PROGRESS IN ENGINEERING APPLICATION AND TECHNOLOGY
e-ISSN: 2773-5303

PEAT

Vol. 7 No. 1 (2026) 457-465
https://publisher.uthm.edu.my/periodicals/index.php/peat

Total Cost of Battery Electric Vehicle (BEV), Hybrid Electric Vehicle (HEV) and Internal Combustion Engine Vehicle (ICEV) in Malaysia

Muhammad Rosmaizam Maidin[1], Norirda Mohamed[1]*

[1] *Department of Mechanical Engineering, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Education Hub, 84600, Johor, MALAYSIA.*

*Corresponding Author: norirda@uthm.edu.my
DOI: https://doi.org/10.30880/peat.2026.07.01.053

Article Info

Received: 12 January 2026
Accepted: 20 February 2026
Available online: 25 May 2026

Keywords

Total Cost of Ownership (TCO), Internal Combustion Engine Vehicle (ICEV), Hybrid Electric Vehicle (HEV), Battery Electric Vehicle (BEV)

Abstract

The increasing adoption of alternative vehicle technologies requires an evaluation of their economic feasibility compared to Internal Combustion Engine Vehicles (ICEVs) in Malaysia. This study compares the Total Cost of Ownership (TCO) of the Proton X70 1.5 TGDi (ICEV), Proton e.MAS 7 (BEV), and Honda HR-V 1.5 RS (HEV) over a 15-year ownership period. The analysis includes purchase price, maintenance, tyre replacement, energy or fuel cost, insurance, and road tax based on market prices and service estimates. Results show that total ownership costs range from RM230,000 to RM255,000. The Proton X70 purchase price of RM125,000 accounts for 52% of its TCO, with 48% (RM115,000) from long-term costs. The Honda HR-V has the highest purchase price at RM145,000, representing 57% of TCO, while operating costs contribute 43% (RM110,000). The Proton e.MAS 7 shows a balanced cost distribution, with RM120,000 (52%) initial cost and RM110,000 (48%) long-term costs. Overall, long-term costs contribute 43–48% of TCO, showing that BEVs are economically viable for long-term ownership in Malaysia.

1. Introduction

The advancement of automotive powertrain technologies has significantly reshaped vehicle performance, cost structures, and environmental impact. In Malaysia, passenger vehicles are predominantly categorized into Internal Combustion Engine Vehicles (ICEVs), Hybrid Electric Vehicles (HEVs), and Battery Electric Vehicles (BEVs). ICEVs operate solely on fossil-fuel combustion engines, HEVs combine an internal combustion engine with an electric motor to improve energy efficiency, while BEVs rely entirely on battery-powered electric propulsion. Each powertrain exhibits distinct technical and economic characteristics that influence overall ownership costs.

To evaluate vehicle affordability comprehensively, the Total Cost of Ownership (TCO) approach is widely adopted. TCO extends beyond the initial purchase price by incorporating all ownership-related costs incurred over the vehicle's lifespan. These include energy consumption, maintenance, tire replacement, insurance premiums, road tax, and other recurring expenses. The TCO framework enables a more accurate long-term comparison between ICEVs, HEVs, and BEVs, whose cost distributions differ significantly over time.

Despite increasing policy support and the growing availability of electrified vehicles, uncertainty remains regarding their economic viability compared to ICEVs under Malaysian ownership conditions. Existing TCO studies often lack sufficient reflection of local factors such as Malaysian energy prices, maintenance practices, and taxation structures, resulting in limited practical guidance for consumers.

Therefore, this study aims to conduct a comparative TCO analysis of ICEVs, HEVs, and BEVs in the Malaysian market. The scope of the study is limited to four key cost criteria: maintenance, tire replacement, energy consumption, and insurance and road tax. The findings are expected to provide clearer insights into long-term cost effectiveness and support informed decision-making toward sustainable mobility.

2. Data Configuration and Methodology

2.1 Data

This section compares Internal Combustion Engine Vehicles (ICEV), Battery Electric Vehicles (BEV), and Hybrid Electric Vehicles (HEV) based on five key criteria: purchase price, engine type, fuel efficiency, fuel or battery capacity, and curb weight. These factors are essential for evaluating differences in energy consumption, vehicle performance, and overall efficiency across the three powertrain types.

Table 1 *Technical Specifications of the Selected ICEV, BEV and HEV Models [1][2][3][4][5][6]*

Item	ICEV (Proton X70 1.5 TGDi)	BEV (Proton e.MAS 7)	HEV (Honda HR-V 1.5 RS)
Purchase Price	RM126,800	RM123,800	RM143,900
Engine / Motor Type	1.5 L Turbocharged Inline-3 Petrol (TGDi)	Single front-mounted electric motor	1.5 L petrol engine (Atkinson cycle) + electric motor
Fuel / Energy Efficiency	7.6 L/100 km	11.2–11.9 kWh/100 km	5.4 L/100 km
Fuel / Battery Capacity	60 L fuel tank	60.22 kWh battery	40 L fuel tank + hybrid battery
Curb Weight	1,605 kg	1,765 kg	1,396 kg

2.2 Methodology

To evaluate the maintenance expenditure of the vehicles, a structured cost calculation method is adopted in this study. The method considers both the maintenance cost incurred at each service interval and the total maintenance cost accumulated over the entire ownership period [7]. This approach enables a systematic assessment of maintenance costs and supports a fair comparison between different vehicle powertrains.

$$MC_y = \sum_{i=1}^{n} Ci \tag{1}$$

MC_y = Maintenance cost in year y

C_i = Cost of maintenance item $i$performed at that mileage

n= Total number of maintenance items required at that service interval

$$TMC = \sum_{y=1}^{n15} MC_y \tag{2}$$

TMC = Total maintenance cost over 15 years

MC_y= Maintenance cost in year y

$$FC_{ICEV} = \left(\frac{D}{100}\right) \times FC_{rate} \tag{3}$$

Progress in Engineering Application and Technology Vol. 7 No. 1 (2026) p. 457-465

$$C_{ICEV} = FC_{ICEV} \times P_{fuel} \quad (4)$$

FC_{ICEV} = Annual fuel consumption of the ICEV
D = Annual driving distance (km)
FC_{rate} = Fuel consumption rate of the vehicle (L/100 km)
$P_{fuel} = Fuel\ price\ per\ liter\ (RM/L)$
C_{ICEV} = *Annual fuel cost of the ICEV*

$$FC_{HEV} = \left(\frac{D}{100}\right) \times EC_{rate} \quad (5)$$

$$C_{HEV} = FC_{HEV} \times P_{fuel} \quad (6)$$

FC_{HEV} = Annual fuel consumption of the HEV
D = Annual driving distance (km)
FC_{rate} = Fuel consumption rate of the vehicle (L/100 km)
$P_{fuel} = Fuel\ price\ per\ liter\ (RM/L)$
C_{HEV} = *Annual fuel cost of the HEV*

$$E_{BEV} = \left(\frac{D}{100}\right) \times EC_{rate} \quad (7)$$

$$E_{home} = E_{BEV} \times \alpha \quad (8)$$

$$E_{public} = E_{BEV} \times (1 - \alpha) \quad (9)$$

$$C_{home} = E_{home} \times P_{home} \quad (10)$$

$$C_{public} = E_{public} \times P_{public} \quad (11)$$

$$C_{BEV} = C_{home} \times C_{public} \quad (12)$$

E_{BEV} = Total annual electrical energy consumption of the BEV
D = Annual driving distance (km)
EC_{rate} = Energy consumption rate (kWh/100 km)
α = Proportion of home charging
P_{home} = Home electricity tariff (RM/kWh)
P_{public} = Public charging tariff (RM/kWh)
C_{BEV} = Total annual energy cost of the BEV

$$INS_1 = \text{IC} \quad (13)$$

INS_1= Insurance cost in the first year of ownership
IC = Initial insurance premium

$$INS_y = INS_1(1 - d)^{(y-1)} \quad (14)$$

INS_y = Insurance cost in year y
INS_1 = Insurance cost in the first year

d = Annual insurance reduction rate
y = Year of ownership ($y = 1,2,3, \dots, 15$)

$$TINS = \sum_{y=1}^{15} INS_y \tag{15}$$

$TINS$ = Total insurance cost over 15 years
INS_y = Insurance cost in year y
$\sum$ = Summation of annual insurance costs
y = Year index from 1 to 15

In this study, the road tax cost is assumed to remain constant throughout the 15-year ownership period. This is because road tax rates are determined by fixed vehicle specifications and are not influenced by vehicle age or mileage. Therefore, the same annual road tax cost is applied for each year of ownership.

3. Criteria and The Cost Analysis

The findings obtained from the cost analysis based on the selected evaluation criteria are presented and discussed using bar charts and graphs to compare ICEVs, HEVs, and BEVs in the Malaysian passenger vehicle market. These visual representations enable effective comparison of cost behavior across different powertrain technologies and highlight the relative financial implications of each criterion under local operating conditions.

3.1 Maintenance Cost

The maintenance cost shown in Figure 1 reveals differences among the three vehicle powertrain types. The Proton X70 1.5 TGDi (ICEV) records the highest and most fluctuating maintenance costs, with notable increases at higher mileage intervals, particularly at 120,000 km and 240,000 km, due to major servicing activities involving engine, transmission, and mechanical component replacements. The Honda HR-V 1.5 RS (HEV) maintains relatively moderate maintenance costs throughout most of the ownership period; however, a substantial cost spike occurs at approximately 240,000 km as a result of high-voltage hybrid battery replacement [8], which significantly increases its total maintenance expenditure. In contrast, the Proton e.MAS 7 (BEV) exhibits the lowest and most consistent maintenance costs, generally remaining below RM600 per service, as its maintenance requirements are limited to inspections, braking systems, and cooling components, with no battery replacement required [9][10]. Overall, the results demonstrate that battery electric vehicles provide superior maintenance cost efficiency compared to hybrid and internal combustion engine vehicles, making the Proton e.MAS 7 most economically advantageous option for long-term ownership.

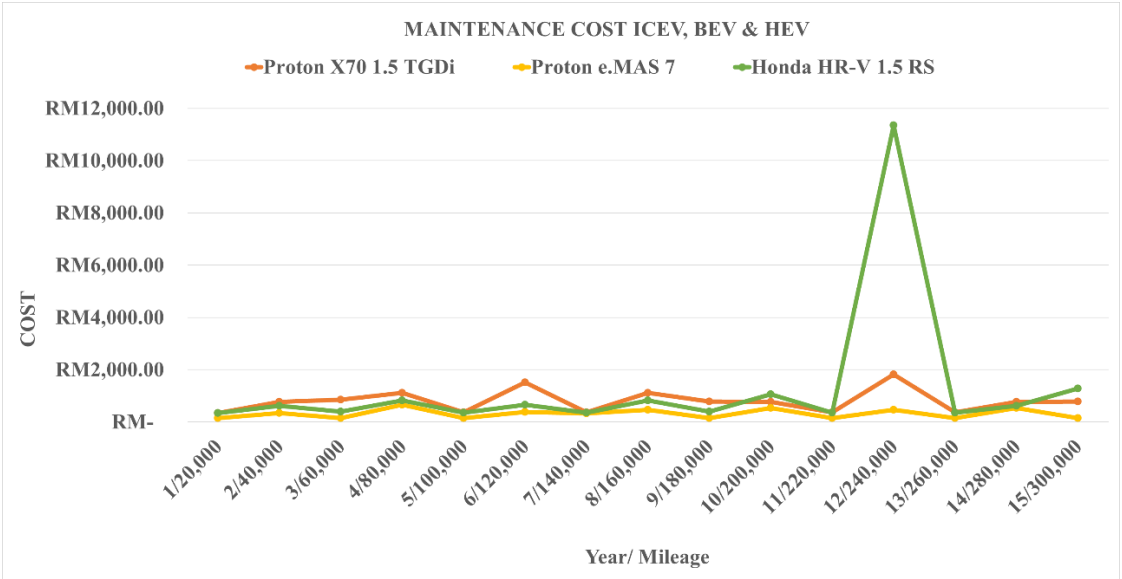

Fig. 1 Graph of maintenance cost

Progress in Engineering Application and Technology Vol. 7 No. 1 (2026) p. 457-465

3.2 Tyre Cost

The cost of tyre replacement in Figure 2 shows similar patterns across Proton X70 1.5 TGDi (ICEV) [11][12], Proton e.MAS 7 (BEV) [13][14], and Honda HR-V 1.5 RS (HEV) [15][11] exhibit sharp spikes in tyre costs every three years, ranging from RM1,000 to RM3,500 per replacement cycle, corresponding to scheduled full tyre changes. This indicates that tyre wear and size are the main determinants of replacement costs, while drivetrain type has minimal effect.

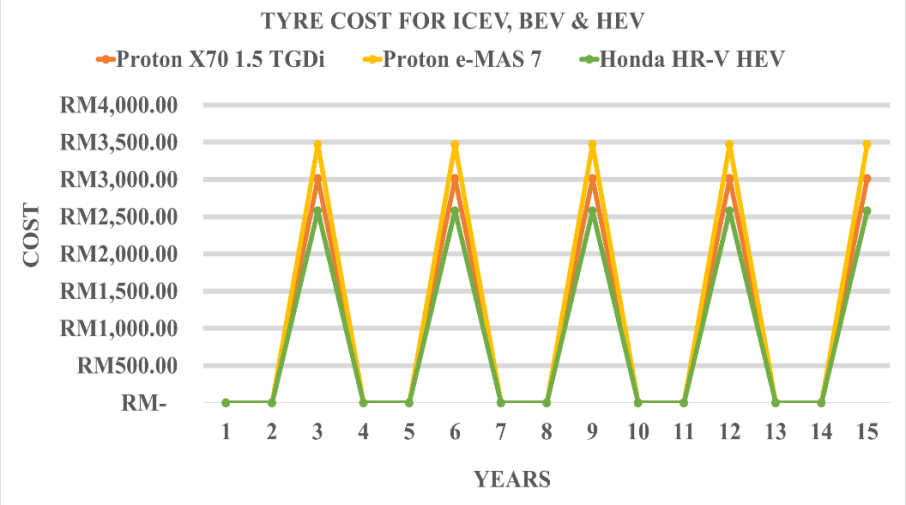

Fig. 2 Graph of Tyre Cost

3.3 Energy Consumption

The cumulative energy costs in Figure 3 reveal clear costs between ICEVs, HEVs, and BEVs, reflecting the impact of drivetrain efficiency and energy pricing. The Honda HR-V 1.5 RS (HEV) consistently has the lowest cumulative energy cost, reaching approximately RM24,500, due to its fuel efficiency and continued access to subsidized fuel [16], while the Proton X70 1.5 TGDi (ICEV) shows higher energy expenditure, increasing to about RM43,500 despite fuel subsidies. The Proton e.MAS 7 (BEV) incurs cumulative energy costs of around RM40,500, slightly lower than the ICEV, but its costs are influenced by electricity tariffs and dependence on public charging infrastructure [17], which contributes to significant variability in long-term energy expenses. These results indicate that hybrid electric vehicles offer the most cost-effective energy consumption under current Malaysian fuel and electricity frameworks, while battery electric vehicles, despite reduced fuel usage, remain vulnerable to electricity pricing and charging behaviors.

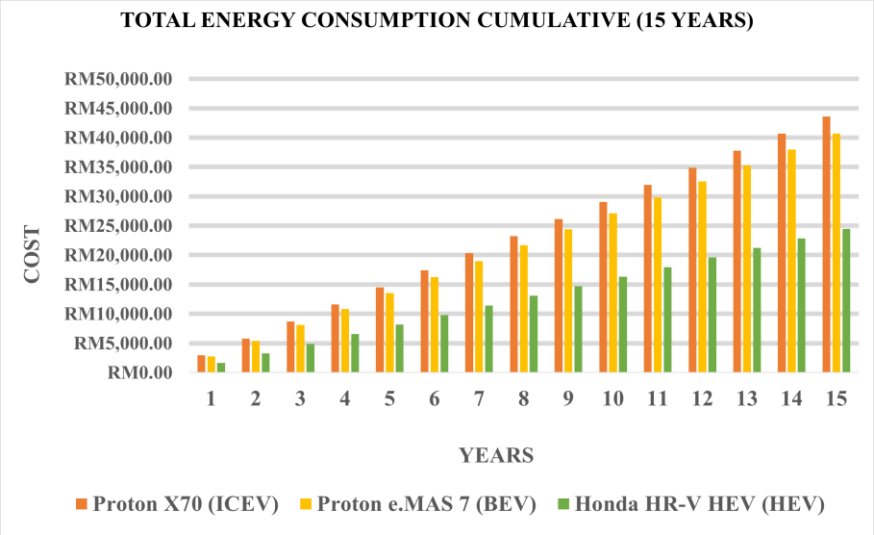

Fig. 3 Bar chart of Total Energy Consumption Cumulative

3.4 Insurance and Road Tax

The analysis of insurance and road tax in Figure 4 shows that all three vehicles experience a gradual reduction in costs, with Proton models demonstrating more economical long-term benefits compared to the Honda HR-V (HEV). The Proton X70 1.5 TGDi (ICEV) and Proton e.MAS 7 (BEV) start at RM3,498.30 and RM3,466.60 in the first year and decrease to RM2,124.80 and RM2,101.40, respectively, due to a 3% annual reduction and the effect of a growing no-claims discount (NCD) [18]. In contrast, the Honda HR-V 1.5 RS begins at RM4,300.00 and only reduces to about RM2,695.00, remaining the most expensive throughout the period. This indicates that while all vehicles benefit from NCD growth and annual cost reductions, the Proton models' lower initial insurance premiums and steady declines result in greater long-term savings. Therefore, in terms of insurance and road tax costs, the Proton X70 and Proton e.MAS 7 are more cost-effective options over 15 years, contributing to a lower total cost of ownership compared to the Honda HR-V.

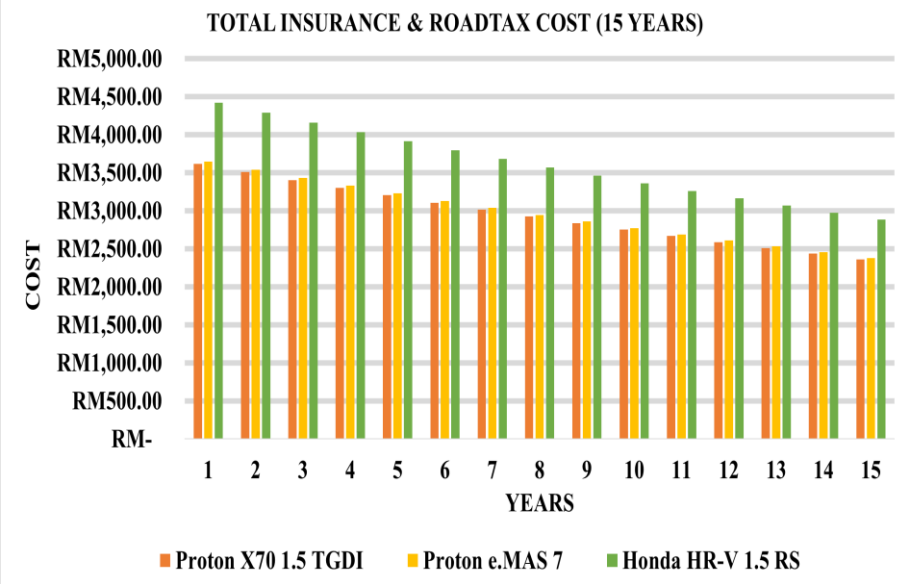

Fig. 4 Bar chart of Total Insurance & Road tax Cost

3.5 Total Cost of Criteria

3.5.1 Total Cost of Criteria Cumulative

The cumulative total cost presented in Figure 5 illustrates the differences in long-term ownership costs among the ICEV, BEV, and HEV over a 15-year period, based on maintenance, energy, insurance, road tax, and related operational expenses. The Proton X70 1.5 TGDi (ICEV) records the highest cumulative cost, increasing steadily from approximately RM7,000 in year 1 to about RM115,000 by year 15. The Honda HR-V 1.5 RS (HEV) follows closely, reaching roughly RM112,000 at the end of the ownership period. Meanwhile, the Proton e.MAS 7 (BEV) demonstrates the lowest cumulative cost growth, rising from around RM6,500 in year 1 to approximately RM107,000 by year 15. The results indicate that although all three vehicles show a consistent upward cost trend over time, the BEV maintains a slight long-term cost advantage, while the ICEV remains the most expensive overall. The gap between the vehicle types gradually widens throughout the ownership period, highlighting the impact of differences in energy efficiency and maintenance requirements on total cumulative cost.

Progress in Engineering Application and Technology Vol. 7 No. 1 (2026) p. 457-465

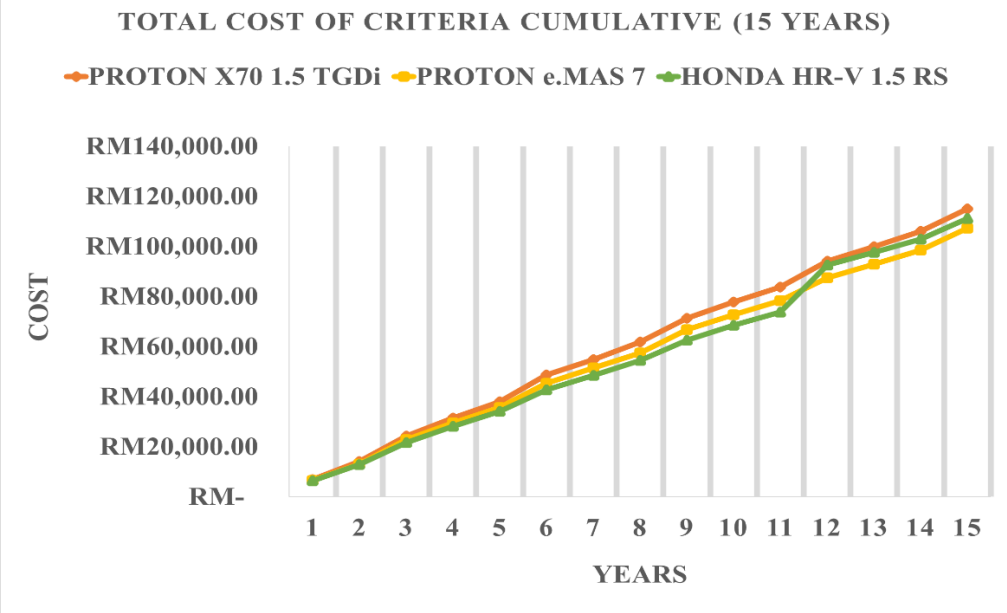

Fig. 5 Graph of Total Cost of Criteria Cumulative

3.5.2 Total Cost of Criteria Annually

The annual cost trends in Figure 6 show noticeable fluctuations for all three vehicle types over the 15-year period, mainly due to scheduled maintenance, tyre replacements, and insurance-related expenses. The Proton X70 1.5 TGDi (ICEV) consistently records the highest annual cost in most years, with values generally ranging between approximately RM6,500 and RM10,500. Its highest annual peak occurs in Year 12 at around RM10,300, which is about 18–20% higher than the BEV in the same year and approximately 45–50% higher than the HEV. The Proton e.MAS 7 (BEV) shows a similar fluctuating pattern, with annual costs mostly between RM6,000 and RM9,500, and a notable peak in Year 12 at roughly RM9,500, which is about 10% lower than the ICEV but nearly 85–90% higher than the HEV in that year. In contrast, the Honda HR-V 1.5 RS (HEV) maintains the lowest annual cost profile throughout most of the ownership period, with costs typically ranging from around RM5,200 to RM8,500. Although the HEV experiences a sharp spike in Year 12 to approximately RM18,500, this is an exceptional year linked to major scheduled costs, representing an increase of more than 200% compared to its average annual cost. Excluding this outlier, the HEV remains consistently more economical than both the BEV and ICEV across the 15-year period. Overall, the ICEV exhibits the highest annual operating burden, followed by the BEV, while the HEV demonstrates the most cost-efficient annual operating pattern despite one significant spike.

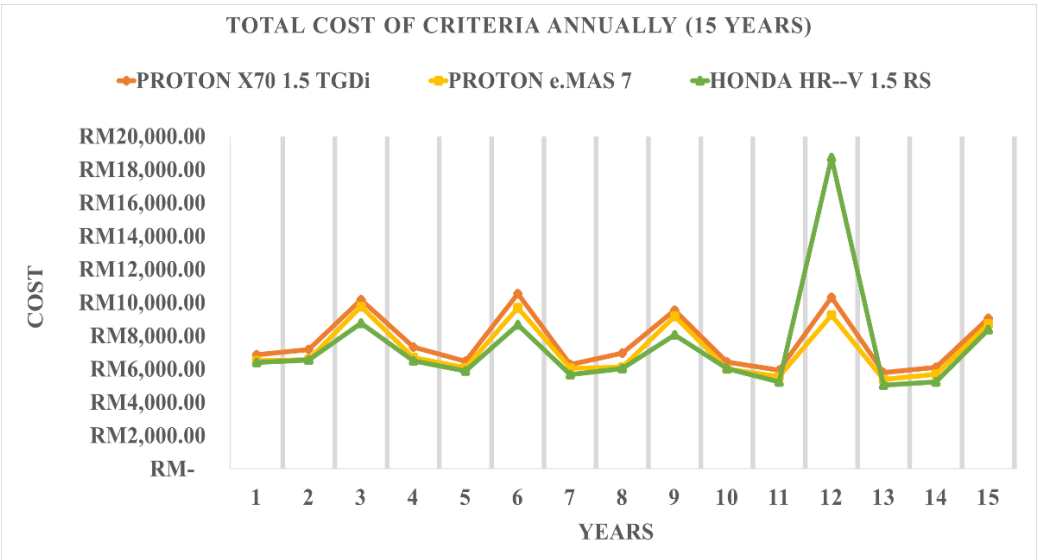

Fig. 6 Graph of Total Cost of Criteria Annually

3.6 Total Cost of Ownership

The total cost of ownership (TCO) over 15 years in Figure 7 highlights clear differences among the three vehicle types, demonstrating the strong influence of cumulative operating costs on long-term affordability. The Honda HR-V 1.5 RS (HEV) records the highest overall TCO at approximately RM255,000, followed by the Proton X70 1.5 TGDi (ICEV) at around RM240,000, while the Proton e.MAS 7 (BEV) shows the lowest TCO at roughly RM230,000. For the X70, the purchase price accounts for about RM125,000, which is approximately 52% of its total ownership cost, while the cumulative operating cost contributes around RM115,000 or 48%. In the case of the e.MAS 7, the purchase price represents about RM125,000, or roughly 54% of its TCO, whereas the cumulative cost over 15 years is around RM105,000, contributing about 46%. Meanwhile, the HR-V, despite having the highest purchase price of approximately RM145,000 about 57% of its TCO, shows a cumulative operating cost of around RM110,000, contributing the remaining 43%. Overall, although the HEV has a higher initial purchase price, the BEV demonstrates the lowest total cost of ownership over the 15-year period, while the ICEV falls in between. This indicates that, under the assumptions of this study, battery electric vehicles offer the most cost-effective option for long-term ownership, followed by internal combustion engine vehicles, with hybrid electric vehicles being the most expensive over the ownership period.

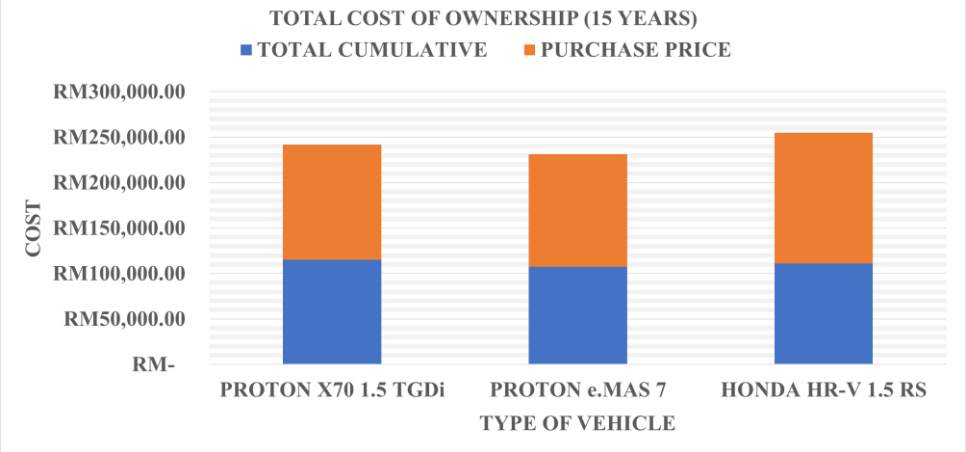

Fig. 7 Bar chart of Total Cost of Ownership

4. Conclusion

This study critically assessed the long-term ownership costs of three vehicles in Malaysia, namely the Proton X70 (ICEV), Proton e.MAS 7 (BEV), and Honda HR-V 1.5 RS (HEV) over a 15-year period, considering key cost elements such as maintenance, tyre replacement, energy consumption, insurance, and road tax. The analysis showed that the Proton e.MAS 7 had the lowest maintenance and energy costs due to its electric drivetrain, while the Honda HR-V was the most cost-effective in terms of tyres, insurance, and road tax, and the Proton X70 incurred the highest overall operating expenses. When all costs were combined to calculate the total cost of ownership (TCO), the Honda HR-V emerged as the most economical option, followed by the Proton e.MAS 7 and the Proton X70, highlighting that cumulative operating costs have a greater impact on long-term affordability than the initial purchase price. Overall, hybrid electric vehicles offer a balanced and economically viable choice for the Malaysian market, while battery electric vehicles provide strong advantages in maintenance and energy efficiency but may be influenced by insurance and depreciation uncertainties. These findings offer useful insights for consumers and policymakers in making informed decisions on sustainable vehicle ownership.

4.1 Recommendation

To improve the accuracy and realism of total cost of ownership (TCO) comparisons, future studies should incorporate real-world driving data obtained through on-road testing. Actual driving conditions, including traffic flow, road gradients, weather, and driver behavior, directly influence fuel consumption, energy usage, and vehicle performance, while detailed charging and refueling patterns such as charging points, timing, and electricity tariffs affect long-term energy costs for battery electric vehicles. Including these real-world data would provide more precise estimations of operating costs and energy consumption, and the integration of actual depreciation and resale values would enhance the evaluation of vehicle value retention over time, particularly for emerging technologies like electric cars. Furthermore, expanding future analyses to include a wider range of vehicle models within the same category would increase the robustness and applicability of TCO comparisons, ultimately supporting more informed consumer and policymaker decisions regarding sustainable vehicle ownership.

Acknowledgement

This research was supported by the faculty of Engineering Technology and Universiti Tun Hussein Onn Malaysia and TIER 1 research fund Q980.

References

[1] "PROTON - PROTON X70." Accessed: Jan. 03, 2026. [Online]. Available: https://www.proton.com/models/x70
[2] "Proton X70 Price 2026 in Malaysia, Latest Variants Specs&Images." Accessed: Jan. 03, 2026. [Online]. Available: https://www.pcauto.com/my/cars/proton/x70
[3] "eMAS 7 Brochure."
[4] "Proton e.Mas 7 Specs Malaysia, Engine & Fuel Consumption." Accessed: Jan. 03, 2026. [Online]. Available: https://www.pcauto.com/my/cars/proton/emas-7/specs
[5] "Specifications - Honda HR-V | Honda Malaysia." Accessed: Jan. 03, 2026. [Online]. Available: https://www.honda.com.my/model/hrv/spec
[6] "Honda HR-V Specs Malaysia, Engine & Fuel Consumption." Accessed: Jan. 03, 2026. [Online]. Available: https://www.pcauto.com/my/cars/honda/hr-v/specs
[7] P. Suttakul, W. Wongsapai, T. Fongsamootr, Y. Mona, and K. Poolsawat, "Total cost of ownership of internal combustion engine and electric vehicles: A real-world comparison for the case of Thailand," *Energy Reports*, vol. 8, pp. 545–553, Nov. 2022, doi: 10.1016/j.egyr.2022.05.213.
[8] "Honda Shares With Us The RM9,800 e:HEV Battery Price." Accessed: Jan. 01, 2026. [Online]. Available: https://www.dsf.my/2025/07/honda-ehev-battery-replacement-will-cost-just-rm9800/
[9] "e.MAS 7 - Proton e.MAS." Accessed: Jan. 01, 2026. [Online]. Available: https://emas.proton.com/e-mas-7/
[10] "Geely Auto Group Unveils its New Short Blade EV Battery Technology." Accessed: Jan. 01, 2026. [Online]. Available: https://www.geely.com/en/news/2024/geely-auto-unveils-new-short-blade-ev-battery-technology
[11] "GOODYEAR MALAYSIA BERHAD".
[12] "225/55 R19 99V Goodyear Assurance Maxguard SUV - Tayaria." Accessed: Jan. 02, 2026. [Online]. Available: https://tayaria.com/product/225-55-r19-99v-goodyear-assurance-maxguard-suv/
[13] "235/50R19 - Goodyear Efficientgrip Performance SUV (With Installation) | Shopee Malaysia." Accessed: Jan. 02, 2026. [Online]. Available: https://shopee.com.my/235-50R19-Goodyear-Efficientgrip-Performance-SUV-(With-Installation)-i.28292615.40967095216
[14] "Goodyear EfficientGrip Performance SUV tyre tayar tire (with installation) 235/55R19 225/65R17 | Shopee Malaysia." Accessed: Jan. 02, 2026. [Online]. Available: https://shopee.com.my/Goodyear-EfficientGrip-Performance-SUV-tyre-tayar-tire-(with-installation)-235-55R19-225-65R17-i.21246535.3701188452
[15] "[INSTALLATION PROVIDED] 225/50 R18 GOODYEAR ASSURANCE MAXGUARD SUV Tyre for BMW X1, Corolla Cross | Shopee Malaysia." Accessed: Jan. 02, 2026. [Online]. Available: https://shopee.com.my/-INSTALLATION-PROVIDED-225-50-R18-GOODYEAR-ASSURANCE-MAXGUARD-SUV-Tyre-for-BMW-X1-Corolla-Cross-i.951207016.22156663180
[16] "BUDI MADANI RON95." Accessed: Jan. 03, 2026. [Online]. Available: https://www.budi95.gov.my/landing
[17] "Gentari EV chargers get a price hike for 2025." Accessed: Jan. 03, 2026. [Online]. Available: https://soyacincau.com/2025/03/17/gentari-ev-chargers-dc-ac-2025-price-revision-overstay-charges/
[18] "No-Claim Discount (NCD): A Comprehensive Guide | Kurnia Insurance." Accessed: Jan. 03, 2026. [Online]. Available: https://www.kurnia.com/blog/no-claim-discount-ncd-rate