

Total Cost Analysis of Combustion and Electric Cars in Indonesia

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Abstract

The electrification of transportation has been identified as a necessary aspect of climate change mitigation in order to limit global temperatures to 1.5°C above pre-industrial levels and prevent potentially catastrophic effects on the environment (Thorne & Hughes 2019). With the Electrified Vehicles (EVs) ventures being in the early stage, the cost-benefit analysis of the vehicles is key towards capturing the Indonesian market. As consumers, however, pricing may not only be the costs they consider; they also consider the total cost of ownership (TCO) of the cars they purchase. The TCO model incorporated the manufacturer's suggested retail price (MSRP), tax, fuel cost, charging cost, maintenance cost, and residual value including depreciation. This study aims to compare the value of total cost of ownership of electric and conventional cars in Indonesia related to the relevant switching cost between EVs and ICEV. In this study it was concluded that the TCO value in HEV is smaller than BEV and ICEV. So that hybrid vehicles will be the most efficient car to have when driving long distances

Keywords

Total Cost of Ownership, Electric Vehicles, Internal Combustion Engine Vehicles, Emissions, Indonesia

1. Introduction

Global warming has become a central issue in recent decades, because it poses a multidimensional threat to ecology, environment, economy and society (Setiawan et al. 2022). Community knowledge has an influence that can affect awareness of environmental impacts (Wibowo et al. 2022). So the trend of clean energy has been increasing in the world since the Paris Agreement which proposed that each country is responsible for keeping the global average temperature rising below 2 °C (Huda et al. 2019). The International Energy Agency creates scenarios that recommend mitigation, countermeasures and actions to reduce the concentration of CO₂ emissions in the atmosphere to below 450 ppm by limiting the use of fossil fuels (Huda et al. 2019).

Electric vehicles (EV) have been identified as the best way to reduce emissions in the transportation sector (Ayeter et al. 2022). The International Energy Agency supports sales of hybrid cars and EVs which are projected to increase to around 40% by 2030 (Huda et al. 2019). The number EV is increasing due to rising oil and gas prices and advances in battery technology (Huda et al. 2018). About 22 countries in the world, such as the United States (US) and the European Union have promised either on the sale of complete internal combustion engine vehicles (ICEV) or a sales target of 100% zero emission vehicles by 2050. By 2020, the global electric vehicle fleet grew to 10 million with around 370 different models but only representing 1% share of the world's vehicle fleet. Most of the EVs are concentrated in a few places such as China (45%), Europe (24%) and the United States (22%) (Ayeter et al. 2022).

The annual growth rate of EVs increases significantly due to their favorable characteristics compared to ICEVs. These advantages include high efficiency, low maintenance, environmentally friendly, especially when combined with renewable energy sources. In addition, several studies have shown other benefits of electric vehicles, namely that they can be used as energy storage in power systems. They can release energy into the tissues when needed to balance tension (Huda et al. 2019). Several challenging research studies and opportunities for EV improvement when

connected to the power grid, such as the unique feature of EV controllable charging and discharging which can be used to discharge and absorb electricity (Huda et al. 2018).

Remembering EV consumes large amounts of electrical energy, there is a challenge to ensure the generation and management of that energy. This is because unlike conventional fuel-based cars, electric cars are primarily designed to drive for a short time and relatively short distances compared to conventional vehicles. (Brady and O'Mahony, 2016). Charging infrastructure is also an important component in EV development (Shaukat et al., 2018), where the biggest challenge compared to producing batteries at affordable costs is developing EV charging infrastructure on a national scale. In this case, the implementation of electric vehicles in Indonesia still facing challenges due to limited charging stations available. However, an effective strategy, substantial marketing effort, and information systems are needed to develop the EV ecosystem (Wibowo et al. 2022).

There are several vehicle brands that dominate Indonesian market. In this case, several brands like Toyota, Daihatsu, Mitsubishi, Honda, Isuzu, Mazda and Nissan are the vehicle manufacturers that have a huge demand. Mazda as Japanese manufacturer that rely on the power of art with "the car is art" slogan has successfully attracting customers interest through numerous cars they produced (Nobeoka et al. 2016). Specifically CX-5 could be considered as one of Mazda's flagship products as ICEV with its success by winning car of the year awards in Japan during 2012-2013 period (Nobeoka et al. 2016). On the EV side, Nissan has become one of the challengers by their commitment in producing Nissan Leaf as electric car (Dooley 2022) with eight year car's battery guarantee, and Nissan Kicks as hybrid car (Voelk 2018).

1.1. Objectives

This study to identify the cost of ownership of numerous types of electrified vehicle (EV) and internal combustion engine vehicles (ICEV). We estimated a eight year TCO for EV namely Nissan Leaf, and ICEV namely Mazda CX-5, and HEV namely Nissan Kicks. We provide a comparative analysis of tax costs, fuel costs, electricity costs, maintenance costs, purchase costs, resale value and depreciation. By using the total cost of ownership (TCO) calculation, a better picture can be drawn to help electric car consumers in Indonesia make informed decisions by understanding when and how the TCO of EVs is lower than ICEVs.

2. Literature Review

According to Parkhi (2005), Total Cost of Ownership (TCO) is a purchasing tool that aims to calculate the costs incurred to purchase goods and services. Vehicle Costs include direct user expenses to own and use private vehicles. TCO is a useful calculation for consumers and firms alike to assess the direct and indirect cost associated with a purchase. TCO is important, since the purchasing price of most capital goods is not the only cost associated with their use and ownership (Hagman et al. 2016). Parkhi also mentioned that there are three methods used to calculate TCO. First, the monetary-based method, which calculates the actual costs incurred by the owner to the purchase costs. There is an overhead component included in the TCO. Second, the cost-ratio or value-based method, where costs obtain from quantitative and qualitative calculations. Third, the mathematical programming decision method.

The concept of the total cost of ownership (TCO) is a useful way to compare the present and future economic competitiveness of different powertrain technologies in different countries. Ellram (1995) defines the TCO as a purchasing tool and concept whose purpose is to understand the real cost of purchasing a particular good or service from a particular supplier. Although the framework used for various TCO models is generally similar, the object that analyzed, country of study, model settings, and assumptions often vary.

The TCO literature has evolved over time from engineering-centric to more consumer-centric models. Early EV TCO studies from the 1990 s through 2015 tended to adopt a lifecycle cost approach, adding cost components to life cycle assessment or bottom-up engineering models of hypothetical BEVs.

The TCO includes the one-time purchase cost of the vehicle (and accessories or services), and all operating costs associated with its ownership. For comparison purposes, all future costs were converted into the net present value (NPV) at the time of vehicle purchase.

3. Methods

3.1 Total Cost of Ownership

In this study we used the TCO model. First, we make assumptions that the service life is 8 years from fiscal year 2022 to 2030. We use this year because the estimated average age of vehicles in Indonesia is 8 years (thegaspol.com, 2015). Vehicles used in calculating TCO are assumed to be new vehicles. Mileage per year is assumed to be 9,000 miles per year. So, the 8 year TCO is calculated in the following equation:

$$TCO = MSRP + TCx + Ecx (d) + Mx - Rx$$

Where TCO is the total cost of ownership, MSRP is the manufacturer's suggested retail price, TC is the tax credits, Ecx is the cost of future refueling/refueling during the year \times d is the distance, Mx is the annual cost maintenance and repairs annually based on the year considered, Rx is the resale value.

3.2 Purchase

Purchase cost is a one-time cost that includes the MSRP, national subsidies (SN), local subsidies (SL) in 2018, and the resale value (RV). This phase includes all the costs and incentives that are related to the purchase of a vehicle. Purchase price refers to the price a buyer pays for purchasing a vehicle (Coffman et al. 2017) and it is considered in all the analysed contributions.

Indonesia plans to provide subsidies to buy electric vehicles starting next year. The government targets to have 2.5 million electric car or electronic vehicle (EV) users by 2025.

Currently, a number of EV sellers, such as Hyundai Indonesia and Prestige Image Motorcars have received a 0% PPnBM incentive. In fact, the Hyundai Ioniq EV and Kona EV have received a 0% transfer fee (BBN) incentive for DKI Jakarta, with the payment of a 5% import duty (BM). However, the price of this electric vehicle is still relatively expensive, around IDR 600 million. In detail, Ioniq Prime Rp. 624.8 million, Ioniq Signature Rp. 664.8 million, and the Kona EV SUV Rp. 674.8 million (OTR Jakarta).

3.3 Energy

The gasoline price data was obtained from mypertamina.id, assumed using Pertamina RON 92, in Indonesia as of 25th November 2022 was Rp 13.900 per litre. The charging cost of the PEV was based on Indonesia's electricity tariff of Rp. 1.699,53 / kWh obtained from web.pln.co.id, assuming tariff group for large household needs with power of 6,600 VA and above (R-3/TR) based on Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia Number 28 of 2016 about The Electricity Tariff Provided by PT Perusahaan Listrik Negara (Persero).

3.4 Maintenance Cost

Maintenance cost includes: engine costs (oil, tune-up, parts, etc), vehicle costs (brake pad, shockbreaker, etc), electric components costs, and equipment costs (Riyanto et al. 2019). Based on Engers et al. (2004), the value of selling (or scrapping) the car depends on its age and observed and unobserved maintenance cost. Therefore, maintenance cost playing a major role to define the future value of the car.

3.5 Tax Credit

Tax payment is an obligation for people who own motor vehicles. Law Number 28 of 2009 states that the Motor Vehicle Tax is a tax on the ownership and/or control of motor vehicles. The motor vehicle tax applied in the province is based on the provincial regulation which is used as the operational and technical legal basis for the realization of the imposition and collection of motor vehicle tax in the province as well as the governor's decision on motor vehicle tax as a rule for implementing regional regulations on PKB in the province (Subekti et al. 2021)

4. Data Collection

All vehicles used in the TCO calculation are assumed to be new vehicles. New vehicles are often sold with predetermined conditions such as financing terms and mileage limits which can be good proxies for this analysis. The scope of this research is to build a TCO calculation for first-time vehicle owners. An assumed annual mileage of 9,000 miles per year and an eight-year ownership period from 2022 to 2030. This is because the estimated average age of electric vehicle batteries in Indonesia is 8 years. The specifications and cost of all vehicles examined in this work are stated in Table 1.

Table 1. Vehicles Specifications and Cost

Spesification	Mazda CX5 (ICEV)	Nissan Kicks (HEV)	Nissan Leaf (BEV)
Fuel type	Gasoline	Gasoline and electricity	Electricity
Descriptor	ICEV	HEV	BEV
Fuel tank capacity	56 L	41 L & 2,1 kWh	39 kWh
Fuel consumption	0,108 ltr/km	0,048 ltr/km	0,144 kWh/km
Cost fuel	Rp 13.900,-/ltr	Rp 13.900,-/ltr	Rp 1699,53,-/kWh
Purchase price	Rp 597.700.000,-	Rp 484.800.000,-	Rp 728.000.000,-
Tax credit	Rp 8.203.000,-	Rp 6.674.000,-	Rp 1.312.700,-
Maintenance cost	Rp 2.200.000,-/ 50.000 km	Rp 2.644.950,-/ 50.000 km	Rp 3.533.130,- /100.000 km

From the data above, it is used to calculate the manufacturer's suggested retail price (MSRP), tax credit (TC), the future cost of charging/fuel (Ec), annual maintenance (M), and resale value (R) for 8 years. Table 2 shows the components of costs incurred for 8 years.

Table 2. Component Cost of TCO

Cost	Mazda CX5 (ICEV)	Nissan Kicks (HEV)	Nissan Leaf (BEV)
MSRP	Rp 597.700.000,-	Rp 484.800.000,-	Rp 728.000.000,-
TCx	Rp 65.624.000,-	Rp 53.392.000,-	Rp 10.501.600,-
ECx (d)	Rp 175.087.473,76,-	Rp 76.701.410,18,-	Rp 28.406.430,-
Mx	Rp 5.098.493,63,-	Rp 6.129.663,96,-	R 4.239.756,-
Rx	Rp 357.619.621,91,-	Rp 212.402.493,60,-	Rp 319.814.705,-

5. Result and Discussion

5.1 Total Cost of Ownership

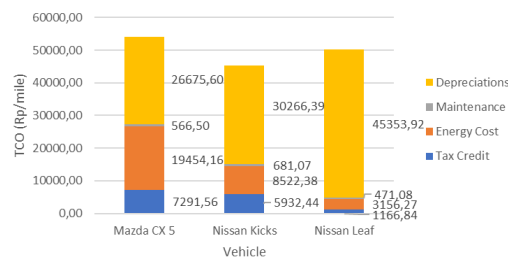


Figure 1. TCO of the 3 vehicles over 8 years

This study attempts to analyze the total cost of ownership (TCO) comparison between conventional cars or ICEVs and HEV and BEV. Total cost of ownership (TCO) is based on the cost of a vehicle per mile through 2030 and factors include purchase costs, taxes credit, fuel and/or electricity cost, maintenance costs and resale value. Fig. 1 shows the TCO for the three vehicles with the highest TCO calculated for the Mazda CX5 (ICEV) of Rp. 53,988/mile, followed by Nissan leaf (BEV) (Rp. 50,148/mile), and Nissan kicks (HEV) (Rp. 45,402. -/million). ICEV's TCO value is higher than HEV and BEV related to energy costs and taxes incurred by ICEV are higher than BEV and HEV. While the TCO value of HEV is smaller than BEV because HEV has an MSRP value of 33.4% smaller than BEV. A Nissan Kicks car can be purchased at a price of Rp. 484,800,000.- much cheaper than a Nissan Leaf car at Rp. 728,00,000.-.

The component that contributes the highest to TCO is the depreciation value. The depreciation value is calculated from the manufacturer's recommended retail price reduction (MSRP) with the release value (R) in the 8th year. At BEV, the depreciation value component is 90.4% of the TCO. This is because the main component of the BEV is battery. Meanwhile, the battery life on the BEV is around 8 years. So there will be a large depreciation value if battery is damaged. This causes BEV depreciation value to be 36% greater than HEV and 83.6% greater than ICEV. However BEV requires less maintenance frequency compared to ICEV and HEV. This is because source of BEV transmission is electricity which has fewer moving parts, in contrast to the power source for ICEV transmission which consists of hundreds of parts. This is supported by the results of this study which provide a BEV maintenance cost value of only 0.9% of TCO which is smaller than ICEV and HEV with a value above 1% of TCO.

The second largest contributor to TCO is energy costs incurred over 8 years (EC). At ICEV, the EC value is 36% of TCO. In contrast to HEV which is only 18.7% and BEV which is only 6.3% of the TCO. The high cost of fuel is related to the price of fuel as well as the efficiency of ICEVs compared to HEVs and BEVs. The more expensive fuel costs, the bigger the difference in TCO between HEV and BEV to ICEV. It has been proven that BEVs are generally six times more efficient than ICEVs in terms of energy costs. The proportion of HEV is still bigger than BEV because the HEV system combines a conventional internal combustion engine propulsion system with an electric propulsion system so that it still requires fuel to operate.

The third highest cost contribution component is the cost of the tax credit. In Indonesia, electric cars are exempt from the imposition of PPnBM and a tax base (DPP) of 0%, as stated in PP No. 74 of 2021. This is in accordance with the results of this study which states that the value of the tax credit on ICEV is greater than HEV and BEV is 13.5% of the TCO.

In this combination, it can be concluded that the total cost of ownership of HEV is still the lowest compared to BEV and ICEV. In other words, a hybrid vehicle will be the most efficient car to own when it comes to long-distance driving. Meanwhile, if fuel costs 57% more than the normal price, the cost of owning a BEV is much lower compared to owning an HEV.

5.2 Future Cost of Charging/Fuel (Ecx)

Ecx is the future cost of refueling over 8 years and d is the annual distance traveled by the vehicle. The fuel used is Pertamina Ron 92 at a price of IDR 13,900 per liter. The charging cost of the PEV was based on Indonesia's electricity tariff of Rp. 1,699.53 / kWh. Fig. 2 below shows that the lowest cost generated is the Nissan Leaf vehicle, which is Rp 28.406.430,- while the highest price is the Mazda CX5 vehicle, which is Rp 175.087.473,76. It can be concluded that vehicles using electric vehicle (EV) can save operational costs on car vehicles.

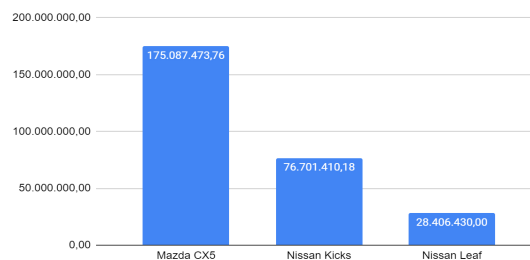


Figure 2. Comparison of Vehicle Operating Cost (Ecx) d

5.3 Maintenance Cost (M)

Mx is the maintenance and repair cost for 8 years use. For this point of view, EV's Nissan Leaf become the lowest cost vehicle with Rp. 4,239,756.00. This is understandable because as newcomer type of car, it equipped by maintenance free cost until 43,496 miles. Fig. 3 shows comparison of vehicle maintenance and repair cost of 8 years.

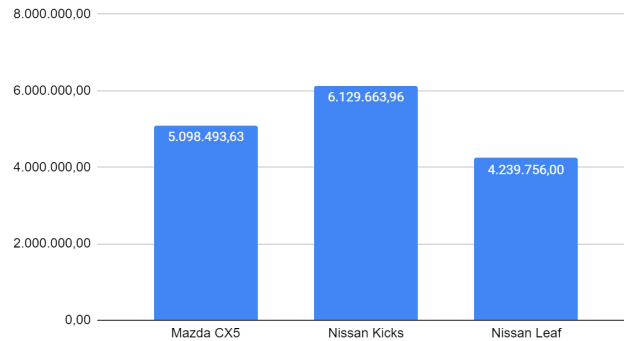


Figure 3. Comparison of Vehicle Maintenance and Repair Cost (Mx)

5.4 Future Cost of Charging/Fuel (Ec)

Rx is the resale value after 8 years. Fig. 4 below shows that the car with the highest resale value is Mazda CX5 vehicle with Rp. 357,619,621.91, followed by Nissan Leaf with Rp. 319,814,705, and the lowest resale value is Nissan Kicks with Rp. 212,402,493.60. However, compared to the manufacturer's suggested retail price (MSRP), the lowest depreciation expected based on caredge.com is Mazda CX5 with around 40.17%, followed by Nissan Leaf with the depreciation around 56.07%, and car with the highest depreciation is Nissan Kicks with around 56.19%.

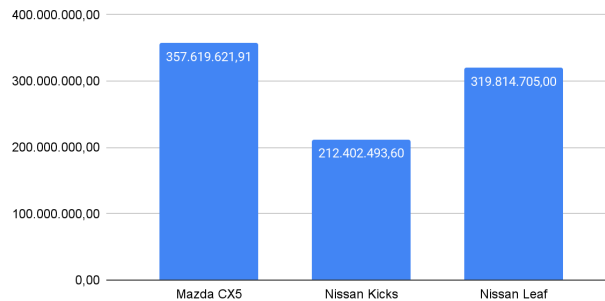


Figure 4. Comparison of Vehicle Resale Value (Rx)

6. Conclusion

We assess the total cost of ownership (TCO) of three different types of vehicles, namely ICEV (Mazda CX 5), HEV (Nissan Kicks), and BEV (Nissan Leaf) according to conditions prevailing in Indonesia over a period of 8 years. In the current situation in Indonesia, we find ICEV's TCO 7% higher than BEV and 15% higher than HEV. The biggest advantage that HEV has is that it costs 56.19% less cost of charging/fuel than ICEV. We found a price differential between fuel and electricity which shows that it is critical to keep the price differential at some level for BEVs to be highly competitive. The TCO of HEVs is lower than BEVs up to year 8 due to the low initial purchase price of HEVs. The tax cost component proves that BEV is 83.9% cheaper than ICEV. Tax waivers should extend to both new and used EVs to further increase their TCO advantage. In this combination it can be concluded that the total cost of ownership of HEV is still the lowest compared to BEV and ICEV. In other words, a hybrid vehicle will be the most efficient car to own for long distance driving.

References

- A comfortable place to spend 38000 hours behind the wheel, Available: <https://www.nytimes.com/2018/11/01/business/seats-cars-safety-comfort.html>, Accessed on November 29, 2022.
- Ayeter, G. K., Opoku, R., Sekyere, C. K. K., Agyei-Agyeman, A. and Deyegbe, G. R., The cost of a transition to electric vehicles in Africa: A case study of Ghana, *Case Studies on Transport Policy*, vol. 10, no. 1, pp. 388–395, 2022.
- Engers, M., Hartmann, M. and Stern, S., Automobile Maintenance Costs, Used Cars, and Adverse Selection, *University of Virginia Working Paper*, 2004.
- Hagman, J., Ritzén, S., Stier, J. J., and Susilo, Y. Total cost of ownership and its potential implications for battery electric vehicle diffusion, *Research in Transportation Business & Management*, vol. 18, pp. 11–17, 2016.
- Huda, M., Aziz, M. and Tokimatsu, K., Potential ancillary services of electric vehicles (vehicle-to-grid) in Indonesia, *Energy Procedia*, vol. 152, pp. 1218–1223, 2018.
- Huda, M., Aziz, M. and Tokimatsu, K., The future of electric vehicles to grid integration in Indonesia, *Energy Procedia*, vol. 158, pp. 4592–4597, 2019.
- Mazda CX-5 Depreciation, Available: <https://caredge.com/mazda/cx-5/depreciation?y=0&p=597700000&o=5&m=10500>, Accessed on November 29, 2022.
- Nissan and Renault seek stronger ties with a commitment to electric cars, Available: <https://www.nytimes.com/2022/01/27/business/nissan-renault-mitsubishi-electric-cars.html>, Accessed on November 29, 2022.
- Nissan Kicks Depreciation, Available: <https://caredge.com/nissan/kicks/depreciation?y=0&p=27325&o=5&m=15000>, Accessed on November 29, 2022.
- Nissan Leaf Depreciation, Available: <https://caredge.com/nissan/leaf/depreciation>, Accessed on November 29, 2022.
- Nobeoka, K. and Kimura, M., Art thinking beyond design thinking mazda design: Car as art, *2016 Portland International Conference on Management of Engineering and Technology (PICMET)*, pp. 2499-2514, Honolulu, USA, September 4-8, 2016.
- Pertamina Fuel Price, Available: <https://mypertamina.id/fuels-harga>, Accessed on November 29, 2022.
- Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia Number 28 of 2016 about The Electricity Tariff Provided by PT Perusahaan Listrik Negara (Persero)
- Riyanto, Nuryakin, C., Riyadi, S. A. and Massie, N. W. G., Estimating the Total Cost of Ownership (TCO) of Electrified Vehicle in Indonesia, *2019 6th International Conference on Electric Vehicular Technology (ICEVT)*, pp 88-99, Bali, Indonesia, November 18-21, 2019.
- Setiawan, A. D., Zahari, T. N., Purba, F. J., Moeis, A. O., and Hidayatno, A., Investigating policies on increasing the adoption of electric vehicles in Indonesia, *Journal of Cleaner Production*, vol. 380, 135097, 2022.
- Subekti, R., Ifrinani, F. N. and Rahmawati, I., Tax Policy of Electric-Based Vehicles to Realize Human Rights for a Good Environment in Indonesia. *Proceedings of the International Conference For Democracy and National Resilience ICDNR 2021*, vol. 60, Solo, Indonesia, October 6-7, 2021.
- Tarif Adjustment PLN, Available: <https://web.pln.co.id/statics/uploads/2022/09/TTL-OKT-DES.jpg>, Accessed on November 29, 2022.
- Thorne, Z. and Hughes, L., Evaluating the effectiveness of electric vehicle subsidies in Canada, *Procedia Computer Science*, vol 155, pp 519–526, 2019.
- Wibowo, N., Nurcahyo, R. and Gabriel, D. S., Environmental awareness factor of used cell phones. *Global Journal of Environmental Science and Management*, vol. 8, no. 1, pp. 87-100, 2022.
- Wibowo, N., Piton, J. K., Nurcahyo, R., Gabriel, D. S., Farizal, F. and Madsuha, A. F., Strategies for Improving the E-Waste Management Supply Chain Sustainability in Indonesia (Jakarta), *Sustainability*, vol. 13, no. 24, 13955, 2021.

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