Exploring the Socio-Economic Impact of Electric Vehicle Innovation

Mohd Hakim Bin Abdul Hamid[1*], Fauzan Sholeh[2], Isma Addi Jumbri[3], Rita Indah Mustikowati[4], Supami Wahyu Setiyowati[5], Ati Retna Sari[6]

[1,2,3]Fakulti Pengurusan Teknologi dan Teknousahawan (FPTT), UNIVERSITI TEKNIKAL MALAYSIA MELAKA

[4,5,6]Faculty Economics and Business, Universitas PGRI Kanjuruhan Malang, Malang, Indonesia

***Corresponding Author**

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ABSTRACT

This study examines the factors influencing electric vehicle (EV) innovation in Malacca, with a focus on the relationships between social impact, economic impact, and government policy. Using a quantitative research approach, data were collected through surveys and analyzed using multiple regression techniques. The findings reveal that social impact, driven by public awareness and inclusivity, has the most substantial positive influence on EV innovation. Economic impact, while significant, presents challenges due to high upfront costs and limited infrastructure. Government policy, including tax incentives, subsidies, and investments in infrastructure, also plays a crucial role in fostering EV adoption and technological advancements. The study emphasizes the importance of an integrated approach that involves policymakers, industry stakeholders, and society to address barriers and promote sustainable transportation solutions. This research contributes valuable insights into EV innovation, providing a foundation for future studies and practical recommendations for accelerating EV adoption in Malaysia.

Keywords: Socio-economic, Electric vehicle innovation

INTRODUCTION

There are several reasons why electric vehicles (EVs) are gaining popularity, including their lower cost and increased awareness of environmental issues and climate change. The automotive sector has become one of the most significant global industries in terms of research and development (R&D) spending and economic impact. To enhance the safety of both passengers and pedestrians, more advanced technology components are being integrated into cars. Furthermore, there are more cars on the road, which enables us to travel quickly and comfortably. However, as a result, air pollution levels in metropolitan areas, including pollutants such as particulate matter (PM), nitrogen oxides (NOX), carbon dioxide (CO2), and sulphur dioxide (SO2), have dramatically increased. (Sanguesa et al., 2021).

Because they require fewer moving parts, electric vehicles are less expensive to operate and have a lower environmental impact, as they consume little to no fossil fuels (such as diesel or petrol). Although some electric cars (EVs) employ lead-acid or nickel-metal-hydride batteries, lithium-ion batteries are now considered the industry standard for battery electric vehicles due to their longer lifespan, excellent energy retention, and a self-discharge rate of only 5% per month. Although attempts have been made to improve the safety of these batteries, problems persist, despite their increased efficiency. One such issue is that they are susceptible to thermal runaway, which has resulted in explosions or fires in Tesla Model S vehicles, among other incidents (TWI, 2023).

To reduce the concentration of air pollutants, such as CO2 and other greenhouse gases, the governments of most developed nations are promoting the use of electric vehicles, or EVs. More precisely, they encourage efficient and sustainable mobility through a variety of programs, primarily through tax breaks, buying subsidies, or other

unique policies, such as free parking in public spaces or unrestricted access to highways. Compared to conventional cars, EVs have the following benefits: Zero emissions: These cars don't release any nitrogen dioxide (NO2) or carbon dioxide (CO2) from their exhaust. Although the production of batteries hurts carbon footprint, the manufacturing techniques also tend to be more environmentally friendly.

Next, because of the simplicity. Electric vehicles (EVs) have fewer engine components, resulting in significantly lower maintenance costs. The engines are smaller and more straightforward; they also don't require a cooling circuit, a gearbox, or any other components to lessen engine noise. Reliability: These cars are less likely to break down since they contain fewer, simpler parts. Furthermore, the natural wear and tear brought on by vibrations, gasoline corrosion, and engine explosions does not affect electric vehicles. Cost: Compared to typical combustion vehicles, the cost of electricity and vehicle maintenance is significantly lower for this type of vehicle. EVs have a far lower energy cost per kilometre than conventional cars. Comfort: Since there are no engine noises or vibrations when driving an EV, it is a more comfortable experience. Efficiency: Compared to traditional vehicles, EVs are more efficient. The power plant efficiency will also impact the overall well-to-wheel (WTW) efficiency. The range of gasoline-powered cars' total WTW efficiency is 11% to 27%. In comparison, EVs powered by renewable energy sources have an overall efficiency of up to 70%, whereas EVs fed by natural gas power plants have a WTW efficiency that ranges from 13% to 31% (Sanguesa et al., 2021).

By comprehensively examining the socio-economic impact of EV innovation, this research aims to provide valuable insights for policymakers, industry leaders, and the public. Ultimately, the goal is to foster informed decision-making that accelerates the adoption of EVs in Malacca while mitigating potential drawbacks.

Although they require significant expenditures on the infrastructure necessary for charging, electric vehicles have significant environmental advantages over conventional vehicles, helping to reduce reliance on fossil fuels. Additionally, their market price is significantly higher than that of ordinary cars. Because the purchasing power of emerging economies is substantially lower than that of industrialized economies, the conditions for market penetration are typically more important in these regions. Moreover, other legislative and technological obstacles impede market growth and penetration (Shatanawi et al., 2020)).

This research categorizes the various risks and challenges associated with EV integration into smart cities into four groups: technical, economic, social, and environmental. This contrasts with most previous research, which has concentrated on individual risk factors or challenges. Through a systematic framework of technological, economic, social, and environmental difficulties, the article offers an organised approach to comprehending the various facets of the integration process. Interoperability and standardization problems, as well as issues with EV infrastructure such as charging stations and battery management systems, are among the technological challenges. The financial difficulties stem from the infrastructure and deployment expenses of EVs, as well as potential impacts on conventional transportation networks and sectors.

Concerns about user acceptability and behavioural change are among the social problems, along with the necessity of addressing concerns about equity and accessibility. The potential effects of EVs on the electrical grid and the need to manage the life cycle emissions associated with EV manufacture and disposal are the primary environmental concerns. The study’s conclusion emphasizes the necessity of addressing the difficulties of EV use from a holistic perspective in order to minimize its socioeconomic impact. Additionally, it suggests future lines of inquiry for addressing these issues and advancing the effective incorporation of better EV usage in the future. All things considered, this report provides valuable insights for scholars and policymakers seeking to develop sustainable urban transport systems. (Apata et al., 2023).

LITERATURE REVIEW

Electric Vehicle

In automotive industry road maps, the electric vehicle (EV) is seen as a critical technology for the future of automotive power systems. The EV has become a main goal for major global automakers and is likely to disrupt the road transportation industry. In Malaysia, electric vehicles have just recently emerged as a significant influence. However, Malaysia's lack of EV infrastructure, along with its heavy reliance on fossil fuels, presents

a considerable hurdle (Veza et al., 2022). To maintain a friendly and long-term global climate, the worldwide power industry is steadily transitioning from traditional nonrenewable to sustainable energy sources. Over the last two centuries, the rising usage of fossil fuels has already taken its toll (Muzir et al., 2022). Replacing traditional internal combustion engines (ICE) with electric battery-powered vehicles (EVs) is driving more and more countries throughout the world to reduce greenhouse gas (GHG) emissions from the transportation industry (Maennel & Kim, 2018). Officials in Malaysia have set a target of 500,000 electric vehicles by the year 2015 and five million by 2020 (Adnan et al., 2017).

Social Impact

The issue of carbon emissions has gained global significance in the contemporary global economy. The transportation industry has grown significantly, which is mostly to blame for this. Millions of gasoline-powered cars drive on the highway day and night, emitting carbon emissions. Using green technology automobiles instead of gasoline-powered ones is one way to thwart these vulnerabilities and advance a more sustainable economy.

Economy Impact

Here in the HICOM Pegoh Industrial Park, a production factory for electric and energy-efficient vehicles (EEVs) and EVs with a combined investment value of over RM100 million is planned. According to Melaka Chief Minister Datuk Seri Ab Rauf Yusoh, the EP Manufacturing Bhd (EPMB) factory is anticipated to produce up to 30,000 EEVs and EVs annually during the first phase following the plant's completion at the end of the following year. He stated that Melaka residents, particularly those residing in the Pegoh area, will have access to approximately 1,000 new job opportunities in the automotive sector, thereby contributing to the state's economic growth and future efforts to reduce carbon dioxide emissions. (The Sun, 2023).

Government Policy

Due to these CO2 emissions, the Malaysian government also faced significant issues. since Malaysia is regarded as a prominent country with high energy efficiency. The primary approach is to transition from petroleum-based vehicles to green vehicle innovation in order to mitigate these vulnerabilities and support a more sustainable economy (Adnan et al., 2017). The transition to a circular economy can be facilitated by government measures, including carbon taxes, incentives for zero-carbon sectors, and mitigation and adaptation plans (Chen et al., 2022). Regarding Malaysia, the government committed to reducing its carbon emissions by up to 40% by 2020, compared to 2005 levels, at the United Nations Climate Change Conference (UNFCCC) in Copenhagen in 2009.

Hypothesis Development

Relationship between social impact and Electric Vehicle

The increasing environmental consciousness of Malaysians has been a significant factor in the country's adoption of electric automobiles. Through our regular market research in Malaysia, we have observed that people there are becoming increasingly aware of the need to reduce their carbon footprint and emissions, and that owning an electric vehicle (EV) is one effective way to achieve this. Government programs that increase the appeal of electric cars to consumers, such as tax breaks, subsidies, and other incentives, exacerbate this. Our survey indicates that 85.4% of Malaysians believe their activities will have a significant impact on whether the earth is improved or destroyed. (Standard Insight, 2023).

Generally, transitioning to electric vehicles is a smart way to mitigate global warming. In fact, we could reduce global emissions by about one-fifth if all automobiles were electric. But the advantages of growing the electric industry go beyond this: in addition to having cleaner air, we would have quieter cities and be less reliant on oil price spikes caused by conflicts. However, it goes beyond automobiles. The electrification of bikes, scooters, buses, goods trains, tractors, and heavy vehicles is accelerating at a rate never seen before in the history of transport, resulting in a quiet revolution in industry. The industry's innovation, combined with the decline in the cost of clean energy, solar energy is now the least expensive source of electricity we have is resulting in lower production costs for EV batteries and, consequently, lower purchase prices.a (Igini, 2023).

Comparing EVs to conventional fuel-powered cars, they are also far more efficient. Compared to a regular fuel engine, which loses 64% to 75% of its energy, an electric drive system in an electric vehicle only loses 15% to 20% of its energy. These convincing arguments make electric cars an enticing and environmentally friendly option. EVs provide a cleaner alternative and are a significant step towards sustainable mobility. The following six main environmental advantages of electric vehicles are firstly zero tailpipe emissions. The ability of electric cars to emit no pollutants from their tailpipes is well recognised. EVs run without a tailpipe, in contrast to conventional Internal Combustion Engines (ICE), which burn petrol or diesel and release toxic carbon pollutants through exhaust. An electric vehicle's battery is its vital component. The majority of EVs are equipped with lithium-ion batteries, which produce no emissions during charging or discharging. Thanks to this technology, it is possible to repeatedly charge and discharge the battery without causing pollution in the air (Shirami, 2024).

Next is to minimise resource depletion. Compared to regular automobiles, electric vehicles require fewer resources during production, giving them a significant environmental advantage. This resource economy can be attributed to EVs' simpler mechanics than those of petrol or diesel vehicles. Moreover, recycling the batteries in electric vehicles (EVs) reduces waste production and the need for new resources. The environmental effects of intensive mining and the depletion of non-renewable resources can be significantly reduced by promoting a higher adoption rate of electric vehicles (EVs). The third benefit is the reduction of less harmful fluids. Since motor oil and other fossil fuel-based goods are not used in electric vehicles, they provide a substantial environmental benefit over petrol and diesel vehicles. EVs don't require a variety of lubricants and fluids that can be hazardous to the environment, unlike ICE cars. Motor oil, which is often found in petrol or diesel cars but is absent from electric vehicles, includes harmful substances that can poison water supplies and endanger people and wildlife. Because of their focus on utilising fewer hazardous fluids, EVs are a more environmentally responsible option (Shirami, 2024).

Moreover, the benefit is to reduce noise pollution. Because electric motors run much more quietly than combustion engines, electric vehicles can significantly contribute to reducing noise pollution. Beyond merely urban areas, electric vehicles play a significant role in reducing noise pollution. The quality of life is enhanced in various settings, including residential neighborhoods and undeveloped areas, as a result of reduced noise levels. EV adoption is crucial for fostering calmer, more serene environments as cities expand and their populations rise. Also, EV is using eco-friendly material. The use of environmentally friendly components and the operating benefits of electric vehicles are what make them so important. EV manufacturers set the standard by incorporating recycled materials into the structure of their vehicles, even if many manufacturers use them in smaller components. The transition to environmentally friendly materials not only minimises the impact on the environment during manufacturing and use, but it also reduces weight. Preserving the environment requires substituting unsustainable resources, such as metals and plastics, with natural or recycled ones (Shirami, 2024).

Lastly, the benefit is to increase the number of clean EV batteries. The technology of electric vehicles continues to make remarkable strides in reducing the carbon footprint associated with their batteries. The carbon trace of EV batteries has dramatically dropped in the last few years. It is currently two to three times lower than it was earlier. Should you still be wondering, "Why an electric vehicle?" Then there's a strong case to be made for switching to cleaner EV batteries, given the existing trend in this direction. EV makers have tightened standards for their battery suppliers due to growing consciousness and the urgent need for sustainability. These regulations require that during the production process, only renewable energy sources be used (Shirami, 2024).

Hypothesis 1: There is a relationship between social impact and Electric Vehicle Innovation

Relationship between the economic impact and the Electric Vehicle

Electric vehicles (EVs) are well recognised for their benefits to the environment. On the other hand, their economic story is similarly optimistic. Every EV will save thousands of dollars in benefits over its lifetime for utility consumers, in-state power generators, EV charging providers, and the driver (or fleet owner). There are three main benefits of using EVs for the economy. Firstly, fuel-cost reduction. The average light-duty vehicle, such as a car or pickup truck, is predicted by the Union of Concerned Scientists to require $22,674 in petrol over the course of its 14-year lifespan. The comparable amount for EVs is $12,132, or a 54 percent savings, based on national average electricity rates (The Untold Story of the Economic Benefits of Electric Vehicles, n.d.). In

Malaysia, because many T20 households already own luxury EVs that are now on the market and because they generally reside in landed homes where EVs can be charged at home, they are well-positioned to make the switch to EVs. Since Tenaga Nasional Berhad (TNB) estimates that the fuel cost of using EVs is 11.4% – 51% lower than using internal combustion (ICE) engine cars, the removal of the fuel subsidies will force them to consider utilizing EVs (Trade, 2023).

Approximately 710,000 people are employed in Malaysia's automotive industry, which also accounts for 4% of the nation's GDP, underscoring the industry's significance to the country's manufacturing sector. The electric vehicle (EV) industry is poised for growth, despite still being in its infancy. Numerous businesses that increase the production of EVs by supplying the necessary inputs, like semiconductors and copper wire fabrication, already have operations in Malaysia (Standard Insight, 2023).

According to Statista, the electric car market in Malaysia is expected to experience growth, with revenue estimated to reach US$115.30 million in 2023 and a compound annual growth rate (CAGR) of 24.15% by 2027, resulting in a projected market volume of US$273.90 million. By 2027, sales of electric vehicles are predicted to rise from 1,472 in 2019 to 5,674.7 units. From an international standpoint, China's electric car market is expected to account for the majority of revenue, with estimates for 2023 totaling over US$ 190 billion. With such a large projected market and room for expansion, Malaysia's automotive electric vehicle industry seems promising both domestically and internationally (Standard Insight, 2023).

Hypothesis 2: There is a relationship between economic impact and Electric Vehicle innovation

Relationship between Government Policy and Electric Vehicle

Through financial aid and other incentives, such as tax cuts and subsidies, the Malaysian government has been aggressively promoting electric vehicles on the country's roads. By doing this, the nation aims to reduce its reliance on petroleum and oil, which together supply around two-thirds of its energy needs. Due to cheaper renewable energy sources, increased efficiency, improved technology, and declining battery costs, the cost of electric vehicles is also becoming more competitive in Malaysia. As a result, in certain regions of Malaysia, the cost of electric vehicles is currently less than that of conventional cars. Additionally, users might save money over time on gasoline and maintenance expenditures due to the lower operating costs of electric vehicles (Standard Insight, 2023).

Deputy Finance Minister Ahmad Maslan hinted that the government would introduce targeted fuel subsidies to curb the government's skyrocketing spending during Malaysia's Budget 2023 parliamentary debate. According to reports, the fuel subsidy cost alone in 2022 totaled RM28 billion, accounting for 7% of the government's total spending. First, there must be a significant increase in EV charging stations by the government. Currently, chargEV and Carput Zap are two EV charge station operators (CPO) that offer fast or slow charging options. The government acknowledges that there are still not enough charging stations to support widespread EV adoption. The government will designate Gentari, a renewable energy solutions division of the national oil corporation Petronas, to install up to 500 public EV chargers as part of Budget 2023. Gentari was founded to assist Petronas in advancing hydrogen, renewable energy, and environmentally friendly transportation options. Installing EV charging stations in 70 designated areas is another duty assigned to TNB, a government-affiliated energy firm. When Tesla joins the Malaysian market, a supercharger network is anticipated to be established (Trade, 2023).

Malaysia's market for electric vehicles (EVs) is still modest but expanding quickly. The number of electric vehicles sold in 2021 was 2,717, as reported by the Malaysian Automotive Association (MAA), a notable rise from the 1,642 units sold in 2020. With just 0.4% of all vehicle sales in Malaysia, the EV market share is currently quite small. Nonetheless, the industry is anticipated to expand in the upcoming years due to the government's objective of having 125,000 EVs on the road by 2030. The Battery Electric Vehicle Global Leaders Initiative (BEV GLI) was launched by Malaysia's Ministry of Investment, Trade, and Industry (MITI) to encourage the expansion of the EV industry in the nation. The BEV program lowers the cost of imported vehicles by enabling international companies to sell automobiles in Malaysia without adhering to the Approved Permit (AP) regulations. The goal of this project is to foster the growth of an ecosystem that supports the adoption of

BEVs and increases demand for EVs in the local market. By 2025, the government plans to install 10,000 charging stations as part of the Low Carbon Mobility Blueprint. Businesses that invest in Malaysian EV infrastructure development will receive tax reductions and other government incentives. (Trade, 2023).

Expectations are high back home that if Proton and Perodua enter the EV manufacturing business, less expensive EVs would soon rule the road and the auto industry's sales figures. The Proton subsidiary that sells the smart #1 EV, Proton New Technology Sdn Bhd (Pro-Net), claims that it is actively working to increase the accessibility of BEVs through projects focused on affordability and expanding charging networks. Malaysians can expect more reasonably priced BEVs in the future, reflecting the changing market conditions. Zhang Qiang, the chief executive officer of Pro-Net, tells StarBizWeek that the current price tactics used by industry participants find a compromise between affordability and essential elements, including appropriate range and automobile characteristics, performance, and ecosystem support (Khoo, 2024).

At the end of the following month, the Melaka government plans to launch electric tourist buses to revive the country's tourism sector, which has been negatively impacted by the COVID-19 outbreak. Starting from Melaka Sentral, the buses will travel through nine or fourteen stations, which include the Taming Sari Tower, the Melaka Zoo, and the UNESCO World Heritage Site located near Banda Hilir. Top-up cards with values between RM20 and RM30 will be used to make payments. The all-electric, environmentally friendly concept buses will include air conditioning, wi-fi, and open areas for visitors. The government intends to expand the bus fleet if visitor feedback is favorable (BloombergNEF, 2022).

Hypothesis 3: There is a relationship between government policy and Electric Vehicle innovation

Framework

This research will be using the Technological Diffusion Theory (TDT) because TDT offers a paradigm for comprehending the social diffusion of EVs as an innovation. Relative advantage (benefits over current options), compatibility (fit with existing infrastructure), simplicity (ease of use), observability (benefits that are visible), and trialability (opportunity to explore) are some of the key aspects it considers. This theory will examine how the adoption of EVs affects social norms and economic activity as it moves through several stages.

Figure 1: Conceptual Framework of the Study

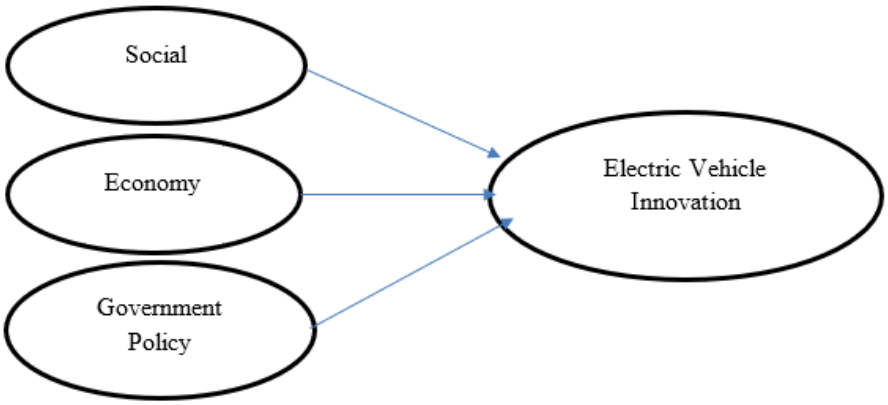

Figure 1 illustrates the plan for this research and outlines the approach to solving the research problem's objective. Using TDT, this study examines the ways in which different social and economic factors impact the adoption of EVs. This can assist in identifying locations where actions (such as public awareness campaigns and infrastructure development) can maximize the beneficial socio-economic effects of electric vehicles and speed up their spread.

METHODOLOGY

The research methodology adopts a quantitative approach to examine the socio-economic impacts of electric vehicle (EV) adoption in Malacca, Malaysia. Data collection integrates both primary and secondary sources.

Primary data is gathered through structured questionnaires distributed via Google Forms to employees across diverse industries, complemented by focus groups for deeper insights. Secondary data is sourced from government databases on EV sales, charging infrastructure, and employment trends. The sampling design targets employees as key respondents, as they are directly exposed to potential economic changes. Malacca was chosen for its manageable population size and unique financial landscape. The questionnaire, divided into demographic, independent (social, economic, and policy), and dependent (EV innovation) sections, is pilot-tested to ensure clarity and reliability before being deployed on large-scale platforms such as WhatsApp, Telegram, and Instagram. Descriptive statistics are initially applied to summarize key trends, followed by advanced analyses using SPSS, including Pearson correlation to examine relationships between variables and Cronbach's Alpha to assess reliability. This rigorous design ensures valid, reliable, and actionable findings, offering crucial insights into workforce perceptions, government policies, and economic prospects related to EVs, thereby informing policymakers, businesses, and stakeholders about opportunities and challenges in transitioning toward sustainable mobility.

RESULTS

Multiple Regression Analysis

In this regression analysis, the independent variables selected for inclusion in the model were social impact (TOTAL_SI), economic impact (TOTAL_EI), and government policy (TOTAL_GP). These variables were chosen based on their theoretical relevance to the dependent variable, electric vehicle innovation (TOTAL_EVI). The goal was to examine how these factors collectively influence EV innovation in Malacca. All of these variables were entered into the model without any exclusions, allowing for a comprehensive evaluation of how each factor contributes to predicting the level of innovation in electric vehicle adoption. The inclusion of these variables reflects the key themes of the study, such as social acceptance, economic benefits, and supportive governmental policies, which are expected to have direct implications on the pace and success of EV innovation.

Table 1. Variables Entered Analysis

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	TOTAL_GP, TOTAL_EI, TOTAL_SI[b]	.	Enter
a. Dependent Variable: TOTAL_EVI			
b. All requested variables entered.			

Model Summary Analysis

The model summary provides crucial information about the explanatory power of the regression model. The adjusted R Square value is 0.934, which means that 93.4% of the variance in the dependent variable, electric vehicle innovation (TOTAL_EVI), is explained by the independent variables in the model. This is a very high level of explanatory power, indicating that the model is highly effective in predicting EV innovation. The R Square value of 0.935 further supports this conclusion, suggesting that the independent variables (social impact, economic impact, and government policy) are strong predictors of the dependent variable. The low standard error of the estimate (1.67415) further reinforces the model's reliability, as it shows that the predicted values closely align with the observed values.

Table 2. Model Summary Analysis

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.967[a]	.935	.934	1.67415
a. Predictors: (Constant), TOTAL_GP, TOTAL_EI, TOTAL_SI				

ANOVA Analysis

The ANOVA (Analysis of Variance) table tests the overall significance of the regression model. The F-statistic value of 1626.776 is highly significant, with a p-value of less than 0.001, indicating that the model is statistically significant and that the independent variables collectively have a significant impact on the dependent variable, electric vehicle innovation. In other words, the likelihood that the observed relationship between the independent variables and the dependent variable occurred by chance is extremely low. This confirms that the model as a whole provides a meaningful explanation for the variation in EV innovation, and we can be confident in the findings that follow.

Table 3. ANOVA Analysis

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	13678.406	3	4559.469	1626.776	<.001[b]
	Residual	952.940	340	2.803		
	Total	14631.346	343			
a. Dependent Variable: TOTAL_EVI						
b. Predictors: (Constant), TOTAL_GP, TOTAL_EI, TOTAL_SI						

Coefficient Analysis

The coefficients table reveals the individual contributions of each independent variable in predicting the dependent variable, electric vehicle innovation (TOTAL_EVI). The social impact (TOTAL_SI) variable is the most influential predictor, with a standardized beta coefficient of 0.891, indicating a strong positive effect on EV innovation. The significance level ($p < 0.001$) further confirms the importance of social factors such as public awareness and inclusivity in driving EV innovation. The economic impact (TOTAL_EI) exhibits a smaller negative relationship with EV innovation ($\beta = -0.226$), with a statistically significant p-value of less than 0.001. This suggests that, although economic factors like cost reduction and job creation are important, there may be challenges in translating these benefits into immediate EV innovation. Lastly, government policy (TOTAL_GP) has a positive impact on EV innovation ($\beta = 0.243$, $p < 0.001$), suggesting that supportive government policies, such as tax incentives and infrastructure development, play a crucial role in fostering innovation. These findings highlight the varying degrees of influence each factor has on the adoption of electric vehicles, with social impact emerging as the most significant predictor.

Table 4. Coefficients Analysis

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.422	.306		4.647	<.001
	Social Impact (SI)	.893	.055	.891	16.215	<.001
	Economic Impact (EI)	-.263	.025	-.226	-10.406	<.001
	Government Policy (GP)	.263	.061	.243	4.285	<.001
a. Dependent Variable: TOTAL_EVI						

DISCUSSION

Social Impact towards Electric Vehicle Innovation

The findings support Hypothesis 1 (H1), which posited a significant positive relationship between social impact and electric vehicle (EV) innovation. The study results indicate that public awareness, social acceptance, and

inclusivity are critical factors in driving EV innovation. The high Beta value (+0.891) and statistically significant p-value ($p < 0.001$) confirm that increased societal awareness about environmental benefits and modernity associated with EVs enhances their adoption and development.

For example, the reduced air and noise pollution from EVs aligns with public demand for cleaner urban spaces, while the perception of EVs as advanced and eco-friendly technology fosters broader acceptance. Additionally, societal trends toward inclusivity, such as the development of accessible and sustainable transportation systems (e.g., electric buses), contribute to their innovation. These findings suggest that public engagement and social factors not only influence the market demand for EVs but also encourage manufacturers and policymakers to prioritize innovation in the sector. (BloombergNEF, 2022).

Economic Impact on Electric Vehicle Innovation

This section aligns with Hypothesis 2 (H2), which examined the relationship between economic impact and EVinnovation. While a statistically significant relationship was found ($p < 0.001$), the negative Beta value (-0.226) suggests that financial factors, such as the high upfront cost of EVs and infrastructure challenges, may hinder innovation despite their potential economic benefits Lower operating costs and government subsidies help make EVs more affordable over time, but the initial price barrier remains a challenge for many consumers. Additionally, the lack of sufficient charging infrastructure can increase costs for manufacturers and limit consumer confidence. On the positive side, the study highlights the potential for job creation in battery production, EV manufacturing, and charging station installation, which can stimulate local economies. These findings suggest that while economic impact is a significant driver of EV innovation, addressing affordability and infrastructure barriers is crucial for maximizing its positive effects. (Mock & Yang, 2014).

Government policy towards Electric Vehicle Innovation

The findings support Hypothesis 3 (H3), which posited a positive relationship between government policy and EV innovation. The results confirm that government interventions, such as subsidies, tax incentives, and infrastructure investments, have a significant influence on the adoption and development of EV technologies (Beta = +0.243, $p < 0.001$).

Tax incentives reduce the financial burden on EV buyers, while subsidies encourage manufacturers to innovate and scale production. Investments in charging infrastructure alleviate range anxiety, a significant barrier to the adoption of electric vehicles. In Malacca, such policies have proven effective in driving consumer interest and encouraging technological advancements. Public awareness campaigns further amplify these efforts by educating citizens on the environmental and economic benefits of EVs. These findings demonstrate that government policies are a cornerstone of EV innovation, providing a supportive ecosystem for sustainable transportation solutions. (BloombergNEF, 2022).

CONCLUSION

The findings of this research have significant implications for various stakeholders, including policymakers, industry players, and society as a whole. For policymakers, the study underscores the importance of developing supportive government policies, including subsidies, tax incentives, and infrastructure investments, to accelerate the adoption and innovation of electric vehicles (EVs). These policies not only drive economic growth but also align with broader environmental sustainability goals. For instance, governments can use the results to focus on expanding public charging infrastructure and integrating renewable energy, which are crucial for fostering confidence in the EV technology industry among players such as EV manufacturers and suppliers. The research provides insights into the importance of addressing both social and economic factors. The data indicate that consumer acceptance is strongly tied to public awareness and perception of EVs as modern, eco-friendly solutions. Companies can leverage this by investing in marketing strategies and partnerships that emphasize the environmental and financial benefits of EV ownership. Additionally, collaboration with governments to develop innovative charging solutions and affordable EV models could further accelerate market penetration.

Launderscores the role of society in driving EV adoption. Public awareness campaigns and education initiatives remain critical in fostering societal acceptance. By engaging communities and emphasizing the long-term

benefits of EVs, such as reduced air pollution and improved urban mobility, stakeholders can create a ripple effect that encourages sustainable transportation practices. The combined efforts of governments, businesses, and communities can ensure that EV innovation contributes to a greener and more inclusive future. (Noel et al., 2019).

While this study provides valuable insights, it is not without limitations. One major limitation is the geographical scope, as the research focuses primarily on Malacca. This localized approach may not fully capture the variations in EV adoption and innovation across different regions or countries. Factors such as cultural differences, economic disparities, and varying government policies can significantly influence the findings. Future research should consider expanding its scope to include multiple regions, thereby obtaining more generalized and comparative insights.

Another limitation lies in the reliance on survey respondents. While the questionnaire was carefully designed and validated, the possibility of response bias cannot be ignored. Participants may have provided socially desirable answers or misunderstood specific questions, which could affect the accuracy of the data. Incorporating a mixed-methods approach, including interviews or focus groups, could help triangulate the findings and provide a more nuanced understanding of the factors influencing EV innovation.

Lastly, the study primarily examines the relationships between policy factors and EV innovation but does not delve deeply into technological or environmental aspects. For example, advancements in battery technology, renewable energy integration, and the environmental impacts of EVs throughout their lifecycle were not addressed in detail. These areas are crucial for comprehending the full spectrum of EV innovation and adoption, and should be explored in future studies to provide a comprehensive view. (Mock & Yang, 2014).

To build on the findings of this study, future research should consider expanding its geographical scope to include diverse regions and countries. Comparing different contexts can provide insights into how cultural, economic, and policy variations influence EV adoption and innovation. For instance, studying regions with advanced EV ecosystems, such as Scandinavia or China, could highlight best practices that could be adapted to areas like Malacca. This comparative analysis would contribute to a broader understanding of global trends and localized strategies.

Additionally, future studies should incorporate emerging technologies and their impact on EV innovations, including advancements in battery technology, vehicle-to-grid systems, and autonomous electric vehicles, which have transformative potential but were beyond the scope of this research. Exploring these aspects would provide a comprehensive view of the technological drivers of EV innovation and their implications for adoption. For instance, analyzing the lifecycle costs and environmental benefits of new battery chemistries could offer valuable insights for both policymakers and industry stakeholders.

Finally, a mixed-methods approach combining quantitative and qualitative data collection is recommended. Surveys can be depth interviews or case studies to capture more nuanced perspectives from diverse stakeholders, including policymakers, manufacturers, and consumers. This would allow researchers better to understand the barriers and opportunities in EV adoption. Furthermore, longitudinal studies tracking the evolution of EV innovation over time would provide valuable insights into how social, economic, and policy factors interact dynamically to influence the adoption of EVs. (Noel et al., 2019)

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