

Electric Vehicle Adoption Factors and an Ecosystem Conceptual Model

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Abstract

The recently increasing development of electric vehicles (EVs) is the world's attention to reducing greenhouse gas emissions as mandated in the Paris Agreement of 2015. The development of EVs in parallel is also aimed at reducing fossil fuel consumption. Countries in Europe, America, China, and South Korea showed leadership in developing the number and market share of EVs. On the other hand, ASEAN countries, including Indonesia, are still in their early stages, and the market share of EVs is still under 1%, although various policies have been launched. Answering this gap, the purpose of this study is to conduct a literature review related to the factors affecting EV adoption and an understanding of the role and relation of each actor or sub-system in the EV ecosystem. Furthermore, based on the literature review results, a conceptual model of the relationship between actors in the EV ecosystem is constructed based on variable EV adoption factors. In the following study, this conceptual model can be further improved regarding the interdependence of actors within the EV ecosystem in the system thinking framework to select effective EV production and adoption policy under a dynamic EV ecosystem.

Keywords

Electric Vehicle, Adoption Factors, Subsidy Policy, Diffusion of Innovation, Ecosystem Conceptual Model

1. Introduction

The world's concern for reducing greenhouse gas emissions was realized with the approval of the Paris Agreement to the United Nations Framework Convention on Climate Change on December 12, 2015, in Paris, which was followed up by the signing of the agreement on April 22, 2016, in New York. The key agreements in the Paris Agreement are mitigation actions to keep global temperature rise below 2°C and strive to keep global temperature rises at 1.5°C, net-

zero emissions as a long-term goal, promises to limit greenhouse gas emissions through a Nationally Determined Contribution (NDC), and conduct a regular global stock take.

In the transportation sector, one of the programs in many countries to reduce greenhouse gas emissions is launching a program to gradually replace fossil fuel vehicles with internal combustion engine (ICE) technology with EVs (IEA 2021). EVs are an option as they include low-emission vehicles for Hybrid EVs and Plug-In Hybrid EVs, and zero-emission vehicles for Battery EVs (Gustafsson et al. 2021, Sheng et al. 2021).

The development program for EVs in the world is carried out with several strategic policies, including a gradual increase in the market share of EVs, and the launching of replacing all types of vehicles with zero-emission vehicles in a specific year (between 2040 – 2060), the provision of sufficient charging stations, as well as the development of significant EV technologies such as batteries (IEA 2021). Countries leading the way in developing EVs, such as the United States, China, and Europe, started this program more than 30 years ago (Wu et al. 2018). However, in the early stages of the introduction to the automotive market, EV sales were supported by massive fiscal policies, including in the form of reduction/elimination of purchase/annual taxes and or the provision of direct subsidies to EV manufacturers and consumers (Srivastava et al. 2022).

The development of EVs in the world has shown a sharp increase in recent years. In 2020 the number of EVs was 3.24 million, but in 2021 it jumped 108% to 6.75 million units. As a result, EV share also increased from 4.2% in 2020 to 8.3% in 2021 (IEA 2022 and EV Volumes 2022). With this number, it is estimated that EVs worldwide until 2022 will amount to more than 16 million units. With total world sales in 2021 of 6.75 million units of electric cars, China leads the way with total sales reaching 50.31%, followed by Germany (10.22%), the USA (9.89%), The United Kingdom (4.83%), France (4.67%), Norway (2.34%), Italy (2.09%), Sweden (2.04%), South Korea (1.70%), the Netherlands (1.45%), Belgium (1.05%), Spain (1.03%), and other countries (8.37%).

At the national level, the Indonesian government has also submitted its Intended Nationally Determined Contribution (INDC) to the UNFCCC, in which Indonesia promises to reduce GHG emissions by 29% compared to Business as Usual (BAU) and with an additional 12% to 41% with international assistance by 2030. This target will be achieved through the forestry and energy sectors, including transportation, waste, industrial processes, product use, and agriculture. Transportation is the most significant contributor to pollution, namely NOx pollutants (72.40%), CO (96.36%), PM10 (57.99%), PM2.5 (67.03%), and the second contributor to SO₂ (43%) (KLH 2020). One of Indonesia's policies in reducing emissions, like other countries in the world, is to encourage the use of environmentally friendly vehicles, especially battery based EVs, as stated in Presidential Regulation Number 22 of 2017 concerning the National Energy General Plan. In parallel, the program to accelerate battery based EVs in Indonesia is also aimed at reducing fuel oil consumption. Reducing fuel consumption will reduce fuel imports, which currently range from 35% of the total final energy consumption. The transportation sector consumed 43.11% of the total energy consumption, industry 34.06%, households 16.8%, commercial 4.79%, and other sectors 1.22% (ESDM 2020).

To accelerate, the government issued Presidential Regulation No. 55 of 2019 concerning the Acceleration of the Battery Electric Vehicle Program for Road Transportation. The primary considerations of this regulation are to improve energy efficiency, energy security, and energy conservation in the transportation sector, and the realization of clean energy, clean and environmentally friendly air quality, as well as Indonesia's commitment to reduce greenhouse gas emissions. The acceleration of the battery-based EV program for road transportation is organized through the acceleration of the development of domestic battery-based EVs, the provision of incentives, the provision of electric charging infrastructure, and regulation of electric power rates for battery-based EVs, compliance with the technical provisions of battery-based EVs, and protection of the environment. In addition, this presidential regulation is expected to encourage the formation of a robust EV ecosystem, which includes the battery-based EV manufacturing industry, researchers, charging station providers, users, government, and related support systems.

Presidential Regulation No. 55 of 2019 relates to the obligation of the minimum local content of battery-based EVs produced by the battery-based EV industry in the country. For example, in 2020, the achievement of local content must be 40%. On the supply of charging stations, The Minister of Energy and Mineral Resources Regulation No. 13 of 2020 assigned PLN to hold a charging station at an early stage to provide convenience in charging electricity. Meanwhile, in terms of incentives for battery-based EV users, Bank Indonesia has issued no down payment for the purchase of battery-based EVs on credit, a 0% PPnBM (Sales Tax on Luxury Goods) incentive for BEVs and FCEV,

as well as a 10% motor vehicle tax incentive, no progressive tax for the ownership of the following battery-based EV, and free of title transfer tax (as in Jakarta).

The policy launched by the government is still in the initial position to form an EV ecosystem so that it can grow as planned. The EV market is still moving slowly. The development of EV adoption in Indonesia is still deficient. The EV market penetration is still around 0.36%, far from the 2020 target of 10% (Gaikindo 2021). Indonesia is not alone concerning the slow development of EV adoption. Other ASEAN countries also have a market share far below 1%. Based on this condition, the result of EV adoption in Indonesia is still low and running slowly. There is a phenomenon of a wide gap between target and realization, which indicates that there are still many solid challenges and significant barriers to EV adoption.

Based on the background discussed above, the research questions are what is the EV ecosystem, the relationship between sub-systems, the level of importance of sub-systems, and the factors (positive and negative) that influence the development of EV adoption in Indonesia?

The objective of this research is to conduct a literature study of the factors that influence EV adoption in Indonesia and develop a conceptual model of relationships between actors in the EV ecosystem as the early stage to feed a further analysis of effective policy alternatives for EV adoption under dynamic EV ecosystem in Indonesia

2. Review of Literature (EV Ecosystem)

EVs are a new type of product that is not immediately accepted by users massively but is adopted slowly in the early stages, so many studies use the Technology of Acceptance (TAM) (Davis 1985), Diffusion of Innovation (DOI) (Rogers 2003), and its development, such as Technological Innovation Systems (TIS) and Unified Theory of Acceptance and Use of Technology (UTAUT). As a sub-system, the buyer/user of EVs in all studies is the same as an EV adopter.

The EV ecosystem has several perspectives, including the industrial, business, management platform, and multi-actor network (Tsujiimoto et al. 2018). Multi-actor is a representation of the number of parties that become a sub-system of the EV ecosystem, where actors are interrelated and have variables or several variables as a link between actors. The variables that bind these actors are related to several aspects of industrial relations, business, and management.

The sub-systems or actors in the EV ecosystem that are the research focus have many variations, depending on the purpose of the research and the theoretical approach taken. Brozynski and Leibowicz (2022) created a multi-level optimization model of EV adoption, which is included in infrastructure-dependent technology adoption to address the chicken-and-egg problem. Sub-systems are called Levels. Level 1 is Policymaker, Level 2 is technology and infrastructure firm, and Level 3 is Consumers. Li and Jiao (2022) evaluated the impact of multi-policy interventions on EV diffusion based on multi-agent system dynamics. EV diffusion involves multi-agent interactions (sub-systems), i.e., government, consumers, manufacturers, and charging infrastructure operators.

Zolfagharian et al. (2020) simulated an E-mobility system with interrelated sub-systems: e-mobility innovation system, EV charging points/stations, EV pricing, EV-related subsidies, and EV purchaser. The e-mobility innovation system is a macro-level attribute, while the other is a micro-level attribute, focusing on EV adoption and market dynamics. This study applies two theoretical approaches to the transition process: the Technological Innovation Systems (TIS) framework and the Unified Theory of Acceptance and Use of Technology (UTAUT). Sub-systems are also interpreted as modules, as did Yue Xiang et al. (2017), namely EV development modules; demand EV modules; and the evolution module. EV ecosystems are complex systems that dynamically influence each other.

Figure 1 shows a conceptual model of EV ecosystems and relationships between sub-systems for understanding the EV adoption ecosystem based on the results of the review literature, the case of Indonesia. The figure illustrates the relationship between actors (sub-systems) in the EV ecosystem: the Government, EV Manufacturer, EV Charging Infrastructure Provider, and EV Adopters. The relationship between the government and the other three sub-systems is related to providing legal and policy umbrellas in developing fiscal and non-fiscal EVs. Meanwhile, the relationship between the EV Adopter and the other three sub-systems is in the form of all offers grouped into two groups of factors (rational and psychological-social) that influence the EV adopter to buy an EV or not to buy an EV.

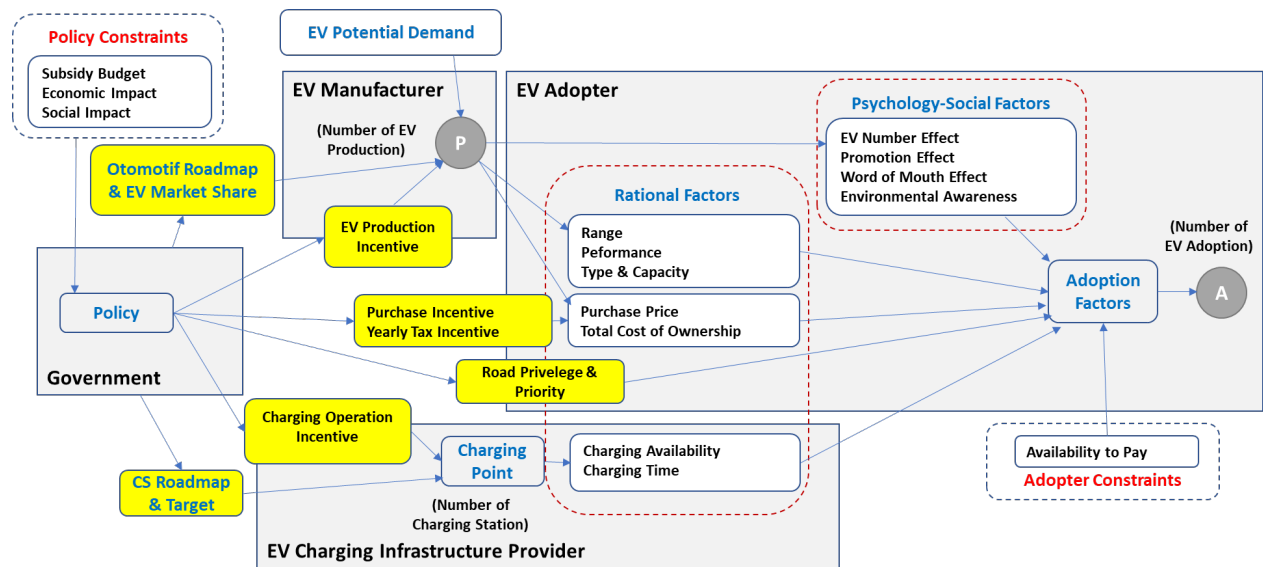


Figure 1. Conceptual Model of EV Ecosystems and Relationships Between Sub-Systems

Government has a role in providing conditions conducive to EV growth by making a roadmap and target market share. Because EV development is infrastructure-dependent technology adoption, overcoming the chicken-and-egg problem requires government intervention, including subsidies/incentives to the other three sub-systems: subsidies to EV manufacturers, EV infrastructure charging station providers, and EV adopters. EV manufacturers urgently need government support to facilitate investment and reduce EV production costs according to the target market and demand of potential buyers. EV products offered to prospective EV adopters are a factor in the attractiveness of EV adoption, in addition to the availability of charging stations and direct subsidies from the government to users. Government support is also urgently needed for EV charging infrastructure to invest in building charging stations and operating them. The increase in the number of charging stations and the ease of locating charging stations are factors in the attractiveness of EV adoption. The policies need to be assessed in more depth before being implemented due to limitations, such as budget constraints. But, on the other hand, policy implications and risks also need to be studied in more depth because EVs, as a disruption of technology, can disrupt the establishment of the ICEV industry and have economic and social impacts.

3. EV Adoption Factors

3.1. Factors Affecting EV Adopters to Purchase/Adopt EVs

Based on the diffusion of innovation theory (Rogers 2003), at least two groups of factors influence a person to adopt an EV. The first is rational factors, where a prospective adapter will learn rationally and measurably how many benefits of buying an electric car. And the second is a psychological-social factor, where a prospective adapter will consider self-confidence to buy an EV by looking at people's behavior regarding the acceptance of this new technology and product. These two main factors will influence each other and convergently will be the primary consideration for a person to become an adopter or not.

Rational factors are quantitatively measurable factors, which include technological attributes of EVs, the economy of EVs, EV charging infrastructure, and government policies for users of EVs.

Table 1 summarizes the factors influencing EV adoption based on the literature review.

Table 1. Factors Affecting EV Adoption in the EV Ecosystem

Key Factors and Its References		
1. Factors Affecting Users (EV Adopters) to Purchase/Adopt EVs		
1.1. Rational Factors		
EV Technology Attributes	Range	Yue et al. (2017), Yu et al. (2018), Novizayanti et al. (2021), Tarei et al. (2021), Kumar et al. (2019), Xue et. al (2015), Adepetu et.al (2015), Kongklaew et al.(2021)
	Performance	Zolfagharian et al (2020), Deuten et al. (2020), Tarei et al. (2021), Kumar et al. (2019), Huang et.al (2021), Abbasi et.al (2021)
	Safety	Nissan (2021)
	Type and capacity	Novizayanti et al. (2021), McDonald (2022)
EV economy	Purchase price	Yue et al. (2017), Zolfagharian et al (2020), Lonan and Ardi (2020), Yu et al. (2018), Novizayanti et al. (2021), Hu et al. (2020), Tarei et al. (2021), Llopis et al. (2021), Xue et al. (2015), Xue et. al (2015), Huang et al. (2021), Adepetu et al. (2015), Bitencourt et al. (2021)
	The total cost of ownership (TCO)	Tarei et al. (2021), Kumar et al. (2019), Adepetu et.al (2015).
EV Charging Infrastructure	Charging station availability	Zolfagharian et al (2020), Lonan and Ardi (2020), Yu et al. (2018), Hu et. al (2020), Tarei et al. (2021)
	Charging time	Yu et al. (2018), Secinaro (2020), Liang et al. (2021)
Fiscal policy	Purchase price subsidy/incentive	Kumar et al. (2019), Secinaro (2020)
	Yearly tax incentive	Deuten et.al. (2020), Llopis et al. (2021)
Non-fiscal policy	Road priority	Novizayanti et.al. (2021), Lu et al (2021), Nissan (2021)
1.2. Psychology-social Factors		
Social network	EV number effect	Deuten et.al. (2020), Abbasi et.al (2021)
Formal marketing	Promotion effect	Tarei et al. (2021), Huang et al. (2021), Abbasi et al. (2021)
Informal marketing	Word of mouth/WoM effect	Deuten et al. (2020), Yu et al. (2018)
Environmental	Environmental awareness	Tarei et al. (2021), Kumar et al. (2019)
2. Factors Affecting EV Charging Infrastructure Provider to Build and Operate Charging Stations		
Fiscal policy	Charging station development subsidy	Zolfagharian et al. (2020), Huang et al. (2021), Kongklaew et al. (2021)
	The initial market of charging station policy	ESDM (2020)
	Charging station and home charging electricity fare discount	Wang (2019), Novizayanti et al. (2021)
3. Factors Affecting EV Manufacturers to Produce EVs		
Fiscal policy	EV production incentive	Hu et al. (2020), Huang et al. (2021)
Non-fiscal policy	EV CBU/CKD/part import policy	Perpres (2019)

Based on Table 1, it is very noticeable that the factors influencing EV adoption are very diverse and involve many actors (sub-systems). In addition, there is also a reflection of the complexity of the EV development ecosystem's problems. Therefore, understanding the EV ecosystem and mapping relationships between sub-systems is very important early to make it easier to formulate effective strategies and policies in driving EV adoption.

3.1.1. EV Technology Attributes

Based on various studies, the aspects of technological attributes that most influence a person to adopt an EV with quantitative and rational considerations are the mileage of a single battery charge (range), the performance of an EV, and the type and capacity. Other aspects that are also taken into consideration are features and design, safety and reliability, technology integration and maturity,

Mileage (range) for EVs is the highest variable related to technological attributes. Yue Xiang et al. (2017), Yu et al. (2018), Novizayanti et al. (2021), Tarei et al. (2021), Kumar et al. (2019), Xue et al. (2015), Adepetu et al. (2015), and Kongklaew et al. (2021) reinforce this and relate to battery technology which in the future is getting cheaper and longer the electric charging period.

Zolfagharian et al. (2020), Deuten et al. (2020), Tarei et al. (2021), Kumar et al. (2019), Huang et al. (2021), and Abbasi et al. (2021) places the performance of EVs is also an important variable and Abbasi aspects of technological attributes that are measurable and can be compared with each other between EVs, and with conventional vehicles. Including the performance here, among others, is the electric motor's speed, durability, and efficiency.

The aspect of better safety standards is the most favored factor in the Nissan survey (2021), in addition to factors related to electric charging (the opportunity to charge electricity in the office, at home/apartment, and the choice of fast charging), as well as incentives from the government (tax exemption/reduction).

Type and capacity are not widely used as variables by researchers from many countries. Still, Novizayanti et al. (2021) put the type and capacity of EVs as essential variables, especially for Indonesian consumers. This can be learned from the tendency of Indonesian automotive consumers, who mostly prefer vehicles with the type of SUV (special use vehicle) and MPV (multi-purpose vehicle), which is a representation of the consideration of the type and capacity of vehicles that are favored in Indonesia.

3.1.2. EV Economy

Rationally, the economic aspect is the aspect that most influences the adoption of EVs. EV economy consists of the purchase price, EV-ICEV price difference, re-sales price, total cost of ownership (TCO), title transfer cost, operating cost, maintenance cost, yearly tax, and insurance.

The purchase price is the most studied variable. It is the most important variable in the economic aspect that affects a person buying an EV, as discussed in the study by Yue et al. (2017), Zolfagharian et al. (2020), Lonan and Ardi (2020), Yu et al. (2018), Novizayanti et al. (2021), Hu et al. (2020), Tarei et al. (2021), Llopis et al. (2021), Xu et al. (2015), Xue et al. (2015), Huang et al. (2021), Adepetu et al. (2015), and Bitencourt et al. (2021).

The purchase price is the primary consideration for prospective adopters, which is also found in the sale of internal combustion engine vehicles (ICEV) so that segmentation of the selling price appears, which is the choice of the majority of consumers, namely prices below IDR 300 million in the Indonesian case. In the same class and type, EVs' price difference compared to ICEVs is still more expensive by more than 50%, even though they have received purchase tax incentives (purchase incentives) and title transfer costs. Therefore, the phenomenon of exploding sales of Wuling Mini-EV in China, which in 2021 reached 424 thousand units (EV Volumes 2022), is a best practice for Indonesia to focus on the EV market niche below IDR 300 million.

The second variable of concern related to the economic aspects of EVs is the total cost of ownership (TCO), as researched by Tarei et al. (2021), Kumar et al. (2019), and Adepetu et al. (2015). Considering TCO is critical to assess the economy of EVs comprehensively. Because if only pay attention to the purchase price, consumers will find the high purchase price of electric cars compared to conventional vehicles of the same class and type. The advantages of EVs will be attractive if all aspects of the cost are calculated simultaneously, such as the cheaper cost of charging electricity for batteries, maintenance costs, the existence of several incentives such as free renaming fees, and the annual tax because free of the carbon tax. Jens et al. (2016) created a TCO calculation model with a consumer-centric approach, concluding that the TCO of BEV is cheaper than the TCO of ICEV and HEV.

3.1.3. Availability of EVs Charging Infrastructure

EVs cannot be separated from battery charging, individual charging at home/apartment (home charging) and charging in public places known as charging stations. The relationship between charging stations and the number of EVs is

described as an "egg and chicken" relationship, as they both influence each other. The increasing number of EVs will require more and more charging stations. Meanwhile, many charging stations will give potential users more confidence to buy EVs.

The availability of charging stations and the number of charging stations are the main factor related to the charging infrastructure of EVs, which is constantly being researched by most authors, including Zolfagharian et al. (2020), Lonan and Ardi (2020), Yu et al. (2018), Hu et al. (2020), and Tarei et al. (2021). Every EV is equipped with an electric charging device at home (home charging), so it will not be a problem if the EV is operated at a short distance and relies on charging at home. However, for long-distance use, the variable number and availability of charging stations in many places is an essential factor.

A variable that concerns EV users is the charging time (Yu et al. 2018, Secinaro 2020, and Liang et al. 2021). The charging time of EVs will vary depending on the type of charging point. For the AC type (regular charging), the charging time can reach about 8 hours. For the DC (fast charging) type, the charging time can only be about 2 hours. As for the DC (super-fast charging) type, the charging time only takes about 30 minutes.

3.1.4. Government Policy for EV Users

The policies issued by the government to encourage the use of EVs in their respective countries are very diverse. The policy was implemented to encourage and provide convenience for all connected actors in the EV industry ecosystem. Regarding demand, policies aimed at adopters (users or potential users) are divided into two types of policies: fiscal policy and non-fiscal policy.

Fiscal policy for users relates to the provision of subsidies, the provision of incentives, reductions, or exemptions from taxes or fees associated with the ownership of EVs. Almost all countries place purchase price subsidies/incentives as the most widely implemented policy to increase the adoption of EVs (Ali and Naushad 2022, Kumar et al. 2019, and Secinaro 2020). The subsidy/incentive for purchasing electric motor vehicles includes a vehicle registration fee (registration cost) and a title transfer incentive. Another fiscal policy often given to EV users is the yearly tax incentive (Deuten et al. 2020 and Llopis et al. 2021). This annual tax reduction is due to the zero-emission element for EVs, which causes the yearly tax on EVs to be lower than for conventional vehicles.

The non-fiscal policy commonly implemented in many countries is related to providing priority privileges on the road to EV users. Some privileges include priority lanes for EVs, odd-even driving permission, and concessions on parking locations, which are equipped with several fiscal conveniences, such as toll fee discounts and discounts or free parking rates (parking fee discount), as studied by many researchers, among others Novizayanti et al. (2021), Lu et al. (2021), and Nissan (2021).

3.1.5. Psychology-social Factors

The factors influencing potential users to buy EVs are not only influenced by rational and measurable factors but also qualitative psychological factors in a social network system that provide confidence and desire to consider purchasing an EV. Although the development of the number of EVs will pass through the initial phase that is not widely known to the public, it will gradually be more and more owned and used on the road. The increase in the number of EVs will further increase one's confidence in buying an EV if one is financially able to buy it, either as a first or a replacement vehicle or as the next addition to the vehicle. This variable is known as the EV number effect variable, as studied by Deuten et al. (2020) and Abbasi et al. (2021).

The adoption of EVs is also influenced by the promotional effects of EVs (Tarei et al. 2021, Huang et al. 2021, Abbasi et al. 2021). Promotion is an official channel of vehicle sales agents, including EVs, to influence consumers to buy the products offered. Promotion is also carried out by the government or non-governmental organizations by socializing the importance of using EVs through mass media and social media.

In addition to official promotion, word of mouth (WoM effect) of EV excellence is also a factor that cannot be ignored in adopting EVs (Deuten et al. 2020 and Yu et al. 2018). Factually, the WoM effect occurs in all social systems, such as in the workplace, housing, communities, public transportation, etc.

Environmental awareness is also a factor that influences a person to choose an environmentally friendly vehicle, which is zero-emission, such as EVs (Tarei et al., 2021, Kim et al., 2018, Kumar et al. 2019 and Jung et al. 2021).

3.2. Factors Affecting EV Charging Infrastructure Provider to Build and Operate Charging Stations

The availability and adequacy of charging stations affect the desire to buy EVs. The ease of finding charging stations will reduce the user's concern about charging the battery that will run out of power. Many governments have made policies to encourage the construction and operation of these charging stations.

The strong relationship between the number of EVs and the number of EVCS (EV charging stations) is shown by Liang et al. (2021), where the number of EVs is the most fundamental factor that affects the economic aspects of EVCS operation and affects other factors. The results of this study reinforce the argument that the number of EVs significantly affects EVCS, and vice versa, so that these two sub-systems (EV adapters and EV charging infrastructure) have a mutual relationship that strengthens/weakens.

A popular policy is to provide charging station development subsidies, as in Zolfagharian et al. (2020), Huang et al. (2021), and Kongklaew et al. (2021). Even in some countries, in the early stages charging stations were built by the state to stimulate the growth of EVs so that the comparison of the number of charging stations and the number of EVs is at an ideal number, namely one charging station: 10 EV units (IEA 2021). In this case, Indonesia is also doing the same by assigning PT PLN to build charging stations in the early stages of the current development of EVs as the initial market for the charging station policy.

The policy of providing discounts on electricity prices for charging stations and home charging is a form of incentive to reduce the operational costs of EVs (Wang 2019 and Novizayanti et al. 2021).

3.3. Factors Affecting EV Manufacturers to Produce EVs

The production of EVs in many countries is initiated with macro-industrial policies, mainly triggered by the target of reducing greenhouse gas emissions and the target of reducing dependence on depleting fossil energy sources. Some countries make market share targets gradually and set a final mark to replace all conventional vehicles switched to EVs in a specific year, for example, 2040 or 2060 (IEA 2021). The acceleration of EV development is covered by automotive industry policies and long-term target market share. It is supported by environmental, energy, low-carbon transportation, investment, fiscal and non-fiscal policies, research policies, etc.

Micro-industrial development policies to develop EV production include EV production incentives (Hu et al. 2020 and Huang et al. 2021). In addition, in the early stages until a particular year, the Indonesian government permits EV manufacturers to import EVs in the form of CBU/CKD/part. However, the choice of the global automotive manufacturing industry to build an EV factory in a country is influenced mainly by the OEM (Original Equipment Manufacturer) business considerations, including the ease of obtaining raw materials, labor costs, and market strength.

4. Discussion

The conceptual model of EV ecosystems described mapping the relationship between sub-systems. EV adoption factors are strongly influenced by the interests of each actor in the EV ecosystem, such as the Government, EV manufacturers, charging station infrastructure providers, and users/EV adopters. Likewise, each perpetrator has interests according to their preferences.

The government is interested in achieving the target number and market share of EVs following the roadmap that has been launched by providing fiscal and non-fiscal policy interventions and socializing the importance of EV development programs. Furthermore, as a regulator, the government makes policies to encourage the production, purchase (adoption), and use of EVs, including encouraging EV research and development (R&D).

Manufacturers are interested in producing EVs that guarantee their profits and business continuity, whether for manufacturers producing ICEVs, EV-specific manufacturers, or start-up industries. As a core EV integrator industry, EV manufacturers are supported by the component industry, supply chain networks, R&D, marketing networks, maintenance networks, and financing networks.

Charging station providers are interested in providing charging services that guarantee profits and business continuity, whether for charging station operators owned by government-owned, private enterprises or cooperation between the two. Therefore, the provision of charging stations is supported by the supply of *charging station* technology (AC-low charging type and DC-fast/*super-fast charging* type) and the supply of electricity network.

The adopter's interest in purchasing an EV is according to the ability to buy it, considering the rational and psychological factors. The factors include the EV technology attribute, the EV economy, the ease of charging, and the socio-psychological considerations.

5. Conclusion

The literature review on the EV ecosystem and adoption factors resulted in the understanding of the relationship between the sub-systems of the EV ecosystem and the factors affecting EV adopters to buy EVs, EV manufacturers to produce EVs, EV charging station providers to serve charging, and government to regulate and drive EV production and adoption by some policy instruments. The conceptual model of the EV ecosystem identifies the relationship between actors in the EV ecosystem.

The limitation of this research was that EV adoption factors were not classified as a driver or a barrier related to EV adoption, especially in the Indonesia case. However, in future research, this conceptual model can be developed regarding the interdependence of actors within the EV ecosystem, determine the main barriers, and analyze the barriers structure for selecting effective EV production and adoption policies in the system thinking framework.

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