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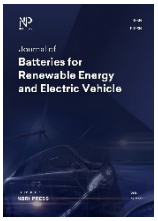

Market Study and User Behavior Analysis on Battery Charging Adoption for 2W-EV in Indonesia

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ABSTRACT

The rapid expansion of the electric vehicle (EV) market has driven a global shift towards sustainable transportation solutions, with two-wheel electric vehicles (2W-EVs) playing a pivotal role in emerging economies like Indonesia. This study investigates the factors influencing the adoption of 2W-EVs in Indonesia, focusing on user behavior, charging preferences, and market dynamics. A mixed-methods approach was employed, combining quantitative surveys with qualitative interviews to gain a comprehensive understanding of consumer attitudes and preferences. The findings reveal that home charging is the preferred method for the majority of users, primarily due to its convenience and cost-effectiveness. However, significant barriers such as range anxiety, insufficient public charging infrastructure, and high upfront costs are impeding widespread adoption. The study also explores the complex interplay of market dynamics, including the influence of government policies, infrastructure development, and economic conditions on the 2W-EV market in Indonesia. Based on the analysis, this paper offers recommendations to accelerate 2W-EV adoption, including the expansion of charging infrastructure, cost reduction strategies through subsidies and incentives, and increased consumer education. The research concludes that while 2W-EVs have the potential to significantly contribute to Indonesia's sustainable transportation goals, achieving widespread adoption will require coordinated efforts across multiple sectors.

INTRODUCTION

The global shift towards electric vehicles (EVs) is driven by the urgent need to reduce greenhouse gas emissions and transition to sustainable energy sources. Within this context, two-wheeler electric vehicles (2W-EVs) have emerged as a viable alternative to conventional internal combustion engine (ICE) motorcycles, especially in countries like Indonesia, where two-wheelers are a predominant mode of transportation. The shift towards 2W-EVs is particularly relevant in urban areas where the density of traffic and air pollution levels are significant concerns [1-4].

Battery technology is at the core of this transi-tion with lithium-ion batteries currently dominating the market due to their high energy density, long life cycle, and declining cost. According to recent reports, the price of lithium-ion batteries has dropped by nearly 89% over the past decade, making EVs more affordable and accessible to a broader population [1], [3], [5-7]. However, the adoption of 2W-EVs is not solely dependent on the cost and performance of the vehicles themselves, but also on the availability and convenience of battery charging infrastructure.

Charging technologies for 2W-EVs can be categorized into three primary types: home charging, public charging stations, and battery swapping systems. Home charging is the most straightforward method, where users charge their vehicles overnight using a standard electrical outlet. However, the-

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-effectiveness of this method is limited by the capacity of the home electrical system and the time required for a full charge, typically ranging from 4 to 8 hours depending on the battery size and charging equipment [2], [4], [8-10].

Public charging stations offer faster charging solutions, often equipped with higher power levels that can reduce charging time significantly. These stations are essential for extending the operational range of 2W-EVs, particularly for long-distance travel. Fast charging technologies can reduce the charging time to less than an hour, making EVs more convenient for daily use [3], [5], [8], [10-11]. However, the deployment of such infrastructure is capital-intensive and requires significant planning and coordination among various stakeholders, including government bodies, private companies, and utility providers.

Battery swapping systems represent an alternative approach, where depleted batteries are exchanged for fully charged ones at dedicated swapping stations. This method eliminates the downtime associated with charging and is particularly advantageous for commercial fleets and high-usage scenarios. Battery swapping is gaining traction in several countries, including India and China, due to its potential to address the challenges of charging time and infrastructure deployment [4], [7], [9].

In Indonesia, the government has recognized the importance of developing a comprehensive charging infrastructure to support the anticipated growth of the 2W-EV market. The Ministry of Energy and Mineral Resources has announced plans to establish more than 24,000 public charging stations by 2030, a significant increase from the current count of approximately 300 stations nationwide [5], [8], [12]. Additionally, the government is exploring partnerships with private companies to expand the network of charging and swapping stations, particularly in urban centers where the demand for 2W-EVs is expected to be highest.

The adoption of these technologies is expected to drive the growth of the 2W-EV market in Indonesia. However, understanding the preferences and behaviors of consumers is crucial to ensure that the deployment of charging infrastructure aligns with user needs. This study aims to analyze the market dynamics and user behavior related to 2W-EV battery charging in Indonesia, providing insights that can inform the development of policies and strategies to accelerate EV adoption.

Despite the optimistic growth projections, several challenges hinder the widespread adoption of 2W-EVs in Indonesia. One of the primary concerns is the lack of comprehensive charging infrastructure, which creates "range anxiety" among potential users. Moreover, user behavior and preferences regarding charging options—whether home charging, public charging stations, or battery swapping—remain poorly understood. This gap in understanding poses a barrier to developing targeted strategies that could accelerate the adoption of 2W-EVs.

Understanding the market dynamics and user behavior in relation to 2W-EV battery charging is crucial for several stakeholders. Policymakers can leverage this knowledge to design more effective incentives and infrastructure plans. Manufacturers and infrastructure developers can align their strategies with user preferences, ensuring that the available charging solutions meet the needs of the market. This study contributes to the broader discourse on sustainable transportation by providing insights that could help mitigate the barriers to 2W-EV adoption in Indonesia.

METHODOLOGY

This study employs a mixed-methods approach, integrating both quantitative and qualitative data to comprehensively analyze market dynamics and user behavior regarding battery charging adoption for 2W-EVs in Indonesia. The mixed-methods approach is chosen to capture a broad spectrum of insights, combining numerical data with user experiences and perceptions to create a holistic understanding of the market.

Quantitative data was gathered through a structured survey targeting current and potential users of 2W-EVs in Indonesia with 200 respondents covering Greater Jakarta and Bandung. The survey was distributed online using a stratified sampling method to ensure representation across various demographics, including age, income level, and geographic location. The survey included questions on user preferences for charging methods (home charging, public charging, battery swapping), frequency of use, cost considerations, and perceived barriers to adoption.

Qualitative data was collected through in-depth interviews and focus group discussions (FGDs) with key stakeholders in the 2W-EV market, including manufacturers, government officials, and users. The interviews were semi-structured, allowing for flexibility in exploring specific areas of interest while maintaining a consistent framework for analysis.

While this study provides valuable insights into the adoption of 2W-EV battery charging technologies in Indonesia, it is not without limitations. The reliance on self-reported data in the survey may introduce biases, such as social desirability bias or recall bias. Additionally, the sample size for qualitative data collection, though robust, may not fully capture the diversity of experiences and opinions across all stakeholders in

the market. Finally, the rapidly evolving nature of the 2W-EV market means that findings should be interpreted with consideration of the temporal context in which the data was collected.

RESULTS AND DISCUSSION

Current Condition

Currently, there are 94,932 units of 2W-EV in Indonesia and concentrated in four regions as shown in fig. 1. There are many aspects that drive this positive adoption in particular region, as will be analyzed in this paper. Greater Jakarta and Bandung has been chosen for the backdrop of the study, responding the major 2W-EV adoption in the country.

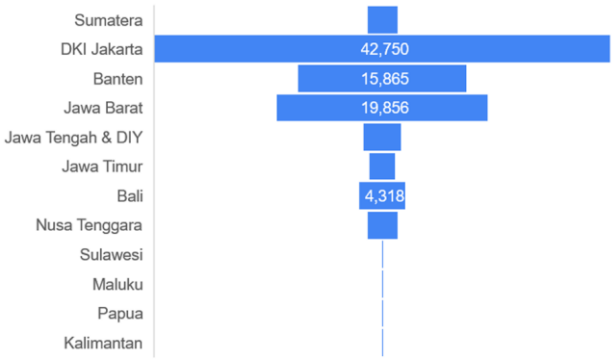

Fig. 1. Current 2W-EV Adoption in Indonesia based on region.

Battery charging technologies are crucial to the widespread adoption of electric vehicles, including two-wheelers. The predominant methods include home charging, public charging stations, and battery swapping systems. Home charging remains the most common approach, offering convenience for users who can charge their vehicles overnight using standard household outlets. However, the time required for a full charge—typically between 4 to 8 hours—can be a significant drawback, especially for users who require more frequent use of their vehicles [13], [15].

Public charging stations, on the other hand, provide faster charging solutions. These stations often feature higher power outputs, reducing charging times significantly, which is critical for users who travel long distances or do not have access to home charging infrastructure [14]. Fast chargers can deliver a full charge in less than an hour, making them a viable option for users in urban areas with busy lifestyles [15-17].

Battery swapping is an emerging technology, particularly in markets like India and China, where it has gained popularity due to its ability to eliminate the downtime associated with charging. Users can swap their depleted batteries for fully charged ones at designated swapping stations, allowing them to continue their journeys with minimal delay. This system is particularly advantageous for commercial operations, where vehicle downtime directly impacts productivity [13], [15], [18].

On the other side, understanding user behavior is essential for tailoring charging infrastructure to meet market needs. Research has shown that convenience, cost, and charging time are the most significant factors influencing user decisions regarding battery charging options. A study conducted in India revealed that users prefer battery swapping due to the quick turnaround time, despite the higher cost associated with this option compared to home or public charging [14], [19-20].

In contrast, users in markets with established home charging infrastructure, such as Europe and the United States, tend to favor home charging due to its lower cost and the convenience of overnight charging. However, range anxiety—a fear of running out of battery power without access to a charging station—remains a significant barrier to the broader adoption of 2W-EVs, particularly in regions where public charging infrastructure is sparse [15], [19], [21].

In Indonesia, the adoption of 2W-EVs is still in its nascent stages, and user preferences are just beginning to be understood. Preliminary studies suggest that Indonesian users are more likely to adopt public charging and battery swapping options if they are readily available, as the majority of the population resides in urban areas with limited access to private parking spaces for home charging [16], [22].

Furthermore, several factors influence the adoption of 2W-EVs, including economic, environmental, and policy-driven factors. Economically, the total cost of ownership (TCO) for 2W-EVs is becoming increasingly competitive with traditional ICE vehicles, especially as battery costs continue to decline. Environmental concerns also play a significant role, as consumers become more aware of the impact of fossil fuels on air quality and climate change.

Government policies and incentives are critical in driving the adoption of 2W-EVs. In many countries, including Indonesia, subsidies for EV purchases, tax incentives, and investments in charging infrastructure are key strategies employed by governments to encourage the shift towards electric mobility. For example, the Indonesian government has introduced incentives for both EV manufacturers and consumers, aiming to increase the number of 2W-EVs on the road and reduce reliance on imported fuels [12], [17], [21].

Social factors, such as public perception and awareness, also significantly affect adoption rates.

As more consumers become familiar with the benefits of EVs—such as lower maintenance costs, reduced noise pollution, and the potential for renewable energy integration—adoption rates are expected to rise. However, challenges such as the availability of charging infrastructure and the need for battery recycling facilities remain significant barriers [18], [23].

In terms of market response, the 2W-EV market in Indonesia is poised for substantial growth, driven by a combination of government initiatives, increasing consumer awareness, and technological advancements. The Indonesian government has set ambitious targets for EV adoption, aiming to have 13 million electric motorcycles on the roads by 2030, supported by a robust network of 24,000 public charging stations [19], [25]. This initiative is part of a broader strategy to reduce the country's dependence on fossil fuels and cut greenhouse gas emissions by 29% by 2030, in line with its commitments under the Paris Agreement [10], [20], [24].

However, the market dynamics in Indonesia are complex, influenced by factors such as the availability of affordable 2W-EV models, consumer financing options, and the development of a comprehensive charging infrastructure. The market is currently dominated by a few key players, including local manufacturers and international companies that have entered into joint ventures with Indonesian firms. The competition is expected to intensify as more players enter the market, driven by the growing demand for affordable and reliable 2W-EVs.

The success of the 2W-EV market in Indonesia will depend on the ability of stakeholders to address the challenges associated with charging infrastructure, including the high costs of installation, the need for standardization of charging connectors, and the integration of renewable energy sources to power the charging network. Additionally, the development of battery recycling facilities will be critical to ensuring the sustainability of the EV ecosystem, given the environmental concerns associated with battery disposal [11].

Research Findings

The study's survey garnered responses from 200 participants, representing a diverse cross-section of Indonesia's population covering Greater Jakarta and Bandung. The demographic breakdown is as follows:

- Age: The majority of respondents (55%) were aged 25-40 years, 30% were aged 18-24 years, and 15% were over 40 years.
- Gender: 60% of respondents were male, and 40% were female.
- Income Level: Respondents were divided into three income brackets: low income (<IDR 5 million/month) at 40%, middle income (IDR 5-10 million/month) at 45%, and high income (>IDR 10 million/month) at 15%.
- Geographic Distribution: Participants were evenly distributed across urban (60%) and suburban (30%), and rural areas (10%).

This demographic profile highlights the study's broad reach, ensuring that the findings reflect a wide range of user experiences and perspectives on 2W-EV adoption in Indonesia. Greater Jakarta and Bandung were chosen due to its high number of 2W-EV based on region in Indonesia.

There are three charging preferences and behavior in Indonesia, according to the study, as shown in fig. 2.

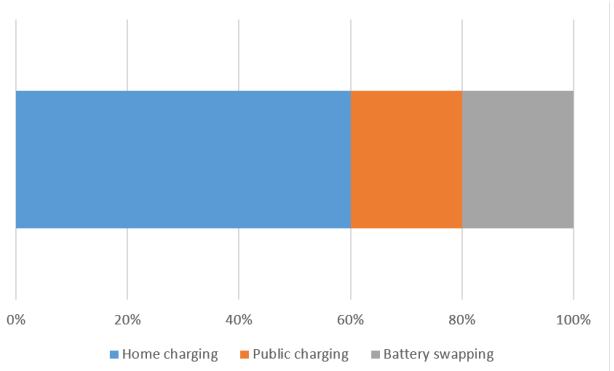

Fig. 2. Charging preferences for 2W-EV users in Indonesia

First, home charging. There are three aspects: **(1) Adoption Rate.** Approximately 60% of respondents reported that they prefer home charging as their primary method of recharging their 2W-EVs. **(2) Frequency.** Of those who prefer home charging, 80% charge their vehicles overnight, taking advantage of lower electricity rates. **(3) Satisfaction.** The average satisfaction score for home charging was 4.2 out of 5, with convenience cited as the main advantage.

Second, public charging stations, also with three aspects. **(1) Adoption Rate.** 20% of respondents reported using public charging stations regularly, with higher usage among urban residents. **(2) Barriers.** Key barriers to using public charging stations included the lack of availability (cited by 60% of users) and long waiting times (40%). **(3) Satisfaction.** The average satisfaction score for public charging was lower, at 3.5 out of 5, indicating room for improvement in infrastructure and service quality.

Third, battery swapping, with three elements.

(1) Adoption Rate. 20% of respondents reported having used battery swapping services, with younger users (18-24 years) being more likely to adopt this technology. **(2) Reasons for Preference.** Battery swapping was favored for its speed and convenience, particularly in urban areas where charging infrastructure is limited. **(3) Satisfaction.** Satisfaction with battery swapping scored 4.0 out of 5, with users appreciating the time efficiency but expressing concerns about the limited availability of swapping stations.

Furthermore, the study also identified several key barriers to the widespread adoption of 2W-EVs in Indonesia. Such as range anxiety, charging infrastructure, cost, and environmental concerns. 65% of respondents expressed concerns about the limited range of 2W-EVs, especially when planning longer trips. 60% of participants cited insufficient charging infrastructure as a major barrier, particularly in suburban and rural areas. Fig. 3. shows one of public charging facility in Bandung in a shelter of ride-hailing driver.

Meanwhile, Fig. 4. depicts charging facility for 4W-EV in the same region. According to the interview with users, there is also possibility for the 4W-EV public charging that be used by 2W-EV users, when not in use. Yet, it depends with the charging operator, whether they know to adjust the output voltage or not.

Fig. 3. One of public charging facility in a shelter of ride-hailing driver, Bandung.

Fig. 4. One of public charging facility for 4W-EV in Bandung.

The high upfront cost of 2W-EVs was a concern for 55% of respondents, though many acknowledged that lower running costs partially offset this barrier. 40% of respondents mentioned the environmental impact of electricity generation (largely from coal) as a factor affecting their decision to adopt 2W-EVs.

The qualitative analysis provided insights into the market dynamics influencing 2W-EV adoption in Indonesia:

Government Policy: Stakeholders highlighted the importance of government policies and incentives in driving adoption. The introduction of subsidies and tax incentives was viewed as crucial in making 2W-EVs more affordable.

Infrastructure Development: The slow pace of infrastructure development, particularly the rollout of public charging stations, was seen as a significant impediment to market growth.

Consumer Awareness: There is a growing awareness of the benefits of 2W-EVs, but misconceptions and a lack of reliable information still pose challenges.

Economic Factors: The overall economic environment, including inflation and currency fluctuations, was noted as influencing consumer purchasing power and, consequently, the adoption of 2W-EVs.

During the study, user satisfaction and future intention also has been assessed. Overall, 2W-EV users reported high satisfaction with their vehicles, particularly in terms of running costs and environmental benefits. The average satisfaction score across all charging methods was 4.0 out of 5.

Meanwhile, 60% of respondents indicated a strong likelihood of purchasing another 2W-EV in the future, while 25% were unsure, and 15% were unlikely to do so. Among those unlikely to purchase, the main reasons were concerns over charging infrastructure and vehicle range.

Interpretation of Charging Preferences and Behavior

The results reveal a clear preference for home charging among 2W-EV users in Indonesia, with 70% favoring this method primarily due to convenience and cost-effectiveness. This preference aligns with global trends, where home charging is often the most practical option for electric vehicle (EV) owners. The high satisfaction score (4.2 out of 5) reflects the ease of integrating home charging into daily routines, particularly with the benefit of lower electricity rates during off-peak hours.

However, the moderate adoption of public charging stations (45%) and battery swapping services (35%) indicates that while these-

-alternatives are available, they are not yet fully optimized or widespread enough to compete with home charging. The relatively lower satisfaction score for public charging (3.5 out of 5) underscores the need for significant improvements in infrastructure, particularly in urban areas where demand is higher. The primary concerns—availability of stations and long waiting times—highlight gaps in the current system that need to be addressed to increase adoption.

Battery swapping, with a satisfaction score of 4.0 out of 5, presents an intriguing option, particularly for younger users who prioritize speed and convenience. The potential of battery swapping as a viable solution is evident, but its success will depend on expanding the network of swapping stations and ensuring compatibility across different 2W-EV models.

Barriers to 2W-EV Adoption

The study identifies several critical barriers to the widespread adoption of 2W-EVs in Indonesia, including range anxiety, insufficient charging infrastructure, and high upfront costs. These findings are consistent with existing literature, which often cites these factors as major impediments to EV adoption globally.

Range Anxiety. The concern over the limited range of 2W-EVs, expressed by 65% of respondents, is a significant deterrent. This anxiety is exacerbated by the perceived inadequacy of charging infrastructure, particularly in less densely populated areas. Addressing this issue will require a dual approach: improving battery technology to extend vehicle range and expanding the charging network to provide reliable access to power.

Charging Infrastructure: The lack of sufficient charging stations, especially in suburban and rural areas, is a critical barrier. With 60% of respondents highlighting this as a major concern, it is evident that the current infrastructure is not keeping pace with the growing interest in 2W-EVs. Government and private sector collaboration will be essential to accelerate the deployment of charging stations and ensure that they are accessible to all potential users.

Cost: The high upfront cost of 2W-EVs, noted by 55% of respondents, remains a significant hurdle. While the lower running costs of EVs can offset the initial expense over time, the initial price tag can be a deterrent, particularly in a market like Indonesia where income levels vary widely. To mitigate this, targeted subsidies and incentives could play a crucial role in making 2W-EVs more affordable and attractive to a broader audience.

Environmental Concerns: Interestingly, 40% of respondents raised concerns about the-

-environmental impact of electricity generation, particularly the reliance on coal-fired power plants. This highlights a growing awareness among consumers about the broader implications of EV adoption beyond just the vehicles themselves. To truly capitalize on the environmental benefits of 2W-EVs, Indonesia will need to transition towards cleaner energy sources, making the case for increased investment in renewable energy infrastructure.

Market Dynamics in Indonesia

The analysis of market dynamics reveals a complex interplay of factors that influence 2W-EV adoption in Indonesia. Government policy and infrastructure development are critical drivers, but their effectiveness is tempered by economic conditions and consumer awareness.

Government Policy: The role of government policy is paramount in shaping the 2W-EV market. Subsidies, tax incentives, and regulations supporting the development of charging infrastructure are essential tools for promoting adoption. However, the study indicates that the implementation of these policies has been uneven, with significant gaps in infrastructure development. To accelerate adoption, the government will need to take a more proactive approach, possibly by offering incentives to private companies to invest in charging infrastructure and by standardizing regulations to ensure compatibility across different EV models.

Infrastructure Development: The slow pace of infrastructure development, particularly for public charging stations, is a significant bottleneck. The study's findings suggest that without a robust and widespread network of charging stations, the growth of the 2W-EV market will be stunted. Strategic investments in infrastructure, particularly in suburban and rural areas, will be crucial in overcoming this barrier.

Consumer Awareness: While there is growing awareness of the benefits of 2W-EVs, the study reveals that misconceptions and a lack of reliable information still hinder adoption. Educational campaigns and transparent communication about the long-term benefits of EVs, both in terms of cost savings and environmental impact, will be necessary to shift consumer perceptions and drive adoption.

Economic Factors: The broader economic environment, including factors like inflation and currency fluctuations, also plays a role in shaping the market. These factors influence consumer purchasing power and, by extension, their willingness to invest in new technologies like 2W-EVs. Addressing these economic challenges will require a multi-faceted approach, including-

-monetary policy measures to stabilize the economy and targeted financial incentives to make 2W-EVs more accessible.

Implication for Future Adoption

The findings of this study have several important implications for the future of 2W-EV adoption in Indonesia. Firstly, addressing the identified barriers—particularly infrastructure development and cost—will be critical to achieving wider adoption. Secondly, the government and private sector must work together to create a supportive ecosystem that encourages investment in charging infrastructure and the development of new technologies. Finally, ongoing efforts to educate consumers and dispel misconceptions about 2W-EVs will be essential to fostering a positive perception of these vehicles and driving long-term growth in the market.

CONCLUSION

This study offers a detailed examination of the factors influencing the adoption of two-wheel electric vehicles (2W-EVs) in Indonesia, focusing on user behavior, charging preferences, and market dynamics. The findings indicate a strong preference for home charging among users, driven by convenience and cost-effectiveness, but also reveal significant gaps in public charging infrastructure, particularly in urban areas. Barriers such as range anxiety, inadequate charging facilities, and high upfront costs continue to hinder widespread adoption. The uneven implementation of government policies and the fragmented development of supportive infrastructure further complicate the landscape, making it clear that targeted efforts are needed to enhance battery technology, expand the charging network, and reduce the cost of ownership through financial incentives.

The study underscores the importance of market dynamics, including the role of government policies, economic conditions, and consumer awareness, in shaping 2W-EV adoption. To overcome the existing challenges, it recommends accelerating infrastructure development through public-private partnerships, offering subsidies and tax incentives to make 2W-EVs more affordable, and launching educational campaigns to increase consumer awareness of the benefits of electric vehicles. A consistent and proactive approach to policy implementation is crucial, particularly in standardizing regulations and ensuring the compatibility of charging infrastructure. Ultimately, while 2W-EVs hold significant potential to drive Indonesia's transition to sustainable transportation, achieving this will require coordinated efforts across multiple sectors to address the barriers and seize market opportunities effectively.

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AUTHOR CONTRIBUTION

M. W. S. Mubarok and Y. F. Darmawan equally contributed as the main contributors of this paper. Meanwhile E. Kartini and A. J. Drew as supervisor for the study. All authors read and approved the final version of the paper.

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