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Research Article

Proposing Electric Motorcycle Adoption-Diffusion Model in Indonesia: A System Dynamics Approach

Dwi Setyo Sulistyono, Yuniaristanto, Wahyudi Sutopo, Muhammad Hisjam

Department of Industrial Engineering, Faculty of Engineering, Sebelas Maret University, Surakarta 57126, Indonesia

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CORRESPONDENCE

Phone : +62 895 31 535455
E-mail : yuniaristanto@ft.uns.ac.id

A B S T R A C T

In 2019, the number of conventional vehicles in Indonesia reached 133,617,012 units, dominated by motorcycles of 112,771,136 units and passenger cars of 15,592,419 units. The high number of conventional motorcycle users can increase the number of pollutants and combustion emissions in the environment. This condition has encouraged the transition to a sustainable transport system that will be needed for decades to come, especially for the electric motorcycle to resolve the issue. This research aims to predict and estimate the market share of electric motorcycles by considering life cycle cost per kilometer. System dynamics simulations are developed to model the adoption-diffusion of electric motorcycles in Indonesia. This model has four main modules: an electric motorcycle module, a conventional motorcycle module, an economy module, and a consumer market module. This model shows a positive trend of EM market share from 2021-2030, with the market share value of EM is 0,411 in 2030. The development of retail price subsidy and electricity price scenarios is also carried out to determine the right policies to accelerate the adoption-diffusion process. Based on the scenario, the provision of retail price subsidy and a decrease in electricity price can increase the value of the EM Market Share.

INTRODUCTION

Fulfilling energy security, halting climate change, improving urban air quality, and reducing human health problems related to air quality are the major challenges governments must address this century [1, 2]. The higher growth of gas-fueled vehicles is the cause of this problem because it contributes to the high level of fuel energy consumption and increases CO2 emissions. In 2019, the number of conventional vehicles in Indonesia reached 133,617,012 units, dominated by motorcycles of 112,771,136 units or 84% of the vehicle population and passenger cars of 15,592,419 units or 11.6% of the vehicle population [3].. The existence of motorcycles in Indonesia is quite large compared to other motorized vehicles. Motorcycles are low-cost vehicles with high flexibility and can adapt to road conditions [4, 5]. The advantages of using a motorcycle motivate consumers to choose these vehicles as the primary mode of transportation.

The high number of conventional motorcycle users can increase the amount of pollutants and combustion emissions in the environment. One strategy that can be applied to overcome this problem is to reduce conventional vehicle uses, especially motorcycles, by switching to environmentally-friendly vehicles. Electric vehicle technology innovation and battery technology innovation can provide environmentally-friendly transportation solutions, energy-efficient, as well as cheaper operating and maintenance costs [6]. As the EV market expands and technology advances to include bidirectional charging, EVs could provide valuable grid resources [7, 8].

Currently, the population of electric motorcycles that already have a Type Test Registration Certification (*Sertifikasi Registrasi Uji Tipe* – SRUT) in Indonesia reached 1,947 units of 24 motorcycle type test letters (*Sertifikat Uji Tipe* – SUT) in September 2020 [9]. This condition has encouraged the transition to a sustainable transport system that will be needed for decades to come, especially for the electric motorcycle to resolve the issue. The number of public electric charging stations (*Stasiun Pengisian Kendaraan Listrik Umum*, SPKLU) in Indonesia to date has reached 7.149 units spread across 3.348 locations [10]. Meanwhile, the number SPKLU has only reached 16 units spread across 10 locations and installed in Jakarta, Bandung, Tangerang, Semarang, Surabaya, and Bali. Illmann and Kluge [11] explain that the average charging capacity and charging speed also play a more critical role than the mere existence of charging stations. Key market players need to accept and support innovative and sustainable technologies to overcome this competitive weakness [12].

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Agency for the Assessment and Application of Technology (*Badan Pengkajian dan Penerapan Teknologi* - BPPT) previously estimated that the total population of electric motorcycles in Indonesia could reach 800,000 units by 2020. Unfortunately, sales of electric motorcycles in 2019 were still low, reaching only 100,000 units with a market share of 1.5% [13]. This proves that the level of electric motorcycles adoption in Indonesia is still relatively low. The low adoption of electric motorcycles in Indonesia is due to several factors inhibiting the bargaining power of buyers, such as the lack of regulations on reducing greenhouse gases, the high price and life cycle cost of electric vehicles compared to conventional vehicles, and the unavailability of charging station that is scattered in public areas [14]. Research on the adoption of electric motorcycles in Indonesia has been conducted to determine the effect of objective factors on consumer purchase interest using logistic regression methods and the Partial Least Square - Structural Equation Model [15]. However, this study has limitations in knowing and predicting the rate of adoption-diffusion of electric motorcycles in Indonesia from year to year. A simulation model can solve the limitations of using this method. Simulation is an imitation of the operation process of a real condition with time [16].

Various simulation models have been developed to provide a better alternative to the barriers and drivers of the success of the electric vehicle market [17]. The Application of Life Cycle Sustainability Assessment (LCSA) with system dynamics is also carried out to see the interaction among the system's economic, environmental, and social impact [18]. System dynamics (SD) was also used as a simulation approach to consider the most influential stakeholders, such as car manufacturers, car dealers, consumers, energy supply systems, fuel stations, and government [19, 20]. The same approach was also utilized systems dynamics (SD) to produce a scenario for product sales and the electric vehicle market in Germany [21]. System dynamics models were applied to examine different strategies of manufacturers for electric vehicle introduction and their impact on market diffusion [22, 23]. System dynamics and Life Cycle Cost (LCC) were also applied to investigate various policies on the diffusion of electric vehicles in China [24]. The policy scenarios were simulated to provide implications for the government to promote EV more efficiently.

This current research is developed from previous research [24] by considering variables that have been adjusted to conditions in Indonesia, such as the application of the financial credit and the addition of variable maintenance costs. Therefore, the selection of system dynamics simulation is used to determine the policies and scenarios that decision-makers can develop to encourage the adoption-diffusion process of electric motorcycles in Indonesia. SD is a well-developed approach for visualizing, analyzing, and understanding complex dynamic feedbacks [25]. In system dynamics modeling, causal loops diagram (CLD) and stock-flow diagrams are used to explain the structure of a complex system [26, 27]. So that SD can find out the relationship between variables in this case study.

This research focuses on developing the adoption-diffusion process of electric motorcycles in Indonesia concerning related stakeholders. On the demand side, actors who play a role are consumers who need vehicles, fuel, technical services, and infrastructure from the market. On the supply side, the agents playing a role are enterprises that offer vehicles, fuel, and technical services to the market. The government can use social norms and financial incentives to influence consumer perception of the economic benefits of electric vehicle technology [28, 29]. Then the financial institution also supported the acceleration of the adoption-diffusion process of electric vehicles in Indonesia to providing motor vehicle loans for electric vehicles. The absorption rate of electric motorcycle products is estimated by considering the life cycle cost variable (LCC/km) over the term of ownership. The comparison of the LCC/km value between electric motorcycles and conventional motorcycles in this model is expected to provide consideration for consumers in choosing a private vehicle that is more profitable than the remaining costs. Based on the findings of this study, policy recommendations can be made for the government and producers as a strategy to accelerate the adoption-diffusion process of electric motorcycles in Indonesia and the right sales strategy to attract public buying interest.

METHOD

This study uses a system dynamics simulation to predict the consumer market for electric motorcycles in Indonesia with AnyLogic software. This model comprises four main modules: the electric motorcycle module, the conventional motorcycle module, the consumer market model, and the economy module. The data used in this study are previous research data that raises the topic of electric vehicles [24, 30, 31]. Based on the data obtained, there are assumptions used as follow:

1. Data from overseas research is assumed to apply to this model because it has similarities in topics
2. The variables used in this study are following the conditions that occur in Indonesia

The first step is to create the model components. This study only considers four stakeholders who influence the adoption-diffusion process: consumers, government, financial institutions, and enterprises. The relationship between these stakeholders can be seen in Figure 1.

The involvement of system's actors in encouraging the EM adoption-diffusion process can be seen from the influence of government on the demand and supply side. On the demand side, the government determines taxes and provides subsidies for vehicle enterprises, accompanied by financial institution support.

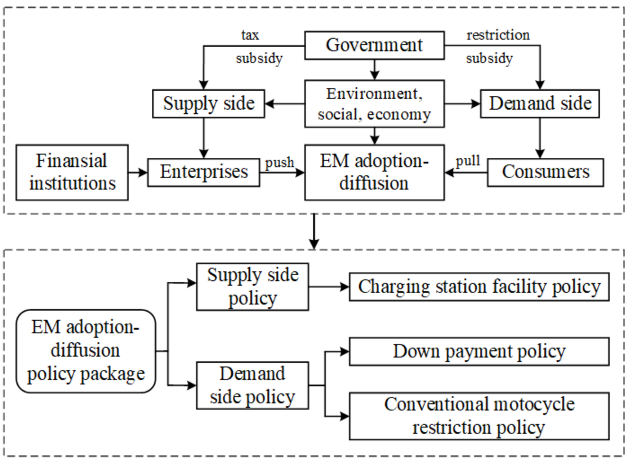

Figure 1. Theoretical Framework

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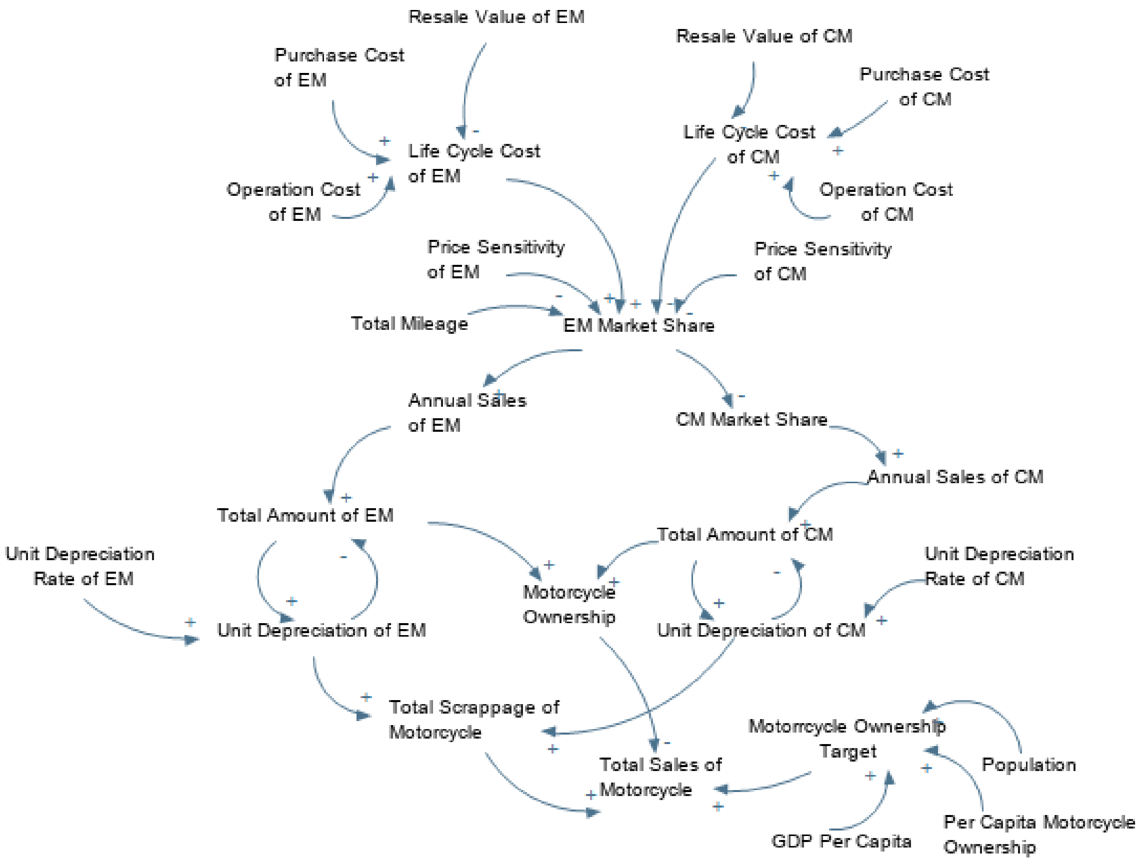

Figure 2. Causal Loops Diagram

The difference from previous research [24], this study considers the financial institution actor that provides capital assistance in credit services. Based on this, the down payment policy becomes a variable that can determine the adoption intention of the society. Meanwhile, on the supply side, the government can impose restrictions in the form of restricting the operation or use of motorcycles over ten years of age and providing subsidies or credit policies for purchasing electric motorcycles. Scrappage schemes are one of the main strategies to reduce emissions because they accelerate the removal of older vehicles from circulation [32]. Thus, the EM adoption-diffusion process can be driven by policies on the demand and supply sides.

After building the model components, the causal loop diagram is designed according to the variables considered in the four modules. Figure 2 shows the causal loops diagram of the electric motorcycle adoption-diffusion simulation model.

The main factor considered in electric motorcycle and conventional motorcycle modules is life cycle cost (LCC). The life cycle costs of these vehicles are influenced by purchase costs, operation costs, and resale value. Operational costs are influenced by insurance costs, maintenance costs, total energy costs, and tax costs. To calculate the purchase cost, this model considers the credit scheme that is influenced by the number of principal installment costs and interest installment costs. Meanwhile, the resale value of conventional motorcycles is influenced by the vehicle's lifetime, the discount rate, the depreciation value of the vehicle, and the purchase price per unit. In electric motorcycle modules, the resale value is also influenced by the resale price of the battery.

Electric Motorcycle Module

The electric motorcycle module is designed to simulate the market conditions for electric motorcycles in Indonesia. This electric motorcycle module is divided into three submodules: an EM life cycle cost submodule, an EM environmental impact cost submodule, and an EM social impact cost submodule that is shown in Figure 3.

The EM life cycle cost sub-module is designed to determine the costs incurred during the life of EM by the vehicle owner when making a purchase in that year. Therefore, according to the calculations of Kong et al. [24] and Mitropoulos et al. [30] about the total purchase cost of an EM (TP_EM), the operation cost of an EM (OP_EM), and the resale value of an EM (RV_EM) are the primary concerns of the LCC_EM namely, Equation (1)-(4), are obtained based on the above assumption.

$$LCC_{EM} = \mathrm{TP_{EM}} + \mathrm{OP_{EM}} - \mathrm{RV_{EM}} \quad (1)$$

$$\mathrm{TP_{EM}} = 36 \times \mathrm{TA_{EM}} \quad (2)$$

$$\mathrm{OP_{EM}} = \mathrm{AS_{EM}} + 6\,(\mathrm{MN_{EM}} + \mathrm{TX_{EM}} + \mathrm{BE_{EM}}) \quad (3)$$

$$\mathrm{RV_{EM}} = \frac{(1-\mathrm{DR_{EM}})^{n} \times \mathrm{PR_{EMt}} + \mathrm{CB}}{(1-r)^{n-1}} \quad (4)$$

The $\mathrm{TP_{EM}}$ includes total installments cost ($\mathrm{TA_{EM}}$) for 36 months. The $\mathrm{OP_{EM}}$ is obtained from the calculation of the EM energy cost ($\mathrm{BE_{EM}}$), the insurance cost of an EM ($\mathrm{AS_{EM}}$), the tax cost of an EM ($\mathrm{TX_{EM}}$), and maintenance cost of an EM ($\mathrm{MN_{EM}}$). The $\mathrm{RV_{EM}}$ is determined jointly by the retail price of EM ($\mathrm{PR_{EM}}$), the battery

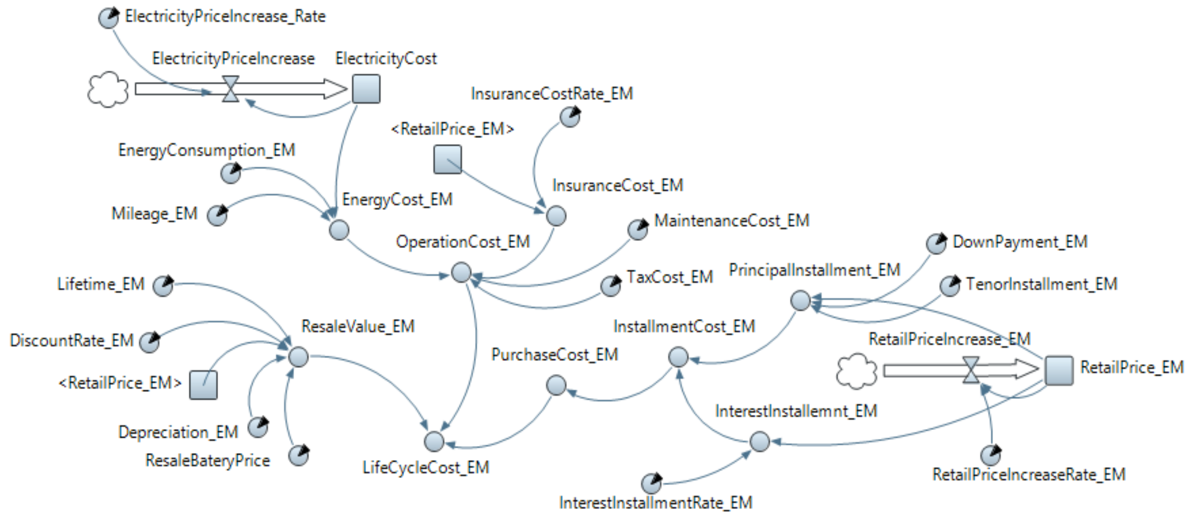

Figure 3. Electric Motorcycle Module

resale price (CB), the depreciation rate of an EM (DR_{EM}), and the discount rate (*r*) with EM lifetime for 6 years (*n*).

Conventional Motorcycle Module

The CM life cycle cost sub-module is designed to determine the costs incurred during the life of the CM by the vehicle owner when purchasing in that year. Similar to the EM module, the stock and flow of this module can be presented in Figure 4.

$$LCC_{CM} = \mathrm{TP_{CM}} + \mathrm{OP_{CM}} - \mathrm{RV_{CM}} \tag{5}$$

$$\mathrm{TP_{CM}} = 36 \times \mathrm{TA_{CM}} \tag{6}$$

$$\mathrm{OP_{CM}} = \mathrm{AS_{CM}} + 6 \times (\mathrm{MN_{CM}} + \mathrm{TX_{CM}} + \mathrm{BE_{CM}}) \tag{7}$$

$$\mathrm{RV_{CM}} = \frac{(1-DR_{CM})^n \times \mathrm{PR_{CM(t)}}}{(1-r)^{n-1}} \tag{8}$$

The total purchase cost of a CM (TP_{CM}), the operation cost of a CM (OP_{CM}), and the resale value of a CM (RV_{CM}) are the essential concerns of the LCC_{CM} as appearing in Equation (5)-(8). The TP_{CM} includes total installments cost (TA_{CM}) for 36 months. The TP_{CM} is obtained from the calculation of the CM energy cost (BE_{CM}), the insurance cost of a CM (AS_{CM}), the tax cost of a CM (TX_{CM}), and maintenance cost of a CM (MN_{CM}). The RV_{CM} is determined jointly by the retail price of CM (PR_{CM}), the depreciation rate of a CM (DR_{CM}), and the discount rate (*r*) with CM lifetime for six years (*n*).

Consumer Market Module

The design of the consumer market model was carried out to determine the level of market share of electric motorcycles and its comparison with conventional motorcycles, as shown in Figure 5.

In addition, this module also predicts the number of EM and CM that will be obtained from the total annual sales and the number of depreciation of motorcycles.

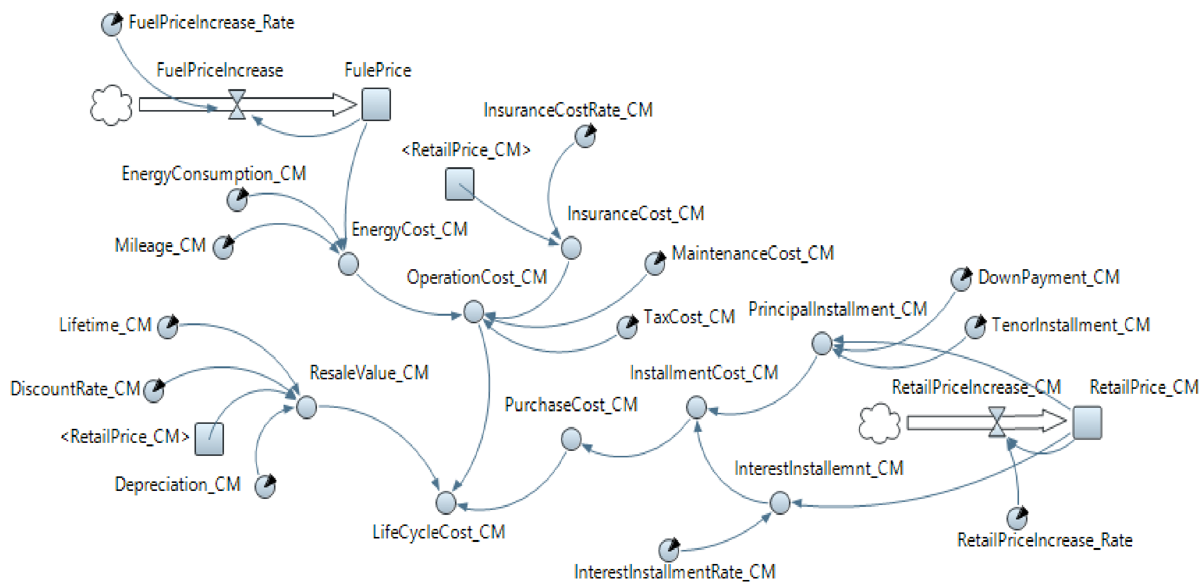

Figure 4. Conventional Motorcycle Module

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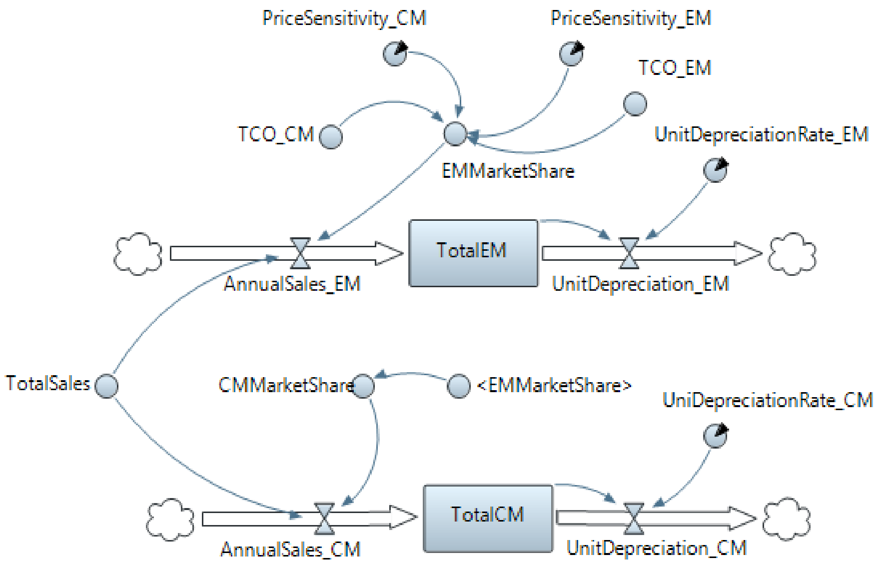

Figure 5. Consumer Market Module

$$TCO_{EM} = \frac{LCC_{EM}}{TM} \quad (9)$$

$$TCO_{CM} = \frac{LCC_{CM}}{TM} \quad (10)$$

TCO_{EM} and TCO_{CM} represent the total cost of ownership per kilometer of EM and CM are used to determine the market share of each motorcycle as shown in Equation (9)-(10). LCC_{EM} and LCC_{CM} represent the life cycle cost of EM and CM, and TM represents the total mileage. Subsequently, within the set of buyers who need to purchase motorcycles, the purchase probabilities of EM and CM, or the market shares of EMs (MS_{EM}) and CMs (MS_{CM}), α_1 and α_2 represent the coefficient of the cost sensitivity of EM and CM are shown in Equation (11)-(12), respectively. This formulation is developed by Kong et al. [24] and Barisa et al. [25].

$$MS_{EM} = \frac{e^{-\alpha 1.TCO_{EM}}}{e^{-\alpha 1.TCO_{EM}+e^{-\alpha 2.TCO_{CM}}}} \quad (11)$$

$$MS_{CM} = 1 - MS_{EM} \quad (12)$$

$$TOW_{EM(t)} = \sum_0^t AS_{EM(t)} - TOS_{EM(t)} + TOW_{EM(t-1)} \quad (13)$$

$$TOW_{CM(t)} = \sum_0^t AS_{CM(t)} - TOS_{CM(t)} + TOW_{CM(t-1)} \quad (14)$$

$$AS_{EM} = MS_{EM} \times TS \quad (15)$$

$$AS_{CM} = MS_{CM} \times TS \quad (16)$$

$$TOS_{EM} = TOW_{EM} \times SR_{EM} \quad (17)$$

$$TOS_{CM} = TOW_{CM} \times SR_{CM} \quad (18)$$

The total number of EMs (TOW_{EM}) is jointly determined by the annual sales of EM (AS_{EM}) and the total unit depreciation of EM (TOS_{EM}) of EMs, as shown in Equation (11)-(18). The AS_{EM} is equal to the total sales of motorcycles (TS) and the EM market share (MS_{EM}). The TOS_{EM} is obtained from the calculation of the total number of EMs (TOW_{EM}) and the depreciation rate of EM (SR_{EM}). The depreciation rate is obtained from the percentage of scrappage of electric motorcycles. However, in this paper, the scrappage value is assumed to be 0% until 2030 because Indonesia's number of electric motorcycles is relatively low. The calculation of CM is the same as above.

Economics Module

The design of a simulation model related to the economic aspect was developed to determine the total sales of motorcycles in a certain period by building a relationship between motorcycle ownership and the economic factors involved, shown in Figure 6. The economics module analyzes the overall motorcycle ownership. This module shows the variable TS depending on the motorcycle ownership target (TO), total scrappage of motorcycle (TOS), and total ownership of motorcycle (TOW). For the TOW, we applied the Gompertz formula based on previous works Onat et al. [18] and Kresnanto [31] to describe the quantitative relationship between GDP per capita and vehicle ownership per capita, as shown in Equation (20).

$$TS = \mathrm{TO} + \mathrm{TOS} - \mathrm{TOW} \quad (20)$$

$$V_t^* = \gamma . e^{\alpha . e^{\beta . G_t}} \quad (21)$$

where γ represents the motorcycle ownership per capita, t represents the year t, and the unit is vehicle/person. V* represents the ultimate target of motorcycle ownership per capita, G represents the GDP per capita, α and β are negative parameters that determine the shape of the function.

RESULTS AND DISCUSSION

In this section, the simulation results using the AnyLogic software were explained the influence of the policy scenario of the government and the role of stakeholders on the acceleration of the diffusion of electric motorcycles in Indonesia. The government, as the decision-maker, has the authority to establish policies regarding providing subsidies, facilitation, and regulation. The initiator of EV implementation in Indonesia is the Indonesian government, with several ministries involved in it, such as the ministry of finance, the ministry of environment and

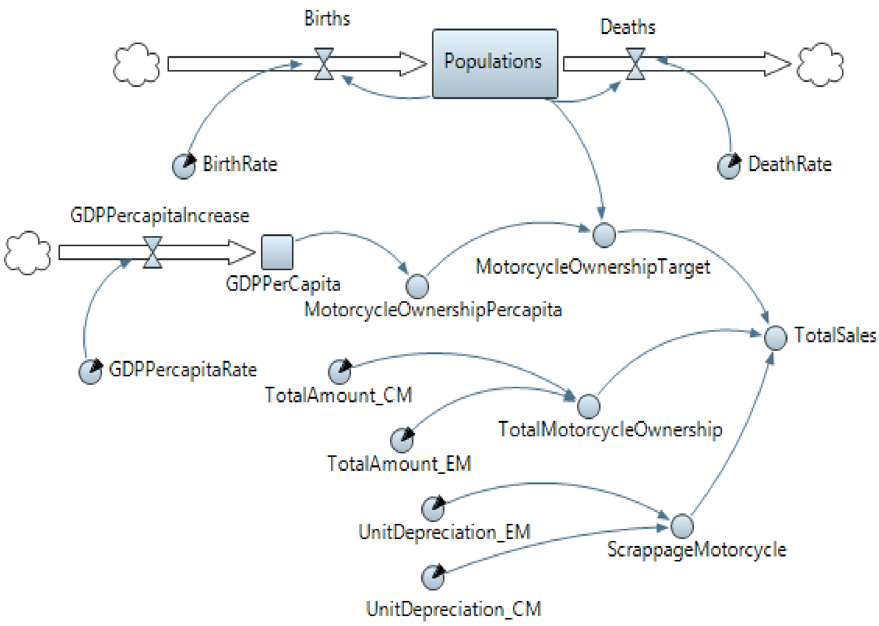

Figure 6. Economics Module

forestry, the ministry of industry, the ministry of energy and mineral resources, and local government. The acceleration of the EM adoption-diffusion process is carried out to reduce CO2 emissions on the environment by considering the more sustainable social and economic impacts. In achieving that goal, the EV adoption process is influenced by several stakeholders and the decision support system model structured on the four modules, as shown in Figure 3-6.

Model Verification and Validation

The verification of the simulation program was conducted by writing, debugging, and checking the logicality of the relationships between variables and unit consistency in the model. The model is running in the AnyLogic software; the results are obtained that the model can be run properly, and there is no warning sign in the form of 'error" on variables or relationships between variables in the model. This condition shows that the relationship between variables in the logical model and the units used in each variable in the model has been consistent, so it can be decided that the model built is a consistent model.

Validation of a model is conducted to ensure the ability of a model to represent a real system. Validation tests were performed using performance validation techniques. The validation test is carried out in two stages: construct validity and model behavior tests. The construct validity test was carried out by assessing whether the variables contained in the model were in accordance with scientific concepts and involved expert judgment. When the causal loop diagram model has been successfully verified, the validation process is carried out by involving experts to see whether the designed model is in accordance with the concept. After the expert carried out the validation process, it was found that the model designed in this model was valid.

The model behavior test is conducted by performing a statistical test to see the deviation between the simulation output for the period of 2015 till 2020 and the actual historical data of the year 2015 till 2020 that is shown in Table 1. The statistical test used is the mean absolute percentage error (MAPE); the test model is declared valid if the deviation between the output of the simulation model and the actual system output can be received statistically. This approach is useful when the size of a prediction variable is significant in evaluating the accuracy of a prediction than another approach [33, 34]. In previous research, Kong et. Al [23], the validity test only compares the consistency of the simulation results and the collecting data without considering the error value. The accuracy criteria of the model with the MAPE test are MAPE < 10% means highly accurate forecasting; MAPE is between 10% -20% means good forecasting, MAPE is between 20%-50% means reasonable forecasting, MAPE more than 50% means weak and inaccurate forecasting. The next is the calculation of the mean absolute percentage error between actual population level with population-level output from the simulation. Data on the population in Indonesia is influenced by the birth rate per year and the death rate per year. The population considered in this study is a population with an age range of 15-64 years who have the potential to be motorcycle users and are learning to ride a motorcycle. The MAPE value for self-sufficiency level performance worth 1,40% means the model is highly accurate forecasting. Table 1 shows a detailed calculation of Mean Absolute Percentage Error (MAPE).

Table 1. Validation Result of Motorcycle User

No	Year	Population (Real System)	Population (Simulation Result)	$\frac{\lvert A_t - f_t \rvert}{A_t}$
1	2015	174,660,500	174,700,000	0.00023
2	2016	176,841,300	176,700,000	0.00136
3	2017	179,160,400	178,700,000	0.00257
4	2018	181,305,000	180,700,000	0.00334
5	2019	183,363,700	182,700,000	0.00362
6	2020	185,339,700	184,800,000	0.00291
			Total	**0.01403**
			MAPE	**1.40%**

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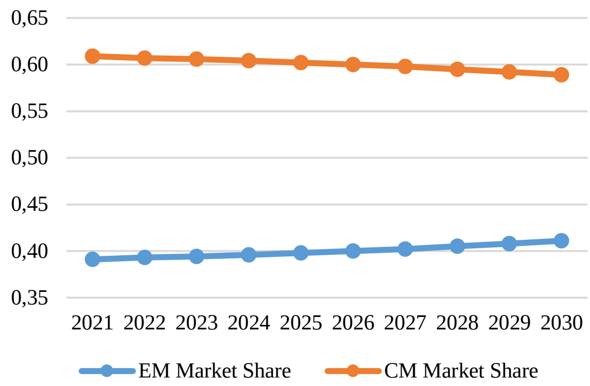


Figure 7. Market Share of Initial Simulation

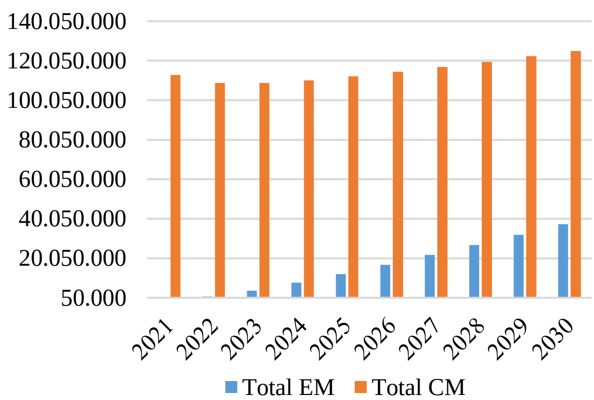


Figure 8. Total Motorcycle of Initial Simulation

Simulation Result

The results of the model adoption-diffusion simulation using AnyLogic were carried out with a period from 2021-2030. Figure 7 shows the market share value of EM and CM. Based on these results, it is found that the value of EM Market share is still lower when compared to CM market share from 2021 to 2030. In 2021 the value of EM market share reaches 0.391, and in 2030 it has reached 0.411. On the other hand, CM market share has decreased to 0,589 in 2030. This positive trend of EM market share is influenced by the lower LCC of EM than CM. The value of CM market share continues to decline every year where this situation is caused by consumers starting to switch from using CM to EM.

Based on BPS 2019 data, the total number of motorcycles continues to increase from year to year [2]. In 2015, the number of motorcycles was 88,656,931 units and grew by 112,771,136 units in 2030, or an increase of 27.2%, although the total sales of motorcycles decreased from 2011-2020 [35]. Meanwhile, the decline in motorcycle sales in 2020 due to COVID-19 was not considered in this study. The decrease in total sales is indicated by the habit of motorcycle users who still use their vehicle with more than ten years of ownership. So this research considers scrappage schemes to influence consumer purchasing decisions.

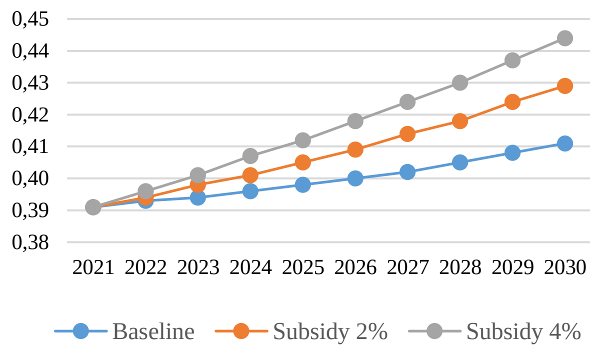
The simulation results also show an increase in the number of motorcycles in Indonesia from 2021-2030 (Figure 8). With the EM market share value increasing, the number of EM in circulation will increase. The total EM is predicted to reach 665,301 units in 2022. For the total CM, in 2022, it has decreased from the previous year with a figure of 108,800,000 million units. This condition was also due to restricting the use of motorcycles with lifetime > 10 years old. LCC comparisons can also encourage CM users to switch to EM because it has lower costs, such as electricity costs and maintenance costs. The government can use this strategy to provide an overview of the use of EM and CM in terms of costs. The number of motorcycles is also influenced by the economic module which is applied to predict total motorcycle sales based on the target ownership factor, total motorcycle ownership, and total scrappage of motorcycles.

Scenarios Analysis

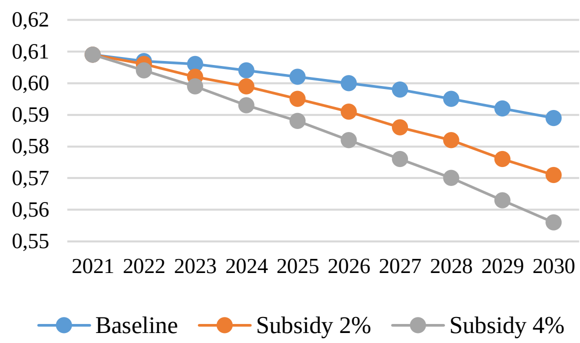
Two scenarios are designed in this work to investigate the impacts of government policy (retail price subsidy and electricity price) on the advancement of the EM industry.

Scenario 1: Retail Price Subsidy

The first scenario is based on the research of Xiang, et al. [36], which uses the purchase price subsidy variable as a way to encourage the adoption of electric vehicles in China. Based on the initial simulation, we changed the esteem of the retail price subsidy for EM and observed the EM market share evolution process. When the retail price value of EM is changed by providing a purchase subsidy of 2% and 4%, the market share results are obtained, as shown in Figure 9. Based on the results of this scenario, providing a subsidy of 2% and 4% will increase the



(a) EM Market Share



(b) CM Market Share

Figure 9. The Result Simulation of Retail Price Subsidy in Market Share

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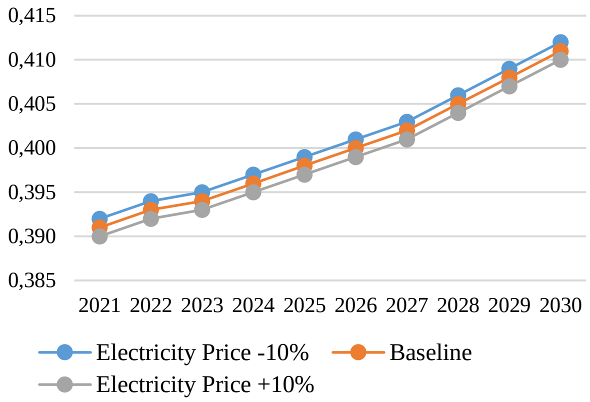
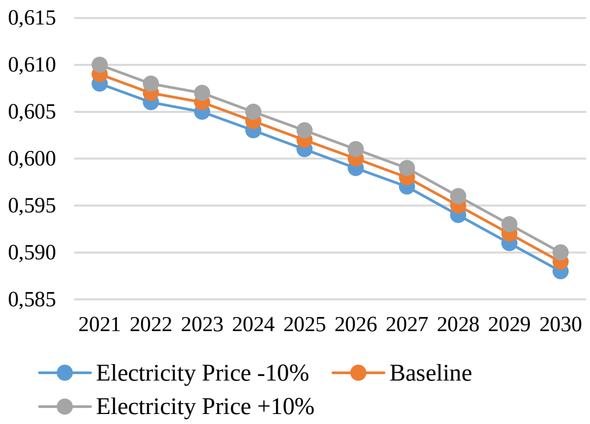


(a) EM Market Share



(b) CM Market Share

Figure 10. The Result Simulation of Electricity Price Subsidy in Market Share

EM market share value. The purchase subsidy scenario of 4% provides a significant result on the increase in EM Market share, especially in 2030 of 0.007. As in 2025, the EM Market share value, valued initially at 0.398, will increase to 0.405 and 0.412 after obtaining subsidies for purchases. This purchase subsidy has a positive impact in encouraging the acceleration of the adoption-diffusion of electric motorcycles.

Scenario 2: Electricity Price

This scenario is built by changing the electricity price parameter to determine the effect on the EM market share. We divide electricity prices into three sub scenarios: high price (price: + 10%), hierarchical price (baseline), and low price (price: -10%). These parameters were obtained from previous studies that value two times more likely to get a significant effect of subsidizing the price of electricity. Figure 10 shows the comparison of the EM Market share results after experiencing these changes. When the electricity price is -10%, the EM market share value has increased as in 2030, which reached 0.412 and experienced an annual average increase of 0.002. When the electricity price +10% is obtained, the EM market share value has decreased, reaching 0.41 in the same year compared to the initial simulation results amounting to 0.411.

The scenarios carried out in this study refer to the work of previous studies Onat et al. [18]. Based on the simulation results, the growth of EM market share has increased every year and has a similar pattern with Kong et al. [24]. This research considers the impact of the interaction between multi-stakeholders and policies, establishes the dynamic system model of the electric motorcycle policy system based on the “enterprise – government – the consumer - financial institution” analysis framework, and predicts the market adoption-diffusion results of the electric motorcycle. The decision-making process of multiple stakeholders in the adoption-diffusion of the electric motorcycle is studied and simulated. The proposed policies are retail price and electricity price subsidy as the main priority to develop the adoption-diffusion process of electric motorcycles in Indonesia. This policy will cause a decrease in the value of the LCC, thereby increasing consumer willingness to buy.

CONCLUSIONS

The research results on the adoption-diffusion model of Indonesian electric motorcycles using this dynamics system predict the value of the EM Market Share from 2021-2030. By considering each type of motorcycle LCC/km value, the EM market share value will increase from year to year. This result shows that the value of LCC/km can influence consumers in deciding to buy a motorcycle. In addition, Indonesia's GDP per capita and population are also influential enough to determine the target per capita ownership as one of the variables that determine total sales, as shown in Equation (21).

The role of the government as a decision-maker is very influential in encouraging the adoption-diffusion process of electric motorcycles in Indonesia. This study uses two scenarios to determine changes in the EM Market share value. If the government can provide subsidies for purchasing electric motorcycles in the retail price subsidy scenario, it will increase the market share value. In the electricity price scenario, if the government decreases the price of electricity, it will increase the value of the EM Market Share. On the other hand, when the government increases the price of electricity, it can reduce the market share value.

This research can support a strategy to accelerate the adoption of electric motorcycles by considering life cycle costs. Based on the simulation results, the life cycle cost of EM is smaller than CM with six years of ownership. The comparison of the life cycle costs of EM and CM can influence the purchasing decisions of customers. This strategy can also help dealers to increase sales of electric motorcycles in influencing consumers.

Based on these results, the formulation of policies has an important role in encouraging the adoption-diffusion process of electric motorcycles in Indonesia. However, this study has not been considered an in-depth study of manufacturing actors regarding production and profit factors. The relationship between the use of technology in producing electric motorcycles to increase company profits can be calculated in encouraging the growth of the electric motorcycle market. Agent-Based Modeling can be developed with system dynamics to describe the behavior of individuals (agents) and variables in further research. The impact of promotions or advertisements on the intention to buy for potential users can also be added to the model. So that the model can be complete in discussing all the agents involved in encouraging the electric motorcycle market in Indonesia.

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AUTHORS BIOGRAPHY

Dwi Setyo Sulistyono

Dwi Setyo Sulistyono is an undergraduate student of Industrial Engineering Department of Sebelas Maret University. He belongs to Logistics and Business System Laboratory. His research interests are supply chain management, financial management, and market research. He published his first publication about calculation of cost of goods sold using time driven activity based costing in one of SME's in 2021.

Yuniaristanto

Yuniaristanto is a lecturer and researcher in Departement of Industrial Engineering, Universitas Sebelas Maret. His research interests are supply chain, simulation modeling, performance measurement and technology commercialization. He has publications that indexed by Scopus, 41 articles with 4 h-index. His email is yuniaristanto@ft.uns.ac.id.

Wahyudi Sutopo

Wahyudi Sutopo, is a lecturer and researcher in Departement of Industrial Engineering, Universitas Sebelas Maret. His research interests are engineering economy & cost analysis, supply chain, and technology commercialization. He obtained more than 30 research grants. He has publications that indexed by Scopus, 117 articles with 9 h-index. His email is wahyudisutopo@staff.uns.ac.id.

Muhammad Hisjam

Muhammad Hisjam is a lecturer and researcher in Departement of Industrial Engineering, Universitas Sebelas Maret. His research interests are supply chain, techno-economic, logistics, and technology commercialization. He has publications that indexed by Scopus, 40 articles with 7 h-index. His email is hisjam@staff.uns.ac.id.

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