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Charging Ahead: Statistics on Electric Vehicle Charging Station Allocation and Uptake Trends in Malaysia

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ABSTRACT

The emergence of electric vehicles (EVs) is attributable to the accessibility of charging stations, which is essential in reducing EV drivers' range anxiety. EV batteries need to recharge after a certain number of miles driven. As a result, for EVs to be widely deployed, a sustainable charging station must be constructed. The National Electric Mobility Blueprint (NEMB) states that Malaysia's primary goal is for the nation to become the marketing hub for the EV industry by 2030. By 2030, Malaysia reportedly expects to have 125,000 electric vehicle charging stations (EVCS). EVCS are available in many types, each with different charging capabilities and speeds. The most popular EVCS are slow charging stations, fast charging stations, battery swap charging stations, and wireless charging stations. The type of EVCS is discussed in this study, particularly from the perspectives of Malaysia. The mechanisms, advantages, disadvantages, and associated issues of these EVCS are thoroughly discussed. Furthermore, to reduce range anxiety among EV users and enhance EV adoptions in Malaysia, several criteria are considered in determining the suitable location for Photovoltaic Electric Vehicle Charging Stations (PEVCS). For future studies, all the selected criteria will be calculated using Multi-Criteria Decision-Making (MCDM) methods.

Keywords: Electric vehicle, Electric Vehicle Charging Station, Photovoltaic Electric Vehicle Charging Station, criteria, charging station, Malaysia.

1 INTRODUCTION

Electric vehicles (EVs) gain widespread acceptance as the world moves towards a more sustainable future because of their positive environmental impacts and the advancement in technology. To guarantee the mass acceptance and practicality of EVs, a capable charging station (CS) is necessary. Electric vehicle charging stations (EVCSs) are essential for EV owners to recharge their vehicles easily and effectively. EVCS must be available to supply the energy required for EVs to drive long distances [1]. According to [2], CSs are fictional of one or more charging points, then the collection of CSs is called a charging pool.

The CS is essential for electric vehicle users who feel anxious about charging their vehicles while driving. The CSs can be set up into three categories according to their connection to the grid,

connected to the public electrical system, or direct connection to renewable energy sources (RES) [3]. The CSs are usually located at home as well as in public places such as petrol stations, shopping malls and so on. Then, [4] mentioned the energy that is transmitted to the battery of an electric vehicle must be provided and controlled by CSs.
Furthermore, this paper studies trends and development of EVCS especially from Malaysia's perspective. Malaysia has endorsed the Malaysian Standard International Electrotechnical Commission (MS IEC 61851) and Society of Automotive Engineers (SAE J1772) as guidelines for conductive connection charging of EVs. Based on [5], MS IEC 61851 defines four different modes of electric vehicle conductive charging in Malaysia and there are three levels of EV charging according to SAE J1772. The development of EVCS in Malaysia is increasing rapidly from year to year as the adoption of EVs becomes more popular. However, there is still minimal allocation for fast CSs, none of the battery swap CSs and wireless CSs are placed in Malaysia. Malaysia should move faster and establish battery CSs and wireless CSs to overcome the range anxiety towards EV users. Then, this paper is organized as follows: Section 2 discusses the types of EVCS such as slow CSs, fast CSs, battery swap CSs, and wireless CSs. The discussion of trends and developments of EVCS in Malaysia appears in Section 3. Finally, the authors conclude the paper in Section 4.

2 TYPE OF ELECTRIC VEHICLE CHARGING STATION

EVCS are available in many types, each with different charging capabilities and charging speeds. The most popular EVCS are slow CSs, fast CSs, battery swap CSs and wireless CSs. The types of EVCS are summarized in Table 1.

2.1 Slow Charging Stations

Slow charging stations (CSs) include Level 1 and Level 2 charging categories. Alternating Current (AC) power supply and Type 2 connection are commonly used in slow CS. Slow charging is frequently associated with overnight charging, and this straightforward definition corresponds to six to eight hours intervals [6]. One of the benefits of slow CSs with longer park durations and extended charging may result in savings on the cost of the charge [7], [8]. The major problem with slow CSs is the time for charging is too long and cannot be fulfilled the users' demands [8] and [9] stated EV users are less likely to wait which long at an uncomfortable location. Hence, the slow CSs only supply 3-35 kW and take 5-8 hours to fully charged [8], [10], [11].

Moreover, Sutopo et al. (2019) mentioned the battery types for slow CSs are Pb-Acid, Ni-MH, Li-ion and ZEBRA [11] and used only 8-15A current [8], [12]. On top of that, slow CSs are often done in the garage or residence of the car owner, at public CSs in commercial or shopping districts, or at parking lots at work if businesses provide such chances to their workers.

2.2 Fast Charging Stations

Level 3 and 4 charging categories mainly include fast charging stations (CSs). Fast CS often employs a direct current (DC) power source, such as CCS 2 and CHAdeMO connectors. Fast CSs considered essential for EV owners to charge their EV batteries in a short time frame, so the fast CSs can lead to the growth and enhancement of batteries, resulting in driver satisfaction [13]. Owing to that, FCSs have 70-400 A of current, 50-350kW of power and take within 20 minutes to two hours s to fully charged [10], [11], [14], [15]. Moreover, they considered that FCSs were ideal for allocation at CSs, service stations, petrol stations and so forth. [16] also agreed that a convenient fast CS is in a big town, on a major highway, and offers a variety of amenities (such as restaurants and stores).

However, the FCSs also have several challenges with their high charging power and potential for significant damage and interference on the power grid, so FCSs must be operated, supervised, and maintained by qualified personnel [8]. [17] also thought that high charging rate batteries, high power charging infrastructure, and grid impacts are the key technological challenges in the development of fast CSs.

2.3 Battery Swap Charging Stations

Battery swapping is the technique used to replace an electric vehicle's depleted battery with a new one that's fully charged [18]. [19] mentioned that battery swap charging stations (BSSs) are replacing a used battery that has drained below the specified state-of-charge (SoC) level with a new and fully charged one to support electric vehicles. Their studies also elaborate on the techniques of BSSs as sideways, rear, bottom, and top swapping. According to [20], the battery swap CSs techniques are categorized into two groups: withdrawable and chassis type. The withdrawable type refers to battery loading and unloading and can handle from the side or rear of the vehicle. However, the chassis type executed it from the top or bottom of the car.

From [19], sideways swapping is typically used with vans and other vehicles since it is most easy to drive them sideways, while rear swapping is often employed by vehicles with significant trunk space because the battery is inserted from the backside. The bottom swapping applies to vehicles whose battery is installed at the bottom of the vehicle. Top swapping is commonly used for electric buses as the batteries are placed on the top. So, when the electric bus arrives, the rooftop opens, allowing the robotic arm to execute the battery exchange. Battery swap CS should construct around a battery swap CS warehouse, which serves as a location for the maintenance, testing, and storage of backup battery packs within a 15-20 km range [21]. Besides, [11] discussed the benefits of battery swap CSs which take less time because the battery's capacity is recharged in less than 1 minute, unlimited driving range, not required to exit the vehicles and battery conservation is not the user's responsibility. Unfortunately, there are still high costs and no battery standards [8], [11].

2.4 Wireless Charging Stations

According to [22], a wireless charging station (WCS) refers to a particular kind of electric vehicle (EV) that charge via Wireless Power Transfer (WPT) technology, which transmits electricity without requiring any physical touch. A wireless magnetic link between the EV and the coils installed on the road enables EVs to charge using wireless power transfer (WPT), a technology [23]. Thus, [8] described three techniques of wireless CS: electromagnetic induction charging, magnetic resonance charging, and radio wave charging. This charging technology relies on the magnetic connection of two inductively linked coils, the primary coil connected to the power grid and the secondary coil connected to the battery, an electromagnetic induction charging [8], [24]. However, magnetic resonance charging often consists of devices that transfer and receive energy and radio wave charging uses a microwave launcher and receiver [8].
Therefore, the three categories of WCS for EVs are stationary, quasi-dynamic, and dynamic. From [22], stationary WCS means that the EV is charged while parked and out of service for a lengthy period in a fixed location, such as a parking lot. A quasi-dynamic WCS is the charging occurs while the EV is driving at a low speed, either decelerating to or accelerating from a state of rest. The

dynamic WCS is the EV gets charged while the vehicle moves at full speed. [25] stated that the power of wireless CSs is within 0.06 – 60 kW depending on wireless CSs technology companies such as Qualcomm halo, WiTricity EV, PATH and so on. Depending on the size of the battery pack, charging periods vary, but it's generally regarded sufficient to have the battery fully charged in 4–6 hours [26].

According to [8], underground parking spots or highway roads [27] were where drivers would find wireless CSs. Thus, the entire system includes a charger, a launching pad, and a receiver placed on the vehicle chassis. Moreover, there will be less wire clutter, more parking spaces are accessible, and the requirement for various adaptors will no longer be necessary, which is the main benefit [28]. The advantages of using wireless CS are security [8], [11], user friendly and the battery can often charge throughout the day if the charging process takes place while the car is moving [24]. Wireless CS is considered environmentally and user-friendly because cables, mechanical connectors, or other infrastructure are not required [29]. However, the challenges of wireless CS are less energy efficiency, high cost, the difficulty of the design, and the problem with magnetic field exposure [11], [24].

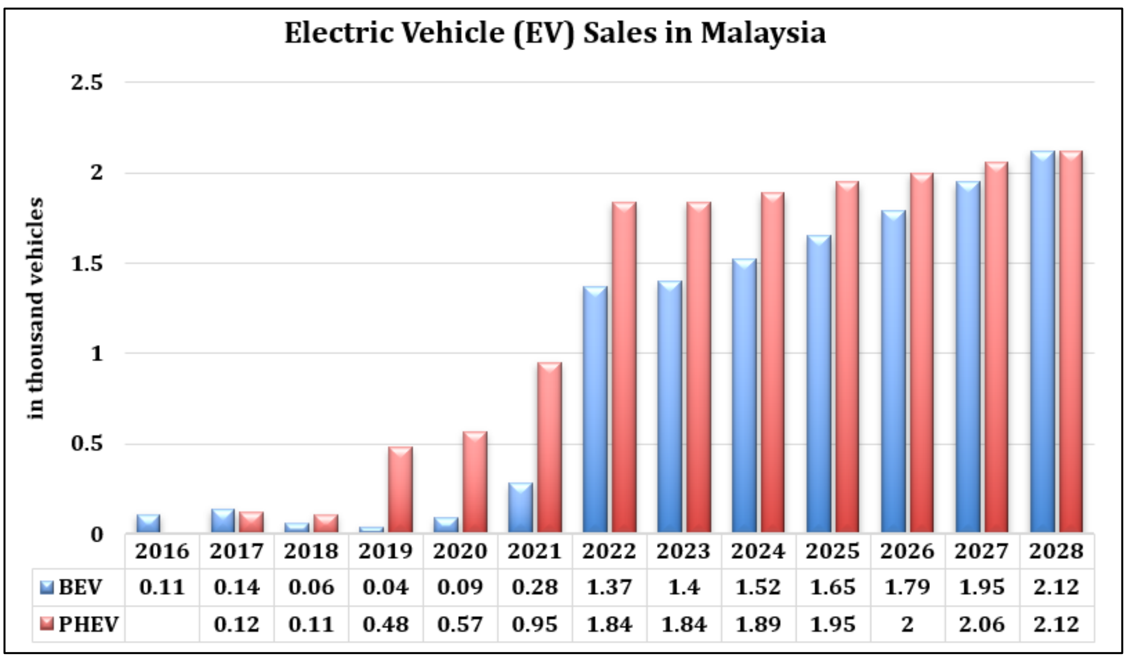
Table 1: Summaries the types of EVCS.

	Slow Charging Stations	**Fast Charging Stations**	**Battery Swap Charging Stations**	**Wireless Charging Stations**
Current	8 - 15 A	70 - 400 A	-	-
Power	3 - 35 kW	50-350 kW	-	0.06 – 60 kW
Period	5 - 8 hours	20 minutes – 2 hours	Less than 1 minute.	Depend on size of battery pack.
Recommend location	Home, public CSs in commercial, parking lots at workplace.	CS, service stations, fuel stations.	Proximity to battery swap CS warehouse.	Underground parking spots, highway roads.
Benefit	Cost saving.	Less charging time.	Less charging time, unlimited driving range, not required to exit the vehicles and battery conservation.	Secure, user-friendly, battery can often charge throughout the day if the charging process takes place while the car is moving

Challenge	Long charging time.	High charging rate batteries, high power charging infrastructure, potential for significant damage and interference on the power grid.	High cost, no battery standards.	Less energy efficiency, high cost, the difficulty of the design, the problem with magnetic field exposure.

3 RESULTS AND DISCUSSION

By 2030, Malaysia goals to have 125,000 EVCS, including solar EVCS, and 100,000 electric vehicles on the road [30]. The forecast data from [31] in Figure 1 and Figure 2 showed that by 2028, EV sales are gradually increasing and might be reached 2,120 EVs on the road. The same goes for EVCS in Malaysia is expected to install around 1,160 CSs in 2027. So, to achieve those goals, the government, policymakers, and any stakeholders should have strategic planning to enhance the widespread of EVs adoption among Malaysians.



	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
BEV	0.11	0.14	0.06	0.04	0.09	0.28	1.37	1.4	1.52	1.65	1.79	1.95	2.12
PHEV		0.12	0.11	0.48	0.57	0.95	1.84	1.84	1.89	1.95	2	2.06	2.12

Figure 1: Electric vehicle (EV) sales in Malaysia [31].

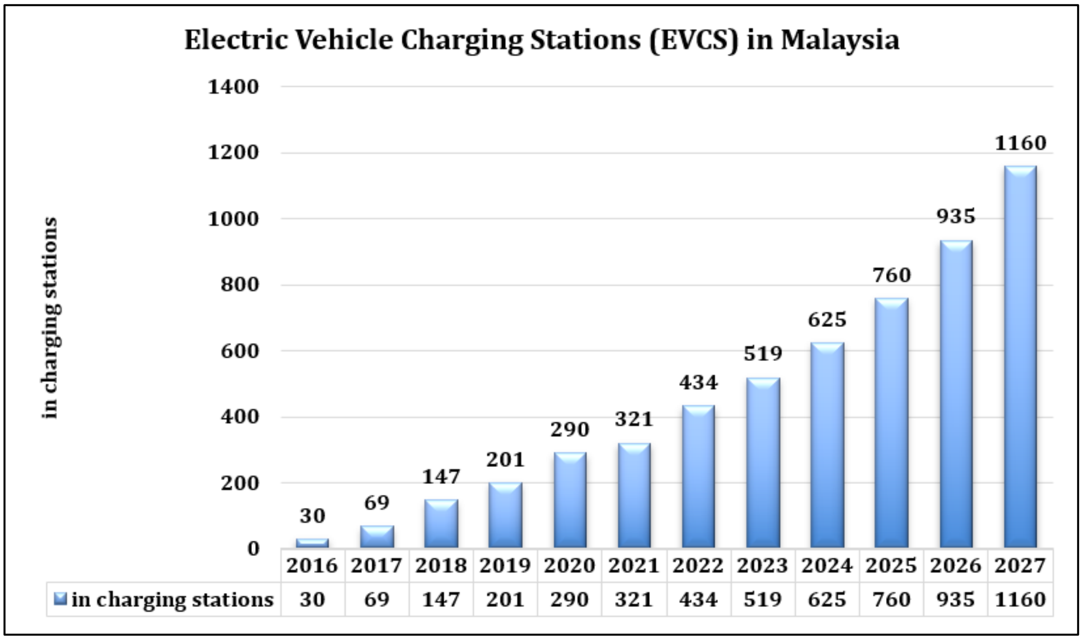


Figure 2: Electric vehicle charging stations in Malaysia [31].

Moreover, according to the Ministry of International Trade and Industry (MITI), Malaysia is scheduled to offer up to 4000 EVCS this year. Additionally, Datuk Phang Ah Tong, chairman of the Malaysia Automotive, Robotics and IoT Institute (MARii), mentioned the standards for the EV industry are being developed. In order to guarantee that the EV technology utilized and produced in this country is thorough, safe, and of high quality, Phang stated that standards linked to the EV sector are also being established. These standards are related to charging systems, battery disposal activities, battery swapping, wireless charging, and other topics [32].

From [31], there are 519 EVCS in Malaysia including slow CSs and fast CSs. The long recharge time, range anxiety, and battery lifetime management are major difficulties with utilizing EVs, so Ecosystem Sdn Bhd has developed battery-swapping technology, yet only for electric motorcycles [33]. The barriers include the lack of an EV market in Malaysia, which means there is no demand for BSS, and 65.7% of respondents had no prior knowledge of the battery-swapping technology, indicating a lack of public understanding [21]. Thus, there are no battery swap CSs and wireless CSs in Malaysia.

Furthermore, [18] mentioned it is important to understand how far and at what level in the development of this technical progress before the technology can be adopted and employed by users. On top of that, [34] concluded that the needs of EV users are considered when deciding the type of charging station. EV users will choose a slow CS if their daily or weekly driving distance is 50 km or less, and a fast CS if their long-distance travel is between 100 and 200 km.

Obviously, every country has an application that allows users to search for the nearest charging station throughout their route. Malaysia is, too. The most popular EV charging applications in Malaysia include JomCharge, chargEV, Go-To-U, Setel, PlugShare, Agmo EV, Shell Recharge, and others. In addition, this study discovered the following comparison of EV charging rates. Most EVCS in Malaysia bases their charging fees on how long it takes to charge an EV as follows in Table 2.

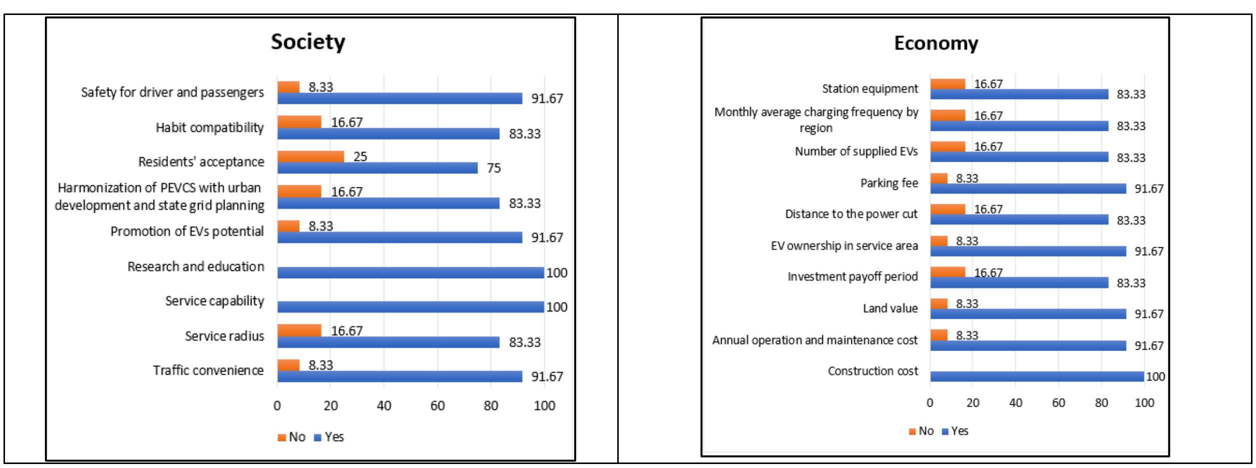
However, a few CSs also cost EV drivers following the battery power capacity of a vehicle. In this regard, the EVCS deployed on PETRONAS charges RM1.00 per kWh for EV customers utilizing a CCS 2 connector with a 120-kWh power supply. From this perspective, recharging an EV at EVCS that charges based on battery power capacity are better than the charging time because of more cost-effectiveness. Moreover, the optimal time to charge an EV is during off-peak hours, particularly at night when rates for electricity are lower because of the advantages of low tariffs and convenience [6], [11].

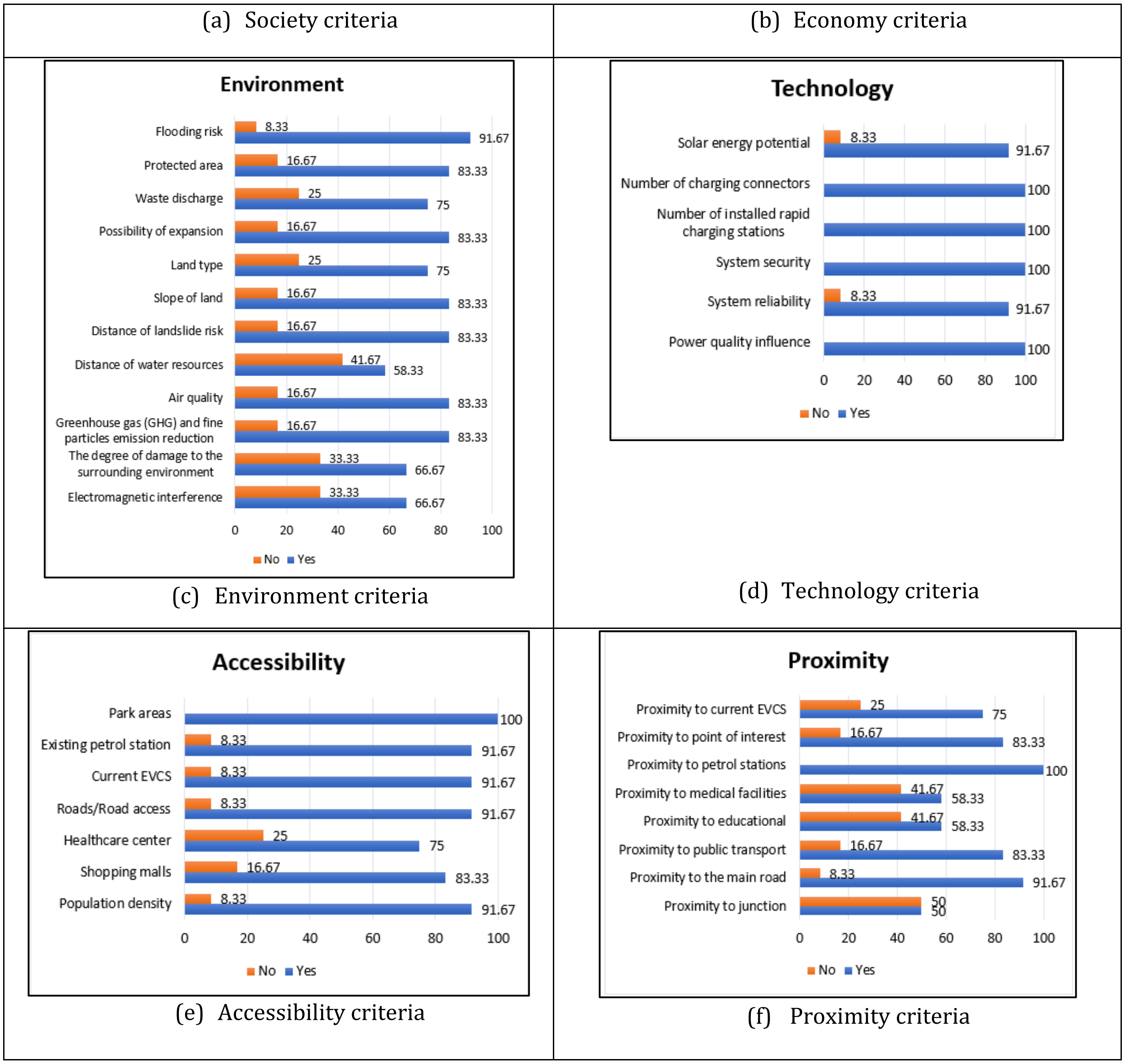
Table 2: Price rate of EVCS in Malaysia.

Connector	Charger	Power supply	Price rate
Type 2	AC	3.7 – 22 kWh	RM0.15 – RM1.20 per minute
CCS 2	DC	30 – 180 kWh	RM0.40 – RM3.00 per minute
CHAdeMO	DC	20 – 60 kWh	RM0.50 – RM1.20 per minute

Moreover, the analysis of forecast data on EVCS usage underscores the vital imperative to install photovoltaic EVCS (PEVCS) to expedite the shift towards more sustainable transportation options and alleviate the impacts of climate change, considering a range of criteria. However, deployment of PEVCS promotes a greener transport infrastructure, leading to lower greenhouse gas emissions. To determine the appropriate sites for PEVCS in Malaysia, this study integrated a survey-driven methodology as a key component of the Need Analysis, aimed at identifying and evaluating the essential criteria for the installation of PEVCS in this country.

In this study, a total of 41 sub-criteria were selected in Need Analysis, categorized into society (8), economics (10), environment (7), technology (6), accessibility (6), and proximity (4). Only the criteria that received an agreement of 80% or higher during the initial Need Analysis were preserved for the current stage of the study. Of these, 9 criteria were fully endorsed, 15 obtained an agreement of 91.67%, and 17 garnered 83.33% approval. Owing to discrepancies among respondents, the remaining criteria were excluded from the scope of this study. The depicted results from the Need Analysis are illustrated in Figure 3.





(a) Society criteria

(b) Economy criteria

(c) Environment criteria

(d) Technology criteria

(e) Accessibility criteria

(f) Proximity criteria

Figure 3: The results from the Need Analysis.

Accordingly, the significance or impact of an individual's decision or action on the well-being, values, and behavior of a community or society as a whole is known as the society criteria. In the context of allocating PEVCS in Malaysia, considerations under the main criteria of society highlight the necessity of strategically situating these CSs. For instance, the criteria of service capability and research and education emphasize the importance of their consideration in determining the ideal sites for PEVCS in Malaysia. To meet the charging demands of diverse EV users across the country, it is essential to ensure the preservation of service capability [35]–[37]. Additionally, strategically allocating PEVCS at research and education institutions can play a vital role in fostering EV adoptions, particularly among the educated populace [38].

Meanwhile, economy aspect focuses on the financial or economic implications of a decision or action in installing the PEVCS in Malaysia. As can be seen, construction costs are a key consideration under the economy criteria. It is critical for the long-term deployment and growth of charging infrastructure to ensure that the construction expenses of the PEVCS remain feasible and within budget. The construction cost of PEVCS includes land costs, infrastructure costs, investment costs, demolition costs, and power distribution facility costs and it is also advantageous if PEVCS are integrated with transportation facilities [35], [36], [39]–[51].

Furthermore, it would be necessary to assess the overall environmental benefits, carbon footprint, and sustainability of the charging infrastructure concerning the installation of PEVCS. Efficient management of PEVCS distribution could support sustainability and resilience in dealing with environmental challenges by prioritizing the evaluation of flooding risks under the environment criteria. Hence, it is crucial to identify locations for the charging infrastructure that are not vulnerable to flood-related hazards, considering the country's susceptibility to periodic heavy rainfall and potential flooding [52].

Another key point is when determining the ideal location for PEVCS, it is necessary to evaluate the technological viability, efficiency, and compatibility of the charging infrastructure. This involves considering charging speeds, model compatibility, and integration with smart grid technologies. Given the dynamic nature of technological advancements, the assessment should incorporate several criteria, including power quality influence, system reliability, system security, number of installed rapid CSs, number of charging connectors and solar energy potential. Thus, the allocation of PEVCS can be managed to meet the diverse requirements of Malaysia's EV market by considering these technological factors. This approach facilitates the fostering of an impressive and future-oriented charging network.

Besides, the accessibility elements refer to the charging infrastructure's overall public accessibility, including considerations of location convenience, ease of use, and inclusivity for various user groups, including those with impairments. In this context, PEVCS should be located at strategically placed sites that are easily accessible for EV users. For example, the placement of PEVCS in park areas not only provides quick access for electric vehicle (EV) users, but also stimulates the adoption of sustainable mobility practices within recreational and social areas. Also, the high concentration of vehicles in parking garages positions them as a prime destination for EV users [38], [46], [47], [53]–[57].

Moreover, in the context of PEVCS deployment in Malaysia, it is essential to examine the proximity of the charging infrastructure to key locations such as residential districts, commercial facilities, and transportation corridors, ensuring convenient access and comprehensive coverage for EV users. In Malaysia, the allocation of PEVCS places significant emphasis on proximity, particularly concerning the main road and petrol stations. To enhance the overall accessibility and visibility of the charging infrastructure, it is essential to strategically install the PEVCS near major roads, providing quick access for EV users [46], [55], [58], [59]. Moreover, situating the PEVCS proximity to petrol stations can encourage the adoption of alternative fuels and facilitate the seamless transition of conventional vehicle owners to EVs [47], [58]–[60].

By all means, several crucial criteria should be considered when establishing the criteria for selecting suitable locations for PEVCS in Malaysia, particularly for fast CSs, battery swap CSs, and wireless CSs. Society, economy, environment, technology, accessibility, and proximity aspects should be taken into account during the allocation of suitable sites for charging stations, aiding in meeting the diverse demands of Malaysia's EV industry and advancing the development of a comprehensive charging infrastructure.

4 CONCLUSION

EVs are becoming more prevalent due to their environmental impacts and advancement in technology. The availability of powerful CSs is essential for EVs to be widely embraced and accepted. EVCSs are necessary for EV users to recharge their vehicles quickly and efficiently. In the EV market, there are four different types of EVCS: slow CSs, fast CSs, battery swap CSs, and wireless CSs. Type of CSs available in Malaysia are slow CSs and fast CSs. While battery swap CSs and wireless CSs are not currently accessible in Malaysia, it is looking forward to that regarded investors or businesses would install both. It is because battery CSs and wireless CSs offer several advantages over fast CSs and snow CSs, such as time savings, user-friendliness, and secure operation. This study predicts that the inclusion of battery swap CSs and wireless CSs, as well as the advancement of rapid CSs, would further encourage the transfer from ICE vehicles to EVs in Malaysia. Additionally, the incorporation of PEVCS should be considered, providing the benefit of clean energy utilisation and sustainable charging infrastructure, thereby promoting greater awareness, and understanding of the benefits of EVs and contributing to the alleviation of range anxiety among potential users. In forthcoming study, the identified criteria will be evaluated utilizing Multi-Criteria Decision-Making (MCDM) approaches to identify appropriate sites for PEVCS in Malaysia.

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