

Development of Mini Electric Vehicle (EV)

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Abstract

Malaysia's advancement toward developed nation status is hindered by the continued use of internal combustion engine (ICE) vehicles, which remain a primary source of greenhouse gas emissions and environmental degradation. This study proposes the development of a Mini Electric Vehicle (EV) as a sustainable alternative for short-distance transportation. The vehicle is designed using Autodesk Inventor and features a compact buggy-style chassis constructed from hollow mild steel, assembled through metal inert gas (MIG) welding. It is powered by a 1000W brushless direct current (BLDC) motor and a 48V lead-acid rechargeable battery. Performance evaluations demonstrate that the Mini EV can reach a maximum speed of 30 km/h and travel up to 37 km on a single charge while accommodating two passengers. The findings suggest that such EV designs offer practical and eco-friendly mobility solutions, particularly in residential, agricultural, and tourism contexts. This work contributes to the broader effort of promoting low-emission transport and aligns with sustainable development objectives in Malaysia.

Key Words: *Electric Vehicle, Battery, Charging, Emission, Brushless Direct Current Motor*

1.0 Introduction

The transportation sector remains one of the largest contributors to greenhouse gas emissions globally, with internal combustion engine (ICE) vehicles playing a major role in environmental degradation. In Malaysia, the high dependency on ICE vehicles not only contributes to air and noise pollution but also increases reliance on fossil fuels, leading to economic and environmental challenges (Sovacool, Axsen, & Kempton, 2018; Veza et al., 2022). With rising concerns over climate change, fuel costs, and urban congestion, there is a growing need for cleaner, more sustainable transport solutions.

Despite these initiatives, challenges remain in the widespread implementation of EVs in Malaysia. High vehicle prices, limited charging infrastructure, and battery performance limitations particularly for rural and lower-income users have slowed EV adoption (Lim, Mustapa, & Amir, 2020). As such, there is a need for alternative solutions that are affordable, simple to maintain, and tailored to local needs. One promising avenue is the development of Mini Electric Vehicles (Mini EVs) low-speed, short-range electric vehicles designed for light commuting, tourism, campus transportation, and agricultural use.

This study addresses that need by focusing on the development of a Mini Electric Vehicle (EV) tailored for short-distance, low-speed travel. The project aligns with national efforts such as the National Automotive Policy (NAP 2020) and Malaysia's Sustainable Development Goals (SDGs), which emphasize the transition toward low-emission, energy-efficient mobility systems (Economic Planning Unit, 2021; MITI, 2020).

The significance of this study lies in its practical contribution to sustainable mobility, offering an affordable and energy-efficient EV prototype that is well-suited for local contexts such as urban areas, tourism zones, campuses, and agricultural environments. By utilizing accessible materials and simple electric drive technologies, the project provides a realistic and scalable solution for reducing carbon emissions and fuel dependency in Malaysia's transportation sector (Casals et al., 2016; Lai, Lim, & Yusoff, 2019).

Overall, this project aims to demonstrate the feasibility of compact EVs as a sustainable alternative to conventional vehicles and to support Malaysia's shift towards greener, smarter, and more inclusive mobility solutions.

2.0 Literature Review

The adoption of electric vehicles (EVs) has gained momentum globally as nations work toward reducing dependence on fossil fuels and minimizing greenhouse gas emissions. According to Sovacool et al. (2018), EVs present a cleaner alternative to internal combustion engine (ICE) vehicles by offering reduced operational emissions and improved energy efficiency. In line with global trends, Malaysia has introduced various incentives to encourage green vehicle technologies, yet the transition remains gradual due to infrastructural, economic, and behavioral challenges (Lim et al., 2020).

The core components of an EV system such as the battery, motor, and control systems have been widely explored in engineering literature. Brushless Direct Current (BLDC) motors are frequently preferred in lightweight EV applications due to their high efficiency, compact size, and low maintenance (Rajashekara, 2013). Likewise, lead-acid batteries, although less energy-dense than lithium-ion alternatives, remain cost-effective for small-scale and low-speed EVs (Lai et al., 2019), making them a practical choice for localized transportation models.

Material selection also plays a critical role in EV design. The use of mild steel for the chassis, particularly in a hollow section form, offers a balance between strength, manufacturability, and cost. MIG welding has been commonly used for such applications due to its simplicity, strength, and suitability for joining mild steel components (Kalpakjian & Schmid, 2014).

Electric vehicle (EV) technology has been well-established in the global market, as evidenced by the growing presence of commercially available EVs. Despite the rapid increase in EV production and adoption worldwide, large-scale manufacturing of batteries and electric motors remains a significant challenge. The current capacity of EV battery manufacturers is still insufficient to meet the rising demand for electric vehicles. As a result, the battery continues to be the most expensive component of an EV, accounting for approximately 40% of the total production cost (König et al., 2021). In addition to cost concerns, issues related to battery safety and disposal at the end of their service life present further challenges for the widespread implementation of EVs.

The development of Malaysia's automotive industry is guided by multiple government agencies under various ministries, with the Malaysia Automotive, Robotics and IoT Institute (MARii) serving as a central coordinating body. Operating under the Ministry of International Trade and Industry (MITI), MARii functions as a policy think tank and facilitator to support the advancement of the national automotive sector and mobility ecosystem. In alignment with these efforts, MITI introduced the National Automotive Policy 2020 (NAP 2020), which outlines strategic directions for enhancing the competitiveness and sustainability of Malaysia's automotive industry. NAP 2020 prioritizes the development of Next Generation Vehicles (NxGVs), with a particular focus on charging infrastructure, energy management, and vehicle safety. The policy further emphasizes the adoption of Mobility as a Service (MaaS), the integration of Industry 4.0 technologies, and the advancement of Automated, Autonomous, and Connected Vehicles (AACVs). Additionally, NAP 2020 promotes research and development in lightweight material technologies and alternative energy vehicles, including hybrid, electric, and fuel cell-powered platforms.

The strategic directions outlined in the National Automotive Policy 2020 (NAP 2020) closely align with Malaysia's national commitment to achieving the United Nations Sustainable Development Goals (SDGs). Malaysia has actively adopted the SDGs as part of its national development agenda, with specific emphasis on promoting sustainable industries, clean energy, climate action, and sustainable urban mobility (Economic Planning Unit, 2021). The advancement of Next Generation Vehicles (NxGVs), electric mobility, and alternative energy

vehicles under NAP 2020 directly contributes to SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation, and Infrastructure), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action). These initiatives support Malaysia's broader efforts to reduce greenhouse gas emissions, promote low-carbon transportation, and foster sustainable economic growth in line with the SDG framework.

As one of the fastest-growing economies in Southeast Asia, Malaysia recorded a population of 32.7 million in the first quarter of 2021, with projections estimating an increase to 41.5 million by 2040. Data from the ASEAN Statistics Division (2020) indicate that Malaysia had 29.96 million registered motor vehicles in 2019. This translates to a vehicle ownership rate of 925 vehicles per 1,000 inhabitants, suggesting that approximately nine out of every ten Malaysians own a motor vehicle. In the absence of ownership restrictions, the country's roads are predominantly occupied by passenger vehicles (46.0%) and motorcycles (48.4%), as reported by Kondo (2018) and illustrated in Figure 1.

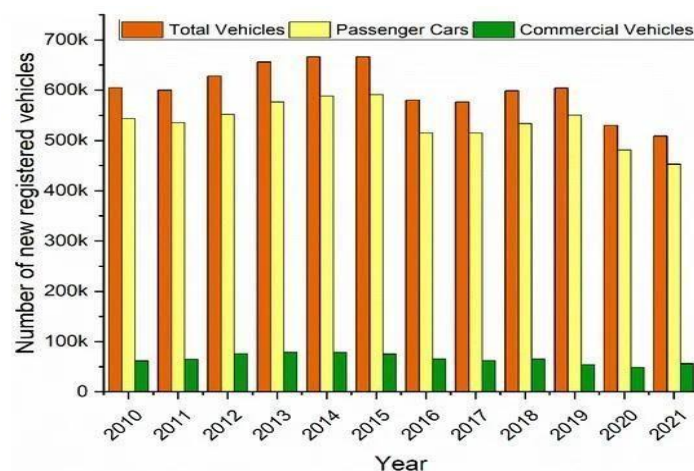


Figure 1: Registration of new passenger and commercial vehicles in Malaysia (MAA, 2021)

Table 1 presents the total registration of new vehicles in Malaysia for the years 2023 and 2024. In 2024, new vehicle registrations increased to 816,747 units, surpassing the previous record total industry volume (TIV) of 799,821 units recorded in 2023. Electrified vehicles (xEV), comprising battery electric vehicles (BEVs) and hybrid vehicles, accounted for 5.6% of the TIV in 2024, reflecting an increase from 4.8% in 2023. xEV sales experienced a notable growth of 19%, rising from 38,214 units in 2023 to 45,562 units in 2024. This figure includes 14,766 units of BEVs and 30,796 hybrid vehicles. According to the Malaysian Automotive Association (MAA, 2025), the demand for xEVs is expected to continue growing, driven in part by the final year of full exemptions on import and excise duties for imported electric vehicles.

Table 1: Total new registered vehicle in 2023 and 2024 (MAA, 2025)

Market Segment	2024	2023	Variance (Units)	Variance (%)
Passenger Vehicles	747,180	719,145	+28,035	+3.9%
Commercial Vehicles	69,567	80,676	-11,109	-13.8%
Total Vehicles	816,747	799,821	+16,926	+2.1%

Mini electric vehicles (mini EVs) are becoming more relevant in Malaysia due to urbanization, sustainable transport goals, and government incentives. They are ideal for low-speed, short-range use such as city commuting, agriculture, and eco-tourism, where high power and long range are not essential. Figure 2 shows the Mini EV Wuling Nano, produced in China.

This compact electric vehicle is used as a reference model in this project due to its simple design, small size, and suitability for urban transportation. Its efficient layout and use of electric components align with the project's goal of developing a cost-effective and environmentally friendly mobility solution.



Figure 2 : Mini EV Wuling Nano

In summary, the integration of green technology into small electric vehicles offers a promising route toward sustainable mobility, especially in developing regions. This project builds upon existing literature by applying these principles in a localized Malaysian context, using accessible materials and technology to develop a practical and sustainable transport solution

2.1 Problem Statement

At the global level, the rising number of internal combustion engine (ICE) vehicles has led to significant environmental concerns, particularly in terms of air pollution caused by vehicle emissions. Additionally, the escalating prices of petrol and diesel fuel impose a financial burden on consumers, contributing to a higher cost of living. ICE vehicles are also inefficient and less practical for short-distance travel, especially in urban and residential areas.

In this context, mini electric vehicles (mini EVs) are gaining attention in Malaysia as a viable alternative, particularly due to increasing urbanization and the demand for sustainable, cost-effective transportation solutions. Mini EVs are well-suited for short-distance travel, offering low operating costs and zero tailpipe emissions.

To address these challenges proactively, it is essential to conduct early-stage research and development focused on the creation of environmentally friendly and affordable electric vehicles. Such efforts will support the transition to sustainable mobility while reducing dependency on fossil fuels and lowering transportation costs for consumers.

2.2 Objective

1. To design a mini electric car suitable for urban mobility.
2. To develop a functional prototype of the mini car powered by an electric drive system.
3. To analyze the performance of the electric car and evaluate the endurance of its battery system.

2.3 Scope

The scope of these projects is:

1. This vehicle has two seats that can accommodate a load of up to 200kg.
2. The vehicle is powered by a 48V lead-acid battery system, comprising four 12V rechargeable batteries connected in series.
3. The chassis uses mild steel rectangular hollow sections to support the load.

4. A 1000W BLDC motor powers the car, capable of carrying passengers and full load.
5. The car is equipped with reverse gear.
6. The car measures 6 feet in length and 4 feet in width.

3.0 Methodology

Several steps must be carefully followed to ensure the successful and high-quality completion of a project. For this project, the process was carried out according to the flow chart illustrated in Figure 3.

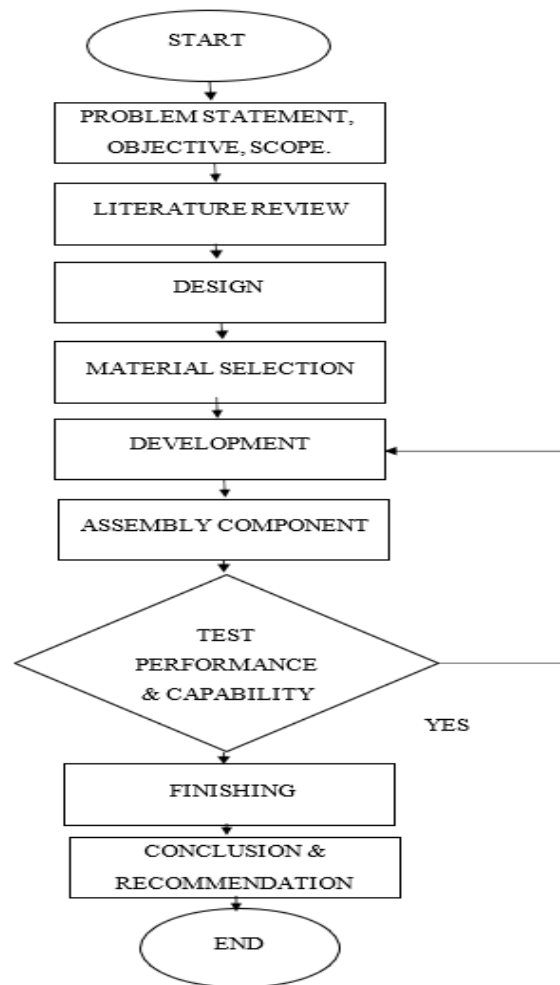


Figure 3: Flow chart Mini EV Car Project

3.1 Morphology Chart

The morphology chart in Table 2 is used to generate conceptual designs for the Mini EV car. The best combination of three selected ideas will be applied to develop three design concepts.

Table 2: Morphology Chart of Mini EV

BIL	NAME	IDEA 1	IDEA 2	IDEA 3
1	BATTERY	 Li-Ion Battery	 Lead-Acid Battery	 Wet Battery
2	AXLE	 CV joint Axle	 Chain and Sprocket	 Rear Differential Axle
3	WHEEL	 ATV Wheel	 Motorcycle Wheel	 Car Wheel
4	MOTOR	 AC Motor	 Brushed DC	 Brushless DC
5	METAL	 ALUMINIUM	 MILD STEEL	 TAINLESS STEEL
6	FRONT SUSPENSION	 Leaf Spring	 MACPHERSON STRUT	 DOUBLE WISHBONE
7	REAR SUSPENSION	 Leaf Spring	 Torsion Beam	 Multi-Link
8	SEAT	 Bucket Seat	 Fabric Seat	 Leather Seat

3.2 Design Selection

The design selection process involves evaluating various design alternatives to determine the most suitable option for construction. This process is guided by technical drawings and considers research findings and key design requirements identified through decomposition analysis.

a. First Conceptual Design

The first conceptual design, referred to as Design A and illustrated in Figure 4, features shock absorbers for both the front and rear suspension systems. It utilizes a constant velocity (CV) joint drive shaft connected to a sprocket, replacing the conventional axle to transmit motion. Power from the DC motor is delivered through a chain and sprocket mechanism, following a similar drivetrain concept commonly found in bicycles and motorcycles.

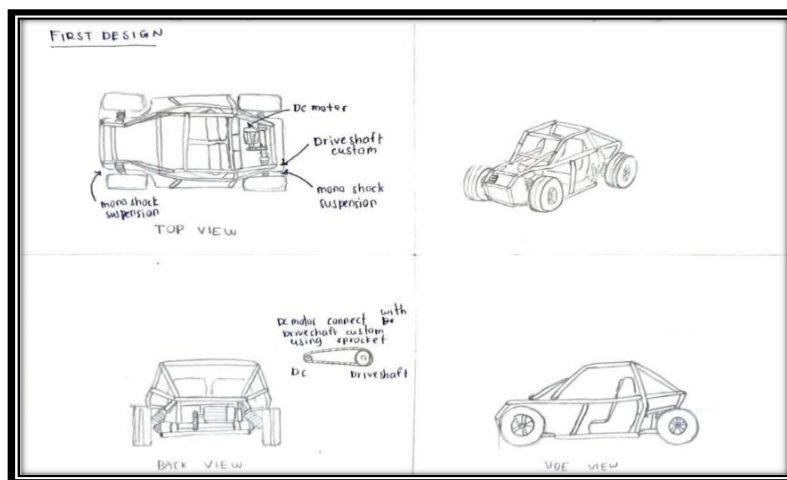


Figure 4: Design A

b. Second Conceptual Design

Design B, as shown in Figure 5, features leaf spring suspension for both the front and rear, combined with a solid front axle and a differential rear axle driven by a brushless DC motor. This setup allows the vehicle to operate similarly to a conventional rear-wheel drive (RWD) system.

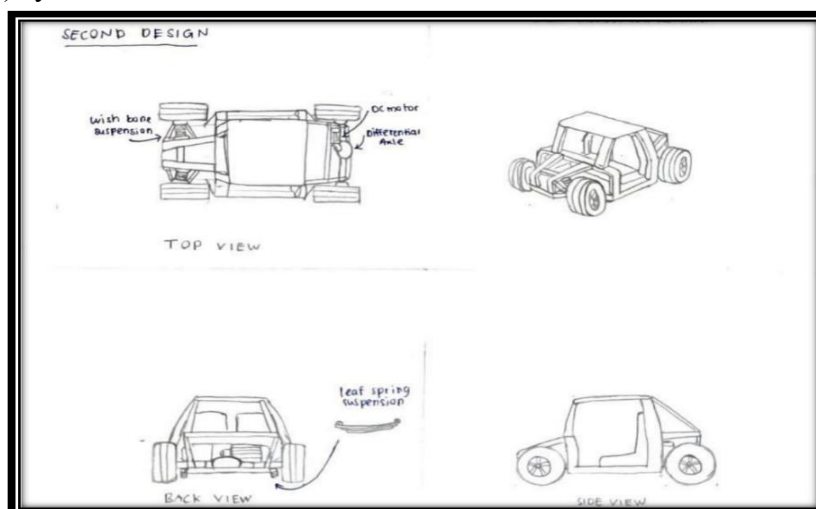


Figure 5: Design B

c. Third Conceptual Design

Design C, shown in Figure 6, employs a sprocket system instead of a conventional axle to transmit motion. Power from the DC motor is transferred through a chain and sprocket setup, similar to bicycle or motorcycle drivetrains. The suspension system is the same as in Design A, featuring front and rear shock absorbers.

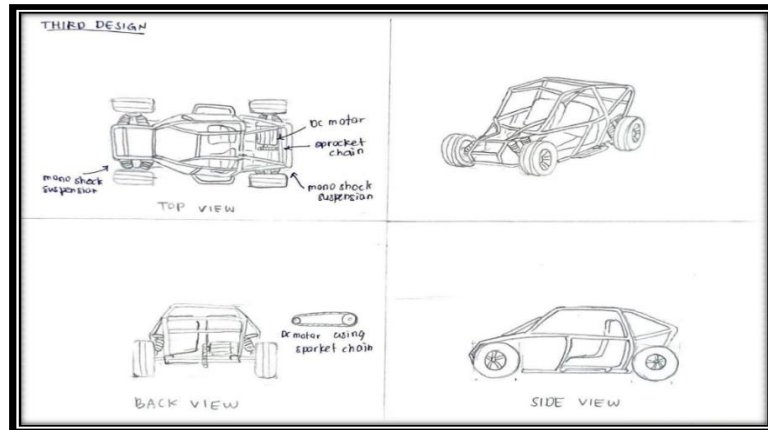


Figure 6: Design C

3.3 Concept Screening

Table 3 presents the concept screening evaluation for Design A, Design B, and Design C based on specific criteria, using the symbols “+” (better than reference), “0” (same as reference), and “-” (worse than reference) for comparison. Based on the results, Design B achieved the highest score and was therefore selected as the final design for the development of the Mini EV Car.

Table 3: Concept Screening

Selection Criteria	Concept			
	Design A	Design B	Design C	REF
Easy to manufacture	-	-	-	0
Cost	-	-	-	0
Practicality	-	+	-	0
Easy to Move	+	+	+	0
Tool Storage	-	+	-	0
Comfort	+	+	+	0
Safety	-	+	-	0
Maintenance	+	+	-	0
Plus	3	6	2	0
Same	4	4	4	0
Minus	5	3	6	0
Net Score	-2	3	-4	0
Rank	2	1	3	0
Continue?	Yes	Yes	No	

3.4 Final Design

The final design of the Mini EV was developed using Autodesk Inventor software, based on the selected conceptual design. Figure 7 illustrates the final structural frame of the Mini EV.

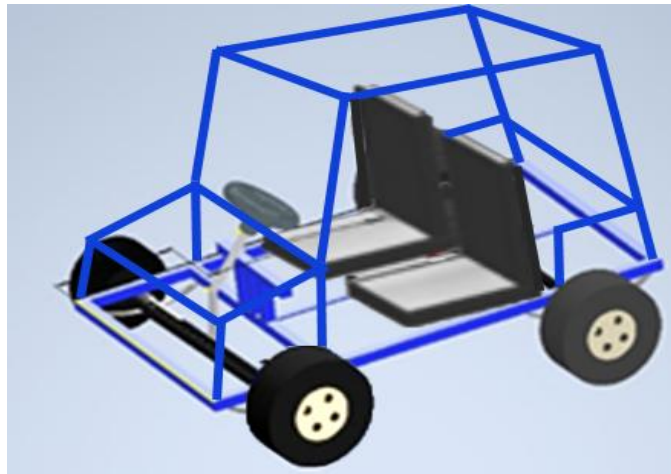


Figure 7: Final design of Mini EV

3.5 Material and Component Selection

The material and component selection for the Mini EV was previously determined using a morphology chart. The main material and component selected are as follows:

1. Lead-acid battery
2. Differential axles (front and rear)
3. Brushless DC motor
4. Car wheels
5. Mild steel frame
6. Leaf springs (front and rear suspension)
7. Car seats
8. Rack and pinion steering rack

3.6 Fabrication Process

The fabrication process for the Mini EV car was carried out in the following sequence to ensure structural accuracy and functionality:

1. The height between the axle and chassis was measured prior to welding.
2. Square hollow steel sections were cut according to the specified dimensions.
3. The chassis frame was assembled using corner joint welding techniques.
4. Leaf springs and axles were mounted onto the chassis.
5. The steering rack was installed and connected to the front wheels.
6. Battery size was measured and the rear mounting area prepared.
7. Metal sheet panels were fitted to complete the chassis structure.
8. Seats were installed onto the chassis frame.
9. Wiring for the controller, battery, and electronics was installed.
10. The chassis was painted for protection and finishing.
11. Final testing was conducted to assess load capacity, speed performance, and battery durability.



Figure 8: Mini EV successfully built.

4.0 Result And Discussion

4.1 Speed Performance

Table 4 presents the speed performance results of the Mini Electric Vehicle (EV), tested under standard driving conditions on a flat road. The Mini EV achieved a maximum speed of 30 km/h with an average speed of 12 km/h. These results indicate that the Mini EV is suitable for short-distance travel, particularly for recreational use.

Table 4: Speed performance of Mini EV Car

Maximum speed	Average speed
30 km/h	12 km/h

4.2 Analysis of Endurance Battery And Distance

The mini electric vehicle (EV) prototype utilizes a battery system comprising four 12V lead-acid batteries connected in series, resulting in a total supply voltage of 48V. This configuration is commonly adopted due to its cost-effectiveness and availability in low-powered EV applications. Performance testing was conducted to evaluate the vehicle's range at varying battery charge levels. The results are summarized in Table 5.

Table 5: Battery Usage Versus Distance Traveled

Battery Percentage (%)	Distance Traveled (km)
20	5
70	20
100	37

As shown in Table 5, a fully charged battery enables the EV to travel a distance of 37 km. However, the relationship between battery percentage and distance is non-linear. At 70% charge, the EV only manages 20 km, which is approximately 77% of the expected linear range (25.9 km). Similarly, at 20% charge, the vehicle achieves 5 km, which is about 68% of the expected linear distance (7.4 km). This decline in range suggests increased internal resistance and reduced efficiency of lead-acid batteries as they discharge (Linden & Reddy, 2002).

Beyond battery capacity, load plays a critical role in determining battery performance. The vehicle was tested with a total load of 160 kg, simulating two adult passengers. Heavier loads demand greater torque and power, thereby increasing energy consumption and reducing operational range. The EV is equipped with a brushless direct current (BLDC) motor, which offers dual functionality: it operates efficiently as a drive motor and also provides regenerative braking capabilities. This regenerative feature allows the motor to act as a generator under certain conditions, converting kinetic energy back into electrical energy during deceleration.

The maximum speed achieved by the vehicle is 30 km/h, which aligns with the intended design for low-speed urban and recreational use. In the event of a depleted battery, the system is designed for rapid charging, with a full recharge completed in approximately one hour. This feature enhances usability for short-distance urban commuting where quick turnaround is beneficial.

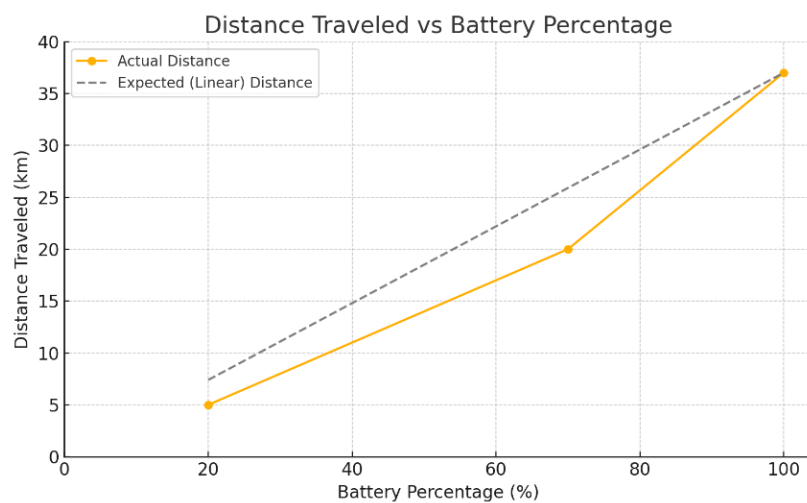


Figure 9: Distance Vs Battery of Mini EV-Car

The line graph in Figure 9 above illustrates the relationship between the battery charge level and the distance traveled by the mini electric vehicle (EV). The solid blue line represents the actual distance achieved during testing, while the dashed grey line indicates the expected distance based on a linear projection from 100% battery capacity.

The data clearly shows a non-linear decline in distance as battery percentage decreases. Table 6 presents the expected distance of mini EV car based on battery percentage.

Table 6: Expected Vs Actual Distance Based on Battery Percentage for Mini EV

Battery Percentage (%)	Expected Distance (km)	Actual Distance (km)
70	25.9	20
20	7.4	5

This suggests that battery efficiency significantly deteriorates at lower charge levels an inherent limitation of lead-acid batteries due to increasing internal resistance and voltage drop during discharge.

The analysis indicates that while the mini EV demonstrates functional range under ideal conditions, the use of lead-acid batteries presents notable inefficiencies at lower charge levels. The impact of passenger load on battery endurance is evident, and although the BLDC motor provides some energy recovery through regeneration, it is insufficient to compensate for the rapid energy depletion under load. Future developments should

consider transitioning to lithium-ion batteries, which offer improved energy density, lighter weight, and greater efficiency. Moreover, integrating a battery management system (BMS) can optimize charge-discharge cycles, ensuring longer battery life and consistent performance.

5.0 Conclusion

The Mini Electric Vehicle (EV) was successfully designed, developed, and fabricated in alignment with the project's objectives. The final prototype features a mild steel chassis, a 1000W brushless DC (BLDC) motor, and a 48V lead-acid battery system—resulting in a fully functional vehicle optimized for short-distance travel. Performance testing confirmed that the Mini EV is capable of reaching a maximum speed of 30 km/h and a range of up to 37 km on a single charge, making it well-suited for low-speed applications such as recreational use, campus transportation, and local commuting.

This project successfully achieved its three main objectives: firstly, the design of a compact and structurally sound Mini EV to address urban mobility needs; secondly, the development and fabrication of a working prototype using accessible and cost-effective materials; and thirdly, the performance analysis, which validated the vehicle's speed and endurance in real-world conditions.

Although the prototype meets its intended functional requirements, there is significant potential for improvement. Future development should focus on increasing battery efficiency by transitioning to lithium-ion batteries, integrating a battery management system (BMS), and enhancing comfort, safety, and user interface features. These improvements will make the Mini EV more energy-efficient, durable, and appealing for broader adoption.

This project contributes meaningfully to the advancement of sustainable mobility solutions in Malaysia. It aligns with the Sustainable Development Goals (SDGs) and supports national strategies under the National Automotive Policy (NAP 2020) by offering a practical, eco-friendly alternative to conventional internal combustion vehicles. By reducing fuel consumption and lowering greenhouse gas emissions, such vehicles promote environmental conservation and offer long-term cost savings to users.

In conclusion, the development of the Mini EV demonstrates the technical feasibility and commercial potential of small electric vehicles in supporting Malaysia's transition to cleaner, smarter, and more sustainable transportation systems.

References

- Casals, L.C.; Martinez-Laserna, E.; García, B.A.; Nieto, N. (2016). Sustainability analysis of the electric vehicle use in Europe for CO₂ emissions reduction. *J. Clean. Prod.*, 127, 425–437.
- Economic Planning Unit. (2021). *Malaysia Sustainable Development Goals Voluntary National Review 2021*. Prime Minister's Department, Malaysia. <https://www.epu.gov.my/en/sdg>
- Kalpakkian, S., & Schmid, S. R. (2014). *Manufacturing engineering and technology* (7th ed.). Pearson Education.
- Kondo, H.(2018). *Sustainable Development of the Transport Sector: Malaysia*; Economic Research Institute for ASEAN and East Asia: Jakarta, Indonesia.
- König, A.; Nicoletti, L.; Schröder, D.; Wolff, S.; Waclaw, A.; Lienkamp, M. (2021). An overview of parameter and cost for battery electricvehicles. *World Electr. Veh. J.* 2021,12, 21.

- Lai, C. M., Lim, Y. H., & Yusoff, M. (2019). Cost-performance evaluation of battery types in low-speed electric vehicles. *International Journal of Energy Research*, 43(3), 1125–1134.
- Lim, C. H., Mustapa, S. I., & Amir, R. (2020). Barriers to electric vehicle adoption in Malaysia: A comprehensive review. *Energy Policy*, 142, 111516.
- Linden, D., & Reddy, T. B. (2002). *Handbook of batteries* (3rd ed.). McGraw-Hill.
- Malaysian Automotive Association. Ministry of International Trade and Industry. National Automotive Policy 2020. (2020). Available online: https://www.miti.gov.my/miti/resources/NAP2020/NAP2020_Booklet.pdf (accessed on 8 September 2021).
- Malaysian Automotive Association. Sales & Production Statistics. Available online: <http://www.maa.org.my/statistics.html> (accessed on 8 September 2021).
- Pavlovic, A., Marinkovic, D., & Sumarac-Pavlovic, D. (2015). Ergonomics in design of small electric vehicles. *International Journal of Industrial Ergonomics*, 50, 1–7.
- Rajashekara, K. (2013). Present status and future trends in electric vehicle propulsion technologies. *IEEE Journal of Emerging and Selected Topics in Power Electronics*, 1(1), 3–10.
- Sovacool, B. K., Axsen, J., & Kempton, W. (2018). The future promise of EVs: A critical review. *Energy Policy*, 119, 1–7.
- Veza, I., Abas, M. A., Djamari, D. W., Tamaldin, N., Endrasari, F., Budiman, B. A., Idris, M., Opia, A. C., Juangsa, F. B., & Aziz, M. (2022). Electric Vehicles in Malaysia and Indonesia: Opportunities and Challenges. *Energies*, 15(7). <https://doi.org/10.3390/en15072564>