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Challenges and Solutions in Developing Eco-Friendly Electric Vehicles with Extended Range

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ABSTRACT

This research investigates the challenges and solutions associated with the development and adoption of environmentally friendly electric vehicles (EVs) in Jakarta, Indonesia, a densely populated and rapidly urbanizing city facing pressing environmental and transportation issues. Employing a mixed-methods approach, this study combines quantitative surveys with qualitative interviews and focus group discussions to provide a comprehensive understanding of the dynamics influencing EV adoption. The findings reveal a relatively high level of awareness of EVs among Jakarta residents, with positive perceptions centered on environmental benefits. However, barriers such as high initial costs and concerns about charging infrastructure availability hinder adoption. Government policies, including incentives and clearer regulatory frameworks, are identified as pivotal drivers for EV adoption. Insights from government officials, industry stakeholders, and consumers emphasize the importance of collaboration to overcome infrastructure challenges and promote electric mobility. The study's recommendations aim to inform policymakers, industry players, and urban planners in their efforts to facilitate the transition to sustainable electric transportation in Jakarta.

Keywords: *Challenge, Solutions, Eco-Friendly, Electric Vehicle, Extended Range*

1. INTRODUCTION

Electric vehicles (EVs) have emerged as one of the most promising alternatives to traditional fossil fuel-powered cars. Electric vehicles offer the potential to reduce air pollution, cut greenhouse gas emissions, and ease pressure on fossil fuel resources [1], [2]. However, the adoption of electric vehicles in Jakarta and other urban areas is a complex challenge characterized by multiple factors, including infrastructure limitations, economic considerations, consumer preferences, and regulatory frameworks [3], [4]. In the face of global climate change and growing urbanization, the need for sustainable transportation solutions is becoming increasingly important. As urban centers expand and populations grow, the adverse impacts of internal combustion engine vehicles are becoming increasingly apparent, especially in densely populated cities like Jakarta, Indonesia. Rapid industrialization and population growth have led to a surge in vehicle ownership, exacerbating air pollution and traffic congestion (4,5). Jakarta, the capital of Indonesia, provides a poignant case study, grappling with the urgent need to shift to cleaner and more sustainable mobility options [5]–[7].

Jakarta, the capital of Indonesia, is experiencing rapid population growth and urban sprawl, which has led to severe traffic congestion and deteriorating air quality [8]. The city's population is predicted to increase by 3% from 2019 to 2030, reaching around 10,938,900 people [8]. This population growth is expected to increase traffic congestion by 3%, from 70% to 72.1%, and air pollution by 3%, from 39.6 to 40.79 [8]. Electric vehicles (EVs) offer a potential solution to the environmental and health problems associated with traditional gasoline and diesel cars. EVs are more energy-efficient, produce no exhaust emissions, and can be powered by cleaner energy sources. By switching to electric mobility, cities like Jakarta have the potential to significantly reduce air pollution levels and contribute to global efforts to combat climate change. To address the traffic

congestion and air pollution issues in Jakarta, the city could consider promoting the adoption of electric vehicles, improving public transportation infrastructure, and implementing policies that encourage sustainable urban development [9], [10]. Additionally, strict law enforcement on the road and raising public awareness about the importance of traffic order could help improve traffic discipline and reduce congestion [11].

Research Gaps and Significance

This study begins a thorough investigation of the problems and potential fixes related to expanding Jakarta's supply of environmentally friendly electric automobiles. This research intends to shed light on appropriate ways to promote the adoption of electric vehicles as a tool to improve sustainable transportation in this booming city by examining the dynamics of Jakarta's distinctive urban setting and the intricacies of the electric vehicle industry. Although the use of electric vehicles is growing across the globe, Jakarta offers particular difficulties. By examining the unique difficulties and opportunities encountered by Jakarta in its efforts to create a sustainable electric vehicle ecosystem, this study seeks to fill the knowledge vacuum currently in the field. In doing so, the study is anticipated to offer insightful information to researchers, industry stakeholders, urban planners, and policy makers tackling related problems in other metropolitan areas.

2. LITERATURE REVIEW

2.1 Global Electric Vehicle Landscape

The transition to electric mobility is driven by environmental concerns, as conventional internal combustion engine vehicles contribute significantly to air pollution and greenhouse gas emissions. Electric vehicles (EVs) offer a cleaner alternative, as they emit no tailpipe pollutants and can potentially reduce greenhouse gas emissions if charged with renewable energy sources [12]–[14]. Studies have shown that EVs can have lower emissions compared to internal combustion engine vehicles (ICEVs). For example, in China, EVs have modest cradle-to-gate CO2 benefits (on average 29%) compared to ICEVs, but have similar carbon emissions relative to hybrid electric vehicles [13].

In Serbia, the average specific emission factor for EVs is almost the same in terms of CO2 (194.7 g/km) compared to ICEVs (159.6 g/km), while in the case of NOX, the specific emissions factors for EVs almost double, from 0.71 to 1.30 g/km3. However, decarbonizing the national power grid is necessary to achieve net-zero emissions with a complete replacement of the fleet with EVs [14]. The transition to electric mobility can also have positive impacts on energy consumption and cost savings. In Malaysia, EVs were found to consume 30% less energy than ICEVs and achieve a 26% energy cost saving for long-distance highway travel [15]. In urban areas, EVs can provide even higher energy and cost savings, with 86% and 64% respectively9. Light electric freight vehicles (LEFVs) and cargo bikes can also offer a solution for urban freight flows, as they occupy less space, can be maneuvered easily, and do not emit tailpipe pollutants [16]. Parcel and food deliveries have high potential for using LEFVs, while deliveries related to services and the last phase of construction work can also be switched to LEFVs [16]. In conclusion, electric mobility offers a cleaner alternative to conventional vehicles, with the potential to reduce greenhouse gas emissions and air pollution. However, the extent of these benefits depends on the energy sources used to charge EVs and the specific conditions in each country.

The growing global electric vehicle (EV) market presents various economic opportunities for governments and industries around the world. These opportunities include job creation, innovation, and reduced dependence on imported fossil fuels. In addition to the environmental benefits, incentives such as tax rebates and subsidies further encourage consumer adoption of EVs [17]. Job creation can be seen in various sectors related to EVs, such as manufacturing, research and development, and charging infrastructure. For example, the region of Jalisco, Mexico, is home to more than 650 high-tech corporations, exporting a total value of USD 21 billion annually in tech products and services, with micro and small and medium enterprises being a significant part of their companies [18].

The electric vehicle industry involves various technological cooperative innovations, which require collaboration between enterprises within the industry and research institutions [19]. Innovation in the EV market can lead to advancements in battery technology, charging infrastructure, and vehicle design. For instance, a large-scale solar EV concept has been proposed, which involves integrating low-cost, flexible, and thin-film solar cells onto the steel of all upward-facing vehicle body panels. This could help mitigate EV charging and range concerns, as well as the high cost and solar power intermittency of individual residential rooftop solar installations [20]. Reduced dependence on imported fossil fuels can be achieved through the widespread adoption of EVs, which rely on electricity rather than gasoline or diesel. This shift can lead to increased energy security and a more diversified energy mix, as countries can generate electricity from various sources, including renewable energy [21].

2.2 Challenges in Urban Electric Vehicle Adoption

One of the key challenges in urban electric vehicle (EV) adoption is the development of charging infrastructure. Adequate and strategically located charging stations are essential to reduce range anxiety and encourage the use of electric vehicles. Rapid expansion of the charging network is especially important for densely populated urban areas such as Jakarta, where parking and space constraints are common [22] . Electric vehicles often have higher initial costs compared to traditional vehicles, mainly due to the cost of batteries [23]. To address the challenge of deciding where to build solar-assisted charging stations in a city and how to size them, a study proposed an approach to efficiently decide the locations and sizes of solar energy-assisted charging stations for an urban area [22].

The method takes into account factors such as construction cost, solar energy fluctuation, and user requirements. Experiments conducted on real EV history data from 297 users of an EV leasing company showed that the proposed method can produce high-quality decisions within reasonable computation time [22]. Optimal placement of EV charging stations in utility grids is also crucial to ensure a reliable long trip for personal and public needs [24]. If not placed suitably to the utility grid, these highly dynamic loads may result in increased losses, voltage drops, and loss of power system reliability [24]. The placement of EV charging stations depends on factors such as statutory norms, optimal power flow, EV range considerations, and various other factors [24]. In Nigeria, a study investigated the technical and economic feasibility of an electrical vehicle (EV) charging scheme based on the availability of renewable energy (RE) sources in six sites representing diverse geographic and climatic conditions [25]. The study found that the PV/WT/battery charging station with a quantity of two wind turbines, 174 kW of PV panels, a quantity of 380 batteries storage, and a converter of 109 kW located in Sokoto provided the best economic metrics with the lowest

NPC, electricity cost, and initial costs [25]. The optimal charging scheme was able to reliably satisfy most of the EV charging demand.

In conclusion, the development of charging infrastructure for urban electric vehicle adoption requires careful planning and consideration of various factors such as location, construction cost, energy sources, and user requirements. Optimizing the placement of charging stations and integrating renewable energy sources can help address these challenges and promote the widespread adoption of electric vehicles in densely populated urban areas.

3. METHODS

This research adopts a mixed methods research approach, which integrates quantitative and qualitative methods. This combination of approaches allows for a comprehensive exploration of the research problem, providing both quantitative data for analysis and qualitative insights to understand the factors underlying electric vehicle adoption. Quantitative methods will be used to collect numerical data on aspects such as EV adoption rates, availability of charging infrastructure, and consumer preferences. Surveys and statistical analysis will be used to quantify and identify patterns in these variables. Qualitative research methods will complement the quantitative data by providing deep insights into challenges and potential solutions. Semi-structured interviews, focus group discussions, and content analysis of relevant documents and reports will be conducted. These methods aim to uncover the nuances of attitudes, perceptions and experiences relating to electric vehicles in Jakarta. For the quantitative survey, the sample size will be determined using a 95% confidence level and a 5% margin of error. For qualitative data collection, the sample size for interviews and focus group discussions will be determined through data saturation, to ensure that no new insights are gained from additional participants.

Quantitative data from the survey will be analyzed using SPSS statistical software. Descriptive statistics, such as mean, median, and standard deviation, will be used to summarize the data Qualitative data from the interviews and focus groups will undergo thematic analysis. This process involves identifying recurring themes and patterns in the data. Coding of the data will be done using qualitative analysis software to facilitate the identification of similarities and differences in participants' responses.

4. RESULTS AND DISCUSSION

Understanding the demographic characteristics of the respondents is crucial for contextualizing the findings of our study. The following table provides an overview of the demographic profile of the survey participants:

Tabel 1. Demographic Respondent

Demographic Information	Percentage
Central Jakarta	22%
South Jakarta	30%
East Jakarta	15%
West Jakarta	18%
North Jakarta	10%

Outlying Areas	5%
Age Distribution	**Percentage**
18 – 25 years	15%
26 – 35 years	32%
36 – 45 years	22%
46 – 55 years	18%
56 and above	13%
Gender	**Percentage**
Male	55%
Female	45%
Educational Backgrond	**Percentage**
High School	12%
Bachelor's Degree	45%
Master's Degree	30
Doctoral Degree	13%
Employment Status	**Percentage**
Employed full-time	58%
Employed part-time	8%
Self-employed	12%
Unemployed	10%
Student	8%
Retired	4%
Income Level	**Percentage**
Less than IDR-5 million/month	15%
IDR 5 million – IDR 10 million/month	32%
IDR 10 million – IDR 20 million/month	28%
More than IDR 20 million/month	25%
Vehicle Ownership	**Percentage**
No vehicle ownership	40%
Gasoline-powered vehicle	45%
Electric vehicle (EV)	10%
Hybrid vehicle	5%

Source: Primary Data (2023)

4.1 Quantitative Results

Awareness and Perception of Electric Vehicles

This quantitative survey aims to assess the level of awareness and perception towards electric vehicles (EVs) among Jakarta residents. Of the 500 survey respondents, 68% stated that they

were aware of electric vehicles. This indicates a fairly high level of awareness among the surveyed population. Of those who are aware of EVs, 45% expressed a positive perception towards EVs. The main motivation cited for considering EV adoption was the perceived environmental benefits, with 58% of respondents in this category emphasizing the reduced environmental impact of EVs.

Barriers to Electric Vehicle Adoption

The survey also sought to identify the main barriers preventing respondents from adopting electric vehicles. Participants were asked to select one or more barriers from a list of available options. About 42% of respondents considered the high initial cost of electric vehicles as a significant barrier to adoption. This finding is in line with the global understanding that the initial purchase price remains a major challenge for potential buyers of electric vehicles. Concerns about the availability and accessibility of charging stations were expressed by 31% of respondents. This highlights the importance of developing charging infrastructure in Jakarta to reduce range anxiety and encourage electric vehicle adoption. Around 22% of respondents mentioned that the limited variety of electric vehicle models in the market is a concern for them. Diversifying electric vehicle model offerings in Jakarta could help attract more consumers.

Policy Influence on Electric Vehicle Adoption

The survey asked about the influence of government policies on respondents' decisions regarding electric vehicle adoption. When asked if government incentives and subsidies would have a positive impact on their decision to adopt electric vehicles, 55% of respondents answered in the affirmative. This suggests that financial incentives can play an important role in driving electric vehicle adoption in Jakarta. The majority of respondents, 67%, felt that there is a need for clearer policies to support the adoption of electric vehicles. This indicates that there may be room for improvement in the regulatory framework to promote electric vehicles in Jakarta.

4.2 Qualitative Results

Government Perspective

In-depth interviews were conducted with government officials responsible for transportation and environmental policy in Jakarta. Key findings from these interviews include: Government officials emphasized the important role of government policy in shaping the electric vehicle landscape. They recognized the need for a comprehensive policy framework to promote the adoption of electric vehicles in Jakarta. Government representatives expressed their commitment to investing in charging infrastructure to address the concerns of potential electric vehicle users. They highlighted plans to expand the charging network to improve convenience for users.

Industry Perspectives

Interviews were conducted with representatives from electric vehicle manufacturers and industry experts. Key insights from these interviews include: Electric vehicle manufacturers emphasized the importance of government support in addressing infrastructure challenges. They highlighted the need for public-private partnerships to accelerate the development of charging networks. Industry stakeholders identified regulatory uncertainty as a significant hurdle. Clear and stable regulations are considered essential to give manufacturers the confidence to invest in the Jakarta market.

Consumer Perspective

Focus group discussions were organized with Jakarta residents to explore their perspectives and concerns regarding electric vehicles. Key findings from these discussions include: Participants expressed concerns about charging convenience, highlighting the need for easily accessible and reliable charging stations to reduce range anxiety. Electric vehicle affordability was a common topic of discussion. Participants expressed interest in more affordable EV options to make adoption financially viable. Participants saw potential in electric ride-sharing services to address Jakarta's notorious traffic congestion. They see shared electric mobility as a way to reduce the number of vehicles on the road.

5. CONCLUSION

In the face of increasing urbanization and environmental challenges, this research has examined the complex landscape of environmentally-friendly electric vehicle (EV) adoption in Jakarta. Its findings provide a nuanced perspective on the challenges and potential solutions, shedding light on the path to sustainable urban mobility in this dynamic city. The study reveals a fairly high level of awareness of electric vehicles among Jakarta residents, with a key emphasis on the environmental benefits of electric mobility. This suggests there is potential for adoption. High upfront costs and concerns about the availability of charging infrastructure emerged as significant barriers to electric vehicle adoption. These findings underscore the importance of addressing cost concerns and expanding charging networks to reduce range anxiety. Government policies play an important role in shaping the electric vehicle landscape. The majority of respondents recognized the positive impact of government incentives and subsidies on their decision to adopt electric vehicles. Clearer and more supportive policies are essential to drive electric vehicle adoption. Views from government officials, industry stakeholders and consumers underscore the need for collaboration and clear policies. Public-private partnerships are essential to address infrastructure challenges and regulatory uncertainty. Focus group discussions highlighted the importance of charging convenience, affordability, and the potential of electric ride-sharing services to address urban traffic congestion.

IMPLICATIONS

Based on the research findings, several implications and recommendations emerge:

Policymakers should focus on refining and clarifying regulations that support the adoption of electric vehicles, including incentives and subsidies to make electric vehicles more affordable. Investment in charging infrastructure should be a priority, with a focus on expanding the network across Jakarta to improve convenience and address mileage issues. Public-private partnerships should be fostered to address infrastructure and regulatory challenges. Industry stakeholders should actively engage with the government to drive the growth of the electric vehicle market. A comprehensive consumer education campaign should be launched to address misconceptions and promote the benefits of EVs, especially their environmental advantages. Efforts to diversify the range of affordable electric vehicle models available in Jakarta should be supported to cater to a wider consumer base.

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