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The Challenges in Adopting Electric Buses: A Case from Melaka, Malaysia

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Abstract: The Malaysian government has initiated a collaboration with private agencies to expand the green transport ecosystem by introducing electric buses. Despite these efforts, the adoption of electric buses in urban areas remains minimal. This paper addresses two research objectives: (a) to identify the challenges in adopting electric buses, and (b) to recommend improvements for adopting electric buses in Malaysia. Utilizing a qualitative methodology, this study aims to capture the experiences and reflections of interviewees through targeted population or place studies. This approach allows for the collection of detailed information and the development of new concepts and theories. The interviews revealed three main barriers to adopting electric buses in Melaka: battery reliability and durability, a lack of charging infrastructure, and insufficient operational knowledge. The paper suggests that the government and policymakers should take proactive measures to promote green technology and increase the acceptance of electric buses in urban areas through awareness campaigns.

Keywords: *Electric Buses, Battery Electric Bus, Charging Infrastructure, Operational Knowledge.*

1. Introduction

With the rapid increase in urbanization and motorization, Malaysian cities have witnessed a significant rise in the number of vehicles on the roads, leading to heightened levels of air pollution and greenhouse gas emissions. This surge in transportation contributes to the growing greenhouse effect, impacting both the environment and the quality of life in urban areas (Uddin, 2022). To address these challenges, shifting towards sustainable transportation, such as public transit, is essential for creating livable and less polluted cities. Recognizing this need, Malaysia introduced the National Automotive Policy (NAP) in 2014, which aims to establish the country as a regional hub for energy-efficient vehicles (EEVs) by 2022. This initiative is part of a broader strategy to promote a cleaner environment by reducing carbon dioxide emissions and the reliance on petroleum-based fuels. The NAP has encouraged automotive manufacturers to produce a range of EEVs, including fuel-efficient internal combustion engine (ICE) vehicles, hybrid and electric vehicles (EVs), and vehicles powered by alternative fuels such as compressed natural gas (CNG), liquefied petroleum gas (LPG), biodiesel, ethanol, hydrogen, and fuel cells (Ridhuan, Abdul Latif, Ahmad, Asat, & Mohd Noor , 2017) .

The first electric bus in Melaka to operate on the road was in August 2015. This bus route covers the Melaka Heritage Area as an initiative to promote tourism activities in Melaka (Green City Action Plan, 2020). However, due to the lack of incentives for EEVs in Malaysia, public transportation has resulted in the slow adoption of EEVs on the road. Malaysia targets 100,000 electric cars and 2,000 electric buses on the road by 2020 (Shukor, Sulaiman, Ai Chin, & Mas'od, 2018). Unfortunately, until 2018, the number of targeted EEVs on the road was still unachievable, and in 2017, Melaka had only two electric buses on the road and was still waiting for another 38.

A few criteria need to be considered before adopting an electric bus in Melaka, including battery reliability and durability. The battery acts as a power source for the bus; it stores electricity for the bus to operate efficiently (Asian Development Bank, 2014). However, there are some problems encountered with it, such as that it is heavy, expensive, easily affected by atmospheric temperature, needs longer charging time, is sensitive to overcharge or undercharge, contains toxic heavy metals, and requires different ways of disposal (Salehen, Su'Ait, Razali, & Sopian, 2017). The battery requires a large capacity to ensure its long-term performance because almost no electric bus has been proven to operate long enough to reach its estimated decommissioning date (Asian Development Bank, 2014). Batteries, therefore, require a high investment because they depend on the battery life cycle (Sclar, Gorguinpour, Castellanos, & Li, 2019).

Furthermore, the charging infrastructure plays a crucial role in the adoption of electric buses. A small number of charging stations can cause "distance anxiety" among electric vehicle users and cause them to be afraid of not reaching their destination (Panday & Bansal, 2014). Buses require a large battery capacity, yet they rely on fast charging opportunities to store large amounts of electricity for longer use (Habib, et al., 2023). Fast charging stations can provide 80%–90% battery capacity in a short time by supplying a large current flow, but they involve a higher level of charging technology, safety requirements, and charging costs than slow-charging models (Bird, et al., 2022). This requires a high cost to construct the charging station, which is one of the challenges in adopting electric buses in Melaka.

Besides batteries and charging infrastructure, operational knowledge of managing electric buses can also influence the decision to adopt electric buses in Melaka. This knowledge encompasses the battery storage, technical maintenance, and planning requirements of the electric bus infrastructure (Asian Development Bank, 2014). Before adopting electric buses, we need to equip the manufacturers and engineers with operational knowledge to minimize the current challenges and develop a product that meets the current needs (Habib, et al., 2023).

Three main challenges in adopting electric buses in Malaysia were identified and discussed in this paper, which include battery reliability and durability, a limited number of charging infrastructures, and a lack of operational knowledge. This paper is divided into four sections, beginning with the introduction and followed by the research methodology using the interview method and thematic approach in analyzing the information gathered. In the third section, findings and discussion are presented, and finally, this paper summarises and recommends ways of improvement in adopting electric buses in Malaysia. This paper focuses on two research objectives: (a) to identify the challenges in adopting electric buses, and (b) to recommend ways of improvement in adopting electric buses in Malaysia.

2. Materials and Methods

Sampling Design: In this study, the sampling design comprises both the sample size and purposive sampling. Qualitative methods often require in-depth studies or 'thick description,' which is not feasible with a large number of observations and small samples (Ghauri & Grønhaug, 2010). Furthermore, the population's dispersion or variance and the desired precision of the estimate also influence the sample size under investigation (Cooper & Schindler., 2011). As a result, this study focused on conducting in-depth interviews with a small, targeted sample to achieve the research objectives effectively. The researcher used purposive sampling in this research to conduct in-depth interviews with targeted respondents from Panorama Melaka Sdn Bhd, PTHM, MIGHT, AMDAC Sdn Bhd, and UTHM. This approach aimed to gather rich information on the agencies responsible for implementing the project to adopt electric buses to sustain public transport planning in Melaka Green City State.

In addition, purposive sampling is ideal for interview research, as the researcher requires a few key informants rather than a large sample, as long as it represents the group of respondents (Vogt, Gardner, & Haeffele, 2012). In this study, 30 respondents from five different organizations—Panorama Melaka Sdn Bhd, PTHM, MIGHT, AMDAC Sdn Bhd, and UTHM—were interviewed to validate and gain a deeper understanding of the research topic. Interviewing 30 respondents is considered a practical and acceptable number (Baker, Elsie, Edwards, & Doidge, 2012). The study included 20 to 25 open-ended questions, including probe questions for one-on-one interviews with the 30 targeted respondents. Further, for non-probability sampling techniques, the issue of sample size is ambiguous, and the sample size depends solely on the research questions and objectives (Saunders, Lewis, & Thornhill, 2016). To ensure sufficient data collection, the researcher was recommended to continue conducting interviews until data saturation was reached.

This study's chosen sampling method aimed to effectively gather knowledge and data on the challenges faced by Panorama Melaka Sdn Bhd, PTHM, MIGHT, and AMDAC Sdn Bhd in adopting electric buses, as well as the strategies to overcome these challenges for sustainable public transport planning. The researcher estimated that she would target 30 respondents before the interview sessions and divide them into two groups:

Top Management Group: This group consists of 15 respondents, including deputy chief executive officers, operation executives, R&D executives, and financial executives who are actively involved in daily supervision, planning, and administrative processes.

Middle Management Group: 15 respondents, including operation managers, technical field managers, electrical and mechanical engineers, and project and development managers.
By gathering data from the appropriate respondents who could offer insights into the challenges and strategies for adopting electric buses in Melaka, this sampling approach ensured the achievement of the research objectives.

3. Results and Discussion

Malaysia developed various incentives to promote the use of electric buses. However, the adoption rate remains below expectations. Some of the challenges found that hinder the adoption of electric buses in Melaka are high battery concerns, some charging infrastructure, and limited technical performance.

High Battery Concern: For the high battery concern, Panorama Executive 1 and Panorama Manager 2 strongly agreed that the high battery concern is one of the major challenges in adopting electric buses. This was supported by UTHM Respondent 2, who also highlighted the high battery concern as a challenge in adopting electric buses because the advancement of battery technology and its use can be further enhanced in the future. In addition, PTHM Executive claimed that *"actually, the battery for this green technology is evolving because it has the biggest impact and has a high cost. Furthermore, this battery poses the highest risk in electrical technology because it has its resistance. So, it also happened in the operations of an electric bus, as it needs well-studied battery technology when fully utilizing it on the road"*.

Besides that, from the point of view of AMDAC Manager 1 high battery concern is related to the specification of the battery itself.

"EV vehicles have three important parts that consist of the engine, motor, and battery. One of these important parts is the battery. To operate the electric bus, it must use a high-voltage battery. The minimum voltage of the battery is 460 volts, and it cannot reach below that. This is because the high-voltage battery plays a role in converting the alternating current (AC) that can operate the motor in an electric bus, as it uses the alternating current (AC) instead of direct current (DC) when operating it. Meanwhile, the voltage of the battery for the electric bus in Melaka is 640V, with a weight of 1.92 tonnes, and it consists of nine packs of the battery in a big size".

Furthermore, based on the explanation above, AMDAC Engineer 1 further explained that *"To make this concept clear, the most important thing in the capacity of the battery is that it does not rely on the size or weight of the battery, but rather on how much it can deliver or travel for each kilowatt hour (kWh) per kilometer in the battery. If the usage of conventional buses was counted on the kilometer per liter, That's how far this bus can travel if it fills up the fuel tank with 4.56 liters, around RM10. On the other hand, an electric bus uses the kilowatt hour per kilometer. This kWh refers to the energy consumption of the electric bus, and it can be influenced by three factors: the technique of driving, the rate of the bus, and traffic conditions. For example, once the electric bus is stuck in jams for three to four hours, it still cannot travel too far, and it does not change anything. Since then, the electric bus in Melaka has used 168 kWh per kilometer because the bus's capacity is too large and heavy. It can be summarised that by adding more energy to this battery technology, it could travel a long distance because the higher the battery storage, the longer the distance it can travel. Not only that, but this battery technology is also evolving from time to time, and until today, some batteries could reach up to 500 kWh per kilometer."*.

Referring to Panday & Bansal., (2014), claimed that "since the battery is one of the power sources of this clean technology on the road, it consists of a few issues, like being heavy, expensive, and generally affected by atmospheric temperature; it needs a long charging time; it is sensitive to overcharge or undercharge; and it also contains toxic heavy metals; hence, the disposal of waste becomes a challenge." Other than that, another study found that the high battery concern also includes the limited mileage offered by the batteries as well as the inability to charge the batteries with the frequency needed, which hinders the acceptability of EVs (Adnan, Nordin, & Rahman, 2017).

Based on the respondent's opinions from Panorama Melaka, UTHM, and AMDAC, the high battery concern is one of the challenges in adopting electric buses because this battery technology evolves too fast from time to time, and it is still in the development phase, where until today it is so hard to prove finding the best battery in terms of its lifetime, price, and weight. Besides that, this electric bus is fully powered by the battery to operate, and choosing the best battery will significantly affect the travel range that might be earned by the electric bus while it is operated on the road. Therefore, the researcher also concludes that with regards to battery capacity, the energy consumption of an electric bus can be influenced by three factors: the technique of driving, the rate of the bus, and traffic congestion, which relatively perform the electric bus to deliver the longer distance to travel with.

Limited Number of Charging Infrastructure: PTHM Executive agreed that the small number of charging stations led to the challenges of electric bus adoption towards sustainable public transport planning.

"The charging station for electric buses is not like an electric car charging station, where it can be centralized in a certain area. Therefore, we manage the route of the electric bus during its operation on the road. It means that if this electric bus can travel up to 120 km with a full charge, then it will be arranged to travel on a short route that is up to 80 km per trip only so that it can recharge again at Melaka Sentral and avoid traveling to long-distance areas at the same time" (PTHM Executive).

In further analysis, AMDAC Engineer 2 acknowledges that the deficiency of charging stations certainly contributes to the challenges of adopting electric buses because this green fleet used its charging station instead of using the public charging infrastructure. The electric bus is public transportation that uses a dedicated charging station; in fact, it is not a private vehicle. Besides that, the respondent also added that there is a different amount of usage current to plug in the charger, where the public charger for an electric car allocates a maximum current of 30 amps, whereas the electric bus in Melaka uses a maximum current of 250 amps. Hence, the respondent clarifies that this electric bus is not suitable for using the public charger. On the other hand, Panorama Executive 3 admitted that the limited number of charging infrastructures is because of the high cost of building them.

"The problem that we faced when expanding this charging infrastructure was the cost of building it, as it is very expensive. This is because one slot charging station costs around RM50,000. After all, the charger nozzle itself costs up to RM30,000, even though it is a fast charging station. I admit it is so pricey to build one charging station." (Panorama Executive 3).

The limited number of charging stations generates "range anxiety" among users of electric vehicles and causes them to fear not reaching their destination (Wu & Niu, 2017). In addition, based on research by Hardinghaus, Blümel, & Seidel, (2016), the deficiency of the public charging infrastructure, in combination with its limited range, is a crucial barrier to electromobility. Moreover, Pelletier, Jabali, & Laporte., (2014) clarify that the number of electric recharging stations is still very small compared with conventional fuel stations; hence, the limited range of EVs becomes a critical constraint in purchasing and operational decisions. The charging infrastructure scheme also generally comprises slow-charging and fast-charging models, as they differ due to the type of electric bus. Correspondingly, Fang, Ke, & Chung., (2017) claimed that the fast-charging model can provide 80%–90% battery capacity in a short time by supplying a substantial amount of current; however, it involves a higher level of charging technology, greater safety requirements, and higher charging costs than the slow charging model does. Thus, Karl, (2021) verified that the public charging infrastructure is rather expensive to install, and major public investments seem required as long as viable business models are absent. The researcher acknowledges that the limited number of charging infrastructures is a critical challenge in adopting electric buses because the PTHM Executive notes that, due to the implication of a lack of charging infrastructure, it encourages the operator of electric buses to be selective in the short route of operation to overcome the range anxiety that might be faced by this electric bus when operated on the road. Moreover, increasing the number of charging infrastructures for electric buses, definitely incurred a high cost. Therefore, the researcher concludes that since this electric bus is still a new green technology operated on the road with a small quantity of its arrival, the location to install this charging facility is also limited because of its resources and funding factor. Hence, it can be summarised as a concrete reason that Malaysia still has a limited number of charging infrastructures for electric buses.

Limited Technical Performance: In this regard, the MIGHT Vice President strongly agrees that limited technical performance is a challenge in adopting electric buses in Melaka. This is because MIGHT Vice President has been highlighted as:

"This limited technical performance is usually connected with the operation of electric buses. The electric bus in Melaka is imported from China, where, as we know, China is declared a four-season country. This electric bus consists of a compressor that provides the sensor temperature. Since the electric bus was manufactured in China, basically the trial is being done there, but once it arrives in Malaysia, it meets the limited technical performance requirements to operate this electric bus on the road. This is because Malaysia has an equator climate, which consists of high humidity and temperature, and at the beginning of its operation, it affected the compressor of the electric bus. It can be said that the electric bus depends on its air compressor to ensure smooth operation on the road" (MIGHT Vice President).

Apart from that, AMDAC Manager 1 supported the view from the MIGHT Vice President that, along the process of operating an electric bus in Melaka, they need to comprehend the suitability of its operation with the weather and road conditions in Malaysia. Since it has become a challenge to operate an electric bus, AMDAC Sdn Bhd has used a variety of data collection methods to analyze whether this electric bus is compatible with the weather and road conditions in Malaysia or not. The respondent also elaborated that, until now, the requirement to adjust the temperature and air compressor of the electric bus is still in the struggling phase because it is interrelated with the environment and humidity due to the equator climate of Malaysia. In addition, these challenges also led AMDAC Sdn Bhd to create its research team to study the preferences and requirements of customers regarding this electric bus. For example, the Government State of Melaka requested to have an electric bus that can cover its twenty-seven routes in Melaka, including its top routes at Ujong Pasir, Melaka Sentral, and Dataran Pahlawan. Melaka consists of three parts of the route, which are categorized into town, congested, and rural regions. To fulfill the requirement of the Government State of Melaka, the respondent research to select the best bus that can cover all the routes that have been mentioned by the Government State of Melaka. Besides that, in support of the above statement, Panorama Executive 1 has another perspective that remarked that this limited technical performance is being categorized as one of the biggest challenges in adopting electric buses. This is because there are also a limited number of people in Malaysia who have been recognized with approval certificates to be able to handle and solve the technical problems of electric buses. The first one comes from BYD's staff, and the second is the Technical Field Manager from AMDAC Sdn Bhd.

Based on the research by Sakhnevych, et al., (2021), environmental conditions are one of the issues in EV range estimation. When it rains, it has been observed that the rolling resistance of a tire on a wet road is increased by up to 10% when compared to that on a dry road surface. Furthermore, in rainy weather, windscreen wipers and possibly window demisting are required. Moreover, Wang, Lu, Wang, Chenyu, & Wang, (2020) also reveal that the battery temperature can have a significant impact on the effective capacity of a battery cell. In addition, the requirement to maintain the temperature in the vehicle cabin to make it comfortable for the passengers is also being considered. The heating and air conditioning loads can significantly affect the total energy used during a trip. Other than that, it has been observed that the technical issues consist of failing batteries (and limited or late) support, equipment availability issues, quite long charging times, and the necessity to adapt charging infrastructure for fleet needs. Hence, "the maximum power flow between the electric vehicle and the power grid, which depends on the line power capacity of the charging infrastructure, shows that the power level of charging will also affect the duration of charging cycles" (Das, Rahman, Li, & Tan, 2020).

According to the perspective of the respondent's MIGHT and AMDAC, it is mentioned that the limited technical performance is one of the challenges in adopting electric buses. The researcher found that this technical performance led to limitations in environmental conditions, and unstable temperatures certainly affected the range estimation and energy used during the operation of electric buses on the road. Since Malaysia is located in an equatorial climate, the requirement to frequently adjust and overcome technical problems is in high demand due to the suitability of the weather and road conditions in the Melaka context area. Thus, the researcher concludes that this limited technical performance will be a critical challenge in adopting electric buses because, based on the observations, it will bind towards the technical issue that might shut down the viable electric bus operating system.

4. Conclusion and Recommendations

Despite the various incentives and efforts made to promote the use of electric buses in Malaysia, their adoption remains at an unsatisfactory level. The research conducted on the adoption of electric buses in Melaka has identified several critical challenges that need to be addressed to ensure the successful implementation of this sustainable transportation technology.

One of the primary challenges identified is the concern over battery technology, which includes issues such as battery capacity, cost, and the rate of technological advancement. Respondents from Panorama Melaka, UTHM, and AMDAC emphasized the evolving nature of battery technology, noting that the high costs and risks associated with current battery options present significant barriers to adoption. The Panorama Executive highlighted that the battery's resistance and the need for comprehensive studies on battery technology are critical for the effective operation of electric buses. Additionally, the AMDAC engineer pointed out that the efficiency of the electric bus is dependent on how the battery's capacity is utilized, especially in terms of energy consumption per kilometer. This challenge is exacerbated by the current limitations in battery technology, which impact the operational range and efficiency of electric buses.

Another significant challenge is the limited number of charging stations available for electric buses. Unlike electric cars, electric buses require dedicated charging stations due to their higher voltage and current requirements. The PTHM Executive and AMDAC Engineer noted that the scarcity of charging stations necessitates careful route planning to avoid range anxiety and ensure the buses can complete their routes without interruption. The high cost of building charging infrastructure, as highlighted by Panorama Executive 3, is a considerable obstacle, with each charging slot costing approximately RM50,000. The lack of charging infrastructure not only hinders the expansion of electric bus routes but also affects the overall feasibility of integrating electric buses into the existing public transportation system.

The limited technical performance of electric buses, particularly concerning their adaptation to the local climate and road conditions, is another critical challenge. The Vice President of MIGHT and AMDAC Manager 1 highlighted that the electric buses, mainly imported from China, necessitate substantial modifications to function efficiently in Malaysia's equatorial climate. Barriers to the seamless operation of electric buses include issues like air compressor performance, battery temperature management, and the need for frequent technical adjustments. The technical expertise required to manage and maintain these buses is currently limited, with only a few individuals possessing the necessary certifications to handle technical issues. This limitation poses a significant challenge to ensuring the reliability and efficiency of electric buses in Melaka.

The challenges identified in the adoption of electric buses in Melaka highlight the need for comprehensive strategies to overcome these barriers. To address the high battery concerns, continuous research and development are required to enhance battery technology, focussing on improving capacity, reducing costs, and increasing durability. Investment in charging infrastructure is crucial to support the operation of electric buses and alleviate range anxiety among operators and users. Additionally, adapting the technical specifications of electric buses to suit local environmental conditions and increasing the availability of technical expertise are essential steps towards improving the performance and reliability of electric buses.

In conclusion, while the adoption of electric buses in Melaka presents significant challenges, it also offers opportunities for innovation and sustainable transportation development. By addressing the identified challenges through targeted investments and strategic planning, Melaka can enhance its public transportation system and contribute to the broader goals of sustainable urban development in Malaysia.

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