consumer	22,861.95	19,924.41	25,831.32	21,795.65	31,557.94	26,011.90

The purchase price value had the same value for all types of mobility because the cost component was a one-time cost that was influenced by the withdrawn value using a discount factor for a particular year. However, while the CM resale value also had the same value, the EM had a different value for each type of mobility. The difference was in the remaining value of the battery at the end of ownership, which affected the resale value. As with high mobility, the resale value had a higher value than other types of mobility, because, in high mobility, there was a cost of replacing the battery. After all, the cycle life of the battery ran out and required replacement. Thus, at the end of ownership, the residual value of the battery had a higher value as it was a new battery and was added to the resale value of the EM. This component was essential to consider because, in previous

studies, such as in Riyanto, et al. [30], they did not consider the value of the remaining battery in the TCO calculation. Furthermore, the battery was still in the warranty period.

Therefore, based on Table 5, the component cost of replacing the battery for low mobility and moderate mobility was IDR 0.00 because the charging frequency during its lifetime had not exceeded the economic life of the battery, so it did not need replacing. At the same time, high mobility requires one-time battery replacement because high mileage results in higher charging frequency and influences battery economy during its lifetime.

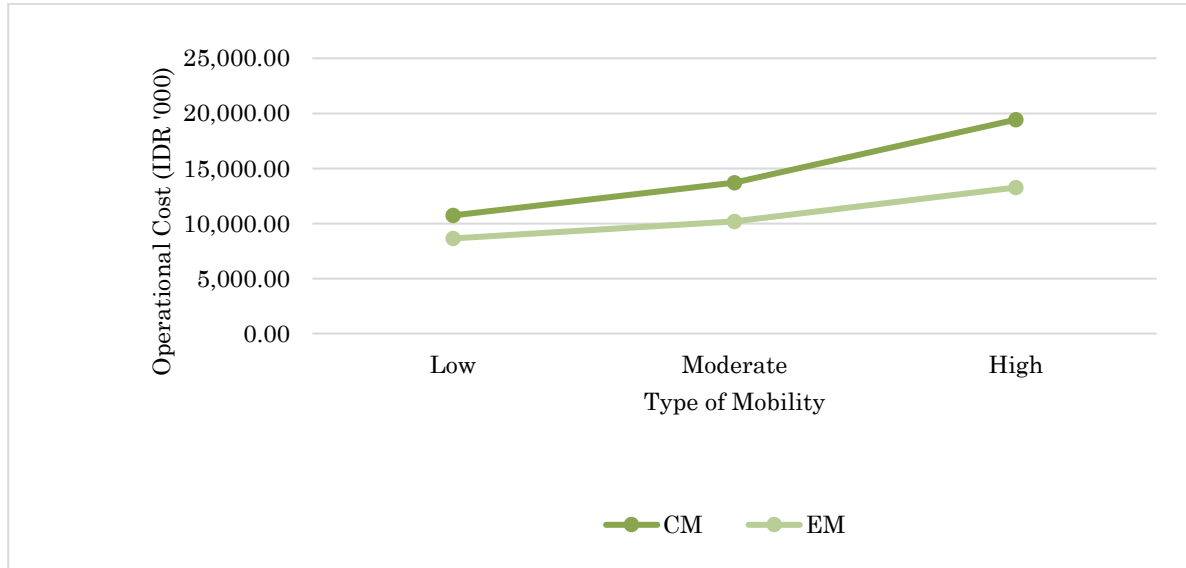


Fig. 2. Comparison of Operational Cost

Based on Fig. 2, the cost component that affected the difference between EM and CM consisted of operational costs, namely the energy consumption cost, repairs, and maintenance costs, which the distance traveled by the user influenced. Table 6 displays the CM respondents with the type of work. Meanwhile, EM respondents mainly consisted of respondents with low and medium mobility types. Based on these facts, CM could be used for all users. At the same time, EM was more suitable for low and medium-mobility users who only traveled within the city.

Table 6. The Types of Work in Every Mobility

Low Mobility	Medium Mobility	High Mobility
Students	Private employees	Drivers
Housewives	Entrepreneurs	Couriers
	Job seekers	Laborers or construction workers

In addition to energy consumption costs, the cost components that affected operational cost savings in EM were repair and maintenance costs explained in the detailed data in Table 4. This cost consisted of routine service costs and spare parts replacement costs. CM periodic service fees had a percentage of 41% higher than EM service fees because EM did not require oil changes in engine components. As for the cost of replacing spare parts, considering the components that require repair according to the



replacement period. EM had a lower replacement cost because it only required the replacement of brake pads and belts and did not require replacing the oil filter as a filter for engine combustion dirt which had a replacement period of every 30,000 km, such as CM. Thus, the ease of maintenance of EM provided a service cost savings of IDR. 5.16/km compared to CM [42].

The method in this study was seen as beneficial compared to previous studies that used input data based on assumptions and similar research data [43, 44]. In addition, because this study considered actual data according to each user's behavior and the remaining value of the battery outside the warranty period, it resulted in a more accurate TCO value and according to actual conditions.

### 3.3 Sensitivity Analysis

Sensitivity analysis was intended to see the model's sensitivity to changes in existing parameters [45]. Based on Fig. 3, during the six-year ownership period and nine years, the savings on TCO-EM were 9%, while in the 12 years of ownership period, the value of the TCO-EM savings decreased 1% compared to TCO-CM. Therefore, with the higher duration of ownership, the use of EM had a value that remained superior but not too significant. This condition was consistent with the research in Indonesia, which implemented a similar scenario on electric cars [30].

One of the reasons for the insignificant difference in TCOc value due to the increase in ownership period in this condition was the battery replacement factor, which was user mobility. The higher user's mobility, the higher frequency of charging the battery, and it decreases the economic life of the battery. Therefore, when a battery passes its useful life, it reduces capacity when used, and it becomes ineffective. In addition, the high battery price meant that the savings in EV TCO value were insignificant. Several similar studies in Thailand [24] have also shown a similar case in battery replacement costs because of the absence of regulations regarding battery recycling efficiency and the minimum number of business actors engaged in this field [46].

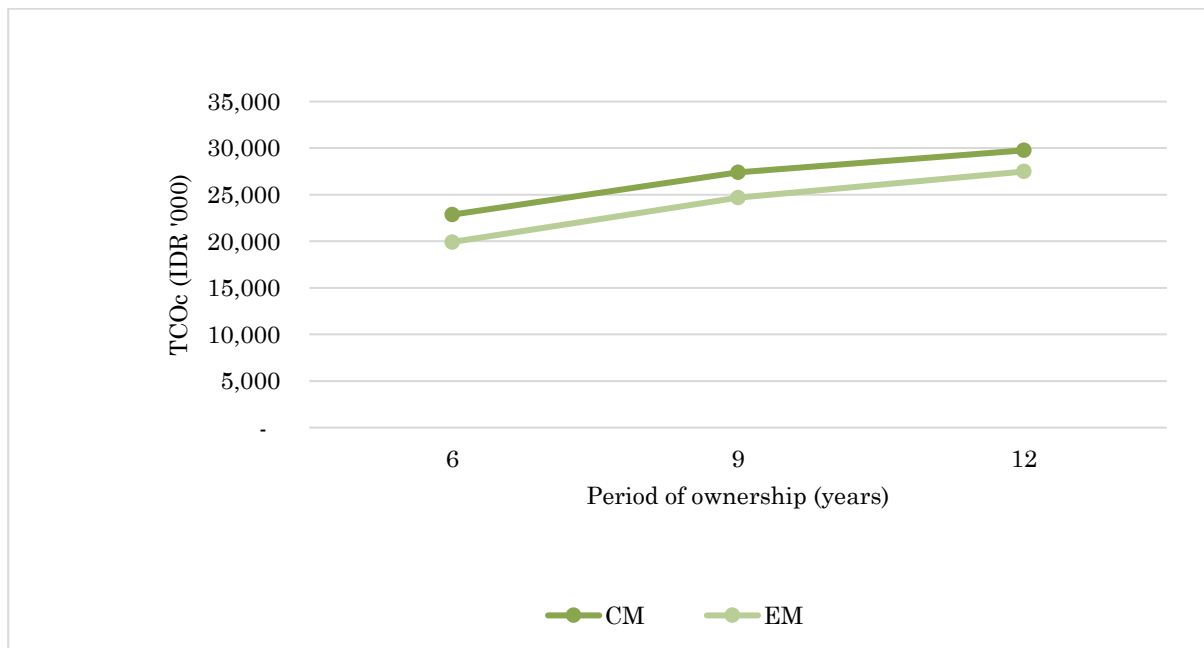


Fig. 3. Sensitivity Analysis of Duration Ownership

### 3.4 Policy Recommendation

Based on the calculation of the TCOc value of all types of mobility, the TCOc value of CM had a higher value than EM. If some subsidy was applied in EM, TCOc EM could be more competitive than CM. It is hoped to provide more operational cost savings for EM than CM and encourage consumer purchasing decisions towards EM. This scenario was shown in Fig. 4, where the existence of a tax subsidy reduced the value of EM TCOc by 2.9% (IDR 627,000). As discussed by the government, exemption from parking fees could also be one of the subsidies provided to further reduce the value of TCOc in EM. However, in this case, the government also needs to consider subsidies for the inclusion of parking attendants as compensation for the free parking policy for EMs in Indonesia. This scenario is shown in Fig. 5, where parking free reduced TCOc EM by 15% (2.9 million).

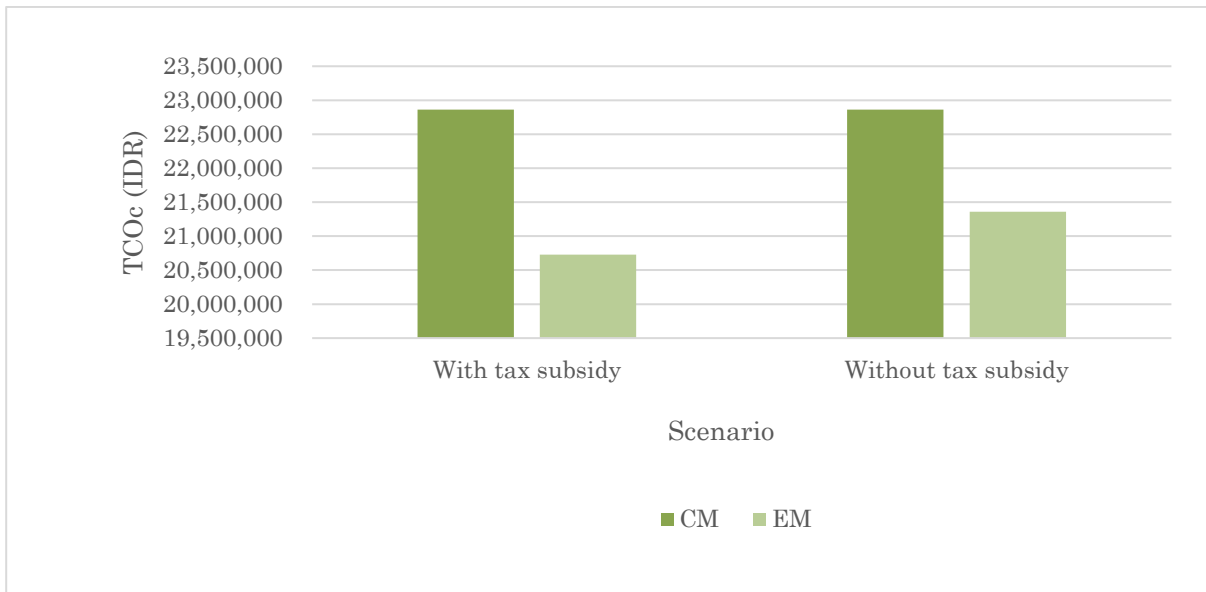


Fig. 4. The Influence of Tax Subsidy to TCOc in Low Mobility

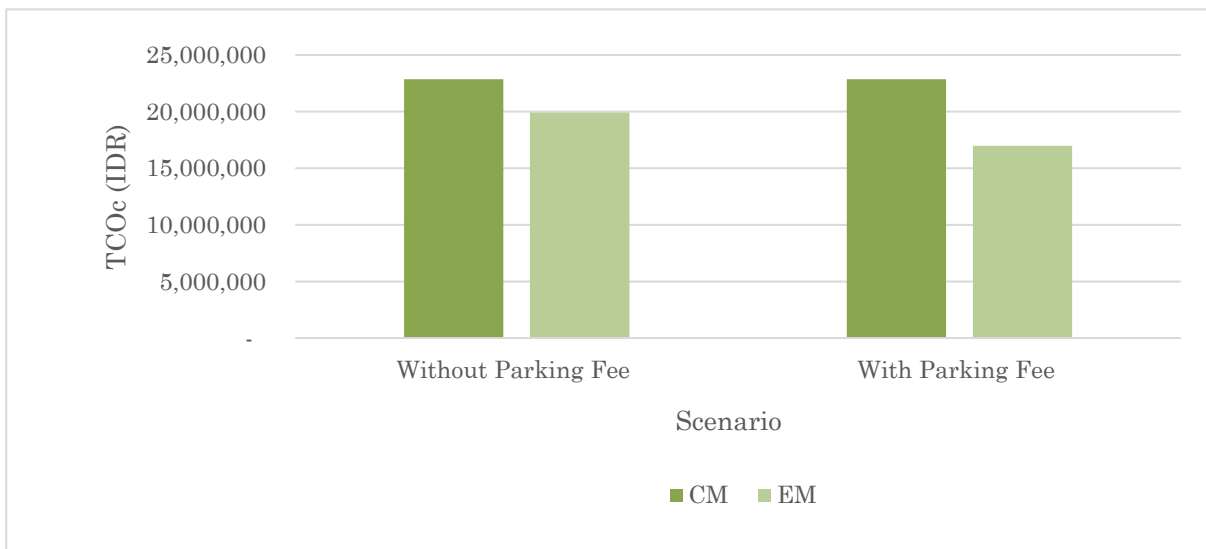


Fig. 5. The influence of Free Parking Fee on TCOc in Low Mobility

The reduction in TCOc in EM through the subsidy provision scenario, both on tax costs, parking fees, and other operational costs, could be taken into consideration by policymakers so that the public as users know in more detail about the amount of savings in EM use. In addition, replacement battery cost, which affected saving TCOc EM value, could be overcome with the support of infrastructures. It was presented in the Public Electric Vehicle Charging Station (SPKLU) with fast charging mode and General Electric Vehicle Battery Exchange Station (SPBKLU), which was realized immediately to overcome the impact of the disruptive decrease in battery capacity when driving. Policymakers also needed to review the battery recycling technology to reduce the purchase of existing batteries [47]. Hence, providing subsidies and supporting infrastructure, it was hoped to stimulate public interest to start shifting from CM to EM, which was more environmentally friendly and saved operating costs. It could also be a consideration for agents or manufacturers in determining the appropriate market segment and in determining suppliers for technology development to determine prices that can compete with CM products [48, 49].

#### 4. Conclusion

The TCO model developed consisted of the sum of the TCO value of consumer orientation capital expenditure (vehicle investment costs, battery investment costs, vehicle resale prices, battery resale prices), operational expenditure (energy consumption costs, repair and maintenance costs, insurance costs, annual taxes, interest payments, parking fees), and battery replacement costs. When the battery exceeds the economic life of the charge cycle, the capacity would be reduced by up to 70%. In addition, the battery replacement process affected the remaining value of the battery at the end of ownership. Therefore, it caused a difference in the resale value. Based on the calculation results, the TCOc value for six years was directly borne by the user. Furthermore, the calculation results showed that the EM value had a lower average value percentage. There were savings compared to CM of 12% (IDR 3 million) on low mobility, 16% (IDR 4 million) on medium mobility, and 18% (IDR 5.5 million) on high mobility. Finally, this research allowed the users to know that the purchase decision did not only consider the purchase price; it incurred total cost during the ownership period of the vehicle that was also considered.

Electric motorcycle manufacturers needed to understand the characteristics of the intended target market to increase sales [50]. Although not fully used as a marketing tool, education about TCO regarding the importance of understanding the value of TCO compared to the selling price offered could be conveyed by producers to consumers when they make direct offers. In addition, policy scenarios were needed in fiscal and non-fiscal to support the adoption of electric motorcycles and TCO value to be more competitive. It could encourage the achievement of the government's target, where there are as many as 2.1 million electric motorcycle owners by 2025.

Future research may consider more comprehensive components, such as the benefits of EV in terms of benefits in addition to the advantages of cost of ownership. In addition, the TCO component can also consider broader cost components such as external costs with an environmental or social orientation due to the impact of their use.

#### Data Availability

All data generated or analyzed during this study are included in this article.

## Declarations

**Author contribution:** Conceptualization is performed by Y. Yuniaristanto and W. Sutopo; methodology is carried out by Y. Yuniaristanto; data processing is performed by S. M. Afraah; validation is carried out by Y. Yuniaristanto and W. Sutopo; formal analysis is performed by S. M. Afraah and Y. Yuniaristanto; writing paper is performed by S. M. Afraah, Y. Yuniaristanto, W. Sutopo, and M. Hisjam; funding acquisition by M. Hisjam and Y. Yuniaristanto. All authors read and approved the final paper.

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