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TOPICAL REVIEW

Social Acceptance and Preference of EV Users–A Review

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ABSTRACT Electric vehicles (EVs) are drawing increasing attention, given the volatile fuel prices and impending reduction in fuel supplies. EVs are also preferred in the automotive industry as they reduce the environmental impact and fuel consumption while achieving a higher efficiency when compared to internal combustion engine vehicles (ICEVs). Although most of energy and environmental policies worldwide have set targets with the goal to shift from classic fossil fuel driven vehicles to electrified transport, the share of EVs is still rather low. The complexity of changing the human perception of transportation goes beyond technical and economic aspects and very few research activities managed to capture the additional factors. This paper presents a comprehensive review of studies on consumer preferences for EV, aiming to better inform policy-makers and give direction to further research. In addition, this paper discusses the main obstacles that limit the social acceptance in adopting EVs such as driving obstacles, charging obstacles and willingness-to-pay from consumers. Furthermore, mitigation strategies are outlined as the recommendation to promote a better EV deployment.

INDEX TERMS Driving behavior, electric vehicles, electric vehicle policy, energy, social acceptance, user preference.

I. INTRODUCTION

The increase of carbon dioxide (CO2) emissions has led to the global warming phenomenon. In 2020, the global CO2 emissions dropped by 5.8% (nearly 2 Gtonne CO2), which was the largest decline that followed the global financial crisis. CO2 emissions fell in 2020 mainly due to the COVID-19 pandemic hitting the global demand for fuel. Despite the decline in 2020, global energy-related CO2 emissions remained at 31.5 Gtonne, which contributed to CO2 reaching its highest ever average annual concentration in the atmosphere of 412.5 parts per million in 2020 – around 50% higher than when the industrial revolution began [1]. Nevertheless, the global energy-related CO2 emissions are projected to rebound and grow by 4.8% as demand for coal, oil and gas rebounds with the economy in year 2021. The increase of over 1500 Mtonne CO2 would be the largest single increase since the carbon-intensive economic recovery from the global financial crisis more than a decade ago. It leaves global emissions in 2021 around 400 Mtonne CO2, or 1.2%, below the 2019 peak [1]. Therefore, many countries have resorted to reduce the global warming phenomenon by increasing the reliance on renewable energy sources.

In the last few decades, the ICEVs had dominated the transportation market. However, the toxic emissions from ICEVs which caused air pollution problem had threatened

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human life and the environment. Additionally, the fuel depletion also imposed a crisis to the ICE transportation industry. Hence, the introduction of EVs creates an opportunity to resolve both issues. With the increased interest in environmental issues including greenhouse gas emissions, a number of nations and manufacturers have started paying more attentions to EVs deployment [2]. Developing appropriate environmentally-friendly vehicles will reduce the urban population's dependence on ICEVs [3]. One crucial reason to the rising popularity of EVs is the increasing level of public awareness on environmental issues. A more informed public leads to a stronger demand for changes that can reduce health risks.

The successful adoption rate by the public depends upon two factors, which are the performance and the cost of EVs. In initial introduction of EV to the market faces high competition as the cost is high. Thus, Hybrid Electric Vehicle (HEV) was introduced. HEV combines an ICE and an electric motor [4], as the battery for this type of vehicle is charged when the car is decelerated. HEVs are more economical and efficient compared to conventional vehicles [5]. One of the most common HEVs is Toyota Prius [6]. As the cost of EV dropped, the global sales of EVs increased very quickly in 2020. The EV sales increased by 43% to more than three million vehicles, despite the decline in total sales of conventional cars by a fifth during the Covid-19 pandemic [7]. Tesla Model-3 was the world leader in electric car sales, selling about 500,000 cars [8], followed by Volkswagen. Sales of EVs doubled in Europe, pushing the European Union to second place after China in the list of electric car sales. This is a particularly attractive alternative since power generation is moving towards clean renewable energy sources and thus, the negative ecological impact of EVs compared with conventional vehicles is expected to be significantly improved.

The US National Resources Defense Council has found that EVs can solve environmental pollution, thus encouraging car manufacturers to develop EVs and provide them to the local and global markets [9], [10]. EVs are powered by electric energy which can be obtained from renewable energy sources such as wind, water and solar energy, thus preserving the environment from pollution. Although EVs are a promising solution for future transportation systems, the mass distribution of EVs can be challenging. This is due to several limitations and technological differences [11]. For example, the high cost of EV batteries prevents these vehicles from being widely adopted [12], [13]. Meanwhile, restrictions on battery capacity and vehicle weight constitute another barrier to the marketing of EVs [14]. In addition, the lack of EV charging infrastructure also limits the acceptance of EV market [13].

EV deployment is without doubt an important transition for the transportation industry. Despite the fact that some countries are making good progress in EV market adoption, many others are still under-performing. The ambition of emission free global society will not be achievable if EV is not well adopted around the globe. Hence, this paper presents the investigation of the important factors that influence EV social acceptance, with the intention of identifying challenges and finding effective solutions to promote EV deployment. The main contributions of this paper include: (i) to present a comprehensive assessment of social acceptance theory to identify factors that can influence EV social acceptance in terms of individual, community and institute measures, (ii) to determine obstacles and challenges in EV driving, EV charging and energy price aspects that hinder the deployment of EV market and (iii) to provide recommendations to different entities such as government, stakeholders, OEMs, power utilities with related solutions in encouraging the development of EV industry.

II. SOCIAL ACCEPTANCE OF ELECTRIC VEHICLE

Social acceptance is the extent to which an individual desires to acquire a certain new technology, that affects the individual's behavior in particular and the society in general. Social acceptance can be an important factor that influences the quality of selection [15], [16]. Figure 1 summarizes various theory of social acceptance, which include ''Individual, Community and Institute Acceptance'', ''Socio-Political Acceptance, Community Acceptance and Market Acceptance'', ''Theory of Reasoned Action'', ''Technology Acceptance Model'', as well as the purchase intention towards EV. The following sub-sections discuss these research approaches used in the social acceptance study.

A. INDIVIDUAL, COMMUNITY AND INSTITUTE ACCEPTANCE

According to authors in [17], the foundation to a social cohesion is the individual, community and institute factors. Each of this aspect is interconnected and influences each other from time to time. For a social cohesion to exist, each individual shall be motivated to want to belong to a community that share a common values and beliefs. On top of that, individuals will only be free to take part in the community when the public regulations, norms, values and laws agree with them. In [18], the authors indicated that social culture and individual attitudes are assessed by the group of individuals. People often describe themselves as members of a group and it is known as social identity, which has an effective role in adopting EVs [19]. People who belong to a certain group or a certain race, effectively influence the processes of self-stereotyping. Therefore, this concept affects the issue of adopting a new technology, as individuals have a strong drive to follow the rules of the group to which they belong [20], [21], [22]. There are different types of norms and all of them could be relevant for the adoption of EVs. When a norm refers to what group members commonly do, it is called a descriptive norm (e.g., ''Germans do not drive EVs'') [23]. When it refers to what is commonly approved and disapproved within the group, it is called an injunctive norm (e.g., ''Germans approve of driving EVs'') [24]. Social

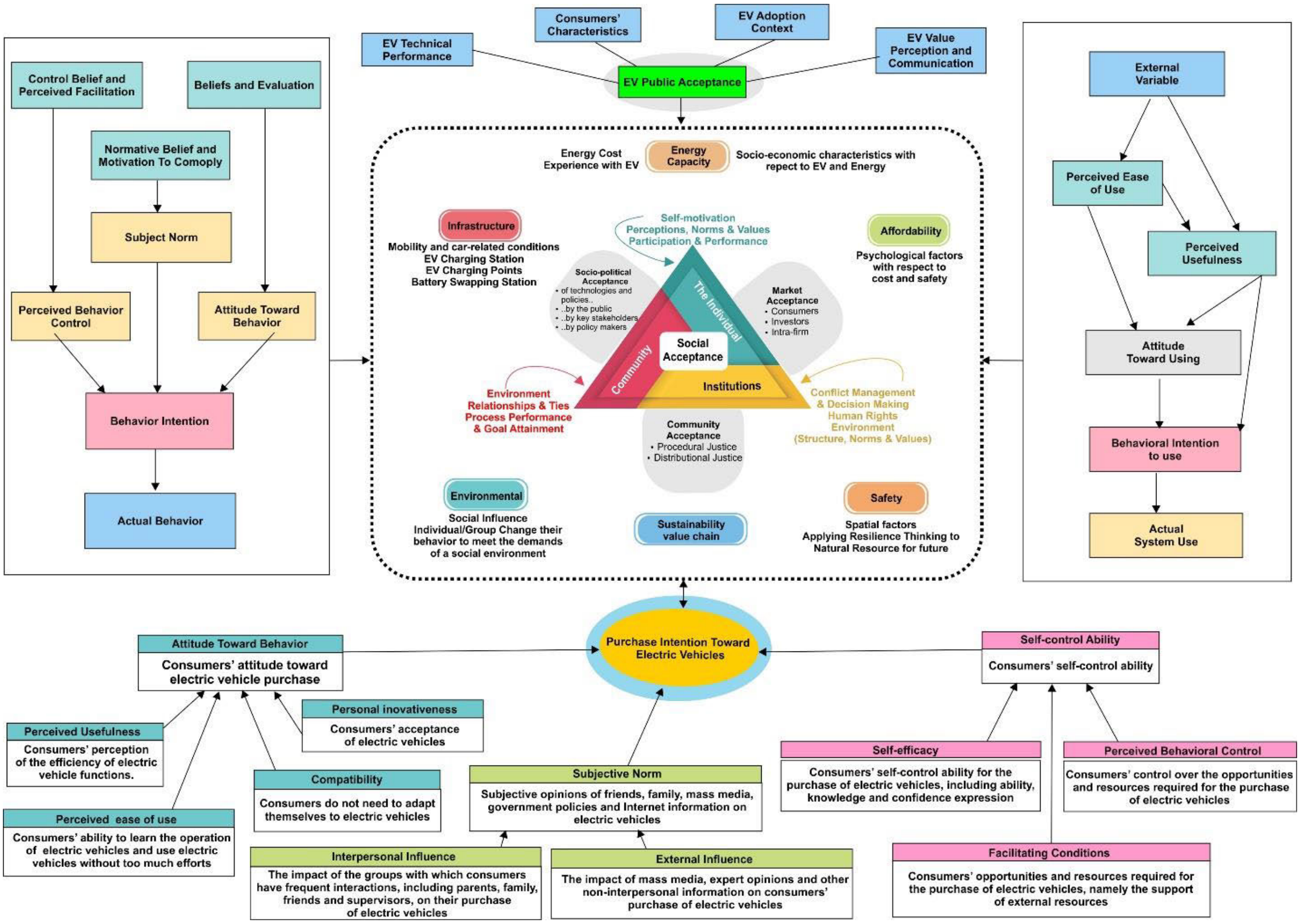

FIGURE 1. Influencing factors of social acceptance.

norms could therefore influence the decision to adopt an EV if an individual perceives other group members to be in favor of adoption (injunctive norm). Of course, the perception that very few people use EVs could have the opposite effect and decrease the likelihood of adoption [25].

B. SOCIO-POLITICAL ACCEPTANCE, COMMUNITY ACCEPTANCE AND MARKET ACCEPTANCE

Authors in [26] listed the factors that influence the social acceptance as socio-political acceptance, community acceptance and market acceptance. These categories are defined as the ''triangle of social acceptance''. Socio-political acceptance is the broadest level of acceptance, where the nation policy makers introduce policy and technology stimulation agenda to urge the development of the technology. Meanwhile, community acceptance refers to the willingness of relevant stakeholders and developers to invest in the technology. Lastly, the market acceptance is the response of public, especially the consumers toward this technology. Nowadays, mass media plays an important role in shaping the social acceptance. When the media emphasizes the information related to the technology, it will ignite the public debate with individual perspectives and viewpoints. If social acceptance cannot be reached and public resistance is formed, the new idea such as EV can easily be misled.

C. THEORY OF REASONED ACTION

According to Theory of Reasoned Action, the behavior intension of an individual is simultaneously influenced by their subjective norm and attitude [27]. Behavioral intention refers to the own interest of an individual to engage a particular action. Meanwhile, subjective norms are the social pressure that the individual will receive when perform the action. If the subjective norms are strong, it can greatly influence the behavioral intention of an individual.

D. TECHNOLOGY ACCEPTANCE MODEL

According Davis proposed a Technology Acceptance Model in year 1989 [27]. This model described the influencing factors to social acceptance which are the perceived usefulness and ease of use. Perceived usefulness refers to the social beliefs in the improvement that can be achieved by the new technology such as electrified transportation. And, the perceived ease of use is defined as the social opinions in the difficulties to implement this new technology.

E. INDIVIDUAL VARIABLES AND TECHNOLOGY ATTRIBUTES

In [28], the factors that influence the social choice when purchasing a vehicle is classified as the individual related variables and attributes. Individual related variables include the individual experience with the vehicle, social influence, mobility and car-related conditions, socio-economic characteristics, psychological factors and spatial factors. On the other hand, the vehicle attributes are the financial, technical, infrastructure and policy attributes. Hence, to urge the adoption of EV, government are active in introducing policy to reduce owning cost, developing EV charging infrastructure, and encourage development of EV related technology.

F. PROVINCIAL NORMS AND SUBJECTIVE NORMS

There are two other conceptualizations of norms relevant in social acceptance. Provincial norms refer to the influence that behavior of others can have on our decisions when those others occupy a comparable setting [29]. Therefore, people in similar life conditions or people who are physically proximate can influence our actions as their behavior may inform us about what is appropriate in these situations, and they may do this also when we do not conceive of them as members of our own group [29]. On the other hand, subjective norms describe the perceived expectations of significant other individuals [30]. The opinions of family members and friends who are important to the self can have an impact on individual behavior. Subjective norms differ from provincial norms in that significant others need not to share the same living conditions (e.g., to live close by) to have an influence on behavior.

III. INFLUENCING FACTORS TO EV SOCIAL ACCPETANCE

The direction of the future transportation system is influenced by political, economic, social, technological and environmental reasons. This section summarizes the most relevant ones, focusing on those promoting or hindering a wider usage of EVs. Despite the benefits of EVs in reducing the environmental issues, they still face obstacles that limit their social acceptance. Figure 2 shows the graphical illustration of the challenges of EV social acceptance, where the influencing factors are further summarized in Table 1 and discussed comprehensively in following sub-sections.

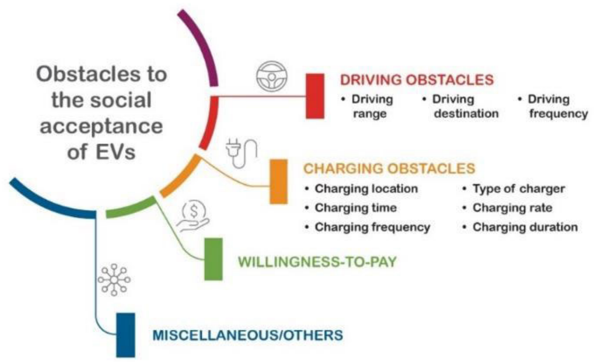

FIGURE 2. Obstacles to the social acceptance of EVs.

TABLE 1. Influencing factors to social EV acceptance.

Influencing Factor	Description
Driving Range	EV has a shorter driving range when compare to the mature ICE technology. The current EV driving range is insufficient to meet the requirements for consumers wishing to travel long distances.
Charging Location	EV charging consumed a certain amount of time. Each user has their own routine and preference as to where and when to charge. This specific attribute is crucial where the determination of location could increase the confidence of potential users.
Charging Duration	EV takes hours to recharge. The long EV charging time increases users' range anxiety
Charger Type	Fast charger is higher in demand for its quick charge up capability. However, this technology comes with high price and electricity rate. Additionally, fast charging is reported to have significant health impact to EV battery.
Charging Rate	Increase of EV charging demand can cause power congestion to the electric grid. Time-of-Use (TOU) billing scheme is a strategy that encourage the EV users to charge their EV during off-peak hours.
Willingness-to-Pay	EV is still considered an expensive vehicle to own in most places. Despite the high EV price, some consumers are willing to pay more to own an EV for various reasons, such as awareness to environmental crisis and social responsibility.
Environmental Factor	Although EV is promoted as a zero-emission vehicle, the environmental factor of its manufacturing process has raised the social concern. This concern was mainly due to the environmental impact caused by mining and manufacturing Lithium-ion (Li-ion) battery.

A. DRIVING RANGE

The limited EV driving range is one of the main factors that affect the EV social acceptance [31], [32], [33], [34], [35], [36], [37]. The authors found that 33%, 22% and 22% of the people interviewed in Germany, UK and China respectively, were concerned about the driving range as the main barrier to their adoption of EVs [31]. In [38], the authors conducted a survey to analyze the opinion of consumers in India on the adoption of EVs. The authors found that the driving range is one of the most important factors influencing consumers' perception when purchasing EVs and that 60% of current EVs do not meet their range expectations. Interestingly, 66% of consumers do not trust the driving range specified by the EVs manufacturers. In addition, the authors in [38] pointed out that the driving range still has a long way to develop and that the current range is insufficient to meet the requirements for consumers wishing to travel long distances.

However, the range of today's EVs is much greater than EVs from several years ago. In recent years, the driving range of EVs has increased by 46.67%. In 2014, the driving range of small EVs was less than 150 km, while the average range for the same class of car was 220 km in 2019 [39]. Presently, with the spread of different types of batteries, the diversity of EV models has increased, as the range of EVs has become highly dependent on the type of battery. Figure 3 shows the driving range for different models of EVs based on the battery capacity [40].

Research in [41], [42], [43], [44], [45], [46], [47], [48], and [49] found that the daily driving rage of countries like India, America, Finland, Denmark, and Norway were below 50 km. These shows that the current EV technology is well capable to fulfill users daily driving range requirement. In [50] the authors surveyed respondents in Qatar to find their readiness to adopt EVs. The results of the survey showed that most respondents were willing to buy EVs despite their knowledge of the shorter driving range, as Qatar has many fueling stations that can be combined with electric charging stations. Hence, the short driving range of EVs can be resolved by having well developed EV charging facilities. Moreover, providing the drivers with accurate driving range information reduces range anxiety and increases drivers' acceptance [51]. Table 2 summarizes the reviewed studies of the driving range of EVs.

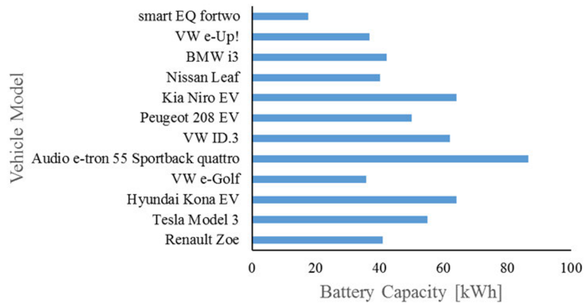

FIGURE 3. Driving range for different EV models based on the battery capacity [40].

B. CHARGING LOCATION

EV charging location is another influencing factor of EV adoption. Each user has their own routine and preference as to where and when to charge. EV charger is commonly found at home, workplace, public parking lot such as malls and petrol stations. This specific attribute is crucial where the determination of location could increase the confidence of potential users.

In [52], research found that women preferred nearby charging stations more than men. While the younger age of respondents was preferred that the charging place for EVs be in their place of residence. In [53] and [54], the authors emphasized the importance of household charging of EVs, especially during the night period, where charging rate are reduced. Also, it is one of the easiest ways to fully charge the battery of EVs for the next morning. It is also possible to take advantage of home charging in cold weather conditions, as the vehicles can be preheated in the morning to avoid using the battery capacity for heating purposes. Social studies carried out in China [55] showed that the EV charging service has a great influence on consumers' decisions, as it depended on the level of the service provision and speed of service in public stations. Also, the availability of a home charging facility played a big role in consumers' decision to adopt EVs. Chinese consumers were willing to pay more for a free license for EVs and allowed them to install a home charging port. In [56], research also found that users preferred home charging places compared to public charging places, as it is a more economical-friendly and convenient option. Hence, the provision of home charging stations will encourage users to purchase EVs [34].

Nevertheless, survey in [49] indicate that more charging stations are needed to keep pace with the increase in EVs sales. Public charger is especially important for EV users on long distance trips. In [57], the authors found by summarizing studies conducted in 20 countries that most respondents emphasized the need for charging stations, especially on highways, to promote the adoption of EVs. In [58], the authors emphasized that respondents who do not have a garage in their homes are interested in public charging stations. Authors explained in [59] that public charging stations can be used by providing the necessary services and convenience to users and providing easily accessible charging stations in various locations. In [60], survey found that in EV users in Sweden, Denmark and Finland preferred public charging stations. Moreover, parking lots were also seen to be preferred by EVs users for charging their vehicles [61]. A comprehensive literature review conducted in [35] emphasized the need to increase the number of public charging stations to make it easier for user to access them, thus reducing their driving range concerns. Hence, there is a demand to increase public chargers between cities, city streets and shopping malls [49], [56].

In [62], the authors showed that shorter distances between charging stations help to improve the charging of EVs. The adoption of EVs in Muscat will improve if the driving range between charging station is between 100 km to 200 km. In [63], the authors explained that EV users still suffer from a lack of charging points and many of them do not know where and how to charge. Hence, authors suggest in [50] that a mobile application that helps the user to identify the nearest available EV charging stations will improve the charging experience.

C. CHARGING DURATION

EV long charging time has been the main barrier to EV social acceptance [64], [65], [66]. In [67], the authors studied

TABLE 2. Review of the driving range of EVs.

Ref	Year	Location of Study	Method	Findings
[31]	2020	Global	Online report	· 33%, 22% and 22% of the people interviewed in Germany, UK and China respectively, were concerned about the driving range as the main barrier to their adoption of EVs.
[40]	2020	USA	Online survey	· The daily mileage of American citizens was 30 miles daily on average.
[37]	2019	Global	Online report	· The driving range of EVs has increased by 46.67%. · The driving range of small EVs increased to 220 km in 2019.
[38]	2018	Germany	Field study	· Users typically drove 37 km with the EV per day.
[36]	2021	India	Analyze study	· 60% of current EVs do not meet range expectations by users. · 66% of consumers do not trust the driving range offered by EVs manufacturers. · The driving range still has a long way to develop and that the current range is insufficient to meet the requirements for consumers wishing to travel long distances.
[39]	2021	India	Interview	· Two-thirds of the respondents drove less than 20 km per day, which was well below the driving range of EVs available in India. · Most respondents with a monthly income of at least INR 30,000 have the ability to purchase and maintain vehicles. · 19% of respondents described driving range as the biggest obstacle when buying EVs.
[48]	2020	Qatar	Questionnaire survey	· Most respondents were willing to buy EVs despite their knowledge of the shorter driving range.
[41]	2015	California	Questionnaire survey	· 70% of participants preferred plug-in hybrid electric vehicles (PHEVs), even when Battery Electric Vehicles (BEVs) had a 150-mile range and similar purchase price.
[42]	2016	China	Survey report	· NEV consumers commuted with average daily travel distance < 60 km and even < 35 km during weekdays.
[43]	2020	North America	Aggregator data collection - MyFord mobile app	· BEV owners have self-selected BEV ownership because of their confidence that the vehicle range will meet their needs / will modify their usage to adopt new technology. · PHEV owners on average drove further than conventional gasoline vehicle, likely due in part to the increased fuel efficiency. · BEV owners drove significantly fewer miles annually than their conventional or PHEV counterparts unless accompanied by charging infrastructure, particularly workplace charging.
[46]	2020	Germany	Data from long-term study	· The BEVs had a lower average daily mileage than comparable commercially used vehicles with ICE.
[47]	2015	Norway	Interview and data collection	· Almost all respondents travelled less than 100 km per day. · Annual distance travelled is relative short with average about 10250 km.
[32]	2015	Europe	Online report	· The respondents were willing to adopt EVs with a range of more than 350 km.
[33]	2016	UK	Experience study	· Most drivers preferred driving EVs with a long range.
[34]	2018	Switzerland and Finland	Travel surveys	· The respondents preferred the long driving range when driving EVs. · They need to provide a residential charging option.
[35]	2020	Europe	Literature review	· Limited driving range and the high price of EVs significantly influenced respondents' decision to adopt EVs.

the charging time required for EVs with a range 300 km, 400 km and 500 km. The results showed that EVs with a range of 300 km needed 30 minutes using quick charging and 6 hours using normal charging, while vehicles with a range of 400 km needed 45 minutes using quick charging and 8 hours using normal charging and vehicles with a range of 500 km needed 60 minutes using quick charging and 10 hours using normal charging. Research found that many are willing to spend up to 3 hours to charge their EV [68]. However, there are still a number of them who wants the fast charger with capability to finish charging in less than half an hour. Long charging time of EVs increases the range anxiety problem, so the authors suggested reducing the charging time by using fast chargers, provision battery replacement stations and developing battery technology to overcome the range anxiety problem [52], [69], [70], [71], [72].

Different charger type and charger location affect the preferred charging time of users [49]. In [47], the authors studied the charging time preferred by users. Most of the users prefer to charge their EVs using private home charger during the night hours from 6 PM until 6 AM, where the peak of electricity consumption of private EVSEs reaches during midnight from 12 until 3 AM. Generally, users prefer fast public electric vehicle supply equipment (EVSEs) during the day. Electricity consumption of fast public EVSEs reaches its peak from 6 to 9 PM.

D. CHARGER TYPE

It is ideal to have EV to charge as fast as it takes to refuel a conventional vehicle. Hence, fast charger was in high demand for EV users [49]. The usage of public fast charger surpasses the normal public chargers and it is frequently used in the morning and early evening [47]. Research indicates that drivers will only be willing to select routes without fast chargers if the EV departed at higher SOC or when slow charging is available at the destination of the users [73]. Nevertheless, having fast charger around creates the sense of security to EV users, as they know fast charging is available during emergency case [49], [58], [61], [70].

In [74] the authors emphasized the importance of providing fast-charging devices to increase the adoption of EVs by respondents. Recently, fast-charging devices reached 83,395 in China, 7,327 in Japan and 6,267 in the United States. This confirms the need to provide fast charging to reduce the time required to charge EVs and thus encourage respondents to purchase EVs. Some international companies, such as Tesla, have introduced their fast charger technologies in some areas such as Abu Dhabi and Dubai, to promote their adoption by users [75]. In 2020, despite the COVID-19 pandemic, electric mobility in European countries increased to 10.5%, compared to 3% in 2019 [76]. Also, the report in [65] indicated that by the end of 2020, charging networks were expanded by 37% throughout European countries and fast charging stations increased by 67% to meet the requirements of respondents.

Nevertheless, it is challenging to install fast charger in residential area and power-constrained area, as it is a high-power equipment. In [77], the authors stated that fast-charging stations require a large amount of power in a short period of time which causes a challenge to maintain the technical limitations of distribution networks. In addition to the fact that the fast charging system is complex, therefore, another source must be provided to deal with it in order to maintain the stability of the power system. To reduce this problem, the authors in [78] suggested integrating fast-charging stations with storage units.

E. CHARGING RATE

Increase of EV charging demand can cause power congestion to the electric grid, especially during peak loading hours. This can potentially damage or shorten the life span of the network. The Time-of-Use (TOU) billing scheme is a strategy that encourage the EV users to charge their EV during off-peak hours. With this scheme, it can effectively reduce the electric grid burden during peak loading hours [54], [61]. Its implementation leads the users to charge accordingly, whereby most charge events happen at residential area during the time frame as to which usually starts in the evening or 6 PM onwards. It was also found that midnight is the by far the most economical time to charge an EV and-that it is advantageous to the users as they can program their home charging system to shift appropriately via smart phone application setting [54]. Having said that, study in [79] showed that by implementing a flat-fee rate, is disadvantageous towards the coherent utilization of Direct-Current Fast Charger (DCFC) station because of reduced amount of charge per minute of park duration. Despite that, most of the respondents in [49] are willing to pay extra for a fast charging in emergency case.

F. WILLINGNESS-TO-PAY

As EV developed, the price may or may not be directional prior to its growth. Even so, there are consumers that are willingness-to-pay (WTP) more for the deployment of EV. In [68], the authors showed that most of the consumers are WTP higher prices provided the time of charging is conveniently fast. It was found that the charging infrastructure is the attribute of which the consumers are looking forward such as home charging facility and reduced time of charging or fast chargers' availability are important for their charging convenience.

The average Chinese and U.S consumers' WTP are commonly dependent on the fast charging availability and capability [80]. Along with that, technology development and reduced subsequent cost are seen to be the second important attribute for the consumers. For instance, in [80], the authors found that a certain percentage of consumers insisted that EV has new technology that ought to be paid extra for its development. Many are willing to step-up their investment on EV and expect a reduced in driving costs [81].

Besides, green portrayal and driving range of EV are other influential attributes to consumers. Empirical results from [68] showed that the enhancement of EV attribute such as lowering pollution emission is attractive. This enhances the willingness to pay among consumers to adopt EVs. However, apart from the obvious, there is a case in [48], whereby the Italian consumers are starting to get convinced on the

TABLE 3. Studies on countries with high WTP for EV technology.

Ref	Year	Location of Study	Findings
[46]	2020	Italy	· WTP for 1-km increase in the driving range is lower - Italian consumers becoming more confident on EV driving range.
[47]	2015	Norway	· Majority willing to pay for fast charging even if the max amt (0-60 euro). · Majority seems to think that maximum price of between 2.5 and 6 Euros per 15 minutes fast charge is acceptable. · About 10% - Can accept the price of up to 12.5 euros. · A substantial part is willing to pay double of what charging per kWh at home costs.
[33]	2016	UK	· Respondents were unwilling to pay if the driving range is low.
[78]	2015	US & China	· They find that with the combined bundle of attributes offered by vehicles available today, gasoline vehicles continue in both countries to be most attractive to consumers, and American respondents have significantly lower relative willingness-to-pay for BEV technology than Chinese respondents. · Their results suggest that with or without each country's 2012–2013 subsidies, Chinese consumers are willing to adopt today's BEVs and mid-range PHEVs at similar rates relative to their respective gasoline counterparts, whereas American consumers prefer low-range PHEVs despite subsidies. · Results suggest that the expected average U.S. consumer WTP for BEV technology is $10,000–$20,000 lower than equivalent conventional technology (depending on range, fast charging availability, and model specification) ceteris paribus (given the same body, brand, performance, and operating cost). · 4. In contrast, average Chinese consumer WTP for BEV technology is within $10,000 of equivalent conventional vehicles and in some cases (e.g.: with sufficient range and fast charging capability) is larger.
[53]	2019	China	· Free licensing policy for EVs is very attractive for consumers. · Chinese consumers have the highest willingness to pay for obtaining a free vehicle license for EVs and being permitted to install a home charging post.
[60]	2019	Denmark, Finland, Iceland, Norway and Sweden	· Respondents were willing-to-pay €242 for an increased driving range of 150 km and €91 for 400 km. · The governments of these countries were willing-to-pay €5600 for reducing 1h of charging time of EVs.
[56]	2021	United State	· Respondents' willingness-to-pay $113 for one mile extra in battery range to purchase EVs.
[66]	2018	Shanghai	· Consumers are willing to pay for reducing charging time · If charging time is needed above this boundary (e.g., 3h), then consumers are not willing to pay more for speeding up battery charging. · Empirical results states that individuals are willing to pay for enhancing other EV attributes (e.g., reducing charging time, lowering pollution emissions, and increasing maximum speed).
[79]	2020	Global	· 3% of respondents believe EV will never become popular. · Only minority (17%) are not willing to pay more for a new EV. Most of the respondents are willing to increase their initial investments with provided subsequent reduction in the cost of driving. · Most respondents expect a 50% reduction in operation costs from an EV · Almost 60% of respondents would like to have an option of battery swapping · Over 20% are willing to pay extra to use a battery swapping station · 74% of the respondents are more likely to buy an EV if it could be purchased without the battery pack and lease the batteries instead (assuming there are many swapping stations around)
[80]	2020	India	· Respondents were willing-to-pay an additional $10- 34 in the purchase price of EVs for reducing the fast-charging time. · Respondents were willing-to-pay an extra $7- 40 for adding one km to their driving range at 200 km. · Respondents were willing-to-pay an additional amount from $104- 692 for saving of $1 per 100 km of future operating cost.
[81]	2016	Germany	· Respondents were willing-to-pay €95–125 for increasing 1 km on the driving range. · German government was willing-to-pay €2600 to €3330 to reduce the charging time by an hour and a half.
[82]	2019	Europe	· Respondents were willing to pay for fast charging.
[83]	2019	China	· Especially in the initial EV models selection and comparison, consumers pay far more attention to the price than all performance specifications of the vehicle.

driving range which proves the WTP for extended 1-km driving range is lower. Otherwise, a free EV license, speed and battery swapping are also being spoken of as a part of WTP reward such in [55], [68], and [81]. For example, a substantial number of respondents are WTP more for battery swapping functionality [81]. In [58], the authors emphasized respondents' WTP $113 for one mile extra in battery range to purchase EVs.

In [82], the authors surveyed respondents' preferences for their WTP for EVs features in India. The results showed that respondents were WTP an additional $10- 34 in the purchase price of EVs for reducing the fast charging time, also they were WTP an extra $7- 40 for adding one km to their driving range at 200 km. In addition, they were WTP an additional amount from $104- 692 for saving of $1 per 100 km of future operating cost. In [83], the authors stated in a survey in Germany that respondents would be WTP €95–125 for increasing 1 km on the driving range. Also, the German government was WTP €2600 to €3330 to reduce the charging time by an hour and a half. While, in [57], the authors stated that respondents in Denmark, Finland, Iceland, Norway and Sweden were WTP €242 for an increased driving range of 150 km and €91 for 400 km. In addition, the authors in [62] found that the governments of these countries were WTP €5600 for reducing 1h of charging time of EVs.

Previous literature has shown that respondents are WTP extra for the improvements they desire in EVs and this indicates their increased desire and knowledge of the importance of adopting EVs. In [33], the authors made an empirical study of respondents driving EVs. The authors noted that respondents were unwilling to pay if the driving range is low. Where respondents are willing to pay for fees, improvements to the efficiency of EVs and other services that contribute to the development of an effective system for EVs. In [84] the authors conducted a survey to study respondents' opinions about their willingness to pay charging costs. The results indicated that respondents were willing to pay for fast charging. Table 3 summarizes the results of reviewed studies that have been conducted on the consumers that are WTP more for adopting the EVs.

G. ENVIRONMENTAL FACTOR

Although EV is promoted as a zero-emission vehicle, the environmental factor of its manufacturing process has raised the social concern. This concern was mainly due to the environmental impact caused by mining and manufacturing Lithium-ion (Li-ion) battery. Li-ion battery is the most common energy storage type used for an EV. The anode of Li-ion battery is made from graphite; while cathode is constructed using lithium iron phosphate (LiFePO4) or lithium cobalt oxide (LiCoO2). Battery's anode and cathode is separated by electrolyte-filled porous. The main advantages of Li-ion battery are its high energy density, low self-discharge, and large number of charge-discharge cycles characteristics [86].

Although EV can achieve zero emission during propulsion, the process of manufacture and mining for Li-ion battery generates significant amounts of greenhouse gases emissions. According to [87], the emissions during the productions of Li-ion battery range from 114.3 to 137.0 kg CO_2-eq/kWh. Meanwhile, the mining of Lithium requires large amount of saline water, where one ton of Lithium requires 2.2 million gallons of water. This can greatly impact on the water and environmental resources. Lithium battery contains toxic chemicals like, nickel, copper and lead substances. Improper disposal and storage can lead to environmental pollution, as well as cause explosive hazard [88], [89].

H. MISCELLANEOUS

There are already demands in the aesthetic aspects, driving comfort and model variety for the EV car. The aesthetics mentioned in [85] comprises the appearance, interiors and more choices which deemed to be significant to the consumers Most of the consumers are heavier on the size of the car such that it should be desirable small, medium or large car. Small cars are seen to be preferred in [48] for the limited parking space in cities and that is matching with their everyday life and work travel [85]. Nonetheless, sport utility vehicle (SUV) model is also one of the most expressed as main preference for the vehicle size revealed from [48] and [85]. Majority of the respondents though favor a smooth and consistent driving experience as they would get from a conventional car [81]. Anyhow, majority of the consumers in [85] had a pleasant experience with EV such that it affects their driving style for the better in the manner of speeding, aggressiveness and economical.

In [72], the authors surveyed respondents' preferences for the adoption of EVs. The result of the survey was that respondents were dissatisfied with the tax credits granted when purchasing EVs, in addition to their doubts about the effectiveness and reliability of EVs. As most of the respondents assert that EVs should have a long driving range, lower cost and short charging time. In [90], the authors reviewed the various literature on respondents' preferences for the adoption of EVs. The result of the study showed that the price of EVs is one of the important factors affecting respondents to adopt EVs. The authors also emphasized the need for studies on government incentives to support EVs. In [91], the authors stated that the realistic model influences the behavior of the respondents and that there is still a category of respondents who are not aware of the adoption of EVs, this awareness explains the heterogeneity of respondents' preferences for the adoption of EVs. Also, in [92] the authors mentioned that the trip type, user segments, and residential density affect the respondents when purchasing EVs, the price of EVs varies according to vehicle usage patterns. Whereas, in [93] the authors studied the preferences of Chinese respondents to adopt EVs using the stated preference method. The results showed that respondents do not want to purchase EVs due to the high purchase price and low driving range. In addition, respondents view that Chinese car brands differently compared to European brands.

In [94] the authors found that respondents to EV adoption prefer to live in areas where there are incentives and subsidies for EVs and in areas with strong government policies that support infrastructure for EV adoption. Similarly, in [95], the authors stated that government policies consisting of tax subsidies, exemption from traffic fees, reduced parking fees, infrastructure subsidies and exemption from road tax

TABLE 4. EV consumer preferences.

Ref	Year	Location of Study	Findings
[46]	2020	Italy	· Most of the demand is for the small to medium car segment · This result indicates high price sensitivity of Italian customers such that cheap and small EVs with limited driving range would be preferred over sedans with larger batteries to adapt with limited parking space in the cities.
[52]	2018	General	· 83% of respondents are willing to buy an EV provided their driving comfort remains the same.
[70]	2015	Europe	· The respondents were dissatisfied with the tax credits granted when purchasing EVs. · The respondents were doubts about the effectiveness and reliability of EVs. · Most of the respondents assert that EVs should have a long driving range, lower cost and short charging time.
[79]	2018	Korea	· SUV/RV and large-size vehicles are the most preferred vehicle type in terms of size.
[83]	2019	China	· They observed a preference for small battery electric vehicle (BEV) models with fast-charging batteries, which are well-suited to work commutes and daily life. · They noticed that consumers expressed a preference for sport utility vehicle (SUV) models · They found that in addition to price and technical specifications, EV aesthetics play a significant role in consumer choice (Type of EV Owned/Used/Preferred) · Besides the purchase prices and performance parameters, consumers paid more attention on aesthetics, including appearance and interior, than EV brands, services and other factors. Hence, upgrading the exterior and interior of an EV is very attractive to consumers.
[84]	2017	General	· The price of EVs is one of the important factors affecting respondents to adopt EVs. · Need more studies about government incentives to support EVs.
[85]	2017	UK	· The realistic model influences the behavior of the respondents. · There is still a category of respondents who are not aware of the adoption of EVs.
[86]	2015	Switzerland	· The trip type, user segments, and residential density affect the respondents when purchasing EVs. · The price of EVs varies according to vehicle usage patterns.
[87]	2018	China	· The respondents do not want to purchase EVs due to the high purchase price and low driving range. · The respondents view that Chinese car brands differently compared to European brands.
[88]	2018	Austria	· The respondents to EV adoption prefer to live in areas where there are incentives and subsidies for EVs. · In areas with strong government policies that support infrastructure for EV adoption.
[89]	2018	General	· The government policies consisting of tax subsidies, exemption from traffic fees, reduced parking fees, infrastructure subsidies and exemption from road tax influence respondents' decisions to adopt EVs.
[90]	2017	China	· The special perks such as green plate, odd-and-even rule, license plate lottery and purchase support significantly influence the respondents when purchasing EVs.
[91]	2018	Beijing	· The respondents are positively affected by the lottery approach and by purchasing support for EVs.

influence respondents' decisions to adopt EVs. In [96], the authors assert that special perks such as green plate, odd-and-even rule, license plate lottery and purchase support significantly influence Chinese respondents when purchasing EVs. Likewise, in [97] the authors found that respondents in Beijing are positively affected by the lottery approach and by purchasing support for EVs. Table 4 summarizes the finding of various reviewed studies that have been conducted on the consumers about their other preferences for the adoption of EVs.

IV. FUTURE RESEARCH DIRECTIONS AND STRATEGIES FOR EV ADOPTION

The deployment of an industry/product/technology involves a Technological Innovation Systems (TIS). TIS is defined as the group of networks with actors and institutions that corporates in a specific technological field and contribute to the generation, diffusion and utilization of variants of a new technology [98]. As depicted in Figure 4, the process of development, production and usage of a new technology follows the path from research and education, supply and operation, demand system.

For the transportation electrification industry, the professional research and education institute designed the innovative EV to solve the fuel depletion crisis and global warming issues. The supply and operation support system are divided into the production (e.g., material supply chain and OEMs), as well as the sales and operation support categories (e.g., EV dealers, leasing companies, infrastructure, repair and maintenance). And lastly, the demand system includes

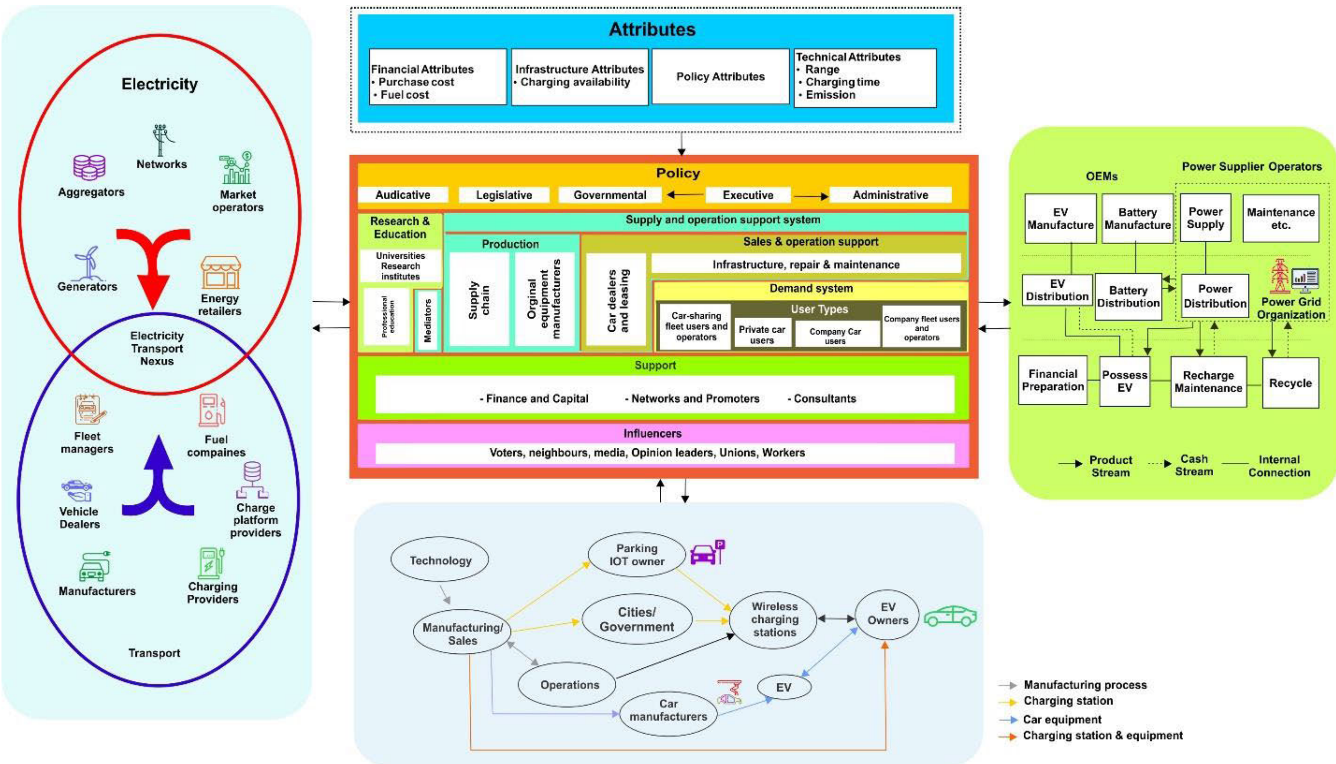

FIGURE 4. Energy and transportation sector coupling.

the private car users, company car users, and vehicle fleet users [98]. In addition, many experts had shown great interest towards Vehicle-to-Grid (V2G) technology, where EVs can be utilized for power grid support. This V2G technology has great potential in supporting smart grid reliability and improving energy sustainability. Despite its advantages, the implementation of the technology has faced many challenges. As discussed in [99], the automotive transportation and electricity had developed as two largely separate systems in past few decades as presented in Figure 4. Each of this industry has their own sets of practices, relationships, user demands, standards and regulation, as well as system infrastructure. In order to realize the V2G concept, a harmony interaction system between both electricity and transportation industry need to be designed. Meanwhile, this transformation shall take place in all aspects of TIS, such as the research and education, supply and operation support system, as well as the demand system.

Another challenge to EV social acceptance relates to the environmental concern of EV battery. The Li-ion battery that serves as energy storage are designed to serve approximately a decade of useful life [100]. EV batteries will be discarded once the residual capacity falls below the required EV performance point, which typically involve 80% of useable capacity and capability to retain self-discharge rate below 5% over 24 hours [101], [102]. Therefore, re-purposing EV batteries is one prominent solution to reduce its impact to the environment. After remanufacturing, retired EV batteries are still capable to serve less-demanding application such as stationary energy storage services [103], [104]. Second-life battery usually undergone several testes to determine the battery state of health, reconfigured to meet required capacity of new application, and equipped with new battery management system [105]. Retired Li-ion batteries with poor performance shall be handle carefully to prevent harm to human health or the environment. With proper recycle process, valuable components can be recovered [106]. Li-ion battery recycling involves chemical and physical processes. The complexity of Li-ion battery configurations means that dissembling these batteries can be harmful. To reduce the risk of leakage of poisonous substance, explosion and combustion, used batteries need to be fully discharged before dissemble. Physical recycling processes involve pretreatment and recovery of electrode materials via disassembly, crushing, screening, magnetic separation, washing, heating treatment, etc. Meanwhile, chemical recycling process divided into pyrometallurgical and hydrometallurgical processes. These include leaching, separation, extraction, and chemical/electrochemical precipitation [107], [108].

The first step taken to encourage the EV social acceptance is to investigate the barriers to the adoption of this technology. The studies shall be carried out in various aspects such as [109]:

- Social, cultural and behavioral,
- Economics and capital cost,
- Technical,

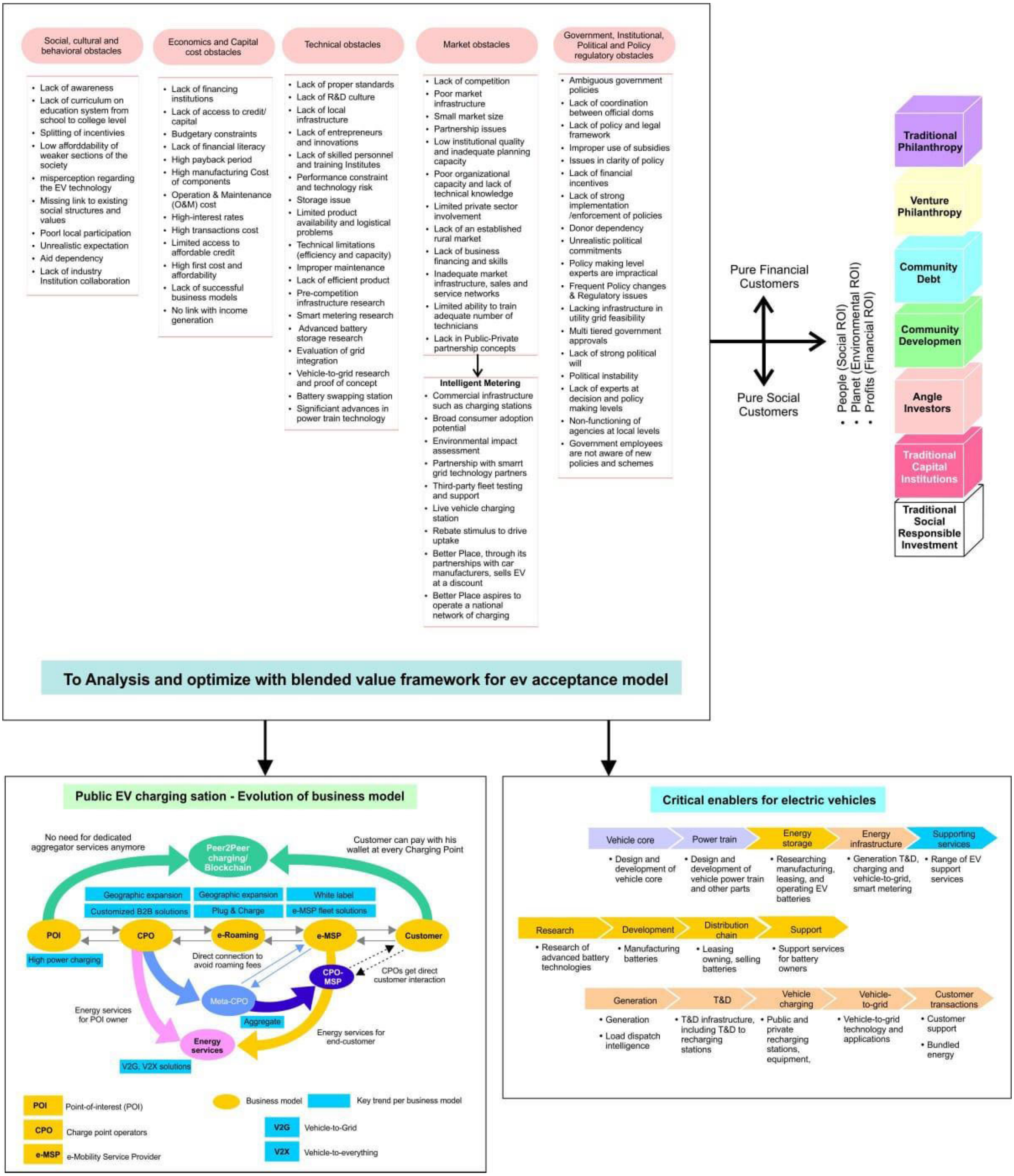

FIGURE 5. Evolution of EV industry.

- Market, and
- Government, institutional, political and policy regulatory.

Figure 5 summarizes the obstacles in regards to each of these aspects. By understanding these challenges, the information can be useful in planning the energy policy and

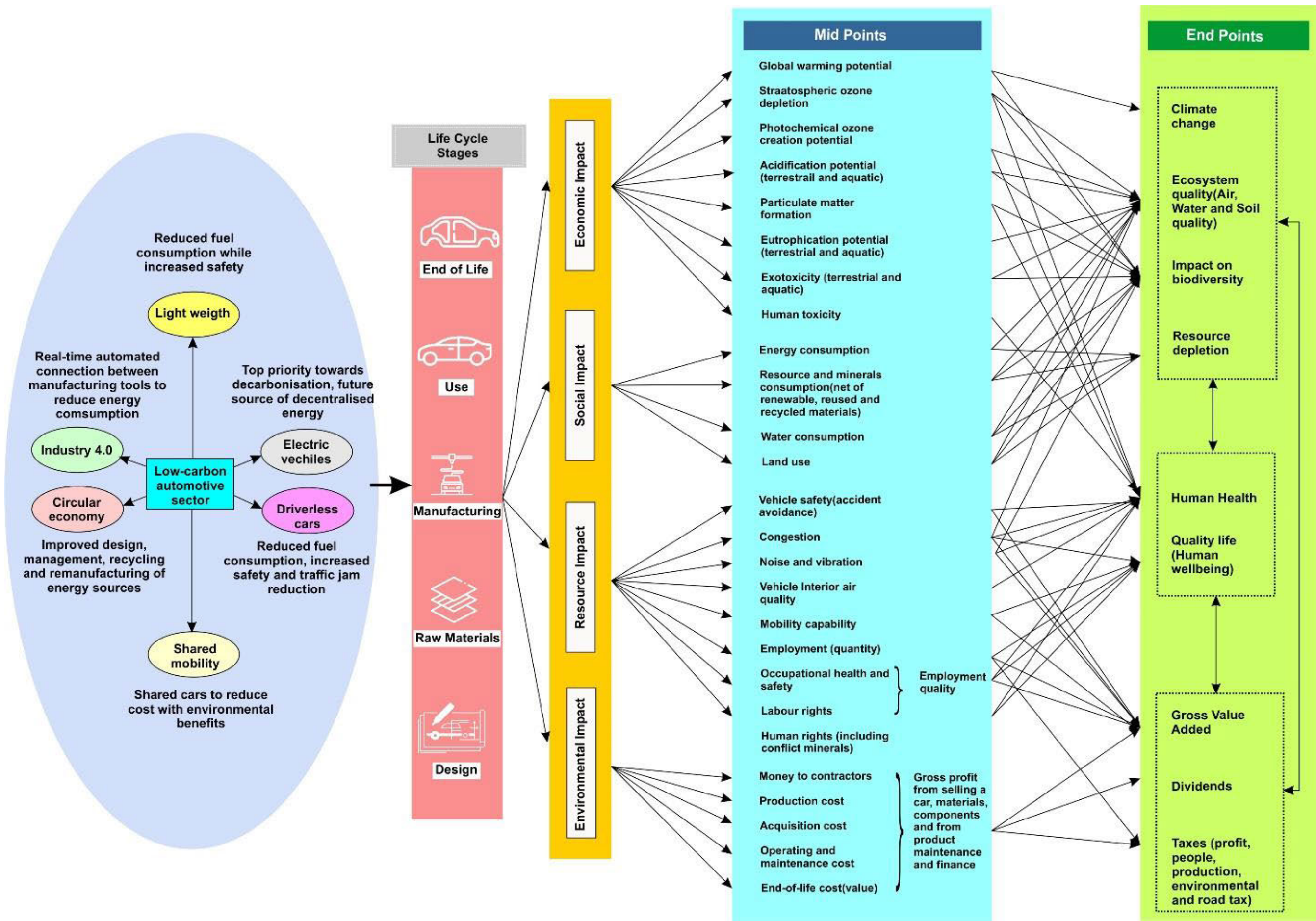

FIGURE 6. Driving range for different EV models based on the battery capacity [38].

strategy to overcome the social barriers. In countries like China, European countries, Japan, India, United State and Korea, these social barriers were well determined and overcome. Hence, the adoption of EVs is raising drastically in the recent years. The utilities, investors and stakeholders are focused on strategizing the business model to properly serve this new value chain. At the time being, numerous business entities are competing to form a new marketplace. During this evolution of automobile industry, the energy supply infrastructure appears to be the most critical field to explore. This is because the EV energy supply infrastructure is the industry that will merge both transportation and electricity industries [110]. The UK, one of the countries with advance development of EV industry, is undergoing an evolution of EV charging business model [111]. With the increasing demand of EV charging services, the charging point owner in shopping malls, parking lots, charging station, restaurant, gas station was pressured to increase their charging points and to upgrade their charging facilities to fast charger. Other than that, the Charging Point Operator (CPO) are introducing the B2B marketplace for EV charging network. This plan allows all EV drivers to charge their EV and make payment in any charging station regardless of their service provider. With this system, EV drivers can travel around the country without having to worry their accessibility to charging point. On top of that, the CPO is also demonstrating the V2G concept to the public, which has great advantages to both energy provider and EV owners [111].

The mankind's ultimate goal of achieving energy sustainability lifestyle had pressured the business efficiency and stakeholders in the automotive sector to develop a vehicle that is environmentally friendly, high efficiency, clean and sustainable. These requirements not only limit to the operation of the vehicle, but also include the design, raw material, manufacture process and vehicle end life stages. To investigate the sustainability of a vehicle, research in [112] had developed an automotive sustainability assessment framework (see Figure 6) that gathered the findings from the automotive expert in the academic field, vehicle manufacturers, consultancies, and non-governmental organizations.

This framework categorizes the impacts into environmental impact, resource impact, social impact and economic impact. This framework serves as a useful decision-making tool during the planning stage for vehicle development process. Automotive OEMs and governments had work together since 1990s in the efforts towards low carbon and sustainable automotive. As shown in Figure 6, several strategies were taken by the OEM and UK governments to achieve low-carbon automotive sector. For instance, the government is committed to introduce EV, encourage shared mobility, promote lightweight vehicles and driverless car with low fuel consumption [113].

V. CONCLUSION

In this article, the authors discuss consumer preferences about the adoption of EVs, aiming to better inform policy-makers and give direction to further research. Respondents' individual and social preferences play an important role in promoting the use of EVs. The previous literature stated that the factors related to utility and price are the most important motives of respondents to adopt EVs, where respondents' satisfaction must be taken into consideration when purchasing EVs. Previous studies had shown that respondents influence each other on their decisions to adopt EVs and that behavior and social influence have an important role in individuals' decisions when purchasing EVs. This paper focused on a comprehensive review of the main obstacles in the adoption of EVs, such as driving obstacles, charging obstacles and willingness to pay. In order to reduce drivers' anxiety about range and energy and to promote the popularization of EVs, there are many approaches. One approach is to research battery technologies like improving battery energy density or decreasing charging time. Other approaches include building more charging facilities and expanding the capacity of the power network. Besides those approaches, a high-performance telematics system is also necessary. Through previous studies, it was found that respondents are willing-to-pay extra for the improvements they desire in EVs and this indicates their increased desire and knowledge of the importance of adopting EVs. finally, there were requirements in the aesthetic aspects, the comfort of driving and enjoyment when driving EVs, a great impact on the respondents, especially the young respondents. All of these preferences must be taken into consideration by different governments and manufacturers in order to enhance and develop the infrastructure for EVs requirements to suit the various preferences of the respondents.

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