Available online at : http://josi.ft.unand.ac.id/

Jurnal Optimasi Sistem Industri

| ISSN (Print) 2088-4842 | ISSN (Online) 2442-8795 |

Research Article

Evaluation of Driving Comparative Life Cycle Cost Assessment of Conventional and Electric Motorcycles in Indonesia: Monte Carlo Analysis

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ARTICLE INFORMATION

Received : July 30, 2022
Revised : September 27, 2022
Available online : November 30, 2022

KEYWORDS

Electric motorcycle, conventional motorcycle, life cycle cost, monte carlo simulation, tangible

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ABSTRACT

The adoption of electric vehicles (EVs) is one of the solutions to reduce emission problems. Vehicle cost analysis is one of the keys to seizing the Indonesian market. As a consumer, it is not only the purchase price that needs to be considered, but the life cycle costs throughout ownership also need to be considered in the purchase. This study discusses the life cycle cost (LCC) of EVs in Indonesia, especially electric motorcycles (EMs), which will be compared with conventional motorcycles (CMs). In particular, this study aims to encourage the government's target for ownership of 2.1 million EMs in Indonesia by 2025. The novelty of this research is to develop a more comprehensive LCC model by considering the costs in terms of tangible and intangible to compare the two types of motorcycles using Monte Carlo simulation. This simulation is used to coordinate the behavioral uncertainty of motorcycle users. As a result, the value of an EM is more economical than CM for various users. The average value percentage of EMs is lower than CMs by 45% (IDR 30,6 million). In addition, several scenarios are also analyzed to maximize consumer welfare in Indonesia.

INTRODUCTION

The transportation sector is an essential pillar in social life and economic development, characterized by energy density. The International Energy Agency reports that global economic activity will increase above 2019 levels in 2021. In addition, global energy demand will also increase above 2019 levels. A full recovery of global transport activity will push oil-related emissions above 2019 and increase global emissions. Carbon dioxide (CO_2) emissions exceed 1.5%, well above 2019 levels. By 2021, oil demand is expected to recover by 6%, faster than all other fuels. Only in Asia and, especially in China, did oil demand rise well above pre-Covid-19 levels [1]. In particular, energy consumption for passenger vehicle travel is expected to experience a substantial increase as a result of the dramatic growth in the middle class and increased urbanization in developing countries [2].

In addition, conventional vehicles (CVs) are highly dependent on oil, which poses several challenges. The risks to global oil supplies are exacerbated, particularly by the extreme mismatch between oil production and oil consumption locations in outer space. Some major oil consumers in Asia and Europe, such as China, India, Japan, and Germany, have an external dependence on oil of more than 46% [3]. In addition, CV's contribution to urban air pollution is significant, which seriously affects human health. A major step towards transitioning the Fleet CV to electric vehicles (EV) has been observed worldwide to address this challenge.

In 2021, the development of fueled vehicles in Indonesia will increase rapidly to reach 143.7 million units, consisting of 11.8% passenger cars, 0.2% bus cars; 3.8% freight cars; and 84.3% motorcycles [4]. In addition, motorcycle-fueled or conventional sales will continue to increase to 5,057,516 units in 2021[5]. Based on this, the presence of motorcycles in Indonesia is quite significant compared to other motorized vehicles because motorcycles are low-cost vehicles with high flexibility and can adapt to road conditions [6]. The advantages of using motorcycles encourage consumers to choose these vehicles as the primary mode of transportation. In fact, the higher the number of conventional motorcycle users will also increase the number of

DOI: 10.25077/josi.v21.n2.p55-65.2022

pollutants and combustion emissions in the environment. Because of this, a solution for environmentally friendly and energy-efficient transportation is urgently needed, such as through innovation in EV technology and battery technology innovation [7]. So it is necessary to migrate from conventional motorcycles (CMs) to electric motorcycles (EMs) that are more environmentally friendly.

This solution was later strengthened by Presidential Regulation No. 55 of 2019 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 gases. Through this regulation, the government also promotes the usage of EMs and cars, followed by the issuance of 17 incentives for electric cars. The Ministry of Transportation noted that until March 16, 2022, there were only 16,060 units of battery-based electric motorized vehicles in Indonesia. Until September 2021, the Ministry of Energy and Mineral Resources noted that 187 Public Charging Station (PCS) units were operating and spread across 155 locations in Indonesia, and 153 units of Battery Swapping Station (BSS) spread across 86 locations (Jakarta and Tangerang) to support the EM ecosystem [8].

Electric motorcycles can be produced in 2 types in Indonesia. The first type is a battery charging EM, an EM made by a company with a new design using electric technology. Charging this motorcycle can take 6 to 8 hours in one charge cycle. There are 24 brands of motorcycles that have received motorcycle-type test letters from 16 EM manufacturers. However, only six brands have produced and received Type Test Registration Certification, namely VIAR, SDR, Gesits, Selis, Mygo, and Kymco [9]. The second type is the battery swapping EM, which applies a battery swap system in charging the battery. Charging this motorcycle does not take as long as an EM battery charging. Drivers only need to swap their batteries at the nearest BSS. For example, the SWAP Battery System is a BSS that is specifically intended to charge the battery of the Combat Smoot EM. The used battery can be swapped for a fully charged one at the BSS called SWAPPoin. This battery replacement process only takes 9 seconds [10].

The total population of EMs until mid-November 2021 reaches approximately 10,300 units circulating in the community. The government aims to have 2.1 million EMs by 2025 [11]. However, the fact shows that the adoption of EMs in Indonesia is still low. The low level of adoption of EVs is caused by several factors that hinder the bargaining power of buyers, such as the lack of strict regulations on reducing greenhouse gases, the high price and cost of owning EVs compared to CVs, and the unavailability of charging infrastructure in public places [12]. In addition, it is necessary to consider the comfort and safety of EM riders. Consideration of environmentally friendly waste treatment is also needed so as not to cause waste to accumulate [13]. Based on these obstacles, policy proposals such as subsidized cost incentives, discounts, tax breaks, and other policies can be factors that can attract interest and accelerate the adoption process by consumers. EMs in Indonesia have a varied selling price range, ranging from tens of millions of rupiahs to more than one hundred million. The selling price of the battery is still relatively high, which is above five million rupiahs for one battery. However, compared to CMs in the same class, EMs have a lower life cycle cost (LCC) than CMs. One component of LCC is the cost of energy consumption, fuel, and electricity. Fuel prices are projected to increase when compared to electricity prices. Crude oil prices are above US$ 100 per barrel, triggering fuel oil prices in many countries, including the United States (US), Europe, and Asia.

In Indonesia, the fuel oil sold by the Oil and Gas Mining State Company (Pertamina) is still below the economical price. For example, the price of RON 95 or Pertamax Turbo is only IDR. 14,500 - IDR. 14,800 per liter. While the price of Pertamax reached IDR 12,500 per liter, and the price of Pertalite reached IDR 7,650 per liter. The increase in fuel prices can be triggered by the Organization of the Petroleum Exporting Countries (OPEC), oil-producing countries' situation, technological developments discoveries, oil companies, and the higher global oil demand [14]. In addition, oil reserves in Indonesia are projected to only be available for the next 9.5 years, while the lifespan of Indonesia's natural gas reserves is 19.9 years [15]. However, most consumers only see the selling price as a decision-making factor in buying the vehicle. Knowing LCCs can help consumers in making purchasing decisions and can assist manufacturers in determining the selling price of vehicles.

Research on adopting EMs in Indonesia has been conducted to determine the effect of objective factors on consumer buying interest using logistic regression methods and Partial Least Square - Structural Equation Model [16]. However, this study has limitations in knowing and predicting the rate of adoption-diffusion of EMs in Indonesia from year to year. A simulation model can solve the limitations of using this method. Simulation is an imitation of the operational process of an actual condition or system from time to time [17]. Simulation models are a suitable alternative for describing a complex system, especially when analytical mathematical models are difficult to do [18].

Previous research on various vehicle LCCs emphasized tangible costs, including purchase, operation, and residual costs, as in this study [19]. Estimates the policy costs of incentivizing electric and hydrogen vehicles through established mechanisms for the transport sector. The weakness of this study is that it does not take into account intangible costs, so it does not fully measure the implicit costs of vehicles. Different from research [20] that has explored intangible costs for purchasing and driving restrictions. However, this study has not implemented a credit scheme for consumers buying vehicles. Therefore, in addition to considering intangible costs, this study also considers credit schemes in the vehicle payment process.

A simulation model makes it easier for modelers to develop demand, market, and consumer behavior models in adopting EVs. As in research [21] which calculates the economic benefits of BEV compared to CV, which is analyzed in various scenarios, and then the Monte Carlo model is used to explain the sensitivity of the variables in the total cost of ownership model. Besides that, Letmathe [22] also applied a Monte Carlo simulation to determine the overall distribution and the overlap between the cost of ownership between EV and ICEV, which was interpreted by 500,000 iterations per simulation to determine the validity of various assumptions that could affect the market penetration by

DOI: 10.25077/josi.v21.n2.p55-65.2022

EVs in Germany. However, both studies still use cars as their research objects. Not many studies use CMs and battery electricity as research objects. Therefore, this study uses Monte Carlo simulation to determine the overall distribution and overlap of the total LCCs between the EM and CM. Thus, it is possible to validate the reliability of the results under various assumptions and how this might affect market penetration by EVs in Indonesia. This research focuses on the market for CMs and battery EMs in Indonesia.

Based on the background of these problems, this paper aims to compare the LCCs of electric and CMs in Indonesia. Parts of this article are organized as below. First, the LCC model is expected to support studies and considerations regarding the importance of understanding LCCs, which include tangible and intangible costs in purchasing electric and CMs in Indonesia, so that consumers do not only look at the selling price of the motorcycle. Second, the Monte Carlo simulation is expected to accommodate motorcycle users' operational behavior and maintenance. Third, this research is also expected to be a supporting study in analyzing and providing recommendations in making decisions regarding prices and market segments in the sale of EMs, as well as policy advice related to EMs.

METHOD

Conceptual Framework Design

The conceptual framework is designed from the attributes that affect the LCC. The LCC consists of tangible cost attributes consisting of purchase costs (manufacturer's retail price, license fees, vehicle purchase tax, government subsidies), operation cost (annual insurance fee, vehicle usage tax, annual energy usage fee, and annual maintenance fee), and residual cost (battery recycling price). Next are intangible costs, which consist of the purchase and driving restriction costs. Then, each attribute is grouped, which attributes are directly affected by user behavior and retrieved through primary data and which attributes can be retrieved through secondary data.

Data Collection and Processing

Based on previous research [23], the questionnaire designed in this study was divided into a CM questionnaire and an EM questionnaire. The question scale given to the main question consists of an interval scale. The number of samples in this study used the minimum number of samples for survey research, which was 100 respondents. The sampling technique used in previous research is Non-Probability Sampling, which is a sampling technique that does not provide equal opportunities for each element or member of the population to be selected as a sample. The population in this study was huge, so the sample selection used the cluster sampling method or area sampling. In addition, it also uses the purposive sampling method. Purposive sampling is a method of determining the sample based on specific criteria. The following are the requirements for respondents to previous research surveys: 18 years old, have a SIM C, one of the decision-makers to buy a motorcycle, and domiciled in one of the provinces, namely West Java, East Java, DKI Jakarta, Central Java, Sumatra North, West Sumatra, DI Yogyakarta, South Sulawesi, South Sumatra, and Bali. Ten provinces were chosen as the respondents' domicile requirements with the assumption that they could represent motorcycle users in Indonesia. However, due to the more updated regulations regarding EMs in Jabodetabek (an acronym for Jakarta–Bogor–Depok–Tangerang–Bekasi), this area will be used as a reference in this study.

The questionnaire designed in this study was divided into three parts. The first part contains screening questions that ensure that the respondent is said to be valid if they meet the predetermined requirements. The second part contains questions and statements related to sociodemographic factors. The third section contains the main statements regarding user behavior. The questionnaire is semi-open for user profile questions in the form of name, domicile, marital status, age, gender, last education, occupation, monthly income level, number of motorcycle ownership, and size of social network reach. Other/main questions are combined, consisting of semi-open and closed questions—dissemination of online questionnaires through social media and LinkedIn. Questionnaires are distributed to respondents who have been determined, namely with the criteria requirements and selected areas. The online questionnaire was created with the help of the google form service, which makes it easy and has features that help research. The results of the respondents' answers are automatically captured on the google form. To make it easier to recap the data, the researcher also uses the Google Sheet service to recap the data from the questionnaire results so that they can be processed further. Processing of respondent data using Excel 2019 and Crystal Ball software.

LCC Model Development

The LCC model is then developed based on the data collected and the conceptual framework that has been designed. The LCC model refers to research [23] and [20], which adjusted for each parameter with the Indonesia conditions. The developed model significantly contributes to determining tangible and intangible costs in Indonesia. Therefore, this research adds license fee (LF) variables, insurance costs (InC), and interest installments (Bank Indonesia rules Number 22/13/PBI/2020 concerning advances for loans or motor vehicle financing and new rules that come into effect on March 1, 2021) as a consideration in the calculation of the LCC model. The following main models of LCC consist of the purchase cost (PC), operational cost (OC), residual cost (RC), purchase restriction cost (PRC), and driving restriction cost (DRC) that influenced by discount rate (r) and ownership period (n). Equation (1) is obtained based on the above assumption.

$$LCC = \left(PC + OC - \frac{RC}{(1+r)^{n-1}}\right) + (PRC + DRC) \tag{1}$$

A more detailed explanation of the model is described as follows.

Tangible Cost

Tangible Cost (TC) is obtained from the manufacturer's retail price (MRP), license fees (LF), purchase taxes (PT), vehicle usage tax (VuT), energy usage fee (EuF), maintenance fee (MF), year (k), discount rate (r) and ownership period (n). Equation (2) and equation (3) are obtained based on the above assumption.

$$TC = PC + OC - \frac{RC}{(1+r)^{n-1}} \tag{2}$$

$$TC = MRP + LF + PT + \sum_{k=1}^{n} \frac{\mathrm{VuT+EuF+MF}}{(1+r)^{k-1}} - \frac{RC}{(1+r)^{n-1}} \quad (3)$$

The purchase cost (PC) used in this study is the sum of the manufacturer's retail price (MRP), license fee (LF), and purchase tax (PT). Equation (4) is obtained based on the above assumption.

$$PC = MRP + LF + PT \quad (4)$$

The manufacturer's retail price in this study is the initial price purchased in year 0, assumed to be in early 2022. The price will decrease in the following year due to motorcycle depreciation. Meanwhile, the license fee is obtained from the sum of the vehicle ownership book (BPKB), vehicle registration letter (STNK), vehicle plate number (TNKB), and administration fee. Equation (5) is obtained based on the above assumption.

$$LF = BPKB + STNK + TNKB + Admin\ Fee \quad (5)$$

The vehicle purchase tax (PT) is obtained by multiplying the value-added tax (PPN) rate with the manufacturer's retail price (MRP). The PPN rate used is 11%. Equation (6) is obtained based on the above assumption.

$$PT = \%PPN\ x\ MRP \quad (6)$$

r or Discount Rate

The discount rate is also an essential component in economic calculations because using this discount rate makes economic calculations spread over time can be drawn and adjusted to the existing value for the present value. The discount rate in this study is obtained from the sum of the average inflation rate with the average consumption interest rate from the company's bank in the last 12 months so that the discount rate is 12.78% and is assumed to be constant from year to year.

OC or Operation Cost

Vehicle operating costs (OC) is obtained from the sum of vehicle usage tax (VuT), energy consumption costs (EuF), and maintenance costs (MF). Equation (7) is obtained based on the above assumption.

$$\mathrm{OC} = \sum_{k=1}^{n} \frac{\mathrm{VuT+EuF+MF}}{(1+r)^{k-1}} \quad (7)$$

The vehicle usage tax is the percentage of progressive tax (%TP) multiplied by the resale value (RV), then added with traffic accident insurance (SWDKLLJ). The resale value (RV) for the first year is obtained from Samsat data multiplied by the percent depreciation of the vehicle (dv) during a given year (t), while RV in the following year is calculated using the depreciation formula so that it is by the current condition of the vehicle. Equation (8) is obtained based on the above assumption.

$$VuT = \left(\%TP\ x\ ((1-dv)^{t-1} x\ RV)\right) + SWDKLLJ \quad (8)$$

Energy consumption costs are obtained by multiplying the average annual mileage (AAM), energy consumption (EU), and fuel price (FP) divided by the efficiency of refueling energy (η) [23]. Equation (9) is obtained based on the above assumption.

$$EuF = \frac{\mathrm{AAM\ x\ EU\ x\ FP}}{\eta} \quad (9)$$

Maintenance fees (MF) are obtained from the sum of insurance costs (IC), parking fees (PF), service fees (SF), and loan interest costs on motorcycle loans (InC) which are calculated throughout ownership. Equation (10) is obtained based on the above assumption.

$$MF = IC + PF + SF + InC \quad (10)$$

Insurance costs (IC) are obtained from the percentage of the premium (PP) multiplied by the Purchase Cost (PC) and admin fees. Equation (11) is obtained based on the above assumption.

$$IC = \%PP\ x\ PC\ x\ Admin\ Fee \quad (11)$$

The service fee (SF) is obtained by multiplying the cost of routine service (CR) multiplied by the average annual vehicle mileage (AAM), which is added to the cost of component replacement (CM), where routine service costs for all types of motorcycles tend to be the same and consist of tune-up services. At the same time, the cost of component replacement considers the distance traveled by the user within the component replacement period. Equation (12) is obtained based on the above assumption.

$$SF = CM + (CR\ x\ AAM) \quad (12)$$

The daily parking fee (PF) adjusts from the data costs filled in by the user as a result of processing the questionnaire so that the annual parking fee is obtained by multiplying the daily parking fee by 365 days/year. Equation (13) is obtained based on the above assumption.

$$PF = P\ x\ 365 \quad (13)$$

The interest expense on the motorcycle loan per year (InC) is calculated based on the total installment fee, which includes the amount of down payment paid, the purchase price of the vehicle (PC) along with interest charged (IR) for a predetermined tenor (N) less the purchase price initial vehicle. Equation (14) is obtained based on the above assumption.

$$InC = 12\ \left(\left(\frac{PC-DP}{N} + IR\ x\ PC\right) - \frac{1}{N} x\ PC\right) \quad (14)$$

When the battery has passed the economic life of the battery or exceeds the charge cycle limit, the battery requires replacement. Replace the battery using the following formula, where the battery replacement cost (BRC) is obtained from the calculation between the battery capacity (Bbc) and the price of the battery (Cbp) itself, taking into account the discount rate in the year of replacement. Equation (15) is obtained based on the above assumption.

$$\mathrm{BRC} = \mathrm{Bbc\ x\ Cbp} \quad (15)$$

DOI: 10.25077/josi.v21.n2.p55-65.2022

The battery replacement period (i) is obtained by dividing the economic life of the battery (b) by the charging frequency (F_F). Equation (16) is obtained based on the above assumption.

$$i = \frac{b}{Ff} \tag{16}$$

The frequency of battery replacement (f) is obtained by dividing the length of ownership (n) by the battery replacement period (i). Equation (17) is obtained based on the above assumption.

$$f = \frac{n}{i} \tag{17}$$

RV or Resale Value

One of the primary considerations for consumers when buying a motorcycle in Indonesia is the resale value. Thus, resale value declines over time, so it can be seen as a burden on calculating the total cost of ownership of the motorcycle. The total resale formula used in this calculation is sourced from research [20]. Affected by the depreciation value over the life of ownership and multiplied by the manufacturer's retail price, which is then divided by the discounted interest rate over the life of ownership. Equation (18) is obtained based on the above assumption.

$$RV = \frac{(1-dv)^n \ x \ MRP}{(1+r)^{n-1}} \tag{18}$$

RC or Residual Cost

This study's residual cost (RC) calculation came from Li’s research in 2021. Influenced by the value of vehicle depreciation (dv) over the life of ownership multiplied by the manufacturer's retail price (c) and then totaled by the battery recycling cost (RBP). Equation (19) are obtained based on the above assumption.

$$RC = (1 - dv)^n \ x \ MRP + RBP \tag{19}$$

Intangible Cost

The intangible cost comes from the sum of the cost of vehicle purchase restrictions (PRC) and the driving restrictions cost (DRC). Equation (20) and equation (21) are obtained based on the above assumption.

$$IC = PRC + DRC \tag{20}$$

$$PRC = \text{tp x ALP} \tag{21}$$

The purchase restriction fee is obtained by multiplying the waiting time before owning a vehicle (tp) by the motorcycle rental price while waiting for motorcycle ownership and annual lease price (ALP). In this case, the waiting time used in the calculation is assumed that in a year, the consumer only buys one motorcycle after waiting for 21 days.

The cost of driving restrictions is obtained from multiplying the average annual motorcycle mileage with the time and price of motorcycle rental during odd-even periods. Equation (22) are obtained based on the above assumption.

$$DRC = AAM \ x \ \text{td x ALP} \tag{22}$$

Monte Carlo

The Monte Carlo simulation performs variable simulations repeatedly. Depending on the reviewed variable, iteration can be conducted hundreds or thousands of times. Determination of the number of iterations can be done by:

1. Logical assumptions from related experts or the programming language of the tools/software used, for example, to obtain a validity level of up to 99%, 1000 iterations are required for each variable.

2. Using the error value formula (ε). The Monte Carlo Simulation (MCS) technique can predict the error value in the number of iterations. The error value formula is as equation (23).

$$\varepsilon = \frac{3\sigma}{\sqrt{N}} \tag{23}$$

3. Where is the error value, is the Standard deviation, and N is the number of iterations. Based on this formula, the first step in calculating iterations is calculating the variable's standard deviation value (σ) to test. Standard deviation is calculated to measure the distribution of data from these variables. Equation (24) is obtained based on the above assumption.

$$\sigma = \sqrt{\frac{\Sigma(\mathrm{X}1,2-\mu)^2}{N}} \tag{24}$$

4. X_1 is the minimum LCC value, while X_2 is the maximum LCC value on every electric and CM, which will be calculated on the average (μ). The next step is to determine an absolute error value of 1%, which means that it only provides a minimal error tolerance for each random value generated in the simulation. To calculate the number of iterations (N), it used division between standard deviation (σ) and error values (ε). Then, the result of the division is squared. Equation (25) and equation (26) are obtained based on the above assumption.

$$\varepsilon = \frac{\mu}{(\frac{1}{0,01})} \tag{25}$$

$$\mathrm{N} = (\frac{3\sigma}{\varepsilon})^2 \tag{26}$$

Based on the calculation, the discount rate (r) used is 12.78%, with a motorcycle ownership period of six years. The rate of depreciation of the vehicle and the depreciation of the battery used is 6.01% and 33%, respectively. Meanwhile, the charging efficiency of electric and CMs is 80%/charging and 100%/charging. The prices for Pertalite, Pertamax, and household electricity are IDR. 7,650, IDR. 12,500, and IDR. 1,604, respectively. Meanwhile, the price of swapping batteries ranges from IDR. 4,375 to IDR. 6,000.

RESULTS AND DISCUSSION

Model Verification and Validation

Verification aims to determine whether the simulation program created is running as desired. Verification also checks for a change from a conceptual model to a computer program that runs correctly. The technique used in verifying the simulation program in this study was carried out by examining the logical relationship between variables and checking the consistency of the unit variables in the model. The inspection process using the Excel 2019 developer is carried out automatically when running the simulation model. If there is an incorrect input model, then the results of the running model will have a significant error value, and the model cannot be run. The verification stage occurs when the model is run in Excel 2019. The results show that the model can run well, and there are no warning signs in the form of 'errors' on the variables in the model. It shows that the relationship between variables in the logical model and the units used for each variable in the model is consistent, so it can be decided that the model built is consistent.

Model validation was performed using statistical tests to see the deviation between the simulation output and the actual data. The statistical test used to validate this study's simulation model's output is the mean absolute percentage error (MAPE) test. The model is declared valid if the deviation between the simulation model's output and the output of the actual system can be accepted statistically. A validity test is carried out on the response variable, which is the system's performance or external variables.

Based on [24], MAPE values can be interpreted or interpreted into four categories, namely <10% means very accurate, 10-20% means good, 20-50% means reasonable, and >50% means inaccurate. Based on this and data availability, the variables of maintenance fee and energy usage fee of CMs were selected to be tested for validity. Testing the validity of the system simulation output on data acquisition from the actual system is done by making a data table from the simulation results and the actual data table in the same period. In the simulation system, the response variables that become the performance criteria of the system are:

Maintenance Fee

In the maintenance fee, service costs are determined by the frequency of service, insurance costs, parking fees, and loan interest costs. In this case, the frequency of the motorcycle rider's service will determine the annual service fee of the motorcycle. Table 1 shows the result of the maintenance fee variable for six years.

Table 1. Maintenance Fee

Year	Actual (IDR)	Forecast (IDR)	MAPE
1	3.159.370	3.225.808	7%
2	2.800.543	2.869.064	
3	2.800.543	2.867.622	
4	1.477.940	1.163.309	
5	1.090.640	1.156.998	
6	1.090.640	1.158.621	

Based on the validity test, the MAPE value for the maintenance fee variable is 7%, meaning the ability of the built forecasting model is very accurate.

Energy Usage Fee

The energy usage fee includes energy consumption per km, fuel prices, refueling efficiency, and average annual mileage. In this case, the motorcyclist's average annual mileage will determine the motorcycle's annual service fee. Table 2. shows the simulation results for the energy usage fee variable each year. Based on the validity test, the MAPE value for the energy usage fee variable is 0.155%, meaning the ability of the built forecasting model is very accurate.

LCC Value Calculation Results

Table 3 shows the results of calculating the LCC of CM and EM values based on the development of the LCC model in the formulation of model 1. Based on Table 3., it can be seen that the operational costs of EM are much cheaper than those of CM. Due to the higher cost of energy consumption owned by CM. However, the residual Cost of EM is higher than that of CM due to the purchase cost of EM, which is much more expensive than CM. CM has additional costs, namely intangible costs consisting of purchase restriction costs and driving restriction costs, while EM does not. It aims to increase the adoption-diffusion of EMs in Indonesia. So it can be concluded that the value of LCC CM is greater than EM.

Scenario Analysis

Based on Figure 1. The EM savings are 53% over the six-year ownership period, 48% over the nine-year ownership period, and 53% over the 12-year ownership period. The x-axis shows the length of time the users have owned a motorcycle, while the y-axis shows the LCC value in that year. The significant savings on battery EMs compared to CMs are due to the enormous intangible costs of CMs, as in the study [23], which discusses the application of intangible costs to EMs in China. In addition, the residual value of the battery at the end of the ownership period causes a significant difference in the vehicle's resale value each year. In addition, there are battery replacement costs that also affect the remaining value of the battery and the resulting LCC value.

Table 2. Energy Usage Fee

Year	Actual (IDR)	Forecast (IDR)	MAPE
1	2.377.127	2.385.628	0,155%
2	2.381.144	2.383.771	
3	1.458.128	1.459.664	
4	1.456.392	1.460.254	
5	1.455.091	1.456.205	
6	1.457.115	1.456.889	

Table 3. LCC Value

Items	CM (IDR)	EM (IDR)
Purchase Cost	17.432.761	22.130.000
Operational Cost	14.638.610	13.993.653
Residual Cost	9.734.234	17.001.676
Purchase Restriction Cost	1.050.000	-
Driving Restriction Cost	32.130.000	-
LCC	59.757.413	26.527.983

DOI: 10.25077/josi.v21.n2.p55-65.2022

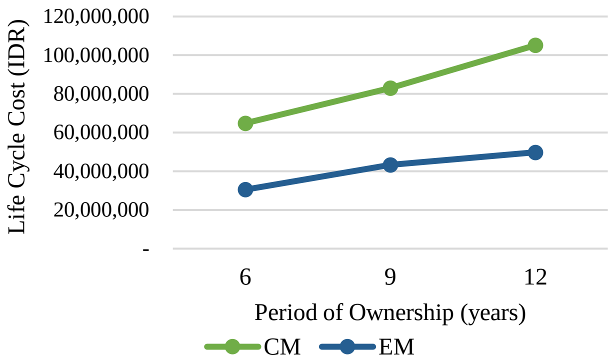

Figure 1. LCC Value Graph

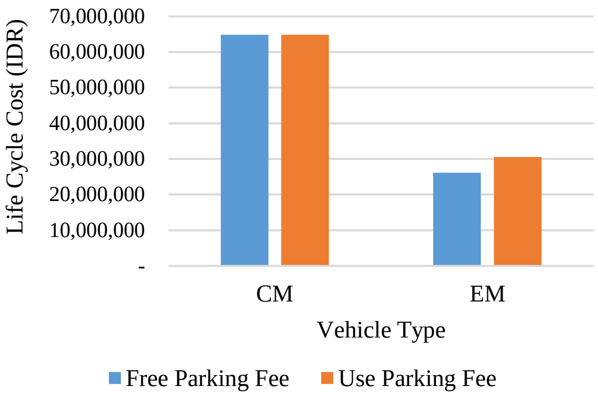

Figure 2. Free Parking Fee Scenario Bar Chart

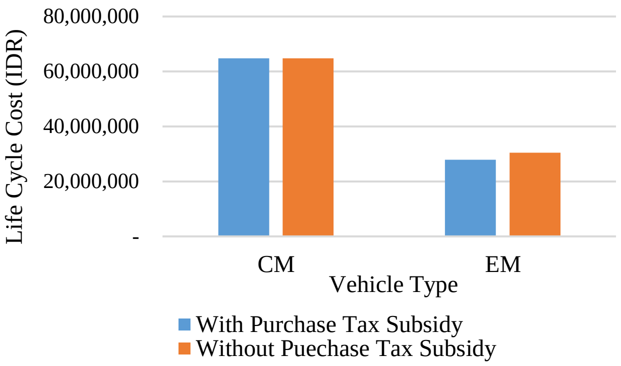

Figure 3. LCC Value Graph

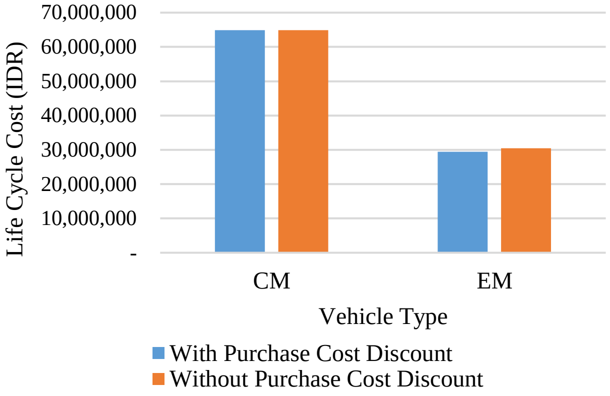

Figure 4. Purchase Cost Discount Scenario Bar Chart

Where on EMs, the battery replacement period is once every seven years, so even in the 6, 9, and 12-year ownership period, there is a 1-time battery replacement, EMs still have a lower and superior value. It shows that the higher the duration of ownership, the LCC value of EM consumers has a value which is still superior but not too significant. This condition is in line with research [25] in Indonesia which uses a similar scenario in electric cars. When the battery has passed its useful life, its capacity decreases and, when used, becomes ineffective. Thus, the battery requires replacement, and the cost of replacing the battery is relatively high and causes significant savings in the LCC value of battery EMs. Several similar studies in Thailand [26] also show a similar case in the case of battery replacement costs. One of the reasons for the high cost of replacing the battery is because there are no regulations regarding the efficiency of battery recycling and the small number of business actors engaged in this field.

Policy Recommendation

To encourage the level of EM adoption, the government needs to develop various policy scenarios to support its achievement.

Scenario Free Parking Fee

Figure 2 shows a decrease in the value of LCC when there is a free parking policy for EM users. The average decline value is 14% (IDR 4.3 million) on EMs. Although the LCC decreases, the policy certainly needs to be adjusted to the Indonesia conditions. When the free parking policy is realized, the government must also provide subsidies to the parking officers concerned so that no party feels disadvantaged due to the policy. This scenario related to the provision of free parking is also a scenario in similar studies to reduce the value of LCC, such as by encouraging EVs in Italy [27]. Therefore, considering the decrease in LCCs for EM users, the recommendation for a free parking fee policy needs to be considered.

Scenario Purchase Tax Subsidy

Figure 3 shows that LCC decreases when a tax subsidy policy is applied for the EM purchase, which is paid at the beginning of the purchase of an EM. The average decline value is 9% (IDR 2.6 million) on EMs. Regulations related to tax subsidies in Indonesia have been applied in several regions, such as the Jakarta area and several other big cities. Scenarios related to the policy of subsidizing or reducing taxes on low-emission vehicles have been implemented in several European countries, which consist of exemption from registration tax when purchasing EVs, exemption from annual taxes, as well as providing direct subsidies which are integrated into the vehicle registration tax through reductions purchase price. A scenario related to subsidies or tax discounts has proven to increase EV sales in the European region, such as in Italy, Norway, and the Netherlands, where sales of Battery Electric vehicles (BEV) and Plug-in Hybrid Electric vehicles (PHEV) are relatively high. Therefore, the recommendation for a purchase tax subsidy should be considered considering the decrease in LCCs for EM users.

Scenario Purchase Cost Discount

Figure 4 shows a decrease in the value of LCC when there is a policy of discounting the purchase price on EMs. The average decline value is 4% (IDR 1.1 million). One of the factors that cause people to be reluctant to buy EVs is the high purchase price and the public's lack of understanding regarding the savings in the value of this LCC on EVs. Therefore, one of the scenarios that the government can implement is providing subsidies for EV purchases, especially EMs.

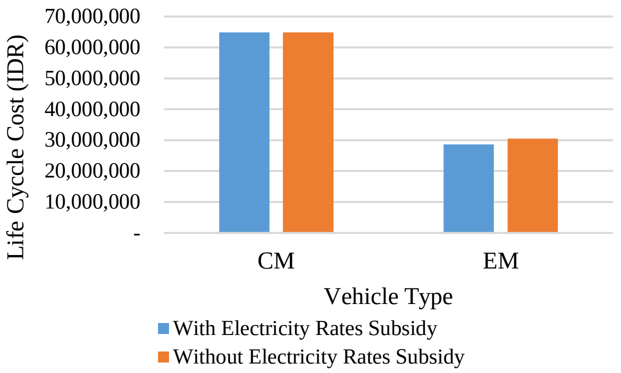

Figure 5. Electricity Rates Subsidy Scenario Bar Chart

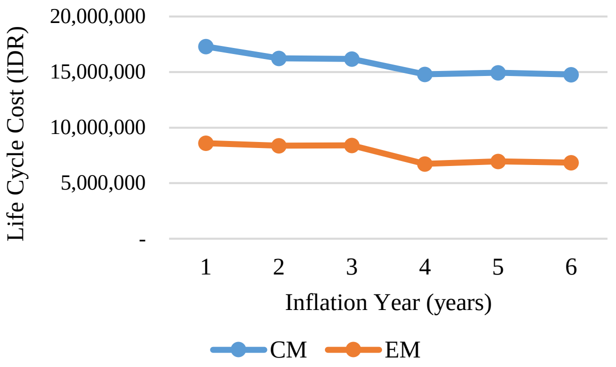

Figure 6. Increase in Fuel Prices and Electricity Tariffs

In this case, several countries are also using this scenario to encourage the adoption of low-emission vehicles in their regions. For example, the UK provides grants from the government to dealers or vehicle manufacturers to eligible consumers when making purchases of low-emission vehicles through discounting the price of the vehicle. In this scenario, the discount on the purchase price for motorcycles can reach 20% of the purchase price. Then, the state of California also applies the same thing by providing rebate funding for low-income residents who are buying low-emission vehicles and meet the requirements. The Japanese state also implements the scenario related to purchasing incentives through the different amounts of subsidies received by users, namely between those who replace old vehicles and those who buy new ones without replacing their old vehicles. Therefore, considering the decrease in LCCs for EM users, the recommendation for a purchase cost discount should be considered.

Scenario Electricity Rates Subsidy

Based on Figure 5. shows that there is a decrease in the value of LCC when there is a policy of subsidizing electricity tariffs on EMs. The average decline value is 6% (IDR 1,8 million) for EMs. The electricity tariff subsidy scenario is based on the research of Kong et al. (2020), which uses the variable electricity price subsidy to encourage the adoption of EVs in China. In this study, the electricity tariff scenario used is 30% of the general tariff. The tariff determination is based on the State Electricity Company (*Perusahaan Listrik Negara*, PLN) policy regarding a 30% discount for EV owners in 2019 [28]. Therefore, the recommendation for an electricity rates subsidy should be considered considering the decrease in LCCs for EM users.

Increase in Fuel Prices and Electricity Tariffs

Figure 6 shows a decrease in the value of LCC when there is a policy of changing the increase in fuel prices and electricity tariffs on the two types of motorcycles. It can be seen that the increase in fuel prices and electricity tariffs has an effect on the increase in the LCC value for both CMs and EMs. However, the LCC value of CM still occupies a higher position than EMs. In general, due to inflation, there is an increase in energy consumption costs from year to year. However, in the LCC calculation, many other cost variables affect the curve so that it looks down. Fuel inflation will also increase LCC and can be seen after the sixth year when other cost variables are not considered. As in the first year, there were components of insurance and purchase restriction costs, while in the following year, there were none. There is a loan interest fee in the first to third years, while in the fifth year, there is an additional five-year tax registration tax.

In this case, the assumptions for fuel and electricity tariffs increase are 10% and 8%. The basis for setting this assumption is calculated from the average changes in fuel and electricity prices for the last six years listed on Oil and Gas Mining State Company (Pertamina), State Electricity Company (PLN), and the Ministry of Energy and Mineral Resources websites.

The increase in fuel prices will support the adoption of EVs, considering that the LCC issued for CVs will be higher than for EVs. Research [29] provides evidence that gasoline prices have a more significant effect on demand for EVs (EV) than electricity prices in California by compiling data from monthly EV registration records to detailed records of gasoline and electricity prices in California from 2014-2017 used to estimate the effect of prices. The Energy on demand EV. The result is that specific changes in gasoline prices can affect EV demand four to six times. As a percentage change in the price of electricity.

In addition, the study results from research [30] show that the relationship between EV sales and gasoline prices in China is also significant. In this case, gasoline prices have a more significant impact on new energy vehicle sales than the price of crude oil. Therefore, the recommendation for an increase in fuel prices needs to be considered considering the decrease in LCCs for EM users.

Battery Waste Recycling Management

Management related to used batteries needs to be done because battery waste is a non-biodegradable waste. The government can make a policy by requiring the collection of used batteries not used by EMs to be recycled in parallel. Without strict regulations regarding the management of used batteries from EVs, Indonesia is threatened with piles of hazardous waste in landfills and exploitation of mining resources. According to [29] and [31], There are three things the Indonesian government must regulate regarding lithium batteries for EVs.

First, the obligation to collect used batteries can be encouraged through the provision of rewards-penalties in the early stages of market development not to affect the profits of EV manufacturers who assemble and produce their batteries. Second, lithium battery waste does not end up in landfills because lithium

DOI: 10.25077/josi.v21.n2.p55-65.2022

batteries directly impact the environment if disposed of irresponsibly. An example is Switzerland. In its Regulations on Reducing Risks Associated with the Use of Certain Hazardous Substances, Switzerland provides a policy for consumers to return batteries to the manufacturer, seller, or battery collection facility. For automotive batteries, it is possible to return them to a company specializing in battery collection. Other policies stipulate the obligation for battery sellers to accept batteries returned by consumers. To fund this series of processes, the Swiss government implemented a type of excise duty paid at the same time as the purchase of the battery. Government-appointed institutions then use the money for collecting, delivering, recycling, increasing the collection ratio, and various activities related to battery waste management.

Third, a particular policy regulates the function of used EV batteries. For example, a study by automotive experts, The School of Industrial, Aerospace and Audiovisual Engineering of Terrassa by Lluc Canals, showed that using used batteries for charging stations can provide both environmental and economic benefits. The same benefits can be obtained by converting used vehicle batteries to power storage for solar power plants. In addition, a study conducted by a research team at the Massachusetts Institute of Technology, United States of America, showed promising results regarding using used batteries to support solar power plants (PLTS).

Based on the two studies above, the government can encourage manufacturers to ensure lithium batteries have specifications that allow batteries to be reused or simplify the recycling process. The government has implemented such intervention efforts in the Roadmap for Reducing Waste by Producers. The regulation issued in 2019 stipulates that producers must change the packaging of their products to make it easier to reduce, reuse, and recycle plastics. Countries can use the same approach to optimize battery usage while minimizing environmental impact [29]. Therefore, battery waste management systems should be considered due to the sustainability of EMs.

Charging Station Infrastructure

EV usage in transportation has increased the demand for electric power, partly through PCSs. Like a gas station, PCS functions to recharge EV batteries. According to research results [32] and [34], availability significantly affects the intention to adopt EMs. [35] Also, PCS infrastructure has an efficiency of 87% because it has a fast charging system with a higher capacity between 22kW and 150 kW, which causes the charging time only to take about 20-30 minutes.

Based on studies [9], Currently, PLN, as a national electricity supplier, has committed to building PCS with locations based on demand for EV parking, such as shopping centers, parking lots, and offices, and aims to build 580 PCS by 2022. The obstacle to providing these PCS is a different type of plug or nozzle, which requires adjustment due to differences in EM manufacturers. Thus, it is necessary to determine the maximum type of nozzle that must follow by the manufacturer concerned. Another solution to overcome concerns about charging EVs while traveling is to provide a BSS. This BSS can be an alternative in terms of charging time and the economic life of the battery itself, and it only takes about 3-5 minutes to complete the battery swapping. Based on [36], the development of BSS in India and China continues, and most of them use for two- and three-wheeled vehicles because of the small battery size so that it is easier to handle manually. However, there are obstacles to the BSS, such as the need for the number of batteries that must be available on demand, and the charging status of the battery must remain within a suitable range for extended battery life so that there is a need for standardization and a consistent time-based structure.

Regulations for the provision of charging infrastructure are regulated in the Minister of Energy and Mineral Resources Regulation number 13/2020 concerning infrastructure rules, incentives, business regimes, and types of filling battery-based electric motorized vehicles. More regulations are needed to provide solutions related to barriers to the provision of related infrastructure. Such as regulations on the BSS and PCS roadmaps, tax incentives related to EV imports, etc. In addition, the government must also reallocate the diesel and CV fuel subsidies to the battery-based electric motorized vehicles electricity subsidy so that the LCC value between electric and CVs is increasingly competitive. Therefore, PCS infrastructure should be considered due to the importance of this public facility for the sustainability of EMs.

CONCLUSIONS

This study tries to develop an LCC model to compare the LCCs of conventional and EMs in Indonesia. In addition, the Monte Carlo simulation is expected to accommodate motorcycle users' operational and maintenance behavior. The LCC model is expected to be used as a supporting study and consideration regarding the importance of understanding LCCs, which include tangible and intangible costs in purchasing EMs in Indonesia so that consumers do not only look at the selling price of the motorcycle. Based on the calculation results, the calculation of the LCC value for six years are internal costs that must be paid by the user directly, showing the value of savings on EMs and battery charging. On battery charging EMs, the average value percentage is lower than CMs by 45% (IDR 30,6 million).

The suggestion is that EM manufacturers need to understand the characteristics of the intended target market to increase sales. Although LCC cannot be fully used as a marketing tool, education regarding the importance of understanding the value of LCC compared to the selling price offered can be conveyed by producers to consumers when making direct offers. In addition, to support the adoption of EMs and support LCC values to be more competitive, policy scenarios are needed, such as vehicle purchase tax subsidies, parking subsidies, purchase price subsidies, electricity tariff subsidies, provision of PCS and BSS infrastructure, used battery management, and supporting regulations. Based on research results, several of these scenarios can reduce the value of LCCs for users of EMs and provide comfort due to the availability of adequate infrastructure to encourage the achievement of the government's target of 2.1 million EM ownership by 2025.

Further research can consider the uncertainties associated with developing the LCC model, such as the increase in energy costs. In addition, the benefits related to the application of motorcycles which include carrying capacity, mileage, and climbing power, also need to be considered to complement the cost side in comparing EMs with CMs in business activities by identifying the characteristics of suitable users from various professions.

ACKNOWLEDGMENT

This research was supported by Penelitian Fundamental (PF) Grant (Contract No.254/UN27.22/PT.01.03/2022).

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