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Article

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Cogent Business & Management

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Suggested Citation: Sasongko, Triyono Widi; Ciptomulyono, Udisubakti; Wirjodirdjo, Budisantoso; Prastawa, Andhika (2024) : Identification of electric vehicle adoption and production factors based on an ecosystem perspective in Indonesia, Cogent Business & Management, ISSN 2331-1975, Taylor & Francis, Abingdon, Vol. 11, Iss. 1, pp. 1-22,
<https://doi.org/10.1080/23311975.2024.2332497>

This Version is available at:

<https://hdl.handle.net/10419/326179>

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To cite this article: Triyono Widi Sasongko, Udisubakti Ciptomulyono, Budisantoso Wirjodirdjo & Andhika Prastawa (2024) Identification of electric vehicle adoption and production factors based on an ecosystem perspective in Indonesia, Cogent Business & Management, 11:1, 2332497, DOI: [10.1080/23311975.2024.2332497](https://doi.org/10.1080/23311975.2024.2332497)

To link to this article: <https://doi.org/10.1080/23311975.2024.2332497>



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Identification of electric vehicle adoption and production factors based on an ecosystem perspective in Indonesia

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ABSTRACT

The program to replace fossil fuels powered vehicles with electric vehicles (EVs) is part of the global endeavor to reduce greenhouse gas emissions. In Indonesia, EV adoption is still low. The EV market share is currently 1.47 percent of the 10 percent goal for 2022. Due to the vulnerability of local industries, including electric vehicle (EV) startup manufacturers, foreign-origin equipment manufacturers (OEMs) continue to dominate the Indonesian automotive industry. Although the government encourages automakers to produce and sell battery electric vehicles (BEVs), the incumbent prefers to introduce hybrid electric vehicles (HEVs) and continues to prioritize internal combustion engine vehicles (ICEVs). Numerous studies have investigated the factors of EV adoption based on user perspective. However, few studies examine the factors influencing automakers to produce EVs, especially in developing nations like Indonesia, where foreign OEMs dominate automotive manufacturers. This study analyzes the drivers and barriers to adopting and producing electric vehicles from an ecosystem perspective, including users, the EV industry, charging infrastructure providers, and the government using the Delphi method. According to the findings, in addition to the user's ability and price barriers in the most demanded 7-seater EVs, the critical adoption and production factors are the effect of the OEM's global strategy and the priority of government policies to promote EVs while maintaining the sustainability of the automotive industry.

ARTICLE HISTORY

Received 28 September 2023
Revised 13 March 2024
Accepted 14 March 2024

KEYWORDS

Electric vehicle; adoption; production; ecosystem; Delphi method; Indonesia

REVIEWING EDITOR

Len Tiu Wright, De Montfort University Faculty of Business and Law, United Kingdom of Great Britain and Northern Ireland

SUBJECTS

Industry & Industrial Studies; Industrial Engineering & Manufacturing; Transport & Vehicle Engineering; Clean Tech; Sustainable Development; Business, Management and Accounting; Environmental Economics

1. Introduction

The Paris Agreement (UNCC, 2015) powers the global effort to reduce greenhouse gas emissions in various sectors. One related program in the transportation sector is replacing fossil fuel vehicles with internal combustion engine (ICE) technology with electric vehicles (EV) of various varieties, including battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), and hybrid electric vehicles (HEV). The transition to EVs also reduces fossil fuel consumption (IEA, 2022).

EVs are eco-green vehicles. The life cycle assessment results indicate that the total emissions of BEV are 39 tCO₂e, the lowest compared with HEV of 47 tCO₂e and ICEV of 55 tCO₂e, even though the production phase emissions of BEV are higher than HEV and ICEV. Decarbonizing the electricity sector can reduce the use phase emissions of BEV (Kearny, 2023). During the use phase, BEV, PHEV, and HEV are more eco-friendly than ICEV (Xia & Li, 2022). In the case of the United States, the European Union, China, and Japan, the life cycle assessment results indicate that BEV outperforms ICEV by 30% to 80% in reducing

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greenhouse gas emissions. By creating low-carbon power plants, EVs will be able to accomplish more significant reductions in greenhouse gas emissions in the future (Peng et al., 2018; Shafique & Luo, 2022). By simulation, a 1% increase in electric vehicles will reduce CO₂ emissions by 0.029% (Xu et al., 2021).

The United States, Europe, China, and Japan, the pioneering nations in the research and development of electric vehicles, launched this program more than three decades ago (Wu et al., 2018). The policy to support the implementation of the global EV program includes a long-term goal for EV market share and ICEV ban, battery technology development, charging infrastructure deployment, and incentive policies (IEA, 2022). While introducing EVs to the automotive market, governments directly subsidized manufacturers and consumers through enormous fiscal incentives, such as tax reduction or exemption (Srivastava et al., 2022). Some nations, including China and the United States, have implemented a radical policy requiring manufacturers to produce an allotment of EVs with a dual-credit policy (Peng & Li, 2022).

In recent years, the global market for electric vehicles for 4-wheeled electric cars of all types (BEV, HEV, and PHEV) has expanded exponentially. In 2020, 3.24 million electric cars were sold. It increased by 108% to 6.75 million units in 2021 and by 55% to 10.52 million in 2022. In addition, the global EV market share rose from 4.2% in 2020 to 8.3% in 2021 and 13% in 2022 (EV Volumes, 2023). China, Europe, and America continue to dominate the EV market. China dominated world EV sales in 2022 with an increase of 82% from 2021 to 6,181 million units (58.74% of world EV sales), followed by Europe with a 15% increase to 2,682 units (25.5% of world EV sales) and North America with a 48% increase to 1,108 units (10.53%) (EV Volumes, 2023).

According to the diffusion of innovation theory (Rogers, 2003), EV adoption is still at the innovator or early adopter stage in developing countries. In 2022, the EV volumes and market share in India were 56,491 units (1.19%), with the domination of hybrid EVs at about 1.08%. EV sales in Thailand reached 34,474 units (2.80%), with hybrid EVs at about 1.71% (MarkLines, 2023). In the same year, EV sales in Indonesia were only 14,437 units (1.47%), with BEV sales around 0.99% (Gaikindo, 2023).

In Indonesia, Presidential Regulation No. 55 of 2019 started accelerating the battery-based EV (BEV) program (GOI, 2019). This policy includes derivative policies on the road map for developing the electric vehicle industry (Kemenperin, 2022), charging station specifications and government procurement (KemenESDM, 2023), import tax exemption of incompleting knock-down for EV parts (Kemenkeu, 2022), purchasing incentives (Kemenkeu, 2023; Kemenperin, 2023) and free of even-old driving policy in Jakarta. The quantitative target of EVs for 4-wheeled EVs is 400 thousand units by 2025, 9 million units by 2030, and 12 million units by 2035 (Kemenperin, 2022). In contrast with the targets, the development of 4-wheeled EVs remains sluggish. The total market penetration of all-electric vehicles in Indonesia in 2022 is only 14,437 EV units or 1.47%, a significant distance from the target of 400 thousand EV units by 2025.

The low EV adoption in Indonesia raises questions regarding the effectiveness of government policy in fostering EV adoption by users on the demand side, EV production by manufacturers, and EV charging service by EV charging infrastructure providers on the supply side. Systematic steps of the decision-making process are needed to evaluate and recommend more suitable policies. The measures include the intelligence, design, and choice phases introduced by Hebert A. Simon (Mintrom, 2015). Identifying the most significant EV adoption and production factors, both driver and barrier factors, in the EV ecosystem is essential in the intelligence phase as the feeding for the next stage of the decision-making process.

Numerous studies have investigated the factors influencing users to employ EVs in developing countries, such (Febransyah, 2021; Novizayanti et al., 2021; Setiawan et al., 2022) in case of Indonesia, (Hoang et al., 2022) in case of Vietnam, (Asadi et al., 2022) in case of Malaysia, (Goel et al., 2021; K V et al., 2022; Shetty et al., 2020) in the case of India. However, few studies discuss the adoption and production factors influencing the other subsystems of the EV ecosystem, like EV manufacturers, charging infrastructure providers, and government, as one EV ecosystem, especially under the condition that foreign automotive manufacturers dominate domestic EV production. In the case of Qatar, the country does not have domestic auto production (Al-Shaiba et al., 2023). Mohamad & Songthaveephon (2020) only focus on the challenges of socio-technical transitions in the automotive industry, not considering other subsystems. Hamzah et al. (2022) only focus on consumer perceptions and strategic frameworks among ASEAN countries.

In developing nations, foreign original equipment manufacturers (OEMs) dominate local automotive manufacturers and have a global strategy to produce EVs besides ICEVs. Although the government encourages prioritizing BEVs, the incumbent automakers prefer to introduce HEVs and continue

prioritizing ICEVs. Conversely, the government continues safeguarding the ICEV industry due to its substantial contribution to the gross domestic product, 1.45% in 2022, with a growth of 10.67% from the previous year (BPS-Statistics Indonesia, 2024). Government policies to promote the adoption and production of EVs must consider several balancing factors, such as budgetary constraints and the equitable treatment of other social groups.

The research question is: what factors influence the users to adopt EVs, the EV manufacturers to produce EVs, the charging infrastructure providers to provide charging service, and the government to foster the EV ecosystem in the context of the EV manufacturers are global players of OEMs? Therefore, this research will cover that gap with a more systematic analysis from many angles. This paper's main contribution is comprehensively analyzing the relationship between the EV subsystems in one EV ecosystem to identify EV adoption and production factors under the condition that foreign automotive manufacturers dominate.

Thus, the research objective is to identify EV adoption and production factors that influence the interests and perceptions of subsystems or stakeholders in the EV ecosystem in Indonesia. Given that electric vehicles are a recent addition to the automotive industry, this study employs the Delphi approach to gather insights from a panel of experts.

2. Literature review

2.1. EV ecosystem

Initially, the ecosystem is an interaction between biological systems, but it can also be applied to other complex systems (OED, 2023). Now, the ecosystem has some perspectives, such as the multi-actor network ecosystem, the industrial ecosystem, the business ecosystem, and the integration of these. Multi-actor represents the many parties that become a subsystem of the ecosystem. The actors are interrelated, with variables as a link between actors related to several aspects of management, industry, and business (Tsujimoto et al., 2018). The ecosystem comprises actors, institutions, activities, technology, innovative performance, and relationships. The relationships are complementary and substitute (Granstrand & Holgersson, 2020). Companies can take the lead by acting as pioneers if they can respond to ecosystem growth dynamics and implement strategies and processes that reach out to key players, including regulators (Amir & Prabawani, 2023). From a new perspective, a business ecosystem is an essential strategic management stream with a new paradigm in innovation and collaboration (Rifa'i et al., 2023).

Based on the literature, Table 1 summarizes the subsystems of the EV ecosystem related to EV adoption and production. In the EV ecosystem context, the subsystem focuses on the four subsystems: users/adopters, EV manufacturers, charging infrastructure providers, and the government. In the case of Indonesia, in 2019, the central government initiated accelerating the battery-electric vehicle program with the involvement of several ministries and state-owned enterprises to foster EV production by EV manufacturers, charging services by charging infrastructure providers, and EV adoption by users (GOI, 2019).

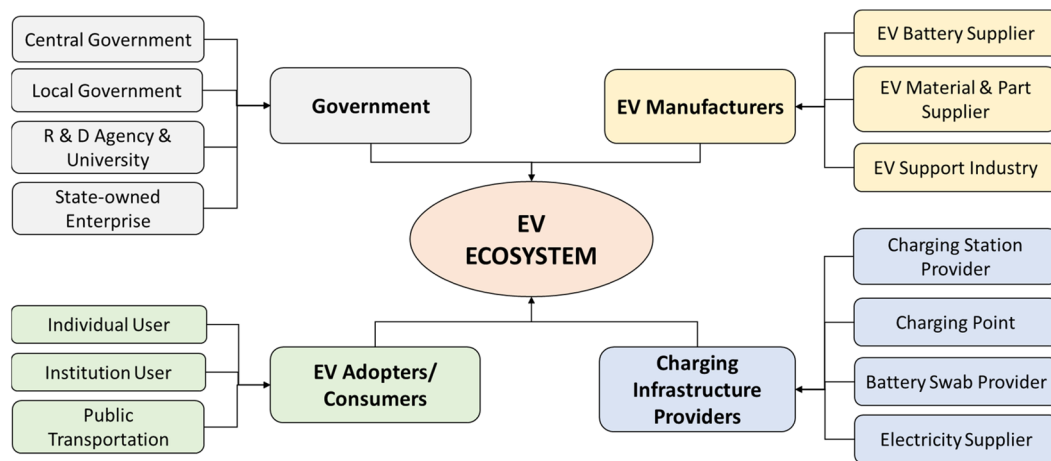
Figure 1 provides a more comprehensive depiction of the various subsystems that need to be considered during the development of the EV ecosystem.

The EV users are divided into three segments based on their ability and willingness to buy EVs. First, lifestyle customers who care about the brand, premium features, and EVs are not the first car owners. Second, responsible customers who care about environmental aspects and provide early promotion of EVs to encourage and create EV popularity, such as for official cars, public transportation such as bus rapid transit, taxis, online motorcycle taxis, and tourism. Third, economic customers, namely the majority of individual users and private companies, buy EVs based on financial calculations, such as total cost of ownership (Wu et al., 2018). The EV users or the EV adopters in the transition stage in developing countries are the early adopters (Rogers, 2003). Lifestyle users dominate the early adopters compared with responsibility users and economy users.

The subsystem of EV manufacturers consists of the new EV manufacturers and the automotive manufacturers that produce both ICEVs and EVs, including global and local OEMs supported by the supply chain of materials, batteries, and other components. In the case of Indonesia, global OEMs are the main actors in the automotive industry. The local startup EV manufacturers and their R&D support face challenges related to technology readiness and mate bottlenecks in integration, safety, and commercialization (Maghfiroh et al., 2021).

Table 1. Grouping of subsystems in the EV ecosystem.

Subsystem	Terminology/Reference	Role	Interest
Users/Adopters	ICEV users (Setiawan et al., 2022), consumer (Brozynski & Leibowicz, 2022); EV purchaser (Zolfagharian et al., 2020)	The users of ICEVs are being specifically targeted and influenced to transition from using ICEVs to EVs.	The users intend to adopt EVs based on their perceived appeal, including technology performance, affordability, operation costs, and ease of charging.
EV Manufacturers	EV manufacturers, car manufacturers (Bakker et al., 2014), automotive companies (Setiawan et al., 2022)	The EV manufacturers produce EVs in response to potential users' demand and purchasing capacity.	To ensure the long-term viability of their operations, makers of EVs and ICEVs must develop a comprehensive and equitable approach.
Charging Infrastructure Providers	Charging station providers (Setiawan et al., 2022), infrastructure firms (Brozynski & Leibowicz, 2022)	The charging infrastructure providers offer services to facilitate the continued mobility of electric vehicles.	Government support is crucial for the substantial investment required in charging infrastructure.
Government	Government (Setiawan et al., 2022); national and local governments (Bakker et al., 2014); policy maker (Brozynski & Leibowicz, 2022)	The government facilitates the implementation of EV programs through various policies, encompassing fiscal and nonfiscal measures.	The government drives the ICEV to EV transition to mitigate emissions and minimize fuel consumption effectively.

**Figure 1.** The EV ecosystem and the subsystems.

The charging infrastructure subsystem consists of the operator of public charging stations and other charging points at home, office, hotels, apartments, malls, restaurants, rest areas, parking parks, etc. As a chicken-and-egg problem, the rate of EV adoption is contingent upon the availability of EVCS (electric vehicle charging station) and vice versa (Brozynski & Leibowicz, 2022). Initially, the Government assigned the state electricity company to build and operate charging stations to overcome the problem.

The government subsystem includes national and local governments, R&D agencies/universities, and state-owned enterprises. As policymakers, the government publishes EV-related regulations at the macro, meso, and micro levels, representing the strategic, tactical, and operational policies. The policies consist of consumer-oriented policies, producer-oriented policies, and infrastructure-oriented policies.

Figure 2 adapts the conceptual model by Sasongko et al. (2022) to describe the relationships between the four subsystems in the EV ecosystem. The government provides fiscal and nonfiscal policies to drive the development of EVs. The adopters build awareness of the technology, economy, and environmental aspects of EVs, charging infrastructure, and government policy. Meanwhile, EV manufacturers and charging infrastructure providers make products and services under user needs and government support. Identifying the critical EV adoption and production factors might help policymakers foster EV adoption and production with relevant strategies and policies.

Subsystems or stakeholders in the EV ecosystem must cooperate broadly, cooperation that must be fought due to the resistance of the existing socio-technical system. They must create protected spaces until the new socio-technical system matures enough to face the current regime (Bakker et al., 2014). Based on the multi-level perspective approach, EV transition is a nonlinear process resulting from a circle of mutual influence between three levels. The first level is niches, the location of radical innovations of

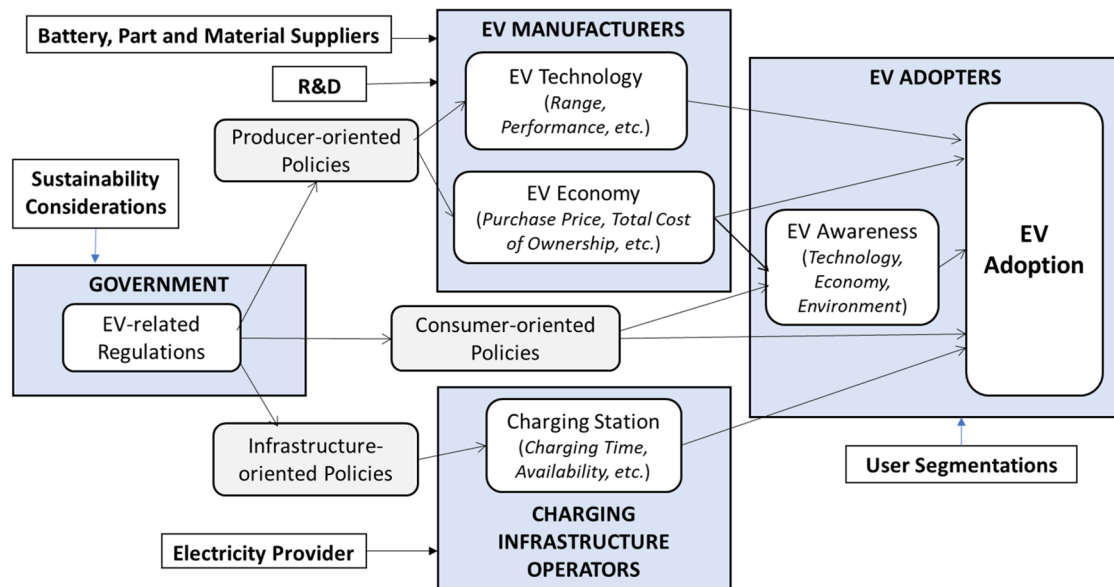


Figure 2. The conceptual relation model of the EV ecosystem.

EVs to seek their forms. The second level is socio-technical regimes, where established systems and rules that stabilize the current system of the ICEV industry, regulation, and user acceptance are predominant. The third level is socio-technical landscapes, the external factors of the Paris Agreement, and the EV acceleration program influencing regimes and niches (Lin & Sovacool, 2020).

2.2. Identification of EV adoption and production factors

EV adoption and production are positively influenced by the driver factors, which include benefits, opportunities, and others. The barrier factors, including costs, hazards, and other factors, have a negative impact on the adoption and production of electric vehicles.

2.2.1. EV adoption factors from user perspectives

EV adoption benefits for users include technical and economic benefits related to operational costs, fiscal incentives, nonfiscal incentives, and environmental benefits. Technical benefits for users are comfortable and safe driving and easy maintenance (Novizayanti et al., 2021; Sanguesa et al., 2021). Driving with an EV is satisfying because there are no distracting sounds, and safety features give the rider peace of mind. EV maintenance is more manageable than ICEV due to longer maintenance time intervals and fewer maintenance items. The development of battery technology strongly influences the development of EVs. For EVs, batteries are critical, as these will determine the vehicle's autonomy because battery technology significantly affects mileage, charging speed, and user acceptance of EVs (Sanguesa et al., 2021).

Economic benefits for users related to operational costs included low charging and maintenance costs (Bhosale et al., 2022; Hagman et al., 2016). The price of charging EV batteries at home and charging stations is much lower than the fuel cost. EV maintenance costs are much lower than ICEV maintenance costs, let alone the battery warranty, up to 8 years, in the case of Indonesia.

Economic benefits for users related to fiscal incentives are purchase price incentives (Dong & Zheng, 2022; Jenn et al., 2018; Jung et al., 2021; Kumar et al., 2021; Secinaro et al., 2020). In the case of Indonesia, there is an incentive to purchase 2-wheeled EVs with a local content level of $\geq 40\%$ and EV conversion of Rp 7 million (Kemenperin, 2023). Other incentives for purchasing EVs are value-added tax (VAT) reduction incentives. For the purchase of electric cars and buses with a local content level $\geq 40\%$, the government-borne VAT is 10% out of 11%, so only 1% must be paid by the user. For the purchase of electric cars and buses with local content levels of 20% to $<40\%$, the Government bears VAT 5%, so the user only pays 6% (Kemenkeu, 2023). Sales tax on luxury goods incentives are also attractive fiscal

incentives for users (Deuten et al., 2020; Llopis-Albert et al., 2021). In the case of Indonesia, there is a sales tax on luxury goods of 0% for BEVs and less than 10% for HEVs and PHEVs (GOI, 2021). There is a reduction in the title transfer tax for electric vehicles by up to 90% and a reduction in the yearly tax for electric cars by 90% (GOJ, 2021). Night electricity rate incentives also offer some benefits for users to charge the EVs in their homes (Wang et al., 2019). PLN (State Electricity Company of Indonesia) provides a 30% discount for electricity usage from 22.00 to 05.00 and special prices for connecting and adding power related to home charging (Antaranews, 2022).

The benefits of nonfiscal policies for users make EVs more attractive (Lu et al., 2022), such as driving with EVs in Jakarta is exempt from the odd-even policy. Environmental benefits for users refer to eco-friendly vehicles. Using EVs will contribute users to the reduction of air emissions that pollute the environment (Kumar et al., 2021; Tarei et al., 2021).

Long-term economic opportunities for users include lower total cost of ownership (TCO), and EV prices are becoming more affordable. The Total Cost of Ownership is getting lower due to the low operational and maintenance costs compared to ICEV, even though EV is more expensive than ICEV (Bhosale et al., 2022; Coffman et al., 2017; Kumar et al., 2021; Tarei et al., 2021). EV prices are getting more affordable. Due to decreased production costs, EV manufacturers can sell EVs at increasingly affordable prices and compete with ICEVs. The projected price of batteries will fall from \$137 per kWh in 2020 to \$80 per kWh in 2026 and \$60 per kWh in 2029, respectively (BloombergNEF, 2021).

EV adoption costs and barriers for users include technical, economic, and charging infrastructure barriers. Technical barriers for users are battery range anxiety, performance anxiety, safety anxiety, and lack of model availability. Battery range anxiety related to limited mileage due to battery capacity (Kongklaew et al., 2021; Kumar et al., 2021; Novizayanti et al., 2021; Tarei et al., 2021). Performance anxiety concerns related to EV operating performance, such as speed, road, flood conditions, reliability, etc. (Abbasi et al., 2021; Deuten et al., 2020; Huang & Qian, 2021; Zolfagharian et al., 2020). Safety anxiety concerns related to EV safety aspects, such as burning batteries and the dysfunction of system software (Abbasi et al., 2021; Deuten et al., 2020; Huang & Qian, 2021). Lack of model availability refers to limited EV model variations that suit user needs, including the number of seats and affordability (Novizayanti et al., 2021). Maintenance anxiety concerns the ease of finding maintenance workshops and the availability of EV components and spare parts (Novizayanti et al., 2021).

Economic barriers for users focus on EV and ICEV price differences. The price of EVs compared to ICEV prices in comparable vehicle classes is still significantly high, based on research results (Bitencourt et al., 2021; Huang & Qian, 2021; Llopis-Albert et al., 2021; Novizayanti et al., 2021; Tarei et al., 2021).

Charging infrastructure barriers for users include a lack of charging stations and charging-time constraints. There is a lack of charging stations since there are still a few charging stations and uneven distribution of charging station locations (Broadbent et al., 2021; Hu et al., 2020; Liang et al., 2022; Zolfagharian et al., 2020). Charging time constraints related to charging time at the charging station is still long due to queues and charging times (Liang et al., 2022; Patyal et al., 2021; Secinaro et al., 2020).

Long-term economic risks for users include re-sale anxiety because there is no certainty about the selling value of used EVs, including the price of used EV batteries that theoretically can be reused for other products and recycled (Kongklaew et al., 2021; Patyal et al., 2021).

2.2.2. EV adoption and production factors for EV manufacturer perspectives

Economic benefits for EV manufacturers include tax holidays, import tax exemption for Incompletely Knocked Down (IKD), and purchase price incentives. In the case of Indonesia, a tax holiday of 5 years to 20 years, according to the investment value for its main industrial components, targeting the steel or non-steel metal industry and its integrated derivatives, nickel smelters, and battery production (Kemenkeu, 2020). Import tax exemption for Incompletely Knocked Down (IKD) policy benefits EV production. VAT is exempted on mining goods, including nickel ore as raw material for making batteries. VAT is exempted on imports and acquisition of capital goods in the form of machinery and factory equipment for the motor vehicle industry. The Government sets a special tariff of zero percent Import Duty for motor vehicles imported in incomplete knock-down condition (IKD) (Kemenkeu, 2022). For EV manufacturers, EV purchase price incentives will further increase EV demand and purchases (Kumar et al., 2021; Secinaro et al., 2020).

As an effort to encourage investment in BEV manufacturing development in Indonesia, during the BEV factory construction process, BEV manufacturers are allowed to import BEVs in the form of completely built-up (CBU) and completely knocked down (CKD) with 0% import duty and the luxury goods sales tax (PPnBM) 0% until the end of 2025. Furthermore, manufacturers must meet domestic BEV production provisions minimum volume as imported CBU or 'production debt' with local content of 40% until the end of 2026, 60% in 2027-2029, and 80% in 2030 and more (GOI, 2023; Kemeninves, 2023).

Long-term opportunities for EV manufacturers include increased potential demand as EV prices become more affordable and car ownership is still low. The projected price of batteries will fall from US\$ 132 in 2021 to US\$ 80 per kWh in 2026 (BloombergNEF, 2021), so EV production costs will become lower. Hopefully, EV prices will become more affordable, and the intention to buy EVs increase, too. Another fact shows that Indonesia's car ownership is only 99 units per 1000 population (Business-Indonesia, 2022)), so the EV demand will increase significantly with economic growth.

Technical barriers for EV manufacturers include the dependence on importing raw materials and critical components and lack of industry readiness. Limited materials and parts depend on imports, especially batteries and major electronic components like semiconductors. The lack of local industry readiness is a significant barrier (Maghfiroh et al., 2021).

2.2.3. EVCS operation factors from charging infrastructure provider perspectives

Economic benefits for charging station providers include simplifying the charging station business model and the initial market of charging station policy. Simplifying the charging station business model makes the charging station provision more attractive (Huang et al., 2022; LaMonaca & Ryan, 2022). In Indonesia, every charging station location can only operate one type of charging device: Type 2, CCS2, or CHAdeMO (KemenESDM, 2023) and create the initial market policy. Operational barriers for charging infrastructure providers are limited electricity supply in some areas (Tarei et al., 2021).

2.2.4. EV adoption and production factors from government perspectives

The government has a role in setting policies, both fiscal and nonfiscal policy, to drive the growth of EVs (Coffman et al., 2017; Kumar & Alok, 2020). For the government, the economic benefits of EV adoption include reducing imported fuel and environmental benefits. Increased EV adoption will reduce fuel use and decrease fuel imports. Increased EV adoption will reduce greenhouse gas emissions from the transportation sector, with the realization of clean energy, clean air quality, and environmentally friendly (GOI, 2019; Lopez-Arboleda et al., 2021). The development of EVs will grow new industries, namely the supply chain network industry, such as the battery raw material industry, the battery industry, the electric motor industry, the IT industry, etc. (GOI, 2019; Lopez-Arboleda et al., 2021).

The provision of EV purchase incentives in the case of Indonesia has several limitations, including budget constraints, and there is still a debate regarding the feasibility of target segmentation of incentives (subsidy) recipients (Brozynski & Leibowicz, 2022; Patyal et al., 2021). There is still low public awareness of EVs because there is still a lack of comprehensive socialization related to EVs, such as technical, economic, social, and environmental aspects (Kumar et al., 2021; Tarei et al., 2021).

3. Methodology

The literature review identifies the drivers and barriers to EV adoption and production factors. The subsequent work is to screen these criteria so that they are indeed essential and meet the factual condition in Indonesia. This filtering method uses the Delphi method. The adoption of EVs into the automotive market is a study of a new product. The public's awareness of EVs is still limited. In the Delphi method, the expert panel opinion or judgment represents all stakeholder elements in EV adoption and production. The Delphi method is suitable for gathering expert panel opinions, as it effectively incorporates subjective perspectives and iterative feedback. The inherent anonymity of experts affords them the freedom to share their ideas without constraint, mitigating any potential dominance or impact of opinions. The active participation of professionals throughout the entire process facilitates identifying and implementing a compromised and effective solution (Ciptomulyo, 2001).

3.1. Delphi method

The steps of the Delphi method are depicted in Figure 3 by adopting the phases of Hakim et al. (2023).

First, select an Expert Panel to represent stakeholders in the EV ecosystem. Conduct preliminary interviews with the Expert Panel to identify EV adoption and production factors and accept some new aspects that significantly deal with the condition of Indonesia. Then, prepare the 1st questionnaire using a systematic list of questions and a Linkert scale of 5 (see Table 2).

In Round 1 of the Delphi method, submit the 1st questionnaire to the Expert Panel to get an opinion of how important/influential the EV adoption and production factors are. Compile and calculate the geometric mean value of each subfactor using the formula below:

$$G = \sqrt[n]{x_1 \cdot x_2 \cdot x_3 \dots x_n}$$

Where n is the number of experts, and x_1, x_2, \dots, x_n is the answer of each expert regarding specific adoption and production factors. Revise the questionnaire to get the 2nd one focusing on the subfactors with $G < 3.5$. Submit the 2nd questionnaire to get confirmation from the Expert Panel. Calculate the geo-mean. If $G \geq 3.5$, the factor is accepted; if $G < 3.5$, then the factor is removed from the list of identified factors. Based on feedback from the Expert Panel, revise and submit it again to the Expert Panel in the 3rd round for validation. If there is still no consensus, repeat the procedure in round 2, and if there is consensus, then compile the final identification of EV adoption and production factors case of Indonesia.

3.2. Expert panel

The expert panel selection is a critical stage in the Delphi method. The criteria for the expert panel are someone who has at least five years of working experience in EV-related fields, works in a minimum manager position, knows factors affecting EV adoption and production, and EV development policies.

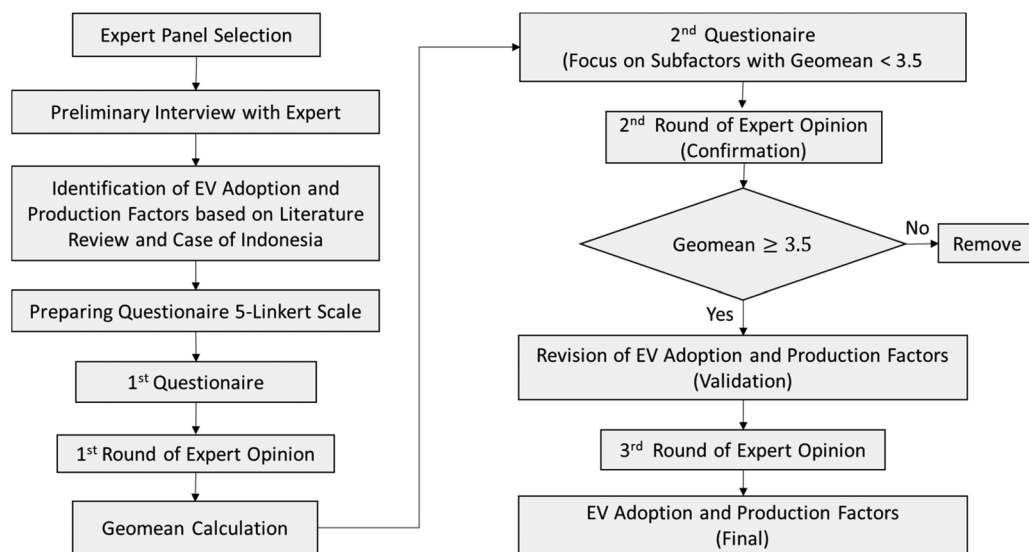


Figure 3. Delphi method.

Table 2. Linkert scale for EV adoption factor assessment.

Linkert Scale Value	Intensity Matters/Influences EV Adoption
1	Not Important/No Effect
2	Less Important/Less Influential
3	Quite Important/Influential Enough
4	Important/Influential
5	Very Important/Very Influential

In the Delphi method, no specific number of experts can validate the factors or variables. The number of experts varied from five experts (Hakim et al., 2023) to seven experts or should be smaller than 20 experts (Baker et al., 2006) or in the low double-digit range (Niederberger & Spranger, 2020). The expert council chosen to represent the subsystem in the EV ecosystem in Indonesia is comprised of ten experts. With 5 and 17 years of experience, the Special Advisor to the Coordinating Minister of Maritime and Investment and the Head of the Sub Directorate for the Ministry of Industry are two subsystem Government experts. Four specialists in subsystem EV Manufacturers comprise the Vice President and Director of two Foreign OEMs, the General Manager, and the Business Development Coordinator of two local startup EV manufacturers, with 15, 15, 10, and 5 years of experience, respectively. Two subsystem charging infrastructure provider experts are the General Manager of a State Electricity Company and the Technical and Engineering Director of a charging station manufacturer with 28 and 5 years of experience. Two specialists in subsystem Users are the Head of the Fleet Design and Standardization Department of the e-bus operator and the Indonesian Electric Car Community Chairman, with 15 and 18 years of experience.

3.3. Questionnaire

In this first interview with experts, the researcher conveyed the research background, objectives, methodology, and discussion about several essential inputs related to EV adoption factors based on the literature review result. The experts individually confirm some aspects and propose some factors associated with the uniqueness of Indonesia's situation. Tables 3–6 display the early identification of the factors related to EV adoption and production into drivers and barriers categories, including the expert's inputs to match the context of Indonesia. There are 58 subfactors involved in the questionnaire.

For users, owning an EV and using EVs for daily transportation will enhance their social status. Prestige is, therefore, a social benefit for EV owners (13*). Maintenance anxiety is a technical barrier for users concerned about the accessibility of maintenance workshops, EV components, and spare parts (19*). The low per capita Gross Domestic Income (in 2022, Rp. 71 million or US\$ 4,783.9) of Indonesia's population affects the low number of car owners and the purchasing capacity of automobiles, including EVs. The data confirms an additional financial barrier for users (22*). One of the obstacles to EV charging is that the cost of charging at charging stations is not yet rigorously regulated, resulting in a wide range of charging prices (25*). As EVs are a relatively new technology, future performance degradation becomes a technical risk for consumers due to deteriorating battery quality and the incompatibility of certain technical aspects with Indonesian conditions (26*).

For EV manufacturers, empirical data indicates that OEMs that produce EVs in Indonesia earn significant sales compared to imported EVs as completely built units (31*). Local production of EVs will increase user confidence in EVs and could result in purchase price rebates to promote EV sales. In 2021, for instance, when there are no domestically produced BEVs, only 685 units of imported BEVs in CBU condition will be sold. However, in 2022, when two OEMs from China and Korea manufactured BEVs in Indonesia, BEV sales reached 10,327 units (Gaikindo, 2023). Environmental benefits for EV manufacturers include the contribution of the manufacturers to making low-emission vehicles become green industries, which impacts incentives for EV production (32*). Additional social advantages for EV manufacturers relate to brand enhancement (33*). Because automotive manufacturers produce EVs to align with e-mobility and sustainable transportation, brand image is improving.

Long-term opportunities for EV manufacturers, such as the ability to produce EVs domestically, will increase the number of EV variants and models and decrease or eradicate vehicle delivery waiting times (indents), thereby accelerating EV adoption (36*). However, limited production capacity became a technical hindrance for EV manufacturers (37*). The production rate has not yet met the high demand for EVs in the early phases, so there is a long line for unit delivery (indent).

EV manufacturers face a substantial threat from the competition with ICEV manufacturers. Because the proportion of the ICEV industry to the gross domestic product (GDP) is still considerable, policy support for ICEV manufacturers remains substantial (40*). Because the ICEV manufacturing industry employs more than 1.5 million people, the sector still has essential policy support (41*). No policy instrument

Table 3. Category of factors and subfactors listed in questionnaire from subsystem of user/adopter.

1. Subsystem of User/Adopter				
Category	Factor	Subfactor & Code		References
Drivers	Technical benefits for users	Comfortable and safe driving	(1)	Sanguesa et al. (2021); Novizayanti et al. (2021)
		Easy maintenance	(2)	Novizayanti et al. (2021)
	Economic benefits for Users related to operational costs	Low charging costs	(3)	Bhosale et al. (2022); Hagman et al. (2016)
		Low maintenance costs	(4)	Bhosale et al. (2022); Hagman et al. (2016)
	Economic benefits related to fiscal incentives for users	Purchase price incentives	(5)	Dong and Zheng (2022); Jung et al. (2021); Kemenperin (2023)
		Value-added tax (VAT) incentives	(6)	Kemenkeu (2023)
		Sales tax on luxury goods incentives	(7)	Deuten et al. (2020); Llopis-Albert et al. (2021)
		Title transfer tax incentives	(8)	Novizayanti et al. (2021); GOJ (2021)
		Yearly tax incentives	(9)	Kemenkeu (2023)
	Benefits of nonfiscal policies for users	Night electricity rate incentives	(10)	Wang et al. (2019); Novizayanti et al. (2021)
		Excluded from odd-even policy	(11)	Novizayanti et al. (2021); Lu et al. (2022)
	Environmental benefits for users	Eco-friendly vehicles	(12)	Jung et al. (2021); Tarei et al. (2021); Kumar and Alok (2020)
	Social benefits for users	Prestige	(13)*	
	Long-term economic opportunities for users	The lower total cost of ownership (TCO)	(14)	Bhosale et al. (2022); Tarei et al. (2021); Kumar and Alok (2020)
		EV prices are getting more affordable.	(15)	BloombergNEF (2021)
Barriers	Technical barriers for users	Battery range anxiety	(16)	Novizayanti et al. (2021); Tarei et al. (2021); Kongklaew et al. (2021)
		Performance anxiety	(17)	Zolfagharian et al. (2020); Deuten et al. (2020); Abbasi et al. (2021)
		Safety anxiety	(18)	Deuten et al. (2020); Tarei et al. (2021); Huang et al. (2022); Abbasi et al. (2021)
		Maintenance anxiety	(19)*	
	Economic barriers for users	Lack of model availability	(20)	Novizayanti et al. (2021)
		EV and ICEV price difference	(21)	Novizayanti et al. (2021); Hu et al. (2020); Tarei et al. (2021); Llopis-Albert et al. (2021); Bitencourt et al. (2021)
	Charging infrastructure barriers for users	GDP per capita	(22)*	
		Lack of charging stations	(23)	Jung et al. (2021); Hu et al. (2020); Liang et al. (2022); Tarei et al. (2021); Broadbent et al. (2021)
		Charging time constraints	(24)	Secinaro et al. (2020); Liang et al. (2022)
	Technical risk for users	Charging cost variations	(25)*	
		Performance degradation	(26)*	
	Economic risks for users	Re-sale anxiety	(27)	Tarei et al. (2021); Kongklaew et al. (2021)

Noted: The number of subfactors denoted by an asterisk (*) represents a newly discovered subfactor from an expert interview.

requires automakers to produce EVs under specific goals. Consequently, ICEV manufacturers are not required to manufacture EVs (42*).

For charging station infrastructure providers, the construction of charging points will directly increase the absorption of electricity supply from the national electricity company (PLN), which is currently overstocked with electricity stock (45*).

Long-term opportunities for charging station providers will make the business more lucrative. Increasing adoption of electric vehicles, the attractiveness of charging station business models, and the adaptability of the electricity network, which permits charging stations in offices, parking lots, apartments, residential areas, rest areas, hotels, shopping malls, commercial centers, tourist attractions, etc. will boost the profitability of charging station businesses (46*).

The EVCS business has not yet created profitable operational obstacles for setting infrastructure providers (47*). In the short term, the charging station business has not been fruitful due to the high cost of investment and the low number of electric vehicles. The most significant safety risk in the charging station area is the occurrence of fires resulting from technical errors in setting electricity and the power grid (49*).

To promote EV adoption in Indonesia, the government can implement new policies, such as requiring ICEV manufacturers to produce a specific number or proportion of EVs (53*). The government may also employ the new tariff exemption or reduction, such as EV drivers receiving a 100 percent exemption or

Table 4. Category of factors and subfactors listed in questionnaire from subsystem of EV manufacturers.

2. Subsystem of EV Manufacturers				
Category	Factor	Subfactor & Code		Reference
Drivers	Economic benefits for EV manufacturers	Tax holiday	(28)	Kemenkeu (2020)
		Import tax exemption for Incompletely Knocked Down (IKD)	(29)	Kemenkeu (2022)
		Purchase price incentives	(30)	Jenn et al. (2018); Kumar and Alok (2020); Secinaro et al. (2020); Kemenperin (2023)
	Environmental benefits for EV manufacturers	Increased sales of domestically produced EVs	(31)*	
		Contribute to becoming a green industry	(32)*	
	Social benefits for EV manufacturers	Improved brand image	(33)*	
	Long-term opportunities for EV Manufacturers	Increased potential demand as EV prices become more affordable	(34)	BloombergNEF (2021)
		High potential demand because car ownership is still low	(35)	Kemenperin (2022)
		Stock availability of EVs with various variants	(36)*	
		Limited production capability	(37)*	
Barriers	Technical barriers for EV manufacturers	Dependence on the import of raw materials and critical components	(38)	Maghfiroh et al. (2021)
		Lack of industry readiness level	(39)	Maghfiroh et al. (2021)
		The ICEV industry's contribution to GDP is still high	(40)*	
	The competitive risk with ICEV manufacturing	The ICEV industry absorbs a lot of labor.	(41)*	
		No obligation to produce EVs	(42)*	

Note: The number of subfactors denoted by an asterisk (*) represents a newly discovered subfactor from an expert interview.

Table 5. Category of factors and subfactors listed in questionnaire from subsystem of charging infrastructure provider.

3. Subsystem of Charging Infrastructure Provider				
Category	Factor	Subfactor & Code		References
Drivers	Economic benefits for charging station providers	Simplification of charging station business model	(43)	Huang et al. (2022); Kongklaew et al. (2021); KemenESDM (2023)
		The initial market of charging station policy	(44)	KemenESDM (2023)
	Benefits for electrical companies	Absorption of oversupplied electricity supply	(45)*	
	Long-term opportunities for charging station providers	Charging station business will be more profitable	(46)*	
Barriers	Operational barriers for charging infrastructure providers	EVCS business is not yet profitable	(47)*	
	Technical barriers to charging infrastructure providers	Limited power supply	(48)	Tarei et al. (2021)
		Charging station safety risks	(49)*	

Noted: The number of subfactors denoted by an asterisk (*) represents a newly discovered subfactor from an expert interview.

Table 6. Category of factors and subfactors listed in questionnaire from subsystem of government.

4. Subsystem of Government				
Category	Factor	Subfactor & Code		References
Drivers	Economic benefits	Reduced imported fuel	(50)	GOI (2019)
	Environmental benefits	Reduced emissions from the transportation sector	(51)	Lopez-Arboleda et al. (2021); GOI (2019)
		The growing EV component supplier industry	(52)	Lopez-Arboleda et al. (2021); GOI (2019)
	New industry opportunities	Obligation to produce EVs	(53)*	
	New policy implementation opportunities	Toll tariff exemption or reduction	(54)*	
Barriers	Policy barriers	Limitations of EV purchase incentives	(55)	Brozynski & Leibowicz (2022)
		Lack of socialization of the importance of EV	(56)	Tarei et al. (2021); Kumar and Alok (2020)
	ICEV industry sustainability risks	EV as a technological disruption	(57)*	
	Local startup EV industry sustainability risks	Local EV startup industry outcompetes	(58)*	

Noted: The number of subfactors denoted by an asterisk (*) represents a newly discovered subfactor from an expert interview.

decreasing toll rates and ferry fares (54*). As an incentive for EV adoption, the policies could include driving privileges.

Government policy must consider the threats to the ICEV industry's sustainability. EV as a technological disruption may substantially disrupt the establishment of the ICEV industry, which could result in the collapse of the ICEV industry and some supporting vendors (57*). Local EV industry startup sustainability

hazards are a further issue. The local EV startup industry finds it difficult to compete with foreign OEMs, which have dominated the ICEV industry, so the brand has earned the recognition and trust of automotive consumers in Indonesia (58*).

4. Result

The EV adoption factor identification survey of 10 Expert Panels was conducted from April 11, 2023, to May 5, 2023, wherein the 1st round of questionnaire filling was carried out online with the help of Google Form, and in the 2nd and 3rd rounds of confirmation via WhatsApp for explanations of answers that are very different from the majority of the Expert Panel to stick to the answers or revise the answers.

4.1. Factors identification result

Table 7 summarizes the analysis results based on the Expert Panel survey with the Delphi method related to identifying EV adoption factors. The answers of 10 Expert Panels to 58 questions stating the adoption subfactors according to the 5-Likert scale values on EV adoption and production were calculated as geometric mean (geomean). A geomean value of 3.5 is used as a limit to assess the final result and whether the subfactor will be accepted for further analysis or removed. The subfactor will be accepted if the geomean value equals or exceeds 3.5. Subfactors will be removed if the geomean value is less than 3.5. Based on the results of geomean calculations, out of 58 subfactors, 44 subfactors were accepted, and 14 subfactors were removed.

4.2. Statistical test

First, the validity of the Expert Panel in filling out the questionnaire was 100% valid, where as many as 10 Experts answered all questions. In addition to using geomean values to test the validity of whether certain sub-factors are accepted or removed, Table 8 summarizes the reliability test results on 58 subfactors. The Cronbach's Alpha value of 0.884 exceeds the reference value of 0.7, so the survey instrument is reliable. The questionnaire is accurate and consistent for further research and at different times.

5. Discussion

5.1. EV adoption factors according to users

For users, 12 driver subfactors are perceived to be influential in EV adoption, including technical benefits (comfortable, safe driving, and easy maintenance), economic benefits related to operational costs (low charging and low maintenance costs), economic benefits associated with fiscal incentives (purchase price incentives, value-added tax incentives, sales tax on luxury goods incentive, title transfer tax incentives, yearly tax incentives, and night electricity rates incentives), benefits of nonfiscal policies (exclusion from the odd-even policy), and environmental benefits related to eco-friendly vehicles. In contrast, people who adopt EVs do not view prestige as a societal gain. In Vietnam, (Hoang et al., 2022) found a similar conclusion: social influence does not impact consumers' intentions to buy electric vehicles. In developing countries, buyers of EVs are frequently innovators or early adopters who are less susceptible to peer pressure. For users, EV adoption will have long-term economic opportunities through a lower total cost of ownership (TCO), making EV prices more affordable.

There are fascinating survey results related to barriers to EV adoption. It turns out that technical things in many kinds of literature become technical barriers for users, such as (Abbasi et al., 2021; Deuten et al., 2020; Kongklaew et al., 2021; Kumar et al., 2021; Tarei et al., 2021), such as concerns related to battery range anxiety, performance anxiety, safety anxiety, maintenance anxiety, and lack of model availability. Still, this has not been a significant obstacle in Indonesia, especially since the EV manufacturers are currently OEMs from abroad that technically have experience producing EVs in various countries, and no severe technical problems have been found. Of course, attention to this technological aspect needs to be evaluated continuously every year.

Table 7. Identification results of EV adoption factors according to the expert panel.

Category	Factor	Subfactor & Code	Geomean Value	Result		
1. Subsystem of User/Adopter						
Drivers	Technical benefits for users	Comfortable and safe driving	(1)	4,54	Accepted	
		Easy maintenance	(2)	4,57	Accepted	
	Economic benefits for Users related to operational costs	Low charging costs	(3)	4,17	Accepted	
		Low maintenance costs	(4)	4,68	Accepted	
	Economic benefits for users related to fiscal incentives	Purchase price incentives	(5)	3,94	Accepted	
		Value-added tax (VAT) incentives	(6)	4,36	Accepted	
		Sales tax on luxury goods incentives	(7)	4,17	Accepted	
		Title transfer tax incentives	(8)	4,36	Accepted	
		Yearly tax incentives	(9)	4,46	Accepted	
		Night electricity rate incentives	(10)	4,47	Accepted	
	Benefits of nonfiscal policies for users	Excluded from odd-even policy	(11)	4,78	Accepted	
	Environmental benefits for users	Eco-friendly vehicles	(12)	4,78	Accepted	
	Social benefits for users	Prestige	(13)*	3,30	Removed	
	Long-term economic opportunities for users	The lower total cost of ownership (TCO)	(14)	4,25	Accepted	
		EV prices are getting more affordable.	(15)	4,47	Accepted	
Barriers	Technical barriers for users	Battery range anxiety	(16)	3,19	Removed	
		Performance anxiety	(17)	2,31	Removed	
		Safety anxiety	(18)	2,52	Removed	
		Maintenance anxiety	(19)*	2,78	Removed	
		Lack of model availability	(20)	2,96	Removed	
		Economic barriers for users	EV and ICEV price difference	(21)	4,06	Accepted
	Charging infrastructure barriers for users	GDP per capita	(22)*	3,38	Removed	
		Lack of charging stations	(23)	3,65	Accepted	
		Charging time constraints	(24)	3,27	Removed	
	Technical risk for users	Charging cost variations	(25)*	2,68	Removed	
		Performance degradation	(26)*	2,38	Removed	
		Economic risks for users	Re-sale anxiety	(27)	3,17	Removed
2. Subsystem of EV Manufacturers						
Drivers	Economic benefits for EV manufacturers	Tax holiday	(28)	4,68	Accepted	
		Import tax exemption for Incompletely Knocked Down (IKD)	(29)	4,24	Accepted	
		Purchase price incentives	(30)	4,47	Accepted	
		Increased sales of domestically produced EVs	(31)*	4,37	Accepted	
	Environmental benefits for EV manufacturers	Contribute to becoming a green industry	(32)*	4,57	Accepted	
	Social benefits for EV manufacturers	Improved brand image	(33)*	4,25	Accepted	
	Long-term opportunities for EV Manufacturers	Increased potential demand as EV prices become more affordable	(34)	4,47	Accepted	
		High potential demand because car ownership is still low	(35)	4,05	Accepted	
	Barriers	Technical barriers for EV manufacturers	Stock availability of EVs with various variants	(36)*	4,36	Accepted
			Limited production capability	(37)*	3,36	Removed
Dependence on the import of raw materials and critical components			(38)	3,96	Accepted	
The competitive risk with ICEV manufacturing		Lack of industry readiness level	(39)	4,04	Accepted	
		The ICEV industry's contribution to GDP is still high	(40)*	3,48	Accepted	
		The ICEV industry absorbs a lot of labor.	(41)*	4,22	Accepted	
No obligation to produce EVs	(42)*	4,68	Accepted			
3. Subsystem of Charging Infrastructure Providers						
Drivers	Economic benefits for charging station providers	Simplification of charging station business model	(43)	4,57	Accepted	
	Benefits for electrical companies	The initial market of charging station policy	(44)	3,96	Accepted	
		Absorption of oversupplied electricity supply	(45)*	4,22	Accepted	
	Long-term opportunities for charging station providers	Charging station business will be more profitable	(46)*	4,47	Accepted	
Barriers	Operational barriers for charging infrastructure providers	EVCS business is not yet profitable	(47)*	3,68	Accepted	
	Technical barriers to charging infrastructure providers	Limited power supply	(48)	2,93	Removed	
		Charging station safety risks	(49)*	2,79	Removed	
4. Subsystem of Government						
Drivers	Economic benefits	Reduced imported fuel	(50)	4,07	Accepted	
	Environmental benefits	Reduced emissions from the transportation sector	(51)	4,16	Accepted	
	New industry opportunities	The growing EV component supplier industry	(52)	4,57	Accepted	
	New policy implementation opportunities	Obligation to produce EVs	(53)*	4,35	Accepted	
		Toll tariff exemption or reduction	(54)*	4,17	Accepted	
Barriers	Policy barriers	Limitations of EV purchase incentives	(55)	4,25	Accepted	
	ICEV industry sustainability risks	Lack of socialization of the importance of EV	(56)	4,27	Accepted	
		EV as a technological disruption	(57)*	3,52	Accepted	
		Local startup EV industry sustainability risks	Local EV startup industry outcompetes	(58)*	3,66	Accepted

Table 8. Reliability test.

Reference Value	Cronbach's Alpha Value	Item Number	Result
0,7	0,884	58	Reliable

In particular, the battery range is not an excessive concern because now, EVs with prices above Rp. 700 million, or US\$ 46.667, has been able to travel above 500km. Meanwhile, the EV, with a cost of Rp 300 million or US\$ 20.000, has been able to travel a distance above 300km. So, the obstacle is not in the battery range, but having a long battery range is only available on EVs at costly prices.

A cumbersome barrier is the EV and ICEV price difference, where the price of EV is still at the premium price level and costs more than 1.5 times the price of ICEV with a commensurate class. The result agrees with the other research results (Broadbent et al., 2021). In Indonesia, the price of the 5-seater BEV which exceeds Rp. 700 million (approximately US\$ 46,667), is met by a market share of less than 1% of automotive consumers. While the price of a 4-seater BEV, which is around Rp. 300 million, or \$20,000, is nominally affordable for most automobile owners. Despite this, the price only affords a small-capacity EV, which must compete with ICEVs that offer seven-passenger seating and more significant cargo space at comparable prices.

The lack of charging stations still affected EV adoption as the charging infrastructure barriers. Meanwhile, mandatory policy instruments have not maximally encouraged the potential for charging stations in public areas such as office buildings, shopping centers, hotels, apartments, and other public facilities. Currently, the procurement of charging stations is still purely a B-to-B business model. The survey results are also interestingly related to EV risks for users, where performance degradation and re-sale anxiety are not significant risks.

Table 9 summarizes EV adoption variables depending on a user subsystem.

5.2. EV production and adoption factors according to EV manufacturers

For EV Manufacturers, there are some attractive drivers for producing EVs in Indonesia. The economic benefits include the provision of a corporate income tax reduction facility or tax holiday, import tax exemption for IKD, purchase price incentives, and increased sales of domestically produced EVs. The environmental benefits for EV manufacturers are becoming a green industry. EV manufacturers' social benefits are due to improved brand image. The long-term opportunities include increased potential demand as EV prices become more affordable, high likely demand because car ownership is still low, and the stock availability of EVs with various variances.

However, there are currently technical barriers for EV manufacturers in the form of dependence on imports of raw materials and critical components and a lack of local industry readiness. Meanwhile, the limitation of production capability is not a critical technical barrier because the development of production facilities is in progress in the early stages. In the future, EV manufacturers face severe risks because there is a competitive risk with ICEV manufacturers where the government still maintains the ICEV industry, and there is no obligation for ICEV manufacturers to produce EVs. Incumbent gradually makes and sells HEV and PHEV, not BEV, as mandated in the Presidential Decree (GOI, 2019). After all, the ICEV industry's contribution to GDP is still high, and the ICEV industry absorbs a lot of labor.

Table 10 resumes EV production factors based on a subsystem of EV manufacturers.

5.3. EV adoption according to charging infrastructure providers

Regarding the charging station, some benefits are starting to be felt. The new regulation simplifies the charging station business model. The policy for shaping the initial charging station market is where the government gives PT PLN the task of building charging stations at various points in Indonesia. Benefits for electrical companies, especially PT PLN, because EV development and charging station construction will positively impact the absorption of oversupplied electricity supply. In the long term, there are also long-term opportunities for charging station providers because the business will be more profitable.

Table 9. Resume of EV adoption factors based on subsystem of users.

Drivers	Barriers
Economic Benefits	Economic Costs
Low operating cost	EV-ICEV price difference
Purchase incentives	Infrastructure Barriers
Yearly tax incentives	Lack of charging stations
Economic Opportunities	
Low total cost of ownership	
EV prices are more affordable.	
Operational Benefits	
Comfortable and easy maintenance	
Excluded from odd-even policy	
Environmental Benefits	
Eco-friendly vehicle	

Table 10. Resume of EV production factors based on subsystem of EV manufacturers.

Drivers	Barriers
Economic Benefits	Operational Barriers
Tax holiday	Dependence on the import of raw materials and critical components
Import tax exemption for Incompletely Knocked Down	
Increased sales of domestically produced EVs	
Economic Opportunities	Economic Risks
Increased sales of EV prices have become more affordable, and various variants are available.	The competitive risk with ICEV manufacturers
Environmental Benefits	
Contribute to becoming a green industry.	
Social Benefits	
Improved brand image	

For current charging station providers, the operational barriers for charging infrastructure providers are because the business is not yet profitable. Meanwhile, the limited power supply is not an obstacle because there is still an excess electricity supply in various regions. Meanwhile, the charging station safety risks also do not affect the provision of charging stations because electricity implementation standards at charging stations in Indonesia have paid great attention to safety standards.

Table 11 resumes EV adoption factors based on a subsystem of charging infrastructure providers.

5.4. EV production and adoption factors according to the government

The government strongly encourages EV adoption because potential benefits include reduced fuel imports, reduced transportation sector emissions, and the opportunity to grow a new EV component supplier industry. The dynamics of the EV market might drive the government to implement and exercise a new user-oriented policy like toll tariff exemption or reduction.

It's just that currently, the government faces policy barriers, namely budget limitations of EV purchase incentives and a lack of socialization of the importance of EVs, so the misunderstanding of EV development programs is still problematic. In the future, the development of the EV industry will affect the ICEV industry's sustainability due to EVs as a disruptive technology, potentially undermining the ICEV industry's dominance. Local startup EV industry sustainability faces risks because the industry outcompetes. OEMs from abroad will continue to dominate the automotive industry in Indonesia.

Table 12 resumes EV adoption and production factors based on a subsystem of government.

6. Conclusions

Identifying EV adoption and production factors under the domination of foreign OEMs in the automotive industry benefits the government by providing a more effective policy to drive EV growth in Indonesia.

Users have previously believed that the technical quality of EVs manufactured by OEMs meets international standards. Thus, the technical merits of EVs are widely acknowledged. There has not been excessive concern regarding technical constraints, both current and prospective risks. Users also consider the

Table 11. Resume of EV adoption factors based on subsystem of charging infrastructure providers.

Drivers	Barriers
Economic Benefits	Costs
Simplification of charging station business model	EVCS business is not yet profitable
The initial market of charging station policy	
Economic Opportunities	
The charging station business will be more profitable.	

Table 12. Resume of EV production factors based on subsystem of government.

Drivers	Barriers
Economic Benefits	Economic Risks
Reduced imported fuel	ICEV industry sustainability risks
The growing EV component supplier industry	Local startup EV industry sustainability risks
Environmental Benefits	
Reduced emissions from the transportation sector	
Policy Opportunities	Policy Barriers
New policy implementation opportunities	Limitations of EV-related incentives budget
	Lack of socialization of the importance of EV

economics of EV operation to be favorable, as charging costs are significantly less than ICEV fuel costs, maintenance costs, and total cost of ownership.

Current EV manufacturers offer numerous BEV models ranging from 300km (city car) to more than 500km (sedan) on a single charge. The range of available batteries is expanding as battery technology develops. Therefore, battery range is a function of EV price and is not a barrier to EV adoption.

These technical and economic benefits and some fiscal incentives cannot accelerate the adoption of EVs. The major barriers to EV adoption for consumers are the significant price difference between EVs and ICEVs and the lack of charging station networks, particularly for intercity travel. BEV buyers are still in the early adopter users or lifestyle users segmentation; those who buy BEVs are not first owners but are second and third-hand car owners, etc. The majority of car consumer choices in Indonesia are MPVs with seven passengers. The culture of Eid homecoming and year-end holidays in the region is why 7-seater cars are more in demand, while BEV-type MPVs like this are not yet available in the market, especially at prices not far from Rp 400 million. The argument also explains why the Innova 7-seater Zenix HEV type is in demand, with sales in 2023 of 52,563 units (Gaikindo, 2024).

Several fiscal incentives for EV manufacturers encourage investors to invest and produce EVs in Indonesia, particularly the possibility of future demand growth. However, there are presently several obstacles, including the small share of the EV market resulting from the transition process and the constraints of high production costs. Significant components, such as batteries, electric motors, controllers, software, and semiconductor components, must be imported from the global supply chain that controls today's EV industry, which can be time-consuming.

EV manufacturers must also compute the risks associated with competing with the ICEV industry. The Indonesian government policy continues to prioritize the growth of the ICEV industry because the contribution of ICEV to GDP and employment remains high. At the same time, there are no indications that the development of the EV industry will supplant that of the ICEV industry. In addition, the government has not enacted a policy mandating that ICEV manufacturers produce EVs with a minimum target share, as have other pioneer nations on EV development like China with a dual-credit policy (Peng & Li, 2022; Yang et al., 2022).

Even though the regulations for managing charging stations have been simplified for charging infrastructure providers, the private sector has no interest in conducting business in this field. In the early stages, the government decided to entrust PT PLN with the construction of charging stations at various locations while taking advantage of PLN's still excessive electricity supply. Private parties operating charging stations are still limited and strictly B to B, for example, collaborating with PLN or Trans Jakarta to construct charging stations for their electric buses. Suppose solid policies require office buildings, trade centers, rest areas, hotels, apartments, and other public areas to construct charging stations as part of their business units or facilities. For instance, hotels with charging station facilities will be more desirable in the future than hotels that do not offer charging stations, either for a fee or as a 'bonus' for staying there.

The acceleration of the EV program provides significant benefits to the government in terms of reducing greenhouse gas emissions and decreasing fuel imports, as well as numerous opportunities for the emergence of new EV-supporting industries and the recruitment of new employees with EV expertise. Nevertheless, government policies on incentives or subsidies are limited by budgetary constraints. Moreover, a fairer and more proportional formula for transferring petroleum subsidies to EV subsidies has not been identified. Meanwhile, public communication about EVs and the benefits of EV subsidies and incentives has not been optimized.

The government estimates a substantial risk if EVs as a disruptive technology are not managed appropriately. The dependence on and dread of the collapse of the ICEV industry, as well as the fact that the majority of ICEV industries are global OEMs in a region where investment competition with neighboring countries such as Thailand and Vietnam is intensifying, have led the government to maintain a cautious stance on EV policy.

The finding is significant because, with moderate policies, reaching the ambitious target of EV market share in the coming years is difficult. The subsequent research for fostering EV adoption should focus on more powerful and effective user-oriented policies for narrowing EV-ICEV price differences, producer-oriented policies for EV manufacturers to produce the MPV type of BEV, and infrastructure-oriented policies attracting investors to emphasize the deployment of additional charging infrastructure facilities.

6.1. Theoretical contribution

The results of this study are expected to make a novel contribution in the form of EV adoption and production factors under ecosystems as part of the intelligent phase of a decision-making process approach that considers the limitations of nations with weak automotive industries, unstructured user segmentation targets, and constrained resources for EV policy implementation.

Theoretically, the findings of this study can help with the decision-making process for creating new technologically advanced items and adopting new technologies that rely on infrastructure (infrastructure-dependent technology adoption). The segmentation of early adopters makes the new technology prevalent in the market's early stages of product assortments. Subsidy and incentives are essential in creating demand and supply of various types and models in the range of users' needs and competitive prices.

6.2. Managerial implication

The findings of this study will be helpful to policymakers as they develop strategies to raise the market share of electric vehicles and strengthen the capacity of the domestic electric vehicle sector with an organized and systematic decision-making process.

In the transition stage, the early adopters help introduce the product to the market. However, the most extensive customer segmentation is the economy users. The condition implies that EV manufacturers' policymakers should set the business strategy to produce MPV (multi-purpose vehicle) EVs with narrower price gaps than ICEVs.

Government policy should support the users with several incentives and an awareness campaign on the sustainability aspect of EVs, as well as technical, economic, environmental, and social factors. The government should provide several fiscal and nonfiscal incentives to attract investors to produce EVs in domestic sites under the local content-based policy and to increase the deployment of charging stations to reduce users' driving anxiety.

6.3. Limitations and Future research

The research can only pinpoint the critical variables affecting EV production and uptake in Indonesia. The elements have not been compared. Future research may classify the factors affecting EV adoption into benefits, opportunities, costs, and risks (BOCR) and use pairwise comparisons to determine which factors are more important. The BOCR structure, according to Saaty & Vargas (2006), will aid in the decision-making process.

Authors' contributions

The conception and design (TWS, UC); analysis and interpretation of the data (TWS, UC, BW); the drafting of the paper (TWS, AP); revising it critically for intellectual content (TWS, UC, BW, AP); the final approval of the version to be published (UC, BW, AP); and all authors agree to be accountable for all aspects of the work.

Disclosure statement

The authors declare no conflict of interest.

Funding

This work was supported by the National Research and Innovation Agency, Indonesia, under scholarship number SK DBR No 61/II.2.3/KP/2023.

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Data availability statement

The data supporting the findings of this study are available within the article.

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