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Review

Current Readiness Status of Electric Vehicles in Indonesia: Multistakeholder Perceptions

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Abstract: As a net oil importer since 2004, Indonesia's success in developing fuel economy and infrastructure for electric vehicles would be vital to ensuring energy security and decarbonization from the transport sector. Following the Presidential Regulation on the Acceleration Program for battery-based EV for Road Transportation in 2019, the Indonesian government provides incentives for the domestic production of EVs. However, as EV technology is relatively new for the domestic automotive industry in Indonesia, it needs to go through stages of development to achieve full readiness in society. This study analyses the key stakeholders' perceptions of EV industries using the Japanese technology readiness assessment (J-TRA) to better understand the current readiness level of EVs in Indonesia. Primary data are collected through interviews with an EV start-up company, experts in the EV field, government officials in charge of the national EV projects, and EV end-users. Extensive literature related to success stories of EV adoption in other countries was conducted as the basis for this study. The results showed that key stakeholders agree that EV technology has reached a high readiness level in technology development. Most of the stakeholders voted that the readiness bottleneck is commercialization, safety, and integration parameters. Furthermore, an elaborate policy recommendation gathered from both literature reviews and interviews with related stakeholders is presented.

Keywords: electric vehicles; Japanese technology readiness assessment (J-TRA); multistakeholders; perception; readiness level

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1. Introduction

Modern-day society relies on people and goods' mobility. Unfortunately, the currently dominant fossil-based fuelled transport systems harm the environment as they emit pollutants and increase greenhouse gas emissions. With fast economic growth and rapid urbanization in Indonesia, it is projected that more people will acquire a personal vehicle for mobility. The transportation sector is one of the most significant contributors to CO_2 emissions in Indonesia, second to the industrial sector. With the fast economic growth of 5% in 2019, which is predicted to rebound in 2022 after the COVID-19 pandemic [1], and the high urbanization rate, it is expected that the necessity for convenient mobility will surge. Private vehicle ownership has been steadily rising by more than 5% yearly, according to the Indonesian Central Bureau of Statistics [2], which statistically comprises motorcycles (82%), cars (11%), buses (1.7%), and freight transport (5.3%). This trend shows that the market for private vehicles is still relatively high.

In 2019, Presidential Regulation Number 55 Year 2019 regarding the Acceleration Program for Battery Electric Vehicles for Road Transportation was enacted. This regulation acts as the legal umbrella for Indonesian electric vehicle development and creates a domino effect for several ministries to start electric vehicle (EV) projects in Indonesia. The regulation is also one of the government's ways to deliver and achieve targets for the Paris Agreement. The International Energy Agency predicted that EVs could be vital for more sustainable transportation due to their low emissions and lower dependability on fossil-based fuel (FF). Renewable energy (RE) in the transportation sector is one way to decarbonize the transportation sector. Many types of vehicles that are considered EVs include hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs), and fuel cell electric vehicles (FCEVs) [3]. EVs offer many advantages compared to internal combustion vehicles, such as high energy efficiency [4], minor environmental impact, and high driving performance [5].

Whereas the Indonesian government tries to boost the EV industry, the challenges come from both the supply and demand sides. EV manufacturers started to foster in Indonesia, from two-wheelers such as electric bikes and electric motorcycles to four-wheelers such as hybrid EVs (HEVs) and battery EVs (BEVs) non-wheelers, such as electric scooters. Some manufacturers produce their EVs domestically, with some parts, especially the battery, being imported. Other manufacturers focus on assembling the parts with whole parts being imported. On the other hand, the government also started regulating and providing an incentive for EV users, although limited. However, the incentives seem to lack socialization and are not being touted enough. While the road map prepared by the Indonesian government, which includes the development of EV industries, is expected to be achieved by 2030, the current situation demonstrates the opposite. In 2020, EV sales did not meet the target set by the government and industries, considering that in 2019, 2020, and 2021, the total EV car sold was less than 500 units [6]. The low selling figure implies that the market might not be ready to purchase and use EVs. As a new trend, EV diffusion in the larger market must go through several stages of development to achieve full readiness in society. Several studies have found that the increase in EV sales since 2009 is due mainly to policy support from the government during the early stages of EV market penetration, such as in China and Norway [7–10]. Indonesia could learn from other countries that have already shifted from conventional vehicles to EVs and integrate EV-related policies into their national transport policy.

To achieve the goals elaborated in the roadmap, cooperation, collaboration, and integration by multiple stakeholders are required. Furthermore, for resource efficiency, collaboration should address the bottleneck of EV penetration in the country. Therefore, it is vital to recognize the readiness level of EVs according to each of the key stakeholders in the country. This study conducts a systematic literature review on EV and EV adoption in several developed and developing countries to understand EV development factors, challenges, and opportunities. Then, we interviewed the key EV stakeholders in Indonesia, the industrial sector, experts, the government, and end-users. Therefore, the objectives of this study can be summarized as follows: (1) systematically review the current trend of EVs and factors affecting EV adoption, challenges, and opportunities; (2) understand the current EV readiness in Indonesia through in-depth interviews with related stakeholders; (3) identify challenges that might block EV readiness from several perspectives; and (4) assess multistakeholder perceptions from in-depth interviews using the Japanese Technology Readiness Assessment (J-TRA) methodology. J-TRA is a methodology adopted by Japan from The Technology Readiness Assessment (TRA) [11] initially developed by the National Aeronautics and Space Administration (NASA) [12] to measure a technology's readiness level (TRL). Observation of a TRL is essential so that technology bottlenecks can be identified and responded to. The rest of this paper is structured as follows. Section 2 presents the methodology for this study. Section 3 presents the results of a systematic literature review regarding EV adoption, its related factors, and how the J-TRA can assist in understanding the readiness level from several perspectives. Section 3 introduces the results of the study, the current status and condition of EVs in Indonesia, the results of in-depth interviews with respondents, and the results of the J-TRA. Finally, Section 4 presents the conclusions and future directions.

2. Methods

2.1. Study Framework

To achieve the first objective of this study, we collected literature on the subject of EV development, EV adoption, and policies regarding EVs in several countries that have been successfully adopting EVs. This study also collected literature containing the current status and development of EVs in Indonesia. The literature regarding EV development in other countries is specifically collected systematically from the journal database pool. Due to limited studies about EV in Indonesia, a combination of different types of literature is being used for the current status in Indonesia. Government regulations, news, and journal papers are reviewed to present a broader view of the status of EV readiness in Indonesia. The literature review aims to answer the following questions: (1) How are EVs being successfully adopted in some countries? (2) What kind of strategies do both the government and industry boost the EV adoption number? (3) What are the challenges and factors that affect EV adoption? (4) What is the trend of EVs in Indonesia? (5) What kind of regulations did the government enact to achieve their road map regarding EV in Indonesia? (6) To what extent does EV penetrate the market in Indonesia? (7) What kind of challenges and obstacles are faced by EV industries in Indonesia?

The results of the literature review regarding policies implemented, barriers and challenges, and EV customer preferences became the basis for the policy recommendations that this study draws on in Section 4. Knowledge synthesized from the literature review becomes the basis of the interviews in this study. Upon constructing the base questions related to our respondents, we conducted an in-depth, semistructured interview with the national key stakeholders of EVs. The interview consists of two parts. First, our respondents consist of the EV industry (start-up), EV users, government officials in charge of EV projects, and EV experts from a research institute. The interview questions were prepared according to the type of respondent, sector-wise, and during the interview, evolved with findings revealed during the interview. For example, to the industrial sector respondents, the start-up and manufacturer, we asked about the technology development status, market, import-export regulations, financial scheme for investment, and governmental supports to initiate the businesses. To the end-users, we asked about the purchasing motivations and main use of the EV they own, purchase- and maintenance-related costs, available government incentives for EV users, their knowledge regarding EV, and their overall experience of using their EVs. To EV experts from a research institute, we asked about the existing government regulations related to the EV market and industry in the country, their observation of changes or growth in society related to EV use, possible hurdles of EV further diffusion in the country, and government roadmaps and actions related to EVs both at the personal usage level and for public transportation.

Second, after the interview, all respondents were given a J-TRA questionnaire containing a compliance checklist containing essential parameters of the current EV technology stage. By having the respondents respond to this checklist, we gathered the quantitative value of EV readiness level. The similarity and dissimilarity from multistakeholder perceptions are presented in a radar graph. Then, we compared the stakeholders' answers from the in-depth interview and the J-TRA questionnaire to identify the bottleneck of EV technology development and its commercialization status in Indonesia. Finally, this study offers some policy recommendations that can be adopted by EV stakeholders in Indonesia. The overall study's research framework is shown by the flowchart (Figure 1). Section 2.3 elaborates the detailed steps of the J-TRA methodology.

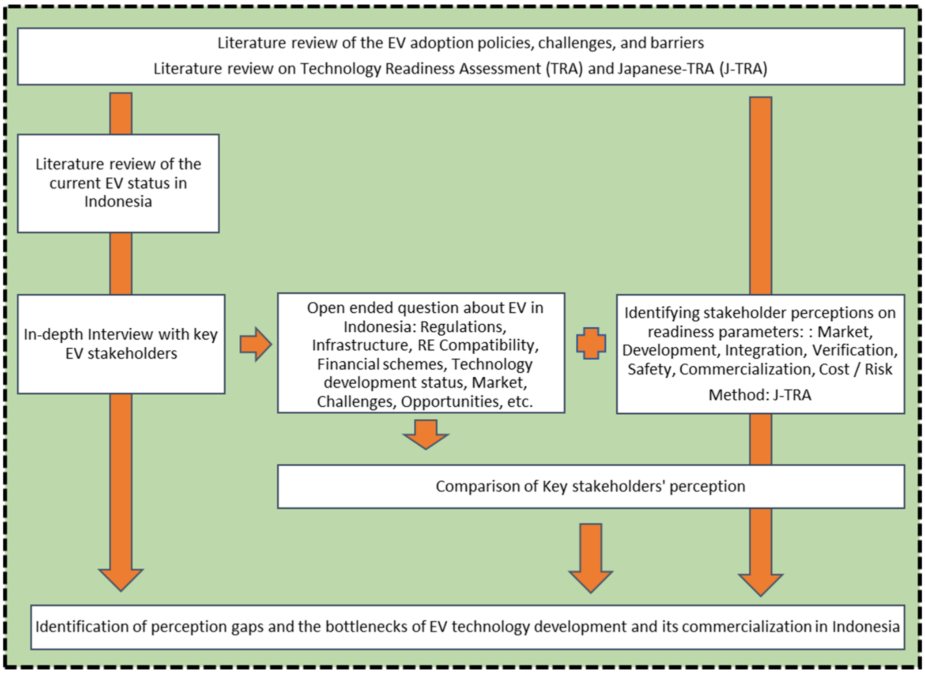


Figure 1. Research Framework.

2.2. Literature Review Method

This study used the systematic literature review as the methodology due to its practicability to produce a base for the knowledge pool and future research regarding the selected criteria/topics [13]. First, as this research aims to understand the current EV status and how EVs can be adopted, we established relevant literature pools. Then, we selected the search criteria with a combination of appropriate keywords "electric vehicle", "adoption", "preference", and "policy" from Scopus, Google Scholar, and Web of Science. All possible journals, Q1 and Q2 rank based on Scimago Journal Rank [14], were selected, and all duplicate publications were removed. We also limited the publishing year and selected only articles after 2010. The review protocol can be seen in Figure 2.

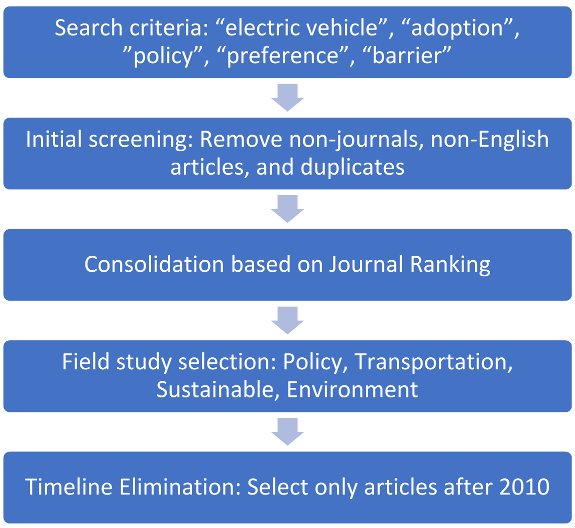


Figure 2. Protocol for Systematic Review.

2.3. The J-TRA Methodology

The J-TRA has seven parameters to determine the readiness level of technology. These parameters are (A) Market, (B) Technology Development, (C) Technology Integration, (D)

Verification, (E) Safety, (F) Commercialization, and (G) Cost and risk (Table 1). Analysis using J-TRA resulted in eight levels of TRL for each of the parameters. Any levels lower than eight indicate the gaps in a technology's readiness status.

Table 1. The J-TRA Scoring Matrix [11].

TRL	A (Market)	B (Development)	C (Integration)	D (Verification)	E (Safety)	F (Commercialization)	G (Cost and Risk)
1	A-1	B-1		D-1			
2	A-2	B-2		D-2			
3	A-3	B-3	C-1	D-3	E-1	F-1	G-1
4	A-4 A-5	B-4	C-2	D-4	E-2	F-2	G-2
5	A-6	B-5	C-3	D-5	E-3	F-3	G-3
6	A-7	B-6	C-4	D-6	E-4	F-4	G-4
7	The equipment and systems have been finalized. Manufacturing and introduction processes have been completed.						
8	Manufacturing and introduction processes have been completed and are in the stage of mass production of products.						

Step 1 in J-TRA: Compliance Checklist

Each of the J-TRA parameters has a compliance checklist. The checklist can be found in the Japanese Ministry of Environment [15]. Table 1 shows an excerpt of the compliance checklist. These checklists must be answered with "yes" and "no" answers based on evidence. The more "yes" answer in each parameter results in a higher TRL score.

Step 2 in J-TRA: Identifying the Mean Value and Normalization

In this study, there were multiple respondents from each key-stakeholder category. Because the present study aims to compare key stakeholder groups, we took the mean value of the respondents' answers in each parameter. Furthermore, as can be observed from Table 1, the number of compliance checklists in each parameter differs from one another. Therefore, normalization of value is required to achieve the accurate level in each parameter selected by the respondents relative to the rest of the parameters. Thus, Equations (1) and (2) show the mean value and the normalization formula, respectively.

$$X_{j,k} = \frac{\sum_i^n X_i}{n} \tag{1}$$

$$N_k = \frac{X_{j,k}}{Max_k - Min_k} \times 100\% \times 8 \tag{2}$$

The mean value of respondents' answers in category j for parameter k is represented by $X_{j,k}$, and the normalized value for parameter k is represented by N_k. The maximum value in category k or Max_k and the minimum value in category k or Min_k can be identified by the alphabet-numeric combination codes in the J-TRA scoring matrix (Table 1). The fixed value, 8, in Equation (2) refers to the maximum TRL score.

Step 3 in J-TRA: Generating the J-TRL

At level 8 of the TRL, technology has achieved its full readiness; it is safe to use, functional in its intended environment, fully integrated into the surrounding infrastructure, complies with energy efficiency standards, and widely used in the market. The J-TRL from stakeholder TRL_j can be determined by the lowest normalized value (Equation (3)) among the parameters generated in the previous step. It is possible that although technology is considered fully ready in its technology development (level 8); however, because there is a problem in the commercialization parameter, the final TRL is 2 or 3 because they are only available as a pilot demonstration product. In such a situation, the results will alarm decision-makers and identify the bottleneck for technology readiness status.

$$TRL_j = Min_{Nk} \tag{3}$$

3. Results and Discussion

Based on the search pool conducted, it is apparent that interest in EV adoption from customers and government points of view has tremendously increased over the past decade. Therefore, regardless of the main point of this study to understand the readiness and current status of EVs in Indonesia, due to the newness of the research itself, this study has taken on a more global focus as a reference for future study in Indonesia.

3.1. Review on Electric Vehicle Adoption

According to the IEA Report in 2019 [16], EVs, specifically electric cars, have a significant increase, with a 45% market share in China, 24% in Europe, and 22% in the United States. Many countries have been promoting and developing the EV industry for environmental and economic benefits, as it reduces emissions, creates new industrial development, and creates new jobs. Therefore, as one solution for reducing GHG emissions, EVs should be integrated into national transport strategies. However, several studies found that the increase in EV sales since 2009 is due mainly to policy support from the government during the early stages of EV market penetration [7–10]. Furthermore, EV adoption is also found to be highly dependent on demand-side policies such as road space privileges, parking options, tax reductions, financial subsidies, and/or exemptions [17–20].

3.1.1. Electric Vehicle Adoption in Countries with Strong Policies and Incentives

In China, the government provides incentives for both the demand and supply sides [21]. Manufacturers are given incentives to push the production of EVs. At the same time, to penetrate and establish the market, purchase incentives for customers are also given. China's government stipulates exemptions from purchases and additional taxes. The policy increased EV sales with a staggering 162% upsurge compared to the previous year's same period [22]. Policy incentives are divided into four categories [23]. First, purchasing incentives include government subsidies, purchase tax exemption, vehicle use tax exemption, and insurance discounts [23,24]. Second, the government eased the EV registration procedure by giving an exception for vehicle registration fees, providing a dedicated registration channel, and providing dedicated license plates [25]. Third, privileges for EV users include no driving restriction, parking benefits, road/bridge toll exemption, and vehicle inspection fee exemption [26]. Last, the policy regarding charging infrastructure construction subsidies and charging discounts.

As the second-largest EV market, EU countries proposed different policies, which mostly In Norway, the government provides an exemption for purchase tax, VAT, and an 80% reduction for registration tax [27]. The regulation resulted in a reduction in EV purchase cost up to 50%. Furthermore, the government provides enough EV infrastructure, with approximately 1800 standard chargers and 70 fast chargers built since 2011. The government's support resulted in an increase in EV sales from 730 units in 2010 to 10,400 units in 2013 [28]. In addition, some OECD countries, such as Belgium, Denmark, Spain, and Portugal, provide direct subsidies to increase the market penetration of EVs [29]. In Denmark, policies regarding taxes due to fuel consumption are imposed to reduce FF dependency. Furthermore, the government gave a 20% exemption for purchase taxes until 2019 [30]. In Iceland, the government gives EV owners purchase, VAT, and annual ownership tax exemption while increasing the charging infrastructure levels [30].

In North America, incentives and policies are dependent on the state or province. For example, in British Columbia and Québec, Canada, the government provides subsidies on the purchase price of a PEV from 500 CAD to 14,000 CAD [31]. Additionally, a flat national incentive of CAD 6000 per PEV sold over the next 20 years [32]. In 2017, only three provinces (British Columbia, Ontario, and Québec) allowed unrestricted access for EVs in the High Occupancy Vehicle (HOV) lane, and the policies were broadening to other provinces [31]. These three provinces also started to incorporate the need for EV charging stations into the building code. Furthermore, an incentive is also given for installing home charging stations across Canada, which varies depending on location [33]. According to the US National Conference of State Legislatures, as of July 2021, 47 states in the US offer incentives for EV deployment [34], including HOV lane exemptions, financial incentives for EV or electric vehicle supply equipment (EVSE) purchases, vehicle inspections or emissions test exemptions, parking incentives, and electricity rate reduction for EV charging during off-peak hours.

In South Korea, subsidy policies include tax rebates per EV at a maximum of 4200 USD, subsidies for BEVs at a maximum of 16,400 USD, and PHEVs at a maximum of $4300 [35]. Furthermore, the subsidy for the installation cost of public charging infrastructure is also given. EV drivers benefited from the government's deployment of chargers in 2019. These chargers included fast chargers, which EV drivers could use in place of slow chargers (3000 USD in subsidies), portable chargers ($350 in subsidies), and private chargers ($1200 in subsidies) [36]. Following Japan, South Korea also tries to boost the global market by giving incentives for the R&D of EVs and subsidies for both battery and fuel cells [37]. In Singapore, as the government imposed an increment on the carbon tax, the market share of EVs is increasing [38]. In Middle Eastern countries, the government also imposed tax incentives to increase the EV sales number, including special consumption taxes in Turkey [39,40], 75% exemptions on custom taxes in Jordan [40,41], and 15% discounts on vehicle registration and renewal fees in the United Arab Emirates [40,42]. Policies imposed for EV adoption in several countries can be found in Table 2 below.

Table 2. Policies Imposed for EV Adoption in the World.

<table>
<tr><th rowspan="2">Country/Countries</th><th colspan="2">Policies and Incentives</th></tr>
<tr><th>Monetary</th><th>Non-Monetary</th></tr>
<tr><td>China</td><td>• government subsidies
• purchase tax exemption
• vehicle use tax exemption insurance discounts
• vehicle inspection fee exemption
• exception for vehicle registration fees,
• charging infrastructure construction subsidies and charging discounts</td><td>• dedicated EV registration channel
• dedicated license plates
• no driving restriction
• parking benefits
• road/bridge toll exemption
• New Energy Vehicle
• Development of city charging</td></tr>
<tr><td>Norway</td><td>• exemption for purchase tax, VAT, and an 80% reduction for registration tax</td><td rowspan="5">• CO_2 emission standards for passenger cars and light-duty commercial vehicles
• Development of city charging</td></tr>
<tr><td>Denmark</td><td>• Exemption for registration tax (until 2016)</td></tr>
<tr><td>Sweden</td><td>• Exemption for registration tax</td></tr>
<tr><td>France</td><td>• Exemption for purchase tax
• Fiscal incentives for the construction and operation of charging infrastructure</td></tr>
<tr><td>Iceland</td><td>• Exemption for purchase tax, VAT, and annual ownership tax</td></tr>
<tr><td>Canada</td><td>• Subsidies for EV purchase</td><td>• Zero Emission Vehicle
• Unrestricted access for EVs in the High Occupancy Vehicle (HOV)</td></tr>
</table>

Table 2. *Cont.*

Country/Countries	**Policies and Incentives**	
	Monetary	**Non-Monetary**
United States	• Incentives for EV development • Incentives for EV or electric vehicle supply equipment (EVSE) purchases	• Zero Emission Vehicle • Development of city charging • Vehicle inspections or emissions test exemptions • Electricity rate reduction for EV charging • Unrestricted access for EVs in the High Occupancy Vehicle (HOV)
South Korea	• Tax rebates for EV purchase • Subsidy for the installation cost of public charging infrastructure	
Japan	• Japan's Incentive for New Clean Energy Vehicle Purchases	• Japan 2030 Fuel Economy Standards
Middle East Countries	• Discount on special tax, custom fee, and registration/renewal fee	
India	• Purchase incentives • Waiver for registration fee • Tax Credit for EV Purchases	• Development of city charging • Intensive public outreach program for raising awareness

A report from IEA in 2020 stated that broader policies regarding EVs should be implemented to accelerate the transition from conventional vehicles to EVs. In particular, IEA noted the policy regarding CO_2-emissions regulation and zero-emission vehicles (ZEVs), which can be implemented gradually to enable a cleaner vehicle industry [43]. Prior to 2019, IEA also suggested gasoline and diesel taxing according to the emission level [44]. IEA also deemed early adoption of EVs can be started from public procurement schemes [16,43,45]. Monetary incentives will be beneficial for attracting new consumers and should be tailored to support the transition [45,46]. Other related supports, including charging stations, battery development, and non-monetary policies, are expected to enhance EV adoption [16,43,45–47].

3.1.2. Study on Customer Preferences on Electric Vehicle

Studies regarding customer preferences for EVs have been conducted in the last decade. Researchers mainly use the stated preference (SP) method, considering a limited number of EV users with various attributes. EV preference studies that have been done include the financial, technical, infrastructure, and policy attributes for vehicle alternatives. Therefore, a comprehensive literature review regarding the factors affecting customer preferences is essential to synthesize the findings of this study, particularly from the user point of view. Table 3 shows respective attributes that have been previously studied for EV customer preference.

Table 3. The Attributes and Factors Studied for EV Customer Preferences.

Attributes	Operationalization/Factor	References
Financial attributes	purchase price	[40,48–63]
	operating cost	[48–53,56,58,59,61,62]
Technical attributes	driving range	[40,45,47,50,52,54–59,64]
	charging time	[54,57,65–72]
	engine power	[49,63,73]
	acceleration time	[45–47,65,71]
	maximum speed	[61]
	CO_2 emission	[49,64,66,70,73]
	brand (Country of origin)	[50]
	warranty (car and battery)	[51,56,67]
Infrastructure attributes	charging station availability (distance from home)	[51,53,54,56,58–60,74,75]
	number of charging station	[50,53,55,58,67,72,75]
	availability in a different area	[66,68]
Policy Attributes	pricing policy: Tax reduction/exemption for purchase tax, cash incentive	[46,49,51,54,56,59,62,65,72,76–78]
	pricing policy: Tax reduction/exemption for the road tax	[65,70,74]

Aside from the factors, the consumer's characteristics also affected EV adoption. According to Hackbarth and Madlener [70] and Briseno et al. [74], consumers with a high education level will likely adopt EVs compared to consumers with lower educational levels. The results from both studies show that early adopters are mostly highly educated. This finding is similar to a study by Higgins et al. [56]. In a study conducted in Malaysia, awareness of environmental consequences and value from having "high-technology" equipment positively affected the possibility of EV adoption [79]. In South Korea, although the awareness of environmental consequences is perceived as positive, the technological aspect is stated otherwise, as many have difficulty with maintenance [75,76]. The same goes with income level, where consumers with higher income levels will likely adopt EV [74,76]. However, a prior study by Hidrue et al. shows that income level did not affect the mindset for having cleaner options [80]. In the same study, Hidrue et al. [80] found that households with multiple vehicles are less likely to adopt EVs. In contrast, a study by [76] in South Korea found that having multiple cars was positively associated with purchase intention. A subsequent study in South Korea revealed that only males aged > 40 years with multiple cars and frequently drive perceived positive purchase intention [75]. The same is also found in a study in Lebanon, where households with multiple cars have a positive attitude toward adopting EVs if the price and driving range are similar to those of conventional vehicles [40]. Moreover, the autonomous feeling of charging EVs on their household turns out to be positively significant for EV adoption [80,81]. In Switzerland, having a private access charging facility positively affects EV adoption [82]. Education level also significantly has a positive perception of adopting EVs.

Following a study by Nayum et al. [77], which introduced sociodemographic and sociopsychological factors, Priessner et al. [78] concluded differently from the previous study. The relationship between sociodemographics, such as education level and income level, and an environmentally friendly mindset is perceived as positive and most likely to be a factor for early adopters [77,83,84]. However, the later study by Priessner et al. could not conclude the same. Although sociodemography is a contributing factor, the relation with an environmentally friendly/cleaner mindset is vague [78]. The results were similar to those of a study by Hardman et al. [85] in which future adopters might not always be high-income, have a high level of education, and have an environmentally friendly mindset but rather disperse from various sociodemographic levels. A study conducted in Japan found that as people get older, their environmental awareness increases, and middle- and older-age segmentation might be the "market" for EVs in Japan [86]. Demographically, females have better environmental awareness than males, who focus more on performance. However, the driving range is not perceived as necessary in the case of middle and older age, whose drive range is limited [86]. A study in Canada [56] found that older people are less likely to adopt EVs, although HEVs are still a comfortable option. Furthermore, a higher educated household has a positive relationship with EV adoption. The increasing number of EV adoption is also associated with environmental awareness both from pollution elimination and reduction in general. According to a study by Jain et al. [87] in India, the performance of EVs and infrastructure positively affect EV adoption intention, whereas perceived risk negatively affects the intention for EV adoption. A study focusing on electric bicycles in Nepal shows that people have a positive attitude towards electric bicycle adoption in consideration of their family members' health issues [88]. Low- and middle-income households also have positive attitudes towards EV adoption in comparison with high-income households.

A study in China by Qian and Soopramanien [58] in 2011 revealed that households with young children prefer conventional vehicles due to safety concerns about new EV technology, although large households with high income have a high intention to adopt either hybrids or EVs. The following study by the same authors in 2015 indicates that early adopters of EVs do not mind EV safety and have a positive attitude even with young children in their household; additionally, nonadopters are perceived as negative [89]. Additionally, since purchase price and annual cost highly impact the adoption of EVs in China, large households tend to purchase EVs [62]. Furthermore, a more comprehensive study across generations and cities was also conducted by Huang et al. [61]. Their study concluded that purchase price along with annual running cost and government incentives (both monetary and non-monetary) in baseline and extended models with generations and cities are significantly impacted the EV preference [61]. However, although the number of households influences EV adoption, this study found that the number of children does not.

Many studies in China show a different result, depending on the maturity of EV technology, the policies implied, and the location of the respondents. For example, a study by He et al. [90] shows that monetary benefits from EV purchases are perceived positively, while risk is perceived negatively. In the same research, environmental awareness has no significant effect on EV adoption intention. Another study in a second-tier city in China suggested that significant household and education levels have a positive attitude toward adopting EV, while a household with young children has a less positive attitude toward adopting EV [59]. As EV adoption might still be perceived as too expensive for some, a broader study regarding different EV business models is conducted in China by Huang et al. [91]. In their study, four different models are considered options for EV adopters, namely EV-buying, battery leasing, EV-leasing, and B2C EV sharing. While in EV-buying and battery leasing models, there is an upfront cost for buying the EV, the last two models exclude the upfront cost. Young generations have a positive preference for adopting EVs through a leasing scheme due to their high monetary value. Household income generally affects the type of EV adoption that can be afforded accordingly. Low-income households may prefer B2C EV sharing, while middle household income does not prefer any type of business model.

3.1.3. Barriers to Electric Vehicle Adoption

A lack of knowledge and information regarding EVs and their regulation hinders EV adoption. Many studies focus on understanding the barriers to EV adoption, both from the demand and supply sides. From the demand side, the low awareness of EVs contributes to the low adoption of EVs. In Canada, for example, many do not know the EV model, particularly PEV, and how they fueled [83]. In addition, some consumers might have misconceptions regarding EV technology; as in a study by Lane and Potter [92], UK consumers lack knowledge of EV characteristics and government incentives for EVs. This problem was also found in a study conducted by [93], where most respondents did not know about EV technology or government incentives. The lack of consumer awareness of EVs and the related regulations settles how consumers' information deficiency against EVs affects their willingness to adopt EVs [94]. A study in India also revealed that although the government has tried to increase the number of EV adoption, the awareness of EV technology impacts EV sales [95,96]. Therefore, offering consumers the correct information or educating them might increase their willingness to purchase EVs. The information includes EV technology, EV safety, EV as a more environmentally friendly vehicle, EV battery lifespan, and EV-related policies and incentives.

Second, the difficulty of home charging and public charging is due to limited infrastructure. The availability of home charging is essential for EV adoption, as is easy access for public charging [97]. However, home charging might not be feasible in multiunit residential buildings or apartments [31]. In North America, public charging is limited, with less than 300 public chargers per million residents, in 2021 [98]. In India, charging has become a hassle due to the higher demand for electricity both for home charging and public charging [95,99,100]. Although the number of EV sales is increasing in South Korea, the availability of public charging is still a concern [55,75]. This barrier could be minimized by deploying a better EV charging infrastructure from the government and other stakeholders.

Third, the high cost of EVs is still one of the barriers to EV adoption, particularly for some countries, such as India [96,99,100], Perugia [101], Chile [102], Sub-Saharan Countries [103], Spain [104], South Africa [105,106], Mexico [74], and South Korea [75]. Not only for private vehicles but also the high initial cost of EVs becomes an obstacle for taxis or public transportation to adopt EVs [107]. Like many countries, particularly developing ones, still have a concern regarding the cost, and the government gives incentives both for supply-side (manufacturer) and demand-side (customers) can ease the burden of purchasing EVs.

3.2. Current Trend of Indonesia's Electric Vehicle Development

In Indonesia, the mobility sector is dominated by road transportation (90% of the share). According to Brahman et al. [108], passenger cars are the leading cause of high CO_2 emissions in road transportation. Thus, sustainable and cleaner transportation, especially road transportation, is needed. Indonesia could learn from other countries that have already shifted from conventional vehicles to EVs and integrate EV-related policies into their national transport policy. In the middle of 2019, through Presidential Regulation Number 55 Year 2019 [109], the Indonesian government introduced the timeline to achieve EV sales targets as private and public vehicles. According to an internal report from the Ministry of Industry in 2020, EV car sales achieved only 0.15% of the total target, while EV motorcycles performed slightly better, with 0.26% of the target set out for 2020. The government has set policies and strategies to accelerate the development of the domestic EV industry through three stages: the development of the national market in the short, medium, and long term; industrial development in the medium to long term; and technology development. To support Presidential Regulation Number 55 Year 2019, other policy instruments have been imposed, as follows:

1. Ministerial Regulation, Ministry of Home Affairs Number 8 Year 2020, regarding Basic Calculation of the Imposition of Motor Vehicle Tax and Motor Vehicle Transfer Fee [110];
2. Ministerial Regulation, Ministry of Transportation Number 44 Year 2020, regarding Physical Type Testing of Motorized Vehicles with Motor Propulsion Using Electric Motors [111];
3. Ministerial Regulation, Ministry of Ministry of Energy and Mineral Resources (MEMR) Number 13 Year 2020, regarding Provision of Electricity Charging Infrastructure for Battery-Based Electric Motor Vehicles [112];
4. Ministerial Regulation, Ministry of Industry Number 27 Year 2020, regarding Specifications, Development Road Map, and Conditions for Calculation of Domestic Component Level Value for Domestic Battery Electric Vehicles [113];

5. Ministerial Regulation, Ministry of Industry Number 28 Year 2020, regarding Battery-Based Electric Motor Vehicles in Completely Decomposed and Incomplete Decomposed State [114].

Evs on the road are dominated by domestic products two-wheelers such as electric bicycles and motorcycles and imported products for four-wheelers. The Ministry of Industry has consented to at least ten battery-electric motorcycle manufacturers, with 44 models of battery-electric motorcycles currently having passed the test on acquiring the Certificate of Type and Certificate of Type Registration [115]. According to data in the National Industrial Information System (SIINAS), Ministry of Industry, the number of four-wheeler Evs imported in 2020 (data until April) is 545 units, some used for taxi services. In 2019, Bluebird, the largest taxi operator in Indonesia, bought 30 units of EV to be operated as their executive and standard taxi [116], among which are Chinese manufactured car brands BYD and Tesla. In addition, Bluebird built 12 charging stations located in their main office. However, Bluebird's plan to add more units in 2020 was halted due to the COVID-19 pandemic [117].

Some provincial governments also adopted Evs as part of their green roadmap. In 2019, Bali created electric bus regulations and deductions on vehicle transfer fees through Regional Regulation Number 9 Year 2019. This action was followed by Jakarta, Banten, East Java, and East Borneo in 2020. Some of the pilot projects for EV implementation are done by multi-company collaboration. Some examples are Blue Bird Group with BYD and Tesla, Grab Indonesia with Hyundai IONIQ, Transjakarta with BYD (Bakrie Auto parts), EV Smart Mobility (Toyota with ITDC Bali), Grab Indonesia with Kymco (Smart Motor Indonesia), Gojek with Gesit (WIKA, Jakarta Timur, Indonesia), and Viar (Triangle Motorindo, Jakarta Utara, Indonesia). GrabCar Elektrik powered by Hyundai, is a tangible form of Grab Indonesia and Hyundai's commitment to supporting the Indonesian government's vision of developing an electric vehicle ecosystem [118]. Grab Indonesia also supports the use of electric motorcycles. It is working with KYMCO to conduct a pilot to provide a fleet of electric-based vehicles and battery exchange support facilities supported by PLN (Indonesia's State Electricity Company, Jakarta Selatan, Indonesia) [119]. As one of the largest car manufacturing companies, Toyota Indonesia has joined the EV ecotourism project proposed by the government. The smart mobility EV (electric vehicle) project by Toyota Indonesia involved 30 environmentally friendly cars, including 20 Toyota COMSs (BEV), five Toyota C+pods (BEV), and five Toyota Prius PHEVs [120].

Some EV research and development activities can be observed in top national universities in Indonesia with EV's most extensive research and development institution, Badan Pengkajian dan Penerapan Teknologi/BPPT (Indonesia's Technology Assessment and Application Agency, Jakarta Pusat, Indonesia). In 2020, BPPT developed several technologies for electric motorcycles and electric buses in Indonesia [121], including battery development, battery testing, and electric car testing facility mentoring. One of BPPT's priority programs in 2021 was a "fast charging station" for EVs.

One hurdle for Indonesia's EV development is the nonexistence of a domestic battery industry. The need for battery imports resulted in higher prices of EVs. To address this issue, Indonesia has posed an export ban of nickel ore since 2020. The ban is hoped to secure the downstream battery industry using nickel ore as a raw material. This ban also hopes to encourage foreign firms and international investors to build all supply chains for nickel-based batteries in the country. Following the ban, international companies such as the German BASF and Japanese Mitsui Sumitomo established nickel processing facilities in Indonesia [122]. With the nickel ore ban, the Indonesian government also invested in the battery industry, a consortium of four states company, named Indonesia Battery Corporation (IBC). IBC has signed a Heads of Agreement (HoA) to invest in an EV factory with a battery consortium LG from South Korea [123]. Furthermore, CATL has stated an investment readiness and willingness with a capital of US$ 5 billion for battery manufacture.

3.3. Multi-Stakeholders Perception

3.3.1. Industry Perception

The current selling rate of two-wheel and four-wheel EVs in Indonesia is relatively low, at approximately thousands of units for two-wheels and a few hundred units for four-wheels a year nationwide. A market survey showed that the typical type of EV currently being developed in the country is the low-cost green car (LCGC) and electric motorcycle, as they match the Indonesian market purchasing power. Some of the existing local brands in the market are Viar (in collaboration with Bosch), Selis, and United Motor Indonesia. These brands target business-to-customer (B to C) and business-to-business (B to B) manners, such as collaboration with passenger and food delivery companies such as Grab Indonesia and Gojek. There have been attempts to develop an online application for electric bike-sharing using these electric motorcycles. However, traffic laws have stalled such businesses, as these electric motorcycles and scooters are not equipped with a license plate [124].

While many studies in Western countries have shown that the majority of people are willing to pay a premium for cleaner technologies and energy [125], this does not seem to be the case in Indonesia at the moment. The Asian Development Bank report [126] stated that affordability concerns are one of the critical hindrances of renewable energy development in Indonesia, along with their inability to integrate renewable energy into the main grid and higher investment risks. High price, low product quality, and weak after-sales services are the three most reported complaints from end-users of domestic EVs. While this finding itself could be a critical factor in building a better business model, it may also indicate a premature readiness of the technology. "*Engineer-to-order*" production is a way to stand up among the local EV industry. In Indonesia, the type of financial support for an EV start-up is the tax abatement for venture capitals registered with the country's Financial Services Authority (OJK) and temporary tax exemption for industries affected by the COVID-19 pandemic.

To obtain the SNI (Indonesian National Standard), rigorous testing of domestically manufactured parts and imported parts and compliance with product quality standards are necessary to obtain the SNI (Indonesian National Standard). While the Presidential Regulation Number 50 Year 2019 has determined that domestically produced EV must be made of 35% locally-made parts by 2021, 40% by 2023, and 60% by 2030, our respondent claimed to have reached 80% and aimed for 90%. The biggest hurdle of independent development of EV parts is the battery due to Indonesia's absence of a domestic battery industry.

3.3.2. Experts Perception

In support of Presidential Regulation Number 55 Year 2019 on the acceleration of battery electric vehicles program for road transportation, the government of Indonesia had passed a couple of regulations to encourage more people to buy and use EVs. EVs are exempted from the PPNBM or sales tax on luxury goods tax effective on 16 October 2021. A vehicle ownership tax is also determined by whether the vehicle meets the national emission standards, where an EV is considered to have zero emissions. Another financial incentive is the discount for charging EVs in households where the electricity rate between 10 PM and 5 AM is reduced by 30% from the regular price per kWh. As a result, most personal vehicles are in idle mode 95% of the time, especially at nighttime [127]. Nonfinancial support from the government includes issuing regulations of the conventional motorcycle to electric motorcycle [128]. This regulation allows owners of conventional motorcycles to convert them to electric motorcycles in appointed vendors at their own cost. The cost for such conversion ranges from 9 to 12 million rupiahs (approximately 600 to 800 USD, at July 2020 conversion rate), while motorcycle owners are thought to have the willingness to pay such conversion at approximately 5 million rupiahs (345 USD or less) [128].

The government planned to build 65 SPKLU or public electric vehicle charging stations in 14 provinces. Several government-owned companies, such as PT Jasa Marga, PLN, and

PT Pertamina, collaborate with the government to achieve charging station establishment goals. These companies are government-owned in charge of highway, electricity, and oil and gas companies.

According to an IESR study [129], emissions from EVs are already lower than those of conventional vehicles under the current energy mix if emissions are only calculated based on the use emissions. However, if manufacturing emissions are included, EVs still impose an environmental burden. Therefore, for EVs to have lower emissions than conventional vehicles, including the manufacturing process, the IESR suggested that the grid emission factor be lower than 734 g CO_2/kWh. Therefore, it is projected that an emission factor of 420 g CO_2/kWh (equivalent to 17.4% emission reduction) can be achieved in 2050 if Indonesia follows its National Energy General Plan (RUEN). This long-term projection, however, did not include emissions from vehicle disposal activities.

3.3.3. Government Perception

Two government institutions working directly for BEV development, the Ministry of Industry (MoI) and the Ministry of Energy and Mineral Resources (MEMR), were interviewed in this study. The MEMR is responsible for infrastructure preparation, and the Ministry of Industry is responsible for industry transformation from conventional to EV and any related industry development.

The Ministry of Industry regulated two ministerial regulations as a derivative of Presidential Regulation Number 55 Year 2019. The first is Minister of Industry Regulation Number 27 Year 2020 concerning Specifications, Development Roadmaps, and Provisions for Calculation of Domestic Component Levels for BEV. The second regulation is Minister of Industry Regulation Number 28 Year 2020 concerning battery-based electric motor vehicles in completely decomposed and incompletely decomposed conditions. Both regulations focus on EV manufacturers and importers concerning the domestic capability of developing EVs and restrictions for global manufacturers. The Ministry of Industry also prepares standardization policies related to battery safety by preparing the Indonesian National Standard (SNI). Currently, there are 27 SNIs related to BEV that have been ratified. The EV standards compiled in Indonesia refer to global standards (International Organization for Standardization, International Electrotechnical Commission, and/or UNR). Therefore, existing EV products in Indonesia and imported to Indonesia must comply with Indonesian standards. In developing the national standard for EV in Indonesia, the Ministry of Industry involved business actors (industry), universities, and government agency experts. Furthermore, a public opinion poll was also conducted. Then, the Ministry of Industry informs the new SNI standard prepared through webinars, FGDs, and meetings.

MEMR Regulation Number 13 Year 2020 concerning the Provision of Electricity Charging Infrastructure for BEV authorized the MEMR to be in charge of the construction of charging facilities and battery exchange facilities (SPKLU) and the General Electric Vehicle Battery Exchange Station (SPBKLU) in Indonesia. MEMR also issued a Business Permit for the Provision of Electricity (IUPTL). Furthermore, the MEMR stipulates business areas for the IUPTL located in business districts such as gas stations, offices, shopping centers, or parking areas. As of July 2021, 166 charging stations (SPKLUs) for EVs have been built at 135 locations, with the majority on Java Island and 74 SPBKLU units in 73 locations in DKI Jakarta, Banten, and West Java. The 135 SPKLU locations accommodate 166 charging units, with Java Island having 148 charging units (89%), four units on Sumatra Island (2%), ten units on Bali Island (6%), 1 unit on Nusa Tenggara Barat (0.6%), and four units on Sulawesi Island (2.4%). Currently, there are 2 (two) SPBKLUs owned by the private sector, Ezyfast and Oyika, installed in the office Directorate General of Electricity, MEMR.

Some challenges to achieving targets in infrastructure development are funding problems due to the COVID-19 pandemic, such as the high price of DC Fast Chargers and the newness of the electric charging infrastructure business for EVs. There are also obstacles to EV development in Indonesia, as the future of EVs depends on battery innovation. Therefore, cheaper battery innovations using the available materials will be crucial. The government also needs to develop battery waste management since the battery is considered a B3 hazardous material and toxic waste.

3.3.4. End-Users Perception

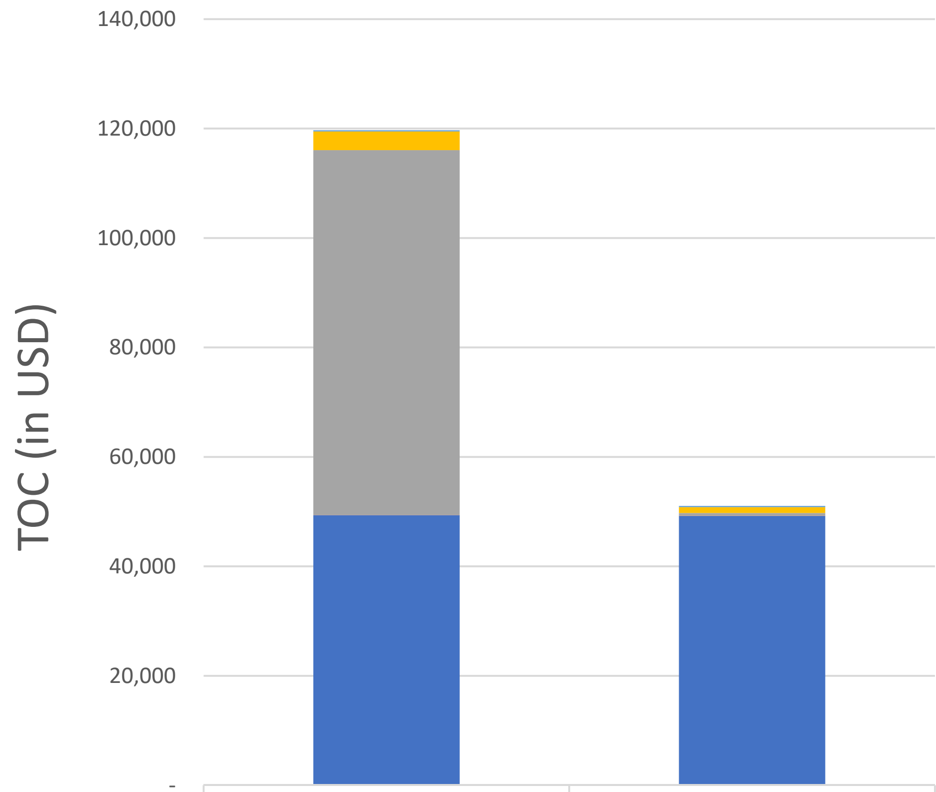
The advantages of EV technology, EV safety factors, government incentives for EV users, supporting infrastructure for EVs, and the overall operating cost of using EVs in the long term are perceived positively as purchasing decision factors for end-users to adopt EVs (Table 2). Based on end-user experience, four-wheeler EVs have higher performance than ICE vehicles in power, acceleration, handling, and comfort. However, some two-wheeler users feel that electric motorcycles are comparably slower and have less power than conventional motorcycles. EV users who lived within the Jakarta area stated that EVs are primarily used for city mobility, which is attuned to by the EV driving range. Charging at home is considered sufficient for round-trip mobility within the city. Some users, however, are concerned about the location of public charging if they need to travel farther than their usual route. Users hoped the government could provide a charging station in mega cities: JABODETABEK (Jakarta, Bogor, Depok, Tangerang, and Bekasi) and on the toll road of Java Island, which can help EVs travel long distances.

According to our respondent, three decision-making factors were considered before adopting EVs: government regulation, incentives, and infrastructure readiness; cost-related (upfront, operational, taxes, and maintenance cost); and machine performance. Table 4 presents the decision-making factors considered by a four-wheeler EV end-user respondent.

Table 4. Decision-making factors considered by an EV end-user respondent.

Decision-Making Factor	EV	Conventional Vehicle
Government regulation Tax-related Regulation Infrastructure planning	• Exception for Tax for luxurious goods • Annual tax = 0.2% (Jakarta case, different in each province) • Exception for a progressive tax, name transfer fee, and emission tax • Plan to build more charging stations, including in every gas station. • Adoption of EV as the official vehicle for West Java province (Bandung city) and installed charging stations in the city • Charging station in State Electricity Company (PLN) offices, and some public places such as parking area, rest area, and department stores	• PpnBm = depending on the gas emission level (15–70%) • Annual tax = 2% • Progressive tax = applied on the annual tax, 2% for the second car, and 2.5% on the third card • Name transfer fee = 12.5% for new cars • Infrastructure is established
Total cost ownership	• Hyundai kona electric = 51,048.4 USD	• Mercedes Benz S-Class = 119,689.4 USD
Other Machine Performance Handling/Comfort Charging time/Refuelling time	• Flat power band (from 0 RPM to max): can reach maximum acceleration anytime the driver needs it. • Lighter body due to aluminum parts • Near to 0 noise (only road noise and fake machine sound to meet road safety regulation) Depends on the charger capacity. In the case of Hyundai: 2.4 kW = 18 to 20 h (full charged) 7.7 kW = 6 h (full charged) 50 kW = 50 min (80% charged)	• Must reach a certain RPM first to enable maximum acceleration • Heavier body (mainly steel) • Machine noise • Negligible (in a few minutes)

The comparison of the total cost of ownership (TCO) for four-wheeler EVs and conventional vehicles is presented in Figure 3. In this study, the upfront cost calculated for conventional vehicles is already included with a tax for luxury goods (PPnBm). Total ownership cost is calculated based on the upfront cost (purchase cost, tax for luxury goods, and name transfer fee), five years of operational cost (±75,000 km), five years of annual taxes, and maintenance cost. The tax value is explained in detail in Table 3 above. The calculation for gasoline consumption is gathered from the average value of similar vehicle characteristics with Mercedes Benz S Class, with an average gasoline consumption of 12 km/L [130], while the calculation for the EV driving range (8 km/kWh) is taken from the study by Bardia and Nils [131]. Considering an electricity price of 1450 IDR/kWh and a gasoline price of 10,000 IDR/L, the EV cost per km is 150 IDR/kWh, while the conventional vehicle cost per km is 1000 IDR/km. The maintenance cost is calculated based on the travel distance of each type of vehicle, with EV per 15,000 km of use and conventional vehicle per 10,000 km of use.



	4-Wheeler ICE	4-Wheeler EV
Maintenance cost (Service and spareparts)	194	212
Operational cost (Fuel)	3438	1071
Taxes	66,644	492
Administration fees	48	48
Purchasing price	49,366	49,225

*EV cost per km is 150 IDR/kWh
*Conventional vehicle cost per km is 1000 IDR/km
*1 USD = 14,300 IDR

Figure 3. Total Cost Ownership Comparison between EV and Conventional Vehicle.

3.3.5. Multistakeholder Analysis

This study conducted a multistakeholder TRA based on judgments from key respondents from the industry, government, experts, and end-users of EVs. First, the EV industry respondent reflected on his EV start-up company's activities. Second, the government respondents reflected on their experiences in technology and regulations development regarding EV in Indonesia. Furthermore, EV experts from the research institute reflected on their experience as government consultants for the EV market, regulations, and roadmap establishment. Last, end-users provided answers based on their experience using the EV.

TRA was conducted based on all respondents' answers, and the generated TRL radar graph is shown in Figure 4. Similarities of readiness level perception between the three respondents, industry, experts, and end-users, can be observed at the EV technology "development" parameter. However, the government perception of this parameter is slightly lower. This implies that most respondents agree that EVs' development is already quite mature in the country technology-wise. The different perceptions of readiness levels in this parameter might transpire due to the broader scope observed by the government, including the nationwide picture of EV technology development, EV battery development, and EV infrastructure development, compared with other stakeholders. Irrespective, all stakeholders agreed that the most significant impediment to manufacturing EVs with 100% domestically produced parts is the battery.

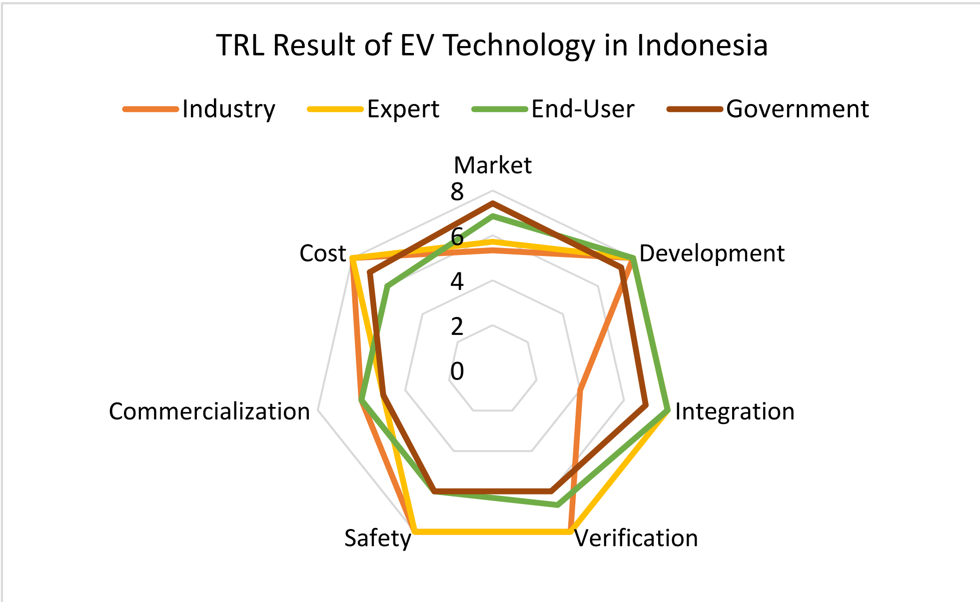


Figure 4. EV technology readiness level based on the perceptions of multistakeholder respondents.

The expert respondents believe that incorporating imported parts into the mix of materials for EV manufacturing could be beneficial for reducing prices, increasing affordability, and eventually improving the commercialization of EVs. Cost-wise, respondents from the industry and the expert agreed that it is already possible to determine a home-grown EV price, while the government and end-user still perceive some uncertainties. For example, the government believed that the EV price could be reduced with the development of the battery industry in Indonesia but felt pressure due to battery technology disruption that might shift nickel-based battery technology to cheaper ones. In contrast, the government and the end-user perceived a higher readiness in the "market" than the expert and the industry. In addition, based on the end-user experience, the minimal number of charging stations in the country is not that much of an issue as most charging was done mainly at home.

In the "integration" parameter, the end-user and the expert expressed awareness about the government plan for building more charging stations in the country, but the industry expressed their concern with investors repeatedly using the present lack of charging stations as a factor that may prevent buyers from purchasing EVs. The government perceived a higher "integration" readiness level, implying that while the industry has identified the risks related to developing EV technology, it has not yet fully taken advantage of the government's roadmap to support the industry. Effective business models for commercializing the technology have also yet to be developed. A respondent from the industry indicated that the TRL indicator "Integrating the technology towards the actual environment where it should operate (in this case, the public roads and other infrastructure)" was not achieved. As part of the "integration", the government currently focuses on expanding charging stations and battery swap stations to be accessible for more cities. Furthermore, the government cooperates with government-owned companies and private sectors to achieve the EV goal in the roadmap.

In the "Verification" parameter, the expert and the industry have examined some findings measuring the CO_2 emission reduction from EV usage done by universities. The end-user reported receiving notifications from the EV's control panel about how much CO_2 they saved every time they completed driving. However, these reports are not based on the actual Indonesian energy mix. Other than CO_2 emission reporting, there are also functions available in EV cars that are not suitable for road conditions in the country, such as the road's white-line detector and autopilot driving functions. These factors affected the end-user differing perception of the "safety" parameter. The government also believes that the current EV technologies and the related infrastructures still need to be verified further. Government perception is related to concern about the current energy mix in Indonesia, which still heavily relies on FF.

Finally, all respondents agreed on the lack of "commercialization" status, although industry and end-users perceived it better. The experts believe there are still many strategies that the government can do to improve EV commercialization, such as airing commercials in the media, providing free parking for EVs, and test-drive opportunities to familiarize people with the technology. While the government understands the lack of "commercialization", the eagerness to give massive information and stimulus for end-users to switch to EVs is not their priority.

Readiness gaps can be found in the "integration", "market", and "commercialization" parameters. The industry should work together with government roadmaps and actions such as taking opportunities from the nickel ore export ban so that domestication of battery production can be optimized. Moreover, the right business plan that complies with government regulations, especially for license plates, B-to-B collaborations, and appropriateness with the purchasing power of the general population in Indonesia, may be the key for the industry to reach its commercialization optimum readiness point. In the "cost/risk" parameter, our respondents judged that EV technology in Indonesia could already be priced appropriately; however, considering the present social security and investment risks, the price for commercialization may need further investigation.

4. Policy Recommendations and Conclusions

This study has explained the current state of EVs in Indonesia based on literature reviews and in-depth interviews with key industrial sector stakeholders, experts, related governments, and end-users. Incorporating the J-TRA method, this study has attempted to understand and explain the current EV readiness level from a multistakeholder perspective. The limitation of the study was the limited number of respondents due to the nature of this paper as an initial introduction of the J-TRA method to be implemented with key stakeholders' perspectives and the early existence of EV in Indonesia.

The TRL results were mainly found to be coherent with the literature reviews and in-depth interviews. (1) For the "Development" parameter of EV in Indonesia, the interviewed stakeholders mostly agreed that it had reached the optimum point of readiness. (2) There are still some works to do in the "commercialization", "integration", and "market" areas, specifically those associated with EV infrastructure, such as increasing the number of charging stations across the country, further marketing and socialization, and reducing prices or developing more affordable EV models for better penetration in the country. (3) Different perceptions of readiness can mainly be found in "safety", "cost", and "verification". Judgment of these three parameters may be prone to ambiguity across stakeholders influenced by their source of information and experiences; therefore, a better explanation of the parameter should be introduced in further study, especially on the emphasis of the safety term and what is included in the cost (not only technology development costs but also commercialization and marketing costs).

From the TRL results, this study found similarities and perception gaps in some areas. Based on the insights gained in the development of this study, this study has some implications for decision-makers and related stakeholders for improving the level of readiness for EVs in Indonesia, including the following:

To create more EV markets through collaboration between government and industries. First, the public procurement of EVs can be used for public buses or official vehicles to build an initial market. Second, public awareness of EV technologies and incentives for EV users should be raised by giving enough information to the public. Third, the current EV industries in Indonesia must comply with government regulations, including quality standards, vehicle certificates from the Ministry of Transportation, and legally registered license plates. Fourth, the appropriate business plan for early EV penetration is B-to-B collaborations. Finally, price appropriateness with the purchasing power of the general population in Indonesia is key to reaching its commercialization optimum readiness level.

To achieve the goals of the government road map to produce both two-wheelers and four-wheelers EVs domestically, collaboration and integration between multiple stakeholders should be performed. The Indonesian government has started to speed up the nickel ore ban as part of its green road map by 2022. If batteries can be produced domestically, EV production can be optimized, and EV production costs can be reduced significantly. Therefore, collaborations between nickel ore mining companies, nickel purification and processing companies, and battery manufacturer companies should be encouraged from the battery industry side.

To increase charging infrastructure investment, a collaboration between the government and related industries is necessary. In addition, infrastructural support, such as a network of public charging stations and after-sale service centers, must be established. It is still the initial days for EV adoption in Indonesia, but the potential for a positive impact on the economy and environment is significant. Collaboration between government stakeholders, state-owned enterprises, and the private sectors will be needed to build a local EV ecosystem—one with the potential to transform environments and economies.

To provide financial and nonfinancial incentives for EV users. The current incentives should be reverberated to increase public awareness. Examples are free parking and road-toll exemption.

The government should improve EV competitiveness in the market by implementing carbon prices, so that competing ICE vehicles and FF fuel prices reflect their true cost to the environment.

While EV is often understood as a clean technology, RE's current Indonesian energy mix is only 7.7% [132]. Thus, if the Indonesian government's long-term goal is to achieve the green road map by IEA, integration for EV development with the RE sector is necessary. Although the trend for RE has improved in recent years, the abundant resources of FF in Indonesia make it difficult for RE to compete cost-wise, even with the existence of feed-in-tariff (FIT). While the nickel ore export ban seems to get things going in the national EV industry, regulations in the RE sector took more careful steps, as interruption of the ongoing powerplant may cause financial costs.

As one solution for reducing GHG emissions, EVs should be integrated into national transport strategies. Indonesia's greatest disadvantages are the low share of RE in the electricity grid and the unpreparedness of the industry's supply chain. With these situations, the following risks may arise, such as (1) additional demand for electricity that results in more use of FF at the primary grid and an increase in its entailing pollution, (2) electricity demand competition with residential and other industrial uses, wherein some parts of the country are not yet stable, (3) importing parts of the EV that are not yet efficiently produced domestically, resulting in an additional environmental burden on import transportation, (4) possible negligence of proper battery disposal and recycling, and (5) other problems related to the end-of-life treatment of used Evs. However, Indonesia could learn from other countries that have already shifted from conventional vehicles to Evs and integrate EV-related policies into their national transport policy.

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