Comparison of Life Cycle Cost (LCC) and Carbon Impact Between Conventional and Electric Motorcycle for Daily Use in Jakarta

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Abstract

There are four types of motorized vehicles in Indonesia. The enormous population is motorcycles, which have become Jakarta's primary transportation mode for daily activities. Currently, it is divided into two types: conventional and electric motorcycles. Conventionally, it runs on refined fuel oil. In terms of environment and sustainability, it leads to air pollution and a high fuel consumption rate. Besides those aspects, because of the raised fuel price, there is also a problem from the owner's perspective. Due to this condition, people have begun to move to an electric motorcycles. This study aims to make a comparison of life cycle cost (LCC) for both motorcycle types. Apart from this, a life cycle impact assessment (LCIA) is also carried out. Based on the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number 01/2021, the impact that must be analyzed include cumulative energy demand (E), global warming potential (GWP), acidification potential (AP), eutrophication potential (EP), and ozone layer depletion potential (ODP). In this study, we focus more on GWP as a measure of carbon impact. Three scenarios will be analyzed: low, medium, and high mobility commuters in Jakarta. People can determine which type gives more benefits by analyzing and comparing LCC and LCIA for both types. As there is incentive policy from government for electric motorcycles, they have the best LCC compared to the conventional ones.

Keywords
Internal Combustion Engine Motorcycle, Electric Motorcycle, Life Cycle Cost, Life Cycle Impact Assessment, Sustainability

1. Introduction
Indonesia is one of the countries that cannot be separated from motorized vehicles in carrying out mobility activities. Law of the Republic of Indonesia Number 22/2009 defines motorized vehicles as any vehicle that is driven by mechanical equipment in the form of an engine other than a vehicle that runs on rails. The population of this vehicle ownership is changing all the time. In 2021 the growth was 6%, while in 2020, it was only 2% (Figure 1). The number of total motorized vehicles on November 15, 2022, is 151.36 million units (Korlantas Polri 2022). Motorcycle has a significant proportion. The population is 82.9% as of November 14, 2022 (Korlantas Polri 2022).

Based on a survey by Badan Pusat Statistik (2019), the motorcycle has become dominant as a primary mode of transportation for daily activities in Jakarta (Figure 2). Motorcycle in Law of the Republic of Indonesia Number 22/2009 is defined as a two-wheeled motorized vehicle with or without housing and with or without a side carriage or a three-wheeled motorized vehicle without housing. One factor that drives the large proportion other than any other vehicle is the lack of public transportation. Therefore, it makes private vehicles preferred to be used by most people (Murtiningrum et al. 2022). Conventionally, the Law of Republic Indonesia Number 3/1963 runs by fuel, other oil, or gas. But right now, it also runs on battery. It is a battery electric vehicle in Presidential Regulation (Perpres) Number 55/2019.

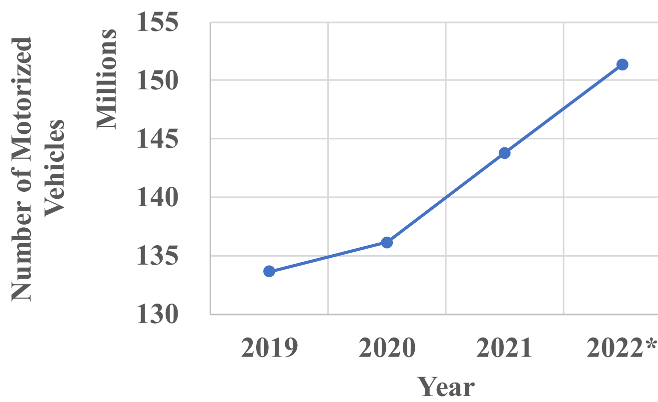

Figure 1. Number of Indonesian motorized vehicles
(source: Badan Pusat Statistik Jumlah Kendaraan Bermotor Menurut Provinsi dan Jenis Kendaraan (unit) https://www.bps.go.id/indikator/indikator/view_data_pub/0000/api_pub/V2w4dFkwdFNLNU5mSE95Und2UDRMQT09/da_10/1)

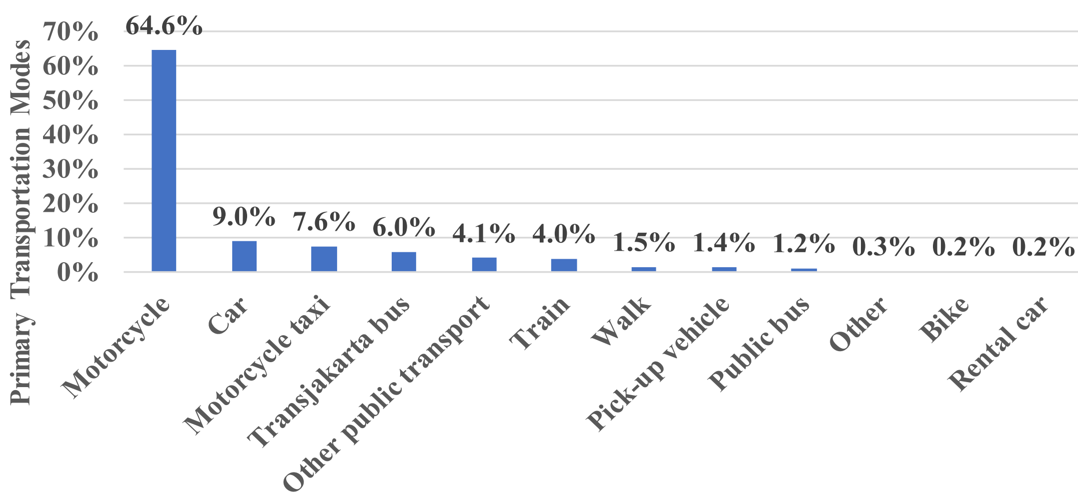

Figure 2. Primary transportation modes for daily activities in Jakarta (Source: Badan Pusat Statistik, 2019)

The motorcycle used most in Indonesia is a conventional vehicle or internal combustion engine (ICE). With a total estimated 151-million-unit conventional motorcycles in Indonesia, in terms of environment and sustainability, this leads to air pollution and high fuel consumption rate (Lin and Wu 2018). As per September 9, 2022, the Indonesian government, via Indonesia's state-owned enterprise, Pertamina, has raised the fuel price (Kompas, 2022). From the motorcycle owner's perspective, this will lead to higher operational costs. To address these problems, adopting an electric motorcycle is one of the answers, as the electric motorcycle offers reduced emissions, higher efficiency, and lower operational cost (Liu et al. 2021, Poornesh et al. 2020). Nowadays, the electric vehicle trend has already occurred in Indonesia, with the increasing number of electric motorcycle population reaching 21,668 units in September 2022 (CNN Indonesia 2022). In the roadmap for the development of the national motor vehicle industry, as stated in Regulation of the Minister of Industry of the Republic of Indonesia Number 27/2020, the Indonesian government has targeted producing 20% electric motorcycles in 2025.

Several studies have been carried out to compare the life cycle cost (LCC) and life cycle assessment (LCA) of conventional ICE and electric vehicles. LCC and LCA might differ because of geographical factors. Qiao et al. (2020) researched LCC and greenhouse gas emissions of electric vehicles in China. Li et al. (2021) also study LCC of conventional, battery electric, and fuel cell electric vehicles in China. Weldon et al. (2018) compared long-term cost ownership between an electric vehicle and an internal combustion engine in Ireland. Liu et al. (2021) also studied the cost of ownership of battery electric vehicles and internal combustion engines in the United States. Shafique et al. (2022) compared Hongkong's LCA of electric vehicles and internal combustion engines. Carranza et al. (2022) studied LCA and economic analysis of electric motorcycles in Barcelona, Spain. In Indonesia, Afraah et al. (2021) compared those vehicles' total cost of ownership, which might not be suitable for recent conditions anymore. Indonesian government is finalizing regulation for electric vehicle (EV). It is illustrated by Kementerian Perindustrian Republik Indonesia (2022) that incentive for electric motorcycle is 8 millions rupiahs.

1.1. Objectives

This study aims to compare LCC and Life Cycle Impact Analysis (LCIA) between conventional and electric motorcycles for normal daily usage behavior with recent tax policy, incentive policy, and fuel price changes in Indonesia Jakarta, Indonesia.

2. Literature Review

2.1. Life Cycle Cost (LCC)

LCC is an economic component of life cycle sustainability assessment that can supplement environmental and social concepts (Petrauskiene et al. 2021). LCC is a method for including pertinent costs from diverse perspectives in an evaluation process (Wang et al. 2019). Life cycle cost analysis is crucial for determining a product's competitiveness early in production (Ayodele and Mustapa 2020). LCC is a measure of economic evaluation typically used to determine all expenses that apply to the owner or user of an asset throughout its life, from the purchase price to operating costs and other related ownership costs like maintenance and disposal (Onat 2022). The life cycle cost consists of three components: the initial cost, ownership or operation costs, and the cost or revenue of recycling (Wang et al. 2019, Ayodele and Mustapa 2020). The LCC framework was utilized to evaluate the economic aspects from the viewpoint of consumers (Wang et al. 2019), as shown in Figure 3.

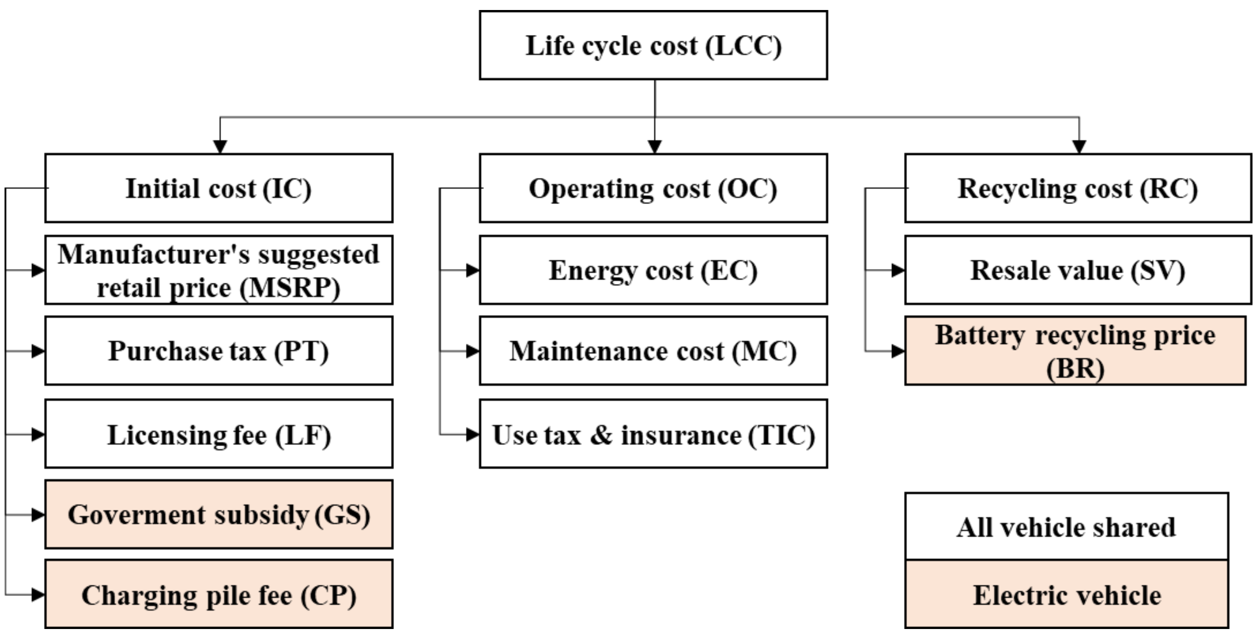

Figure 3. The LCC framework of the vehicles (Wang et al. 2019)

The following equations (1) – (6) show how to calculate the life cycle cost of vehicles:

$$LCC = IC + OC - RC \tag{1}$$

$$IC = MSRP - GS + PT + LF + CP = OTR \tag{2}$$

where OTR is on the road price.

$$OC = EC + MC + TIC \tag{3}$$

$$RC = SV + BR \tag{4}$$

Where S.V. is salvage value, for electric motorcycles, batteries recycling can be sold separately, or as part of the recycling motorcycle's purchase (resale value). For conventional motorcycles, B.R. is zero, so R.C. equals S.V.

$$SV_1 = (100\% - 15\%)\ OTR\ price \tag{5}$$

where SV_1 is the salvage value of the first year.

$$SV_i = SV_{i-1} - Rp\ 1{,}000{,}000 \tag{6}$$

Where SV_i is the salvage value of the i-th year and $i > 1$.

The type of model utilized, the type of electric vehicles used, current governmental legislation, and the prevalent economic conditions in the nations where the study was conducted are just a few examples of the variables that affect how the LCC values vary (Ayodele and Mustapa 2020).

2.2. Life Cycle Impact Assessment (LCIA)

Yu et al. (2018) define LCA as a process for evaluating the lifetime environmental load of products, processes or activities. In general, there are four major phases in conducting LCA: goal and scope definition, inventory analysis, impact assessment, and interpretation (Verma et al. 2021). This technique is used to assess environmental impacts associated with all the stages of a product's life (Muralikrishna and Manickam 2017). The methodology evaluate the environmental impacts of a product or process from its origin to its final disposal. For vehicle, the complete life cycle are raw material production, manufacturing, transportation, operation, and decommissioning (Farzaneh and Jung 2023).

This study will focus on life cycle impact assessment (LCIA). An LCIA of environmental indicators was created based on three types: resource depletion, climate change, and pollutant emissions (Wang et al., 2019). The study will focus on the environmental consequences of Indonesian regulations. The impact categories that must be studied based on the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia, Number 01/2021, include the following: Cumulative energy demand (E), Global warming potential (GWP), acidification potential (AP), eutrophication potential (EP) and ozone layer depletion potential (ODP). There are several criteria to consider impact category. Lehmann et al. (2015) define it into four criteria: stakeholder acceptance, documentation and review, environmental relevance, and applicability. In operation stage, the most important impact is GWP (Carranza et al. 2022). The following equations (7) and (8) show how to calculate the life cycle impact assessment of GWP of vehicles. For electric vehicles, cumulative energy demand (E) is taken based on its specification.

$$E_{conventional} = volume \times heating\ value\ of\ fuel \tag{7}$$

where heating value of fuel (conventional fuel) 34.84 MJ/L (Davis & Boundy, 2022)

$$GWP = E \times emmision\ factor\ of\ CO_2 \tag{8}$$

where for electric motorcycles based on PLN grid emission factor is 0.749 kg CO_2 eq/kWh (Minister of Environment and Forestry of the Republic of Indonesia, 2017) and for conventional motorcycles (motor fuel) with Carbon Dioxide (CO_2) factors is 0.067 kg/M.J. (EIA, 2022).

3. Methods

Life Cycle Cost (LCC) methods were used in a quantitative study. LCC is used for economic analysis, while LCA is used for analyzing the environmental impact of carbon emissions. LCC and LCIA are conducted for a conventional and electric motorcycles. There are two classes of each motorcycle type that will be analyzed. Conventional ones are determined by cylinder capacity, and the numbers of batteries determine electric ones. The specification is explained in Table 1. Some scenarios are made in this analysis. The scenarios are made based on the distance of motorcycle commuters in Jabodetabek. Data is collected from Badan Pusat Statistik in the 2019 Jabodetabek Commuter Survey. The distance is classified into three types of mobility: low, medium, and high. Low, medium, and high mobility distance is 0 – 19 km, 20 – 39 km, and 40 – 59 km, respectively.

The environmental impact issues are frequently separated into five categories based on the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia No. 01/2021. They are cumulative energy demand (E), global warming potential (GWP), acidification potential (AP), eutrophication potential (EP), and ozone layer depletion potential (ODP). For the calculation, we focus on the operation stage. The environmental effects of eutrophication potential and ozone layer depletion potential for electric and conventional motorcycles are not significant. Hence they were not calculated in this study. The LCIA will be based on manual calculations using a spreadsheet with equations (7) and (8). In this study, we focus more on GWP as a measure of carbon impact.

Table 1. Specification of conventional motorcycle A and B

Specification	Conventional Motorcycle		Electric Motorcycle	
	A	B	X	Y
Type	Automatic Scooter	Automatic Scooter	Single Battery	Double Battery
Cylinder Capacity (cc)	110	160		
Fuel consumption (km/l)	60.6	49.5		
Energy (kWh)			1.44	2.88
Mileage/charge (km/charge)			50	100
Energy/km (kWh/km)			0.0288	0.0288
Charging time (h)			4	8

4. Data Collection

Badan Pusat Statistik (2019) surveyed commuters in Jabodetabek (Jakarta, Bogor, Depok, Tangerang, and Bekasi). The result of the survey in motorcycle mode is shown in Table 2. Daily mobility is then divided into three categories: low, medium, and high mobility. The average distance is 19.96 km, 54.55 km, and 95.43 for low, medium, and high mobility. Commuters' main activity is going to work (82.8%), as shown in Figure 4 (Badan Pusat Statistik 2019). Figure 5 shows that most (50.4%) commute five days a week (Badan Pusat Statistik 2019).

Table 2. Distance of motorcycle commuters in Jabodetabek (Source: Badan Pusat Statistik 2019)

Distance (km)	Count of Going Out	Count of Going Home	Total Count	Mobility Category	Average Distance of Going Out (km)	Average Distance of Going Home (km)	Total Distance (km)
0 - 9	590,578	566,831	1,157,409	Low	9.94	10.01	19.96
10 - 19	705,399	696,789	1,402,188				
20 - 29	465,138	462,333	927,471	Medium	27.28	27.28	54.55
30 - 39	178,690	177,876	356,566				
40 - 49	63,819	63,819	127,638	High	47.72	47.72	95.43
50 - 59	30,244	30,244	60,488				
60+	28,678	28,678	57,356				
Total	**2,062,546**	**2,026,570**	**4,089,116**				

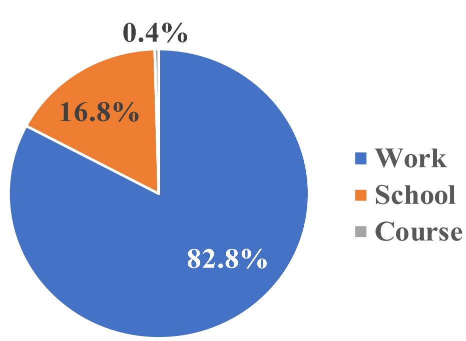

Figure 4. The main activity of commuters in Jakarta (Source: Badan Pusat Statistik 2019)

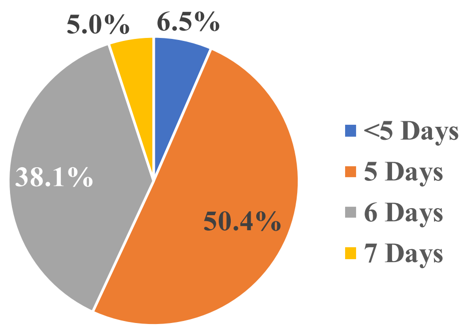

Figure 5. Number of days to commute in Jakarta (source: Badan Pusat Statistik 2019)

We collect OTR (On the Road) price data for the initial cost. Generally, brand holder agents (APM) directly provide OTR prices for vehicles assembled in Indonesia. The price given to the vehicle includes the cost of arranging the complete documents, such as the Motorized Vehicle Ownership Book (BPKB) and the Motorized Vehicle Registration Certificate (STNK), including the tax (Kompas 2020). It means that the OTR price equals to initial cost. Fuel price is based on the price of RON-90 fuel marketed by Pertamina as of November 1, 2022 (Kontan 2022), and electrical energy price is based on the price list from PLN for 2,200 VA of power capacity as of November 1, 2022 (Bisnis 2022). Salvage value in the first year falls by 15% from the initial cost, and for the next years, it will be reduced by one million rupiahs per year (Kompas 2015). In the calculation, we also consider incentive policy as illustrated by Kemerterian Perindustrian Republik Indonesia (2022). A summary of these scenarios is provided in Table 3.

Table 3. Summary of constantly used in LCC calculation

	Mobility Category		
Item	**Low**	**Medium**	**High**
Mileage per day (km/day)	19.96	54.55	95.43
Days in a week	5	5	5
Mileage per year (km/year)	5,189.60	14,183.00	24,811.80
Fuel price (Rp/lt)	10,000	10,000	10,000
Electricity price (Rp/kWh)	1,445	1,445	1,445
Charging efficiency	90%	90%	90%
Battery price (Rp)	6,500,000	6,500,000	6,500,000
Battery charging cycle (times)	1,000	1,000	1,000
Salvage value (Rp)	Year = 1: OTR price - 15% Year > 1: salvage value previous year - Rp 1,000,000		
Incentive (Rp)	8,000,000	8,000,000	8,000,000

In this study, we use the data from two conventional motorcycles (A, 110cc automatic scooter, and B, 160cc automatic scooter) and one brand of electric motorcycle with a different number of installed batteries (X and Y). A is the market leader for a motorcycle under 150cc, and B is the market leader for a motorcycle over 150cc in Indonesia. Specification for the fourth motorcycle is detailed in Table 4. Annual tax and 5-year tax are based on the tax of DKI Jakarta and assumed as the first-owned motorcycle without progressive tax. Specifically for electric motorcycles, there is an incentive that there is no Motorized Vehicle Title Transfer Fee Tax (BBNKB) per five years as stated in Regulation of The Governor of The Special Capital Region of Jakarta Number 3/2020. Annual maintenance cost for conventional motorcycles is based on the maintenance guidance from motorcycle A and B service book, including service fee and fast-moving component cost (lubricants, spark plug, drive belt, air filter, brake lube, brake compound, and tires). The difference with the electric one (X and Y) is without internal combustion engine system maintenance. LCC of conventional motorcycles A and B is compared in Table 4, and the electric one is compared in Table 5.

Table 4. LCC components of conventional motorcycles A and B

Component	A			B		
	Mobility Category			Mobility Category		
	Low	Medium	High	Low	Medium	High
IC (Rp)	**17,720,000**	**17,720,000**	**17,720,000**	**26,640,000**	**26,640,000**	**26,640,000**
OC (Rp)						
EC (Rp/year)	856,370	2,340,429	4,094,356	1,106,525	3,024,094	5,290,362
MC (Rp/year)						
MC Year 1	818,000	818,000	2,105,700	928,000	928,000	2,356,200
MC Year 2	2,105,700	2,230,700	4,397,400	2,356,200	2,491,200	4,903,900
MC Year 3	3,109,700	3,267,700	6,639,100	3,475,700	3,643,700	7,396,100
MC Year 4	4,397,400	4,680,400	8,930,800	4,903,900	5,206,900	9,943,800
MC Year 5	5,215,400	5,684,400	11,161,500	5,831,900	6,326,400	12,435,000
TIC (Rp/year)	269,000	269,000	269,000	343,000	343,000	343,000
TIC (Rp/5 years)	1,689,000	1,689,000	1,689,000	2,133,000	2,133,000	2,133,000
SV (Rp)						
SV Year 1 (Rp)	15,062,000	15,062,000	15,062,000	22,644,000	22,644,000	22,644,000
SV Year 2 (Rp)	14,062,000	14,062,000	14,062,000	21,644,000	21,644,000	21,644,000
SV Year 3 (Rp)	13,062,000	13,062,000	13,062,000	20,644,000	20,644,000	20,644,000
SV Year 4 (Rp)	12,062,000	12,062,000	12,062,000	19,644,000	19,644,000	19,644,000
SV Year 5 (Rp)	11,062,000	11,062,000	11,062,000	18,644,000	18,644,000	18,644,000
LCC (Rp)						
LCC Year 1 (Rp)	4,601,370	6,085,429	9,127,056	6,373,525	8,291,094	11,985,562
LCC Year 2 (Rp)	8,014,439	11,107,558	16,782,113	10,251,249	14,221,388	21,166,625
LCC Year 3 (Rp)	11,143,809	15,753,987	24,387,169	13,820,274	19,740,981	30,292,187
LCC Year 4 (Rp)	14,556,879	20,776,116	32,042,226	17,697,998	25,671,275	39,473,250
LCC Year 5 (Rp)	18,920,248	26,809,545	41,056,282	22,865,523	32,947,869	50,387,812

Table 5. LCC of electric motorcycle X (single battery) and Y (double battery)

Component	X			Y		
	Mobility Category			Mobility Category		
	Low	Medium	High	Low	Medium	High
IC (Rp)	**20,270,000**	**20,270,000**	**20,270,000**	**28,770,000**	**28,770,000**	**28,770,000**
OTR Price (Rp)	28,270,000	28,270,000	28,270,000	36,770,000	36,770,000	36,770,000
GS (Rp)	8,000,000	8,000,000	8,000,000	8,000,000	8,000,000	8,000,000
OC (Rp)						
EC (Rp/year)	239,967	655,822	1,147,298	239,967	655,822	1,147,298
MC (Rp/year)						
MC Year 1	498,000	498,000	1,264,000	498,000	498,000	1,264,000
MC Year 2	1,264,000	1,264,000	2,664,000	1,264,000	1,264,000	2,664,000
MC Year 3	1,898,000	1,986,000	10,564,000	1,898,000	1,986,000	4,064,000
MC Year 4	2,664,000	9,252,000	11,964,000	2,664,000	2,752,000	5,464,000
MC Year 5	3,162,000	9,886,000	19,728,000	3,162,000	3,386,000	19,728,000
TIC (Rp/year)	85,000	85,000	85,000	85,000	85,000	85,000
TIC (Rp/5 years)	335,000	335,000	335,000	335,000	335,000	335,000
SV (Rp)						
SV Year 1 (Rp)	17,229,500	17,229,500	17,229,500	24,454,500	24,454,500	24,454,500
SV Year 2 (Rp)	16,229,500	16,229,500	16,229,500	23,454,500	23,454,500	23,454,500
SV Year 3 (Rp)	15,229,500	15,229,500	15,229,500	22,454,500	22,454,500	22,454,500
SV Year 4 (Rp)	14,229,500	14,229,500	14,229,500	21,454,500	21,454,500	21,454,500
SV Year 5 (Rp)	13,229,500	13,229,500	13,229,500	20,454,500	20,454,500	20,454,500
LCC (Rp)						
LCC Year 1 (Rp)	3,863,467	4,279,322	5,536,798	5,138,467	5,554,322	6,811,798
LCC Year 2 (Rp)	5,954,434	6,786,144	9,169,095	7,229,434	8,061,144	10,444,095
LCC Year 3 (Rp)	7,913,401	9,248,966	19,301,393	9,188,401	10,523,966	14,076,393
LCC Year 4 (Rp)	10,004,368	18,255,788	22,933,691	11,279,368	13,030,788	17,708,691
LCC Year 5 (Rp)	12,077,336	20,880,610	33,179,988	13,352,336	15,655,610	34,454,988

Table 6 shows the LCIA calculation of conventional motorcycles A and B, while Table 7 shows the LCIA calculation of electric motorcycles X and Y. We use several constants for this calculation based on the literature review. The electric emission factor is 0.749 kg CO_2-Eq/kwh. The fuel emission factor is 0.067 kg CO_2-Eq /M.J. Heating value of fuel is 34.84 MJ/l. Because electric motors X and Y have the same specification, their cumulative energy demand and global warming potential have the same value.

Table 6. LCIA component of conventional motorcycles A and B

Category	Unit (Year)	Conventional A			Conventional B		
		Low	Medium	High	Low	Medium	High
Cumulative energy demand (E)	MJ	2,984	8,154	14,265	3,653	9,983	17,463
Global warming potential (GWP)	kg CO_2-Eq	200	546	956	245	669	1,170

Table 7. LCIA of electric motorcycle X (single battery) and Y (double battery)

Category	Unit (Year)	Electric X			Electric Y		
		Low	Medium	High	Low	Medium	High
Cumulative energy demand (E)	MJ	534	1,459	2,552	534	1,459	2,552
Global warming potential (GWP)	kg CO_2-Eq	112	306	535	112	306	535

5. Result and Discussion

Figure 6(a) shows the LCC comparison between conventional and electric motorcycles in low mobility scenarios (less than 20 km). Electric motorcycle X is the lowest LCC from the first year to the fifth year of ownership. Conventional motorcycle B consistently becomes the highest one. Conventional motorcycle B is a high cylinder capacity type. It means that motorcycle X is the best motorcycle in LCC for the compared motorcycles.

Figure 6(b) shows the LCC comparison between conventional and electric motorcycles in a medium mobility scenario (20 – 39 km). Electric motorcycle X is the lowest LCC for the first three years of ownership. For four years and more of ownership, electric motorcycle Y is the lowest one. Electric motorcycle X needs to replace its battery, and it causes the rising of maintenance costs. Conventional motorcycle B consistently becomes the highest one. It means that electric motorcycle is the best motorcycle in LCC for medium mobility scenario. The battery number should be considered in a decision-making process, especially in the year of ownership.

Figure 6(c) shows the LCC comparison between conventional and electric motorcycles in high mobility scenarios (40 km and more). Electric motorcycle X is the lowest LCC for the first two years of ownership. For the next two years, electric motorcycle Y is the lowest. In the fifth year, electric motorcycle X becomes the lowest again. This dynamic condition is caused by battery replacement costs that affect maintenance costs. Conventional motorcycle B consistently becomes the highest one. It means that electric motorcycle is the best motorcycle in LCC for medium mobility scenario. The battery number should be considered in a decision-making process, especially in the year of ownership.

Figure 7 shows the GWP per year comparison between conventional and electric motorcycles in low, medium, and high mobility scenarios. In every scenario, the GWP potential of an electric motorcycle is always lower than a conventional motor. This means electric motorcycle is more environmental-friendly than a conventional motorcycle. There's no difference between single or double batteries in terms of GWP, as they have the same energy consumption rate. For conventional motors, lower cylinder capacity generated lower GWP.

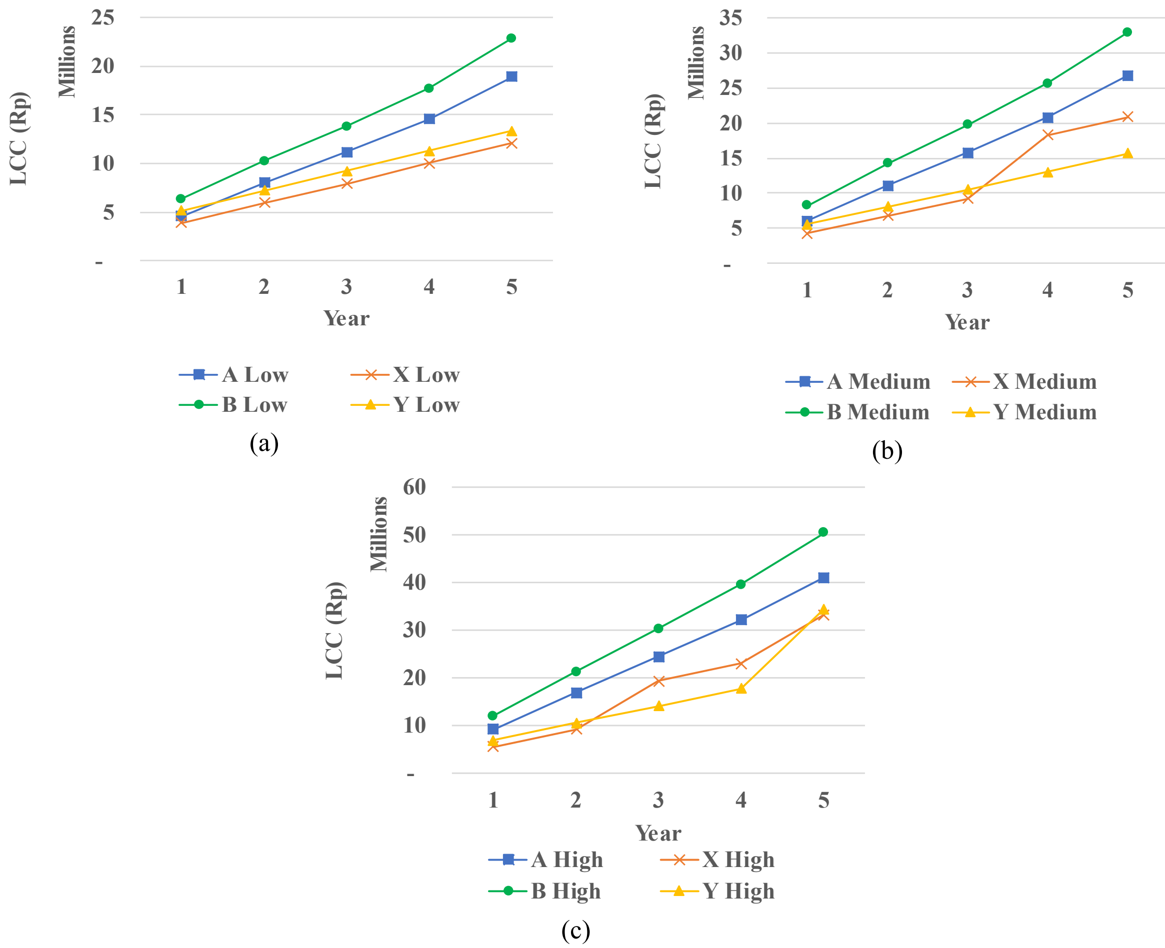

Figure 6. LCC comparison of conventional and electric motorcycles in three different mobility scenarios: (a) low, (b) medium, (c) high

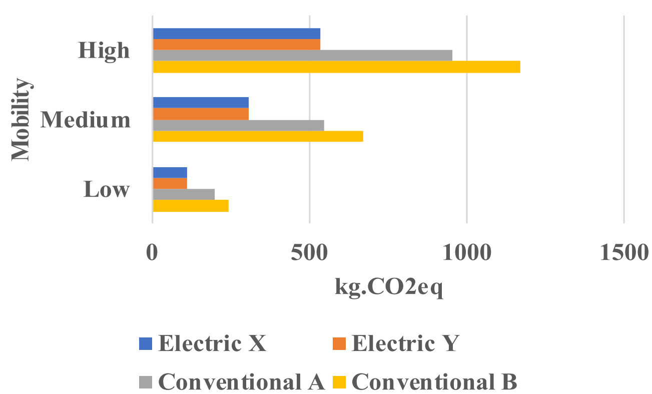

Figure 7. Global warming potential comparison of conventional and electric motorcycles in three different mobility scenarios per year

6. Conclusion

Internal combustion engines (ICEs) are used in most motorcycles in Indonesia, which results in excessive fuel consumption and air pollution. By 2025, the Indonesian government hopes to create 20% electrified motorcycles. This study compares the life cycle costs (LCC) and life cycle impacts (LCIA), especially of the carbon impact of conventional and electric motorcycles for daily use. Average distances for people with low, medium, and high mobility were 19.96 km, 54.55 km, and 95.43 km. Most commuters travel five days a week, with traveling to work being their main activity. In this study, data from two conventional motorcycle brands and one electric motorcycle brand were used.

The lowest LCC in all condition during the first two years of ownership is the electric motorcycle X, while the conventional motorcycle B typically ranks highest. In a low, medium, and high mobility scenarios, electric motorcycles are more environmentally beneficial than conventional motorcycles. Since they use energy at the same rate, single and double batteries have the same GWP. According to the findings of this study, using an electric motorcycle X is recommended for low LCC and carbon impact concerns. An electric motorcycle's most expensive maintenance cost is replacing the battery, which significantly increases the LCC. The following study can provide a comparison between LCC and a battery rental system.

There are some limitations to this study. There is no such reference for electric vehicle maintenance. The assumption of a maintenance interval for electric motorcycles is the same as for ICE motorcycles except for engine maintenance. A more thorough study can be conducted in the following study. For LCIA, the calculation focuses on the carbon impact. The following study may be more in line with government requirements.

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