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Identifying factors influencing electric vehicle adoption in an emerging market: The case of Thailand

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ABSTRACT

Electric vehicles (EVs) are considered a technological innovation that helps reduce not only fuel consumption but also air pollution and greenhouse gases that exacerbate global warming concerns. Despite these benefits, the understanding of factors influencing EV adoption remains obscure, as it varies greatly across countries and perspectives (*e.g.*, the acceptance of EV technology, decisions to purchase and use EVs, and policies that affect user decisions to purchase and use EVs). To better comprehend the dominance of such factors — especially in an emerging market with a huge leap in EV usage, like Thailand — we devise a multi-perspective multi-criteria decision analysis (MCDA) framework and apply it to datasets of Thai EV users, including both general EV user and expert groups. Our results reveal that "Attitude Toward Using EVs" and "Subjective Norms" are crucial for the acceptance of EVs, while "Product and Service Attributes" and "Purchasing Incentive Policies" greatly impact the adoption decisions. Besides these factors, we also identify causal-effect relationships among factors in each of these three different perspectives. This research thus allows stakeholders — including EV manufacturers, transport authorities, and governments — to properly devise relevant mechanisms supporting countrywide EV adoption in a more sustainable fashion.

Introduction

The spectrum of human activities — including transportation, electricity generation, industrial production, agricultural, and energy consumption in residential and commercial buildings — has presented a substantial impact on the environment, especially the rising level of greenhouse gas (GHG) emissions that intensifies global warming (Kabir et al., 2023; Kim et al., 2020). To better support the realization of sustainable development for future generations, it is imperative for people to be conscious of protecting the environment, considering the extensive effects of these activities.

Among such activities, transportation is undeniably a major contributor to air pollution and a significant producer of carbon dioxide (CO2) emissions that continually aggravate global warming concerns (Yang et al., 2020; Parker et al., 2021). As such, proposals to reduce air pollutants and CO2 emissions in the transportation sector have been widely initiated (Kim et al., 2020), including the promotion of sustainable clean energy and eco-friendly electric vehicle (EV) usage. Largely due to the positive trends of EVs toward environmental sustainability (Asadi et al., 2022; Guo et al., 2023; Malima and Moyo, 2023), the number of EVs sold — and their respective market share — keeps increasing from year to year across the globe. According to the International Energy Agency (IEA), in 2022 alone, the global market share of EVs rose by approximately 14 %, which was more than triple the rise in their share in 2020.

As Thailand is a member state of the United Nations (UN) that prioritizes the Sustainable Development Goals (SDGs), the Thai government has diligently implemented a wide range of action plans aiming to achieve a net-zero society by 2050. In line with the global trends, many of these plans rely heavily on sustainable clean energy, including the promoting of EV usage so that at least 30 % of all vehicles in the country could be converted to EVs by 2030.

From the Thai user's perspective, EVs are regarded as automotive technological innovations — ranging from hybrid EVs (HEVs) and plug-in hybrid EVs (PHEVs) to full EVs like battery EVs (BEVs) or fuel cell EVs (FCEVs) — that rely less on fossil fuel. Therefore, users predominantly

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value EVs for their fuel cost savings, followed by their eco-friendly systems that help reduce air pollution, GHG emissions, and hazardous hydrocarbon compounds (Asadi et al., 2022; Guo et al., 2023; Malima and Moyo, 2023; Parker et al., 2021).

In terms of adoption by Thai users, their use and acceptance of EVs have progressively increased. According to the Department of Land Transport, the number of EV user registrations in Thailand has risen astronomically — by more than 100 % each year since 2017. There are three reasons for this (Jin et al., 2014; Kang and Park, 2011; Lane and Potter, 2007; Wang and Zhou, 2019; Yang et al., 2016). Firstly, from the user standpoint, the current EV advancements — including driving technology, safety, and other innovative features — are far superior to those of previous EV generations. Secondly, there are various EV price tiers that users can select based on their driving preferences. Finally, the Thai government supports the infrastructure (*e.g.*, electric charging stations) and supply chain of the EV industry in terms of both tax and provision benefits.

Although the number of EV users in Thailand has increased tremendously over recent years, it still remains minimal compared to the number of internal combustion vehicle users. Moreover, some EV types have been available in the market for some time, but they have not been widely used until recently. These issues may be attributed to several factors — for instance, government policies may fail to attract people's attention in terms of tax cuts, subsidies, special rights, and basic infrastructure (Kang and Park, 2011), or the automotive industry may not be able to demonstrate EV features that meet user desires (Adamson, 2005; Li et al., 2020; Schmalfuß et al., 2017; Wang et al., 2017). Other factors that potentially affect EV adoption include inadequate advertisements, promotions, and warranties for all user groups (Hardman et al., 2017; Lane and Potter, 2007). More specifically, Kang and Park (2011) found that extensive promotions might not effectively boost the EV adoption rates of some user groups, such as those who lacked sufficient education or those who lacked awareness of the benefits and drawbacks of EVs.

Most recent research also finds that factors influencing EV adoption vary greatly across countries, as they depend not only on perception and preferences but also on supportive government policies and the EV features offered by manufacturers. To this end, Asadi et al. (2022) found that price, perceived usefulness, social norms, and perceived benefits of EV usage were significant in influencing EV adoption in Malaysia, while battery capacity and lifespans, tax reductions, and government supports were critical for Chinese users (Kuo et al., 2022). In addition to such factors, perceived ease of use, perceived personal innovation, technology acceptance, and user experience were also indispensable factors for EV adoption in China and Thailand (Tu and Yang, 2019; Kuntawong et al., 2022; Sinsap, 2023).

Since EV technology is perceived as a new technological challenge for customers' driving habits in emerging markets like Thailand, users — as well as other parties aiming to promote EV adoption — must therefore weigh the advantages and disadvantages of EVs across different perspectives. Unfortunately, these factors may not yet be fully comprehended at the present time due to the existence of intervening relationships within and across different perspectives. To better understand EV adoption in Thailand from a multi-perspective standpoint, this research establishes a multi-criteria decision analysis framework capable of identifying and ranking influential factors that potentially affect the countrywide adoption of EVs across three different perspectives (*i.e.*, primary factors): (*i*) user acceptance of EV technology, (*ii*) user decisions to purchase and use EVs, and (*iii*) supportive government policies that encourage user decisions to purchase and use EVs.

To do so, we first extract related factors (*i.e.*, secondary factors and indicator questions) that might affect EV adoption within each of the three primary factors from the literature. We, later, categorize them into groups according to the Thai context using the factor analysis approach. Next, the Decision-Making Trial and Evaluation Laboratory (DEMATEL) approach is applied to prioritize secondary factors and unravel the interrelationships among factors, which could be visualized by the causal-effect diagrams. Based on this proposed framework, we would be able to not only identify the factors that influence the EV adoption by Thai users with greater precision but also gain insights into the causal relationships and the impacts of such factors within their respective domains. This information, in turn, allows us to make informed decisions regarding EV development and prioritize policy improvements (*e.g.*, taxation, subsidies, privileges, infrastructure development to support EV usage, or sales strategies to meet customer demands) more efficiently than before.

Compared to the existing research that primarily focuses on factors influencing EV adoption in one single dimension, this study investigates a wider range of factors that spans across three different dimensions. Additionally, we use factor analysis and the DEMATEL approach, so that only relevant factors are retained and carried forward to the construction of causal-effect diagrams. While our study is conducted based on the Thai context, the underlying research framework is, however, universal, as it can be applied to other contexts with new identified factors, without the need for major modifications. Considering the rapid shifts in the EV industries worldwide, we expect that our proposed research framework would serve as a stepping stone to the enhancement of EV adoption not only in Thailand but also in other countries.

The remainder of this paper is organized as follows. Section 2 provides a thorough review of the literature regarding factors influencing EV adoption from three different perspectives. Section 3 introduces the proposed methodology, and Section 4 presents the comprehensive results. Section 5 concludes our work with some potential research directions.

Literature review

According to the literature, numerous factors could affect user decisions to adopt EVs. Examples include factors related to customer preferences, usage acceptance, environmental aspects, financial considerations, marketing strategies, and policies by both manufacturers and governmental bodies. For ease of analysis, we have divided such factors into three main groups according to their relevance and the state-of-the-art literature, namely (*i*) user acceptance of EV technology, (*ii*) user decisions to purchase and use EVs, and (*iii*) supportive government policies that affect user decisions to purchase and use EVs. The following subsections discuss in detail each primary factor and the derivations of secondary factors, along with their respective indicator questions.

Acceptance of EV technology

According to Ajzen's (1991) theory of planned behavior, the factors that influenced customer behavior in adopting new technologies were behavioral intention, purchase intention, attitude, subjective norms, and perceived behavioral control. Recent research has found several additional factors that potentially influence user attitudes toward new technologies. Prominent examples include perceived usefulness, perceived ease of use, compatibility, and personal innovativeness (Davis, 1989; Williams et al., 1998; Agarwal and Prasad, 1997).

In terms of EV technology, Kuntawong et al. (2022) confirmed that factors related to personal innovation and compatibility perception indeed affected one's attitude toward technological acceptance. In addition, Panson (2018) found that financial benefits were crucial for EV adoption, in which maintenance expenses were identified as one of the significant factors influencing public acceptance of EVs. Apart from such expenses, basic infrastructure and the distance that an EV could travel on a single charge were listed as top-rated influential factors in the study.

Table 1 and Table A1 in Appendix A report all 10 influential factors and 35 indicator questions that contribute to the acceptance of EVs and the behavior associated with EV adoption derived from the literature.

Decisions to purchase and use EVs

Personal perception has long been known as one of the main factors affecting customers' purchasing decisions. This is because it is an important cognitive factor that effectively leads customers to believe

Table 1
Identified factors for EV technology acceptance.

Factors	Definition	Source(s)
Interpersonal Influence	Perspectives of those who are close to EV users, such as family, friends, and others; people's actions, opinions, or beliefs	Bhattacherjee (2000)
Personal Innovativeness	EV users' thoughts, attitudes, willingness, and opinions toward the acceptability of EV technology	Jalajas and Bommer (1999)
Price Acceptance	Acceptance of EVs at various price levels, including the fundamental expenditure of owning an EV, such as upkeep and insurance premiums	Sang and Bekhet (2015)
Subjective Norms	EV users' attitudes, perceptions, and behaviors regarding their views on accepting EV technology	Taylor and Todd (1995)
Compatibility	Users' feelings toward using EVs, such as feeling that EVs are aesthetically pleasing and offer greater convenience, including aspects like maneuverability, cost-effectiveness, and ease of locating electric charging stations	Taylor and Todd (1995)
Environmental Concerns	EV users' attitudes, perceptions, and behaviors toward environmental concerns associated with accepting EV technology as an eco-friendly option that can reduce air pollutants and GHG and conserve energy	Sang and Bekhet (2015)
Attitude Toward Using	EV users' thoughts and attitudes toward accepting EV technology after use, considering whether they view EV technology as good or not, and assessing its overall benefits and drawbacks	Davis (1989)
Perceived Ease of Use	EV users' thoughts and behaviors regarding their acceptance of EV technology, including whether they find EVs easy to use, the level of effort required for learning and adapting to them, and whether they are perceived as easy to learn and quick to adapt to	Davis (1989)
Perceived Usefulness	EV users' thoughts regarding their acceptance of EV technology, including the extent to which using EVs can provide benefits to users, whether they enhance efficiency at work, and whether they can improve users' overall quality of life	Davis (1989)
Social Norms	EV users' attitudes, perceptions, and behaviors on how they can influence their social image as a result of using EVs, such as how using EVs can contribute to a positive image in society or attract the interest of others	Taylor and Todd (1995)

that product differentiation efforts are important for making purchasing decisions (Davis, 1989; Jalajas and Bommer, 1999; Taylor and Todd, 1995). From the EV user's standpoint, Christian et al. (2012) found that the primary reason people decided to buy an EV originated from their desire to reduce fuel consumption, though they all were aware of the positive impacts of EVs on the environment. Likewise, Carley et al. (2013) found that customer perceptions toward EVs and awareness of electric charging station availability within communities had a significant impact on their decisions to instead purchase plug-in hybrid EVs.

In addition to personal perception, economic-related factors (*e.g.,* EV prices and fuel expenses) greatly influence users in their decision-making processes. Haugneland and Hauge (2015), for instance, found that over 59 % of their sample group decided to purchase EVs solely because of fuel expenses savings. This is in line with the study by Segal (1995), where customers largely considered the financial benefits and tended to switch to options that helped save fuel costs. Finally, Garanad (2019) found that EV users normally prioritized promotions and pricing in their decision-making processes over other factors, such as product features and distribution channels.

Besides personal perception and economic concerns, Adamson (2005) and Lane and Potter (2007) pointed out that the efficiency of EVs was also deemed critical in users' decision-making processes. In this regard, Carley et al. (2013) and Schmalfuß et al. (2017) found that one important aspect related to financial rewards for EV users was their acceptance of EV efficiency. To this end, the maximum driving range and charging time of EVs were revealed as significant factors — and thus obstacles — for customers to purchase EVs.

In sum, Table 2 and Table A2 in Appendix A present the eight factors and the 35 indicator questions related to decisions to purchase and use EVs, derived from the literature.

Table 2
Identified factors for decisions to purchase and use EVs.

Factors	Definition	Source(s)
Attributes and Performance	The overall features and performance of EVs, such as exterior design and interior aesthetics, vehicle size, driving performance, and driving range per single charge	Adamson (2005); Kang and Park (2011)
Financial	Savings from transitioning from fuel-powered vehicles to EVs, considering various financial aspects that customers need to deal with (*e.g.*, price of EVs, annual maintenance costs, electricity charging expenses, and even resale value)	Lane and Potter (2007); Mourato et al. (2004); Segal (1995)
Technology	The capabilities of EV technology in terms of use, such as EV type, driving technology, safety technology, maximum electric driving distance, and duration of charging the battery	Tangphet (2017)
Infrastructure Readiness	Basic issues that facilitate the use of EVs, such as the availability of electric charging stations and whether there are enough charging ports to meet customer demands, the readiness of skilled technicians for service, the ease of installing private electric charging equipment, and considerations regarding the privileges that EV users should receive	Sang and Bekhet (2015); Tangphet (2017); Tangtaku (2015); Wang and Zhou (2019)
Values	EV users' values, attitudes, and opinions toward the decision to use EVs in terms of concerns for the environment and the laws and policies from the government	Schulte et al. (2004); Viardot (2004)
Experience	Customers' prior experience in information perception and use of EVs — whether they understand the benefits, the risks, and how EVs work, and their experience using EVs and electric charging	Frewer et al. (2003); Schulte et al. (2004); Slovic et al. (2004)
Environment	EV users' opinions regarding their environmental concerns and the impact of using EVs on the environment, such as EVs being able to reduce pollution, decrease fuel consumption, and mitigate emissions of pollutants and greenhouse gasses	Tangphet (2017); Tangtaku (2015); Wang and Zhou (2019)
Promotion	Information from distributors that is sent to customers regarding information on various issues, such as product advertising and promotional activities	Garanad (2019)

Policies that affect user decisions to purchase and use EVs

Previous research (Wang et al., 2017; Hardman et al., 2017) shows that potential EV users generally have a number of concerns regarding EV price and the limited charging stations within/across communities. Financial incentive policies from the government are therefore necessary to convince such users to adopt EVs. Examples of such policies include financial incentives for purchase, exemption from luxury taxes, insurance discounts, and supports for better electric charging infrastructure (Wang et al., 2018). Indeed, Wang et al. (2017) revealed that better electric charging infrastructure could make it easier and more convenient for users to adopt EVs, as it could reduce anxiety and increase user acceptance of EVs at the same time.

In addition to these policies, Li et al. (2020) found that there were also other interesting forms of policies that positively affected users' decisions to purchase and use EVs. These policies included electric charging discounts, supports for private charging point installation, and driving-related policies that helped users save usage costs, such as exemption from toll fees, electric car parking discounts, and additional driving privileges (Aasness and Odeck, 2015; Wang et al., 2017; Li et al., 2020).

Table 3 and Table A3 in Appendix A summarize the five government incentive policies and the 15 indicator questions that could impact user decisions to purchase and use EVs derived from the literature.

Table 3
Identified factors for policies that affect decisions to purchase and use EVs.

Factors	Definition	Source(s)
Purchasing Incentive Policies	The government's interest in encouraging people to buy EVs in Thailand based on ideas that are helpful and worthwhile for customers to switch to EVs, such as tax exemptions on EV purchases, government subsidies for EV purchases, and insurance reductions for EVs	Bjerkan et al. (2016); Jin et al. (2014); Leurent & Windisch (2011); Mersky et al. (2016); Yang et al. (2016)
Charging Incentive Policies	The appeal of government policies to incentivize electric charging for personal charging and from public and private service stations, such as electric charging receipts being utilized for tax deductions, gaining a discount on electric charging, and procuring subsidies for building private electric chargers	
Driving Incentive Policies	The appeal of government measures that encourage the desire to drive EVs, such as rebates on EV parking, dedicated parking spots for EVs, and exemption for EVs from tolls	
Registering Incentive Policies	The appeal of government policies to provide incentives for various registration privileges, such as annual car tax exemption, EV-only license plates, and driving license fees discounts	
Other Incentive Policies	The appeal of government policies to incentivize the use of EVs by supporting basic amenities to facilitate EV adoption, such as increasing the number of electric charging stations, laws that guarantee longer battery life, and government subsidies for vehicle maintenance	

According to the reviewed literature, most existing research typically focuses on examining factors influencing EV adoption in one single dimension. This study, in contrast, makes new contributions by comprehensively investigating such factors in three different perspectives. Additionally, this study employs both factor analysis and DEMATEL approaches to analyze the collected data. Methodologically, it contributes knowledge on a new framework, including well-designed questions for raw data collection and generic models that can be tailored to identify, prioritize, and analyze the factors influencing EV adoption, as well as their interrelationship. More importantly, the results of this research allow policy makers to better promote wider EV adoption — not only in Thailand but also in other countries — in a more sustainable fashion.

Methodology

This research investigates factors that influence EV adoption in Thailand based on a blended framework of factor analysis and DEMATEL approaches, using surveys as a data collection tool. Fig. 1 illustrates the entire 10-step research process, starting from the extraction of influencing factors from the literature to the design of the data collection process and the data analysis using factor analysis and DEMATEL approaches. In accordance with our proposed framework, the results of this study would identify relevant factors, together with their importance and causal-effect relationships within three primary perspectives on Thai EV users: (*i*) acceptance of EV technology, (*ii*) decisions to purchase and use EVs, and (*iii*) supportive government policies that encourage user decisions to purchase and use EVs.

Extraction of influencing factors from the literature

According to the state-of-the-art literature, we categorize the factors influencing EV adoption into three perspectives, namely (*i*) acceptance of EV technology, (*ii*) decisions to purchase and use EVs, and (*iii*) supportive government policies that affect user decisions to purchase and use EVs. We extracted a set of 23 factors from the literature and then placed them in one of the three perspectives according to their relevance, which is summarized in Tables 1–3. In accordance with these 23 identified factors, the original questionnaire comprises 109 indicator questions. However, only 85 indicator questions remain after the validation phase (*i.e.*, some are removed due to redundancy and ambiguity), as reported in Appendix A.

Data collection

Population and samples

The population and samples used in this research can be divided into two groups, namely the general EV user group and the expert group, whose detailed information is provided below.

1. General EV user group: The users in this group are those who currently use or have experience in using any types EVs in Thailand, including hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and battery electric vehicle (BEVs). According to Yamane (1973), Eq. (1) shows the calculation of sample size (n), where N denotes the population size — or the number of registered EV users in Thailand — and e denotes the confidence level

$$n = \frac{N}{1 + Ne^2} \tag{1}$$

Given the number of registered EV users of 334,308 in 2022 (Transport Statistics Group, Department of Land Transport) and the confidence level of 90 %, the sample size of this group must be at least 100. In this study, we are able to collect information from 269 general EV users; the data from 218 of them are valid (according to the validity tests) and have been carried forward in further analysis using the factor

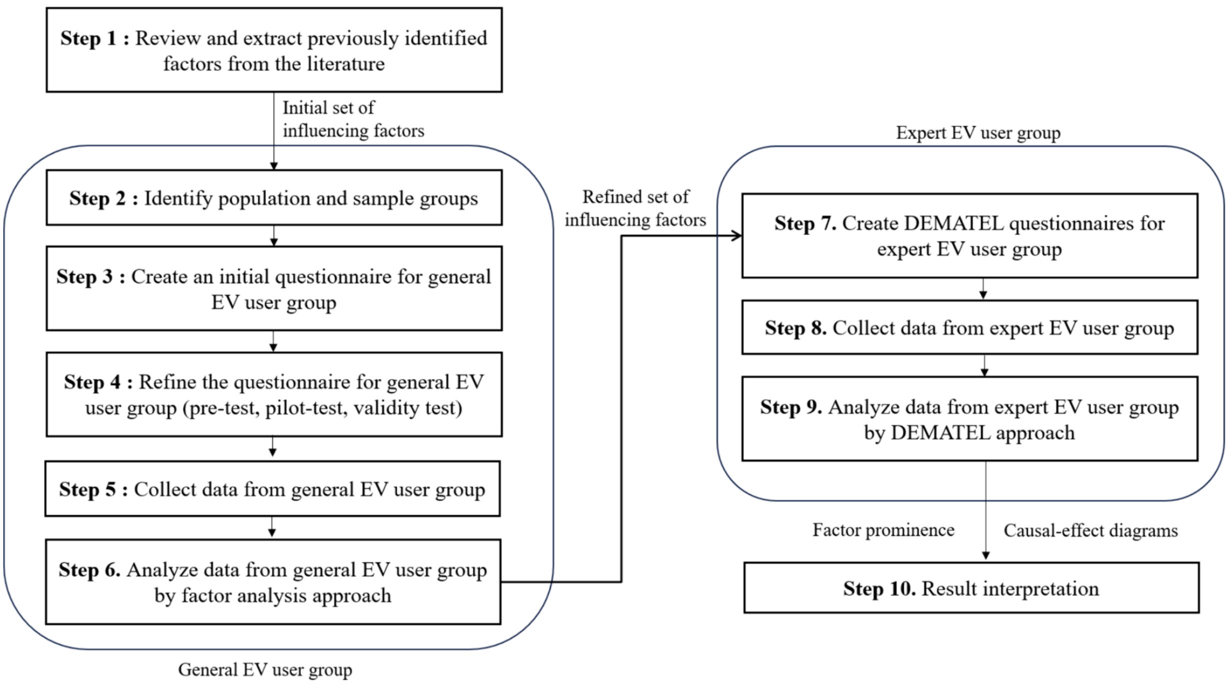

Fig. 1. Overall research procedure.

analysis approach.

2. Expert group: The members of this group are domain experts from academic institutions and EV users with rich experience. We select this group using a purposive sampling method, in which a total of 17 experts are chosen for this research study. For consistency, these 17 experts are selected according to the summarized characteristics and qualifications below

   Academic experts (11 individuals)

- Educational qualifications at the master's level or higher
- Possessing knowledge of EV technology, including a good understanding of EV systems
- Engaged in research related to EVs or EV technology
- Possessing knowledge related to the impacts of EVs on the environment
- Possessing knowledge of battery technology, including battery production and disposal
- Possessing knowledge of economics and marketing, enabling them to analyze EV growth

   Experienced EV users (six individuals)

- Educational qualifications at the bachelor's level or higher
- Having at least three years of experience using EVs (any types)
- Having good understanding of EV usage (*e.g.*, car reviewers or individuals with relevant work experience in EV-related industries)
- Having experience with charging EVs at charging stations (excluding HEVs)

Unlike the general EV user group, the members of the expert group would only conduct assessments of influencing factors within their areas of expertise, with different sets of questionnaires that require more detailed assessment items to be analyzed by the DEMATEL approach (*e.g.*, pairwise assessment). Accordingly, the number of assessments in each primary perspective may vary depending on the experts' areas. To this end, we are able to conduct 12, 16, and 14 assessments respectively for acceptance of EV technology, decisions to purchase and use EVs, and supportive government policies that affect user decisions to purchase and use EVs.

Data collection process

The data collection process in this research involves the collection of two different datasets — one from each sample group and each with different data-utilizing approaches. To be precise, we employ paper-based and online-based questionnaires to collect data regarding factors influencing the respondents' decisions to adopt EVs from the general EV user group. This dataset will be analyzed by the factor analysis framework in order to eliminate irrelevant factors and group highly correlated factors into the same group. On the other hand, more detailed DEMATEL questionnaires are developed and used to collect data from the expert group. These questionnaires are administered in a paper-based format to 11 academic experts and six seasoned EV users.

Validation of instruments

After creating the questionnaire for general EV users, a suitability test (pre-test) is first conducted to assess the questionnaire's ease of understanding and clarity by interviewing a sample group of 10 individuals. The results of this pre-test are, subsequently, utilized in the development of a more refined questionnaire that has been further assessed in a pilot test with another sample group of 30 individuals. To ensure that the questionnaire meets research objectives and covers all relevant criteria before its administration to the sample group, Cronbach's alpha analysis, along with the examination of the Index of Item Objective Congruence (IOC), is herein employed (Turner and Carlson, 2003; Hair, 2010).

Following this refinement process, the final version of the questionnaire administered to the general EV user group comprises a total of 107 questions: (*i*) screening and general information questions (22 questions) and (*ii*) influencing factor-related questions (85 indicator questions, as listed in Appendix A), measured by a five-point Likert scale (Likert, 1932).

Another set of questionnaires to be administered to the expert group (*i.e.*, the DEMATEL questionnaire), also comprises of two main sections, namely (*i*) screening and general information questions — with two question items in total — and (*ii*) influencing factor-related questions —measured by a five-point Likert scale. Yet, the number of questions in the latter section varies greatly across the primary perspectives, largely due to the differences in the numbers of indicator questions in the pairwise assessment. Specifically, there are 150, 196, and 56 questions respectively for the assessments of influencing factors concerning acceptance of EV technology, decisions to purchase and use EVs, and supportive government policies that affect user decisions to purchase and use EVs.

Data analysis

Factor analysis

Factor analysis is conducted to help group factors that have a strong correlation into the same subgroup while excluding factors with weak correlations from the analysis. We have adopted the Exploratory Factor Analysis (EFA) to analyze the data from the general EV user group — in which factor extraction is performed by the Principal Component Factor Analysis method, while axis rotation is conducted using the Varimax with Kaiser Normalization method (Kaiser, 1958). The components (*i.e.*, factor groups) with eigenvalues greater than 1.0 are considered, and the retained factor loading of factors in each component must be equal to or greater than 0.4.

Following the EFA, an initial set of factors and indicator questions is reformed (removed, combined, or created) into a new one based on their interrelationships. And, we use this resulting set of factors and indicator questions as a guideline in the development of the DEMATEL questionnaires administered to the expert group in the next step.

DEMATEL analysis

The Decision-Making Trial and Evaluation Laboratory (DEMATEL) approach is developed primarily to analyze complex decision-making problems, as well as decisions in environments with significant interrelationships (Sumrit, 2013). According to the literature (see, Chiu et al., 2006; Huang et al., 2007; Lin and Tzeng, 2009; Liou et al., 2007; Sumrit, 2013; Liang et al., 2022; Murugan and Marisamynathan, 2022; Konstantinou and Gkritza, 2023, for example), the DEMATEL approach is a promising tool for analyzing multi-criteria decision-making (MCDM) problems — mainly because of its effectiveness in examining cause-and-effect relationships, in addition to impact assessments among evaluated conditions in the decision-making process (Lin and Tzeng, 2009; Sumrit, 2013). Based on the success of DEMATEL in the previous literature (*e.g.*, Shi et al., 2024), the DEMATEL approach has been herein adopted for the analysis of expert group data through six steps, as summarized in Fig. 2.

Step 1: We aggregate scores from expert opinions and calculate the average direct relation represented by the *z*-matrix, whose size is *NxN* (*N* denotes total number of assessed items). Each of the *z*-matrix elements can be computed according to Eq. (2).

$$z_{ij} = \frac{1}{M}\sum_{k=1}^{M} x_{ij}{}^{k} \tag{2}$$

where

z_{ij} denotes the average value of the *z*-matrix when comparing the influence level between factor groups in row *i* and column *j*,
k denotes the sequence of experts participating in the assessment,
M denotes the total number of experts who assess the influence level of the factors, and
$x_{ij}{}^{k}$ represents the score that expert *k* assigns to the influence level between factor groups in row *i* and column *j*.

Step 2: We calculate the normalized initial direct relation represented by the *D*-matrix according to Eq. (3) and Eq. (4).

$$D = \lambda \times Z \tag{3}$$

$$\lambda = Min\left[\frac{1}{max1 \le i \le n\sum_{j=1}^{n}|Z_{ij}|}, \frac{1}{max1 \le i \le n\sum_{i=1}^{n}|Z_{ij}|}\right] \tag{4}$$

where

D denotes the matrix of scores representing the clarity of directional relationships in the initial relationships (*i.e.*, normalized initial direct relation matrix), and
λ denotes the matrix of regression coefficients.

Step 3: We calculate total relations represented by the *T*-matrix according to Eq. (5).

$$T = D(I - D^{-1}) \tag{5}$$

where *T* and *I* denote the total relation matrix and the identity matrix, respectively.

Step 4: We calculate the sum of rows and columns of the *T*-matrix according to Eq. (6) and Eq. (7).

$$r = [r_i]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} \tag{6}$$

$$c = [c_j]^{T}{}_{1\times n} = \left[\sum_{i=1}^{n} t_{ij}\right]^{T}{}_{1\times n} \tag{7}$$

where

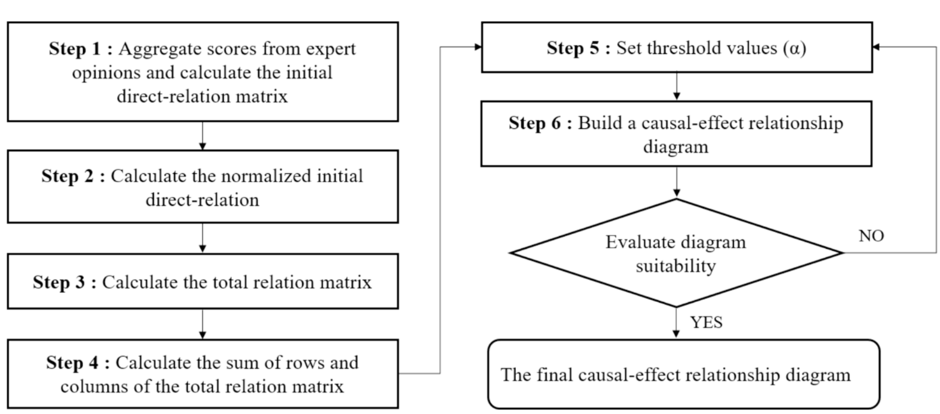

Fig. 2. A summary of the DEMATEL method.

r denotes the vector representing the sum of rows of T (*e.g.,* r_i is the sum of the i^{th} row of matrix T, indicating the effects that factor i has on other factors), and
c denotes the vector representing the sum of columns of T (*e.g.,* c_j is the sum of the j^{th} column of matrix T, indicating the total effects that all factors have on factor j).

According to the definition of r_i and c_j, the value of $(r_i + c_i)$ would represent the total effects given and received by factor i, while the value of $(r_i - c_i)$ indicates the net contribution by factor i on the system. If $(r_i - c_i)$ is positive, factor i may be regarded as a net cause; otherwise, factor i may be thought of as a receiver. Note that, to maintain the generality of DEMATEL use in this context, the terminology "factors" is kept and used to represent the influential factors of EV adoption.

Step 5: We set a threshold value (α to categorize the relationships between cause and effect factors, as well as to eliminate some of the minor effect elements in the T-matrix (Yang et al., 2008). This threshold value can be calculated from the average number of elements in the T-matrix, as outlined by Eq. (8).

$$\alpha = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N}[t_{ij}]}{N} \tag{8}$$

Step 6: We build causal-effect diagrams to prioritize and visualize the complex relationships between factors (Shieh et al., 2010) according to the values of $(r_i + c_i)$ and $(r_i - c_i)$. Note that, in each of these causal-effect diagrams, there are two axes. One axis represents the values of $(r_i + c_i)$, which is sometimes referred to as the factor prominence (*e.g.*, the significance of the factors). The other axis shows the values of $(r_i - c_i)$, representing the relation of the factors, which could be used to categorize whether a particular factor belongs to the cause group or the effect group. In this regard, a factor is classified as a component of the cause group if the value of $(r_i - c_i)$ is positive and as a component of the effect group if the value of $(r_i - c_i)$ is negative (Yang et al., 2008).

Results and discussion

From the collected 269 sets of questionnaires — 16 paper-based questionnaires and 253 online-based questionnaires — only 218 questionnaires meet the screening criteria and will be carried forward to the factor analysis. For the expert group, 12, 16, and 14 sets of questionnaires assessing the influencing factors in the three primary perspectives are successfully collected from 17 experts. The results of the data analyses for both sample groups are summarized in the following sections.

Descriptive statistics

General EV user group

From an initial analysis of data collected from 218 general EV users in Thailand, we can summarize the sample group's characteristics using descriptive statistics as shown in Table 4. According to Table 4, it has been revealed that the majority of EV users in Thailand are married females who live in Bangkok, aged 31 – 40 years, with bachelor's degrees as their highest educational qualification and a monthly income in the 20,001–40,000 THB range. The sample group's outlook with respect to the types of EVs shows that most respondents (50.5 %) adopt HEVs, followed by BEVs (35.5 %) and PHEVs (14.2 %). Furthermore, 67.4 % of the respondents are currently satisfied with their EV usage, and the HEV is the main EV type that they are willing to buy in the future (33.9 %).

Expert group

For the group of 11 academic experts, data are collected from nine university professors, one researcher, and one automotive industrial expert specializing in the marketing of EVs. Regarding the group of six expert users, data are collected from two EV reviewers and four specialist EV users. All of these experts have over four years of experience in the EV industry.

Table 4
Selected descriptive statistics for 218 general EV users in Thailand.

Information	Main Responses	N (sample)	Percentage (%)
Experience with EVs	Yes	218	100.0
Gender	Female	121	55.5
Age	31–40	156	71.6
Status	Married	157	72.0
Highest level of education	Bachelor's degree	189	86.7
Occupation	Private company employees	157	72.0
Monthly income range	20,001–40,000 THB	164	75.2
Province of residence	Bangkok	86	39.4
Province of work	Bangkok	91	41.7
Daily travel distance using EVs	26–50 km	118	53.7
Monthly EV usage days	More than 20 days	174	79.4
EV types used	Hybrid electric vehicle (HEV)	111	50.5
Duration of EV usage	1–2 years	77	34.9
Number of EVs owned	1 car	200	91.7
Experience with EV service center	Never	178	81.2
Usual charging spot	No electric charging, *i.e.*, hybrid vehicles	111	50.5
Satisfaction with past EV usage	Satisfied	147	67.4
Which type of EVs are you interested in buying in the future?	Hybrid electric vehicle (HEV)	74	33.9

Results of the factor analysis

According to the Kaiser–Meyer–Olkin (KMO) and Bartlett's tests for all three main factors, we find that the collected data are suitable for the factor analysis. This is based on the fact that all variables have significant interrelationships, with the KMO values greater than 0.7, as summarized by Table 5.

Acceptance of EV technology

In the analysis of factors concerning the acceptance of EV technology, we find that the initial 10 factors could be regrouped into eight factors, with a total of 29 indicator questions and 61.26 % of the explained variance (*i.e.*, the amount of variance in the collected data to which the underlying set of factors accounts for), as shown in Table 6.

Decisions to purchase and use EVs

Regarding the decisions to purchase and use EVs, we find that the initial eight factors could be regrouped into 12 factors, with a total of 33 indicator questions and 61.42 % of explained variance, as shown in Table 7.

Table 5
Results of the KMO and Bartlett's tests.

Main Factors	KMO	Approx. Chi-Square	df.	Sig.
Acceptance of EV technology	0.709	1727.783	595	< 0.001
Decisions to purchase and use EVs	0.747	1718.252	595	< 0.001
Policies that affect user decisions to purchase and use EVs	0.738	741.763	105	< 0.001

Table 6
Analysis of factors related to the acceptance of EV technology.

Factors	Indicator Questions	Factor Loading
Interpersonal Influence (explained variance: 22.472 %)	Accept 4. Do you have knowledge and understanding of EV innovations and technology?	0.779
	Accept 18. Do you think EVs are suitable for you (price, aesthetics, and technology)?	0.525
	Accept 5. You are willing to give advice on the use of EVs to others.	0.512
	Accept 19. Do you think EVs are compatible with urban driving in communities (sufficient charging and service centers, smooth road surfaces, and high maneuverability)?	0.465
	Accept 25. In this era, EVs are considered essential.	0.418
	Accept 14. The acceptable range of expenses for EV insurance is approximately 18,000 THB to 30,000 THB for standard personal liability coverage.	0.410
Personal Innovativeness and Compatibility (explained variance: 10.407 %)	Accept 16. Members of your family are mostly interested in using EVs.	0.787
	Accept 15. Your friend is mostly interested in using EVs.	0.653
	Accept 17. The person you contacted is mostly interested in using EVs.	0.612
	Accept 11. The EV price of more than 2,000,000 THB is acceptable to you.	0.533
	Accept 10. The price range of EVs of 1,000,000–2,000,000 THB is acceptable to you.	0.482
Price Acceptance and Values (explained variance: 8.372 %)	Accept 26. Overall, do you think using EVs would result in more benefits than drawbacks?	0.658
	Accept 32. Using an EV will make your life more convenient and comfortable.	0.642
	Accept 6. The increasing efficiency levels of EVs create more motivation for you to use EVs.	0.579
	Accept 7. You would use an EV if the maintenance costs are lower than those of a gasoline-powered car.	0.571
	Accept 12. The price range for changing the battery of an EV is acceptable to you.	0.459
Environmental Concerns (explained variance: 5.618 %)	Accept 23. You would use an EV if the EV is energy-efficient.	0.715
	Accept 22. You would use an EV to help reduce environmental problems.	0.567
	Accept 21. You would use an EV if it helps reduce air pollution or improves air quality.	0.523
	Accept 24. Do you have a positive attitude toward the use of EVs?	0.459
Subjective Norms (explained variance: 4.804 %)	Accept 34. People around you perceive using an EV as a positive thing.	0.737
	Accept 33. Having an EV in your possession contributes to a positive image of yourself in society.	0.735
Social Norms (explained variance: 3.379 %)	Accept 2. Your friend or coworker thinks you should use an EV.	0.736
	Accept 1. Members of your family think you should use an EV.	0.661
	Accept 3. The person you have been in touch with thinks that using an EV is a good idea.	0.542
Attitude Toward Using EVs (explained variance: 3.179 %)	Accept 30. Using an EV can enhance the quality of your daily life.	0.734
	Accept 29. EVs are suitable for your daily tasks.	0.445
Perceived Usefulness and Perceived Ease of Use (explained variance: 3.035 %)	Accept 13. The acceptable price for charging the battery of an EV is approximately 300–600 THB per full charge, which can cover a range of about 300–600 Km per charge cycle.	0.685
	Accept 35. The importance of choosing a vehicle that can attract attention from others matters to you.	0.562
Bartlett's Test of Sphericity		0.000
Kaiser–Meyer–Olkin Measure of Sampling Adequacy		0.709
Total Explained Variance		61.264 %

Policies that affect decisions to purchase and use EVs

Finally, in the analysis of factors concerning policies that affect user decisions to purchase and use EVs, we find that the original five factors could be regrouped into a total of four factors and 15 indicator questions, with a total explained variance of 55.412 %, as shown in Table 8.

After regrouping the factors using factor analysis, we can now construct a framework for the DEMATEL questionnaire, as shown in Fig. 3. For ease of referencing, we will refer to factors and indicator questions by the following variables.

- *A* represents the factors related to EV technological acceptance.
- *D* represents the factors related to decisions to purchase and use EVs.
- *P* represents the factors related to policies that affect user decisions to purchase and use EVs.
- *IA* represents the indicator questions of factors related to EV technological acceptance.
- *ID* represents the indicator questions of factors related to decisions to purchase and use EVs.
- *IP* represents the indicator questions of factors related to policies that affect user decisions to purchase and use EVs.

Results from the DEMATEL analysis and implications

The DEMATEL analysis of data from 17 experts is conducted based on the results of factor analysis, in which (*i*) eight factors (*A1–A8*) and 29 indicator questions (*IA1–IA29*) are assessed for the acceptance of EV technology, (*ii*) 12 factors (*D1–D12*) and 33 indicator questions (*ID1–ID33*) are assessed for the decisions to purchase and use EVs, and (*iii*) four factors (*P1–P4*) and 15 indicator questions (*IP1–IP15*) are assessed for the policies that affect user decisions to purchase and use EVs.

Acceptance of EV technology

Regarding the analysis of EV technological acceptance, 12 assessments are assembled from eight academic experts and four seasoned EV users. The results of vector calculations, by rows and columns of total relation matrix (*T*), are summarized by Table B1 in Appendix B and Tables 9–10.

Table 7
Analysis of factors related to the decisions to purchase and use EVs.

Factors	Indicator Questions	Factor Loading
Environment (explained variance: 16.741 %)	Decide 24. Have you heard about the benefits of EVs?	0.770
	Decide 23. Government participation in environmentally friendly incentive policies has a positive impact on society.	0.601
	Decide 29. EVs can reduce noise pollution from the engine, as they tend to operate more quietly than conventional vehicles.	0.501
	Decide 27. EVs can operate without or reduce the amount of traditional fuel used for driving.	0.487
Infrastructure Readiness and Technology (explained variance: 5.665 %)	Decide 17. Number of electric charging stations covering all areas.	0.767
	Decide 3. Safety features.	0.630
	Decide15. Charging time for the battery.	0.612
Financial and Driving Performance (explained variance: 5.257 %)	Decide 8. Price of the EV.	0.753
	Decide 7. Good driving capabilities.	0.642
	Decide 9. Annual maintenance costs.	0.604
Facilities and After-Sales Service (explained variance: 4.507 %)	Decide 18. Special parking or traffic lanes for EV users.	0.752
	Decide 35. The EV dealership engages in buying and selling used EVs.	0.670
Product (explained variance: 4.269 %)	Decide 12. The resale value of used EVs.	0.723
	Decide 11. Cost of EV parts and maintenance.	0.593
	Decide 13. Performance and reliability of the EV and battery brand.	0.483
	Decide 6. Adequate driving range on a single charge.	0.481
Service and Attributes (explained variance: 4.114 %)	Decide 32. The EV dealership employs knowledgeable and experienced sales staff to provide services.	0.757
	Decide 5. Attractive exterior and interior design.	0.474
Values (explained variance: 4.058 %)	Decide 22. Regulations and laws regarding environmental issues in the automotive industry have positive impacts on society.	0.790
	Decide 28. EVs can contribute to a decrease in emissions of pollutants and greenhouse gases.	0.611
	Decide 21. EVs are environmentally friendly and have a lower impact on natural resources and environmental energy compared to traditional fuel-powered vehicles.	0.513
Features and Performance of Evs (explained variance: 3.858 %)	Decide 1. Comfortable driving experience.	0.794
	Decide 2. High-quality overall performance.	0.723
	Decide 14. Maximum driving range on electric power.	0.415
Experience (explained variance: 3.669 %)	Decide 26. Have you studied or learned about the mechanics of EVs?	0.810
	Decide 25. Have you heard about the risks or challenges associated with EVs?	0.618
Advertising (explained variance: 3.367 %)	Decide 30. The EV dealership advertises and promotes its products through various media channels.	0.746
	Decide 31. An EV dealership conducts test drives.	0.456
	Decide 19. Residential accommodations that facilitate electric charger installation.	0.417
Acceptance (explained variance: 3.018 %)	Decide 10. Charging expenses.	0.592
	Decide 16. Safety technology of the EVs.	0.437
Promotion of EVs (explained variance: 2.897 %)	Decide 34. The EV dealership collaborates with presenters, influencers, ambassadors, and bloggers to promote its products.	0.766
	Decide 33. The EV dealership offers promotions, such as special discounts, exclusive financing conditions for EV loans, and complimentary installation of electric chargers as part of their promotional activities.	0.654
Bartlett's Test of Sphericity		0.000
Kaiser–Meyer–Olkin Measure of Sampling Adequacy		0.747
Total Explained Variance		61.418 %

From Table 9, the factors with the highest values of $(r_i + c_j)$ are considered the most important factors; and, based on such values, Attitude Toward Using EVs (*A3*), Subjective Norms (*A2*), and Personal Innovativeness and Compatibility (*A1*) are regarded as the most influential factors within this perspective. This result is in line with the studies by Lai et al. (2015), Panson (2018), and Asadi et al. (2022), where attitude toward using EVs and financial-related factors significantly affected user acceptance of EV technology.

Regarding the causal-effect relationships of factors within the acceptance of EV technology perspective (see Table 10), Attitude Toward Using EVs (*A3*) could be categorized as an effect factor, while Subjective Norms (*A2*) and Personal Innovativeness and Compatibility (*A1*) are classified as causes, whose detailed relationships could be illustrated by Fig. 4.

From Fig. 4, it is evident that Subjective Norms (*A2*) is the factor that has the most significant impact on other factors within this perspective, followed by Attitude Toward Using EVs (*A3*) and Interpersonal Influence (*A6*). Accordingly, it is imperative to prioritize Subjective Norms (*A2*) over other factors in the development of user acceptance — this could be further investigated by analyzing the indicator questions and their respective importance scores under the DEMATEL framework.

Subjective Norms (*A2*)

Similar to the analysis of the factors, the indicator questions with the highest values of $(r_i + c_j)$ are considered the most important indicators that contribute to the importance of such factors. For Subjective Norms (*A2*), the indicator questions that hold the highest levels of importance are *IA11* (The price of EVs of 1,000,000–2,000,000 THB is acceptable to

Table 8
Analysis of factors related to policies that affect user decisions to purchase and use EVs.

Factors	Indicator Questions	Factor Loading
Driving Incentive Policies (explained variance: 23.427 %)	Policy 8. Special parking spaces exclusively for EVs.	0.835
	Policy 9. Exemptions from toll fees for EVs on expressways.	0.732
	Policy 7. Discounts on parking fees for electric vehicles.	0.696
	Policy 15. Government incentives for vehicle maintenance and repairs.	0.594
	Policy 10. Exemptions or reductions in annual vehicle tax and property tax.	0.548
Charging Incentive Policies (explained variance: 14.702 %)	Policy 5. Financial incentives for the installation of private electric charging stations.	0.800
	Policy 4. The ability to use electric charging receipts for tax deductions.	0.705
	Policy 6. Discounts or subsidies for electric charging costs.	0.654
	Policy 13. Expansion of the number of electric charging stations.	0.480
Registering Incentive Policies (explained variance: 8.912 %)	Policy 12. Exemptions from driver's license fees for EV users.	0.803
	Policy 11. Special license plates for EVs.	0.74
	Policy 14. Expansion of the number of electric charging stations.	0.554
Purchasing Incentive Policies (explained variance: 8.371 %)	Policy 2. Tax exemptions for the purchase of EVs.	0.844
	Policy 1. Government financial incentives for purchasing EVs.	0.737
	Policy 3. Discounts on car insurance for EVs.	0.530
Bartlett's Test of Sphericity		0.000
Kaiser–Meyer–Olkin Measure of Sampling Adequacy		0.738
Total Explained Variance		55.412 %

Table 9
Ranking of factors within the EV technological acceptance perspective.

Ranking	$(r_i + c_j)$	Factors
1	15.5741	Attitude Toward Using EVs (A3)
2	15.2584	Subjective Norms (A2)
3	14.5288	Personal Innovativeness and Compatibility (A1)
4	14.3577	Perceived Usefulness and Perceived Ease of Use (A7)
5	13.7565	Price Acceptance and Values (A8)
6	13.5882	Interpersonal Influence (A6)
7	12.9831	Social Norms (A5)
8	12.6332	Environmental Concerns (A4)

Table 10
Causal-effect relationships of factors within the EV technological acceptance perspective.

Relation	$(r_i - c_j)$	Factors
Cause	0.5442	Interpersonal Influence (A6)
Cause	0.1795	Personal Innovativeness and Compatibility (A1)
Cause	0.1511	Social Norms (A5)
Cause	0.1463	Subjective Norms (A2)
Effect	−0.1089	Perceived Usefulness and Perceived Ease of Use (A7)
Effect	−0.2686	Environmental Concerns (A4)
Effect	−0.3041	Price Acceptance and Values (A8)
Effect	−0.3395	Attitude Toward Using EVs (A3)

you), *IA7* (Most members of your family are interested in using EVs), and *IA8* (The majority of your friends are interested in using EVs). Furthermore, the causal-effect relationships, as shown in Fig. 5, indicate that *IA11* and *IA7* are cause indicators, while *IA8* could be regarded as an effect indicator. To this end, the EV industry should accordingly pay attention to Subjective Norms (*A2*) by ensuring that the EVs are reasonably priced according to their performance and features.

Attitude Toward Using EVs (*A3*)

The indicator questions that hold the highest levels of importance in terms of Attitude Toward Using EVs (*A3*) are *IA12* (Overall, do you think using EVs would result in more benefits than drawbacks?), *IA14* (The increasing efficiency levels of EVs create more motivation for you to use EVs), and *IA13* (Using an EV will make your life more convenient and comfortable). The results of the causal-effect relationships, as illustrated in Fig. 6, further indicate that *IA12* and *IA13* are cause indicators, while

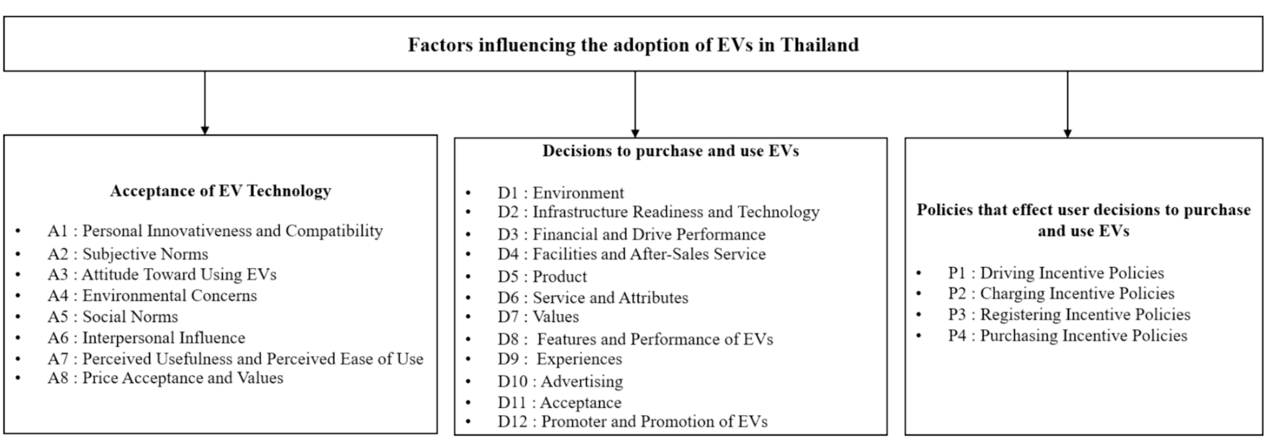

Fig. 3. A resulting framework for identifying factors influencing the use of EVs in Thailand after applying the factor analysis approach.

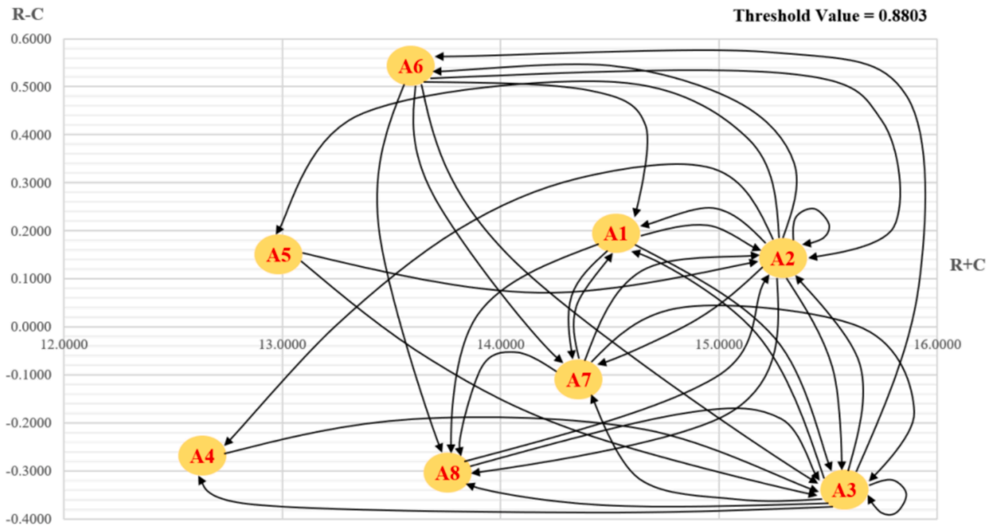

Fig. 4. The causal-effect relationships and impacts of factors influencing the acceptance of EV technology.

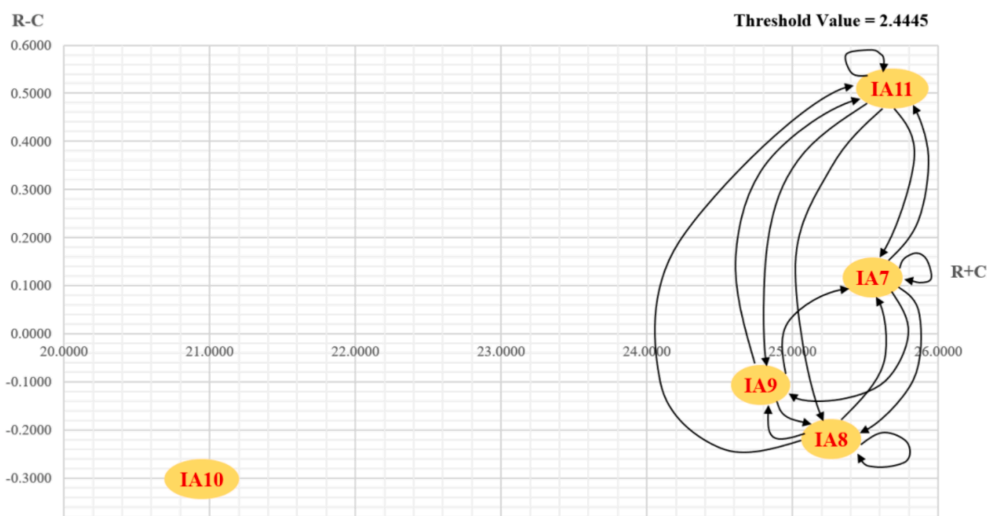

Fig. 5. The causal-effect relationships and impacts of indicator questions influencing Subjective Norms (A2).

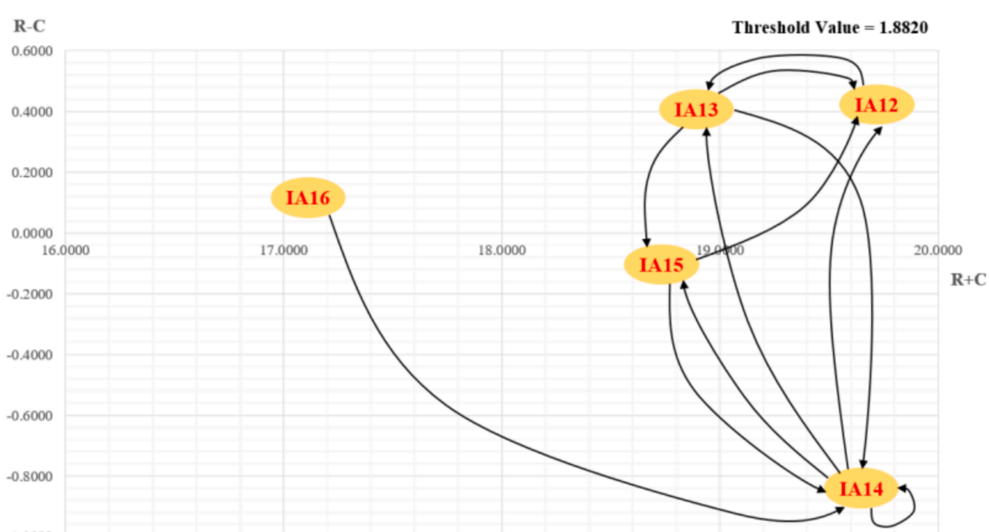

Fig. 6. The causal-effect relationships and impacts of indicator questions influencing Attitude Toward Using EVs (A3).

Table 11
Ranking factors within the domain of decisions to purchase and use EVs.

Ranking	$(r_i + c_j)$	Factor
1	20.7798	Product (D5)
2	20.2152	Service and Attributes (D6)
3	19.8596	Features and Performance of EVs (D8)
4	19.6914	Acceptance (D11)
5	19.6116	Experience (D9)
6	19.4314	Infrastructure Readiness and Technology (D2)
7	19.3282	Financial and Drive Performance (D3)
8	19.3065	Facilities and After-Sales Service (D4)
9	19.1460	Promoter and Promotion of EVs (D12)
10	18.9940	Advertising (D10)
11	17.9765	Values (D7)
12	17.1656	Environment (D1)

Table 12
Causal-effect relationships of factors within the domain of decisions to purchase and use EVs.

Relation	$(r_i - c_j)$	Factor
Cause	0.5300	Financial and Drive Performance (D3)
Cause	0.2634	Promoter and Promotion of EVs (D12)
Cause	0.1584	Facilities and After-Sales Service (D4)
Cause	0.1005	Values (D7)
Cause	0.0970	Infrastructure Readiness and Technology (D2)
Cause	0.0129	Experience (D9)
Effect	−0.0247	Features and Performance of EVs (D8)
Effect	−0.0386	Advertising (D10)
Effect	−0.1097	Acceptance (D11)
Effect	−0.1622	Service and Attributes (D6)
Effect	−0.3857	Product (D5)
Effect	−0.4413	Environment (D1)

IA14 is an effect indicator. This finding suggests that it is essential to raise user awareness by providing more accurate information about EVs — especially that related to financial and environmental aspects — to potential EV users in Thailand.

Decisions to purchase and use EVs

In the analysis of factors related to decisions to purchase and use EVs, 16 assessments are collected from 10 academic experts and six seasoned EV users. The results of vector calculations, by rows and columns of total relation matrix (*T*), are summarized by Table B2 in Appendix B and Tables 11–12.

From Table 11, the factors that hold the highest levels of importance within this perspective are Product (*D5*), Service and Attributes (*D6*), and Features and Performance of EVs (*D8*). The causal-effect relationships of factors related to decisions to purchase and use EVs, as presented in Table 12 and Fig. 7, indicate that *D5*, *D6*, and *D8* are all effect factors, whereas Financial and Drive Performance (*D3*) and Promoter and Promotion of EVs (D12) stand out as cause indicators.

This finding aligns well with the results of several studies in the literature, where factors related to the characteristics and performance of EVs — with an emphasis on safety, driving range per charge, and battery capacity (Kuo et al., 2022; Kuntawong et al., 2022) — as well as those related to marketing promotion (Kang and Park, 2011; Garanad, 2019) could effectively motivate new users to adopt EVs with greater confidence.

Product (*D5*)

Regarding Product (*D5*), the indicator questions that hold the highest levels of importance are *ID15* (Performance and reliability of electric vehicle brands and batteries), followed by *ID13* (Resale price of used EVs) and *ID14* (Cost of EV parts and maintenance) — in which *ID14* is a cause indicator, while *ID13* and *ID15* are effect indicators. It is also evident, from Fig. 8, that *ID15* is the indicator that has the most significant impact on other indicators within this factor group (*D5*). Therefore, in the development of EV products, it is crucial to prioritize the performance and reliability of EVs, along with that of batteries, as it is the most influential indicator that could impact user decisions to purchase and use EVs.

Service and Attributes (*D6*)

The indicator questions that hold the highest levels of importance in terms of Service and Attributes (*D6*) are *ID17* (The EV dealership has knowledgeable and experienced sales staff) and *ID18* (Beautiful exterior design and interior decoration). The results of the causal-effect relationships, as shown in Fig. 9, further reveal that *ID17* is a cause indicator, while *ID18* is an effect indicator. This finding suggests that it is crucial to provide sales staff with sufficient EV knowledge, as this is identified as the most influential indicator in this regard.

Policies that affect user decisions to purchase and use EVs

In the analysis of factors related to policies that affect user decisions to purchase and use EVs, 14 assessments are collected from 11 academic experts and three seasoned EV users. The results of vector calculations, by rows and columns of total relation matrix (*T*), are summarized by Table B3 in Appendix B and Tables 13–14.

According to Tables 13 and 14, the factors that hold the highest levels of importance in terms of policies are Purchasing Incentive Policies (*P4*), Driving Incentive Policies (*P1*), and Charging Incentive Policies (*P2*) — in which Purchasing Incentive Policies (*P4*) is an effect factor, while Driving Incentive Policies (*P1*) and Charging Incentive Policies (*P2*) are causes. Fig. 10 depicts the causal-effect relationships of the factors in this perspective. It reveals that, among all the factors, Purchasing Incentive Policies (*P4*) has the highest significant impact. This finding suggests that it is crucial to prioritize purchasing incentive

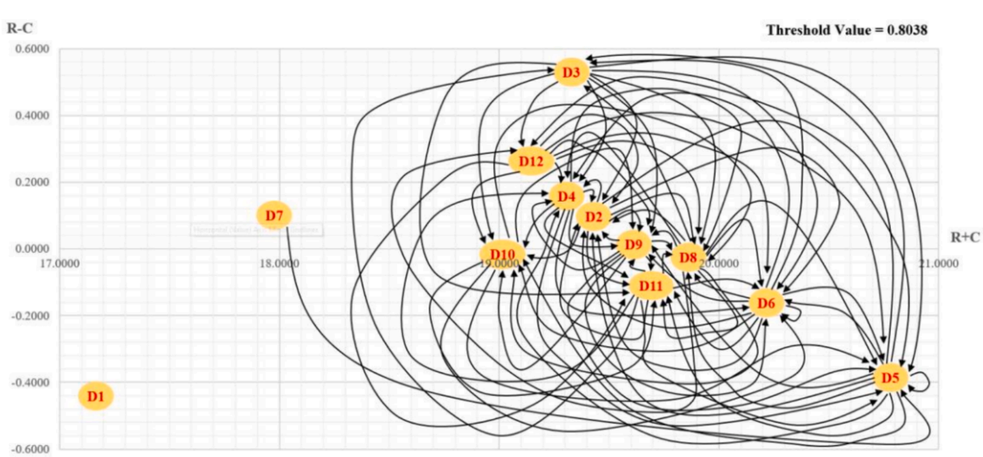

Fig. 7. The causal-effect relationships and impacts of factors influencing decisions to purchase and use EVs.

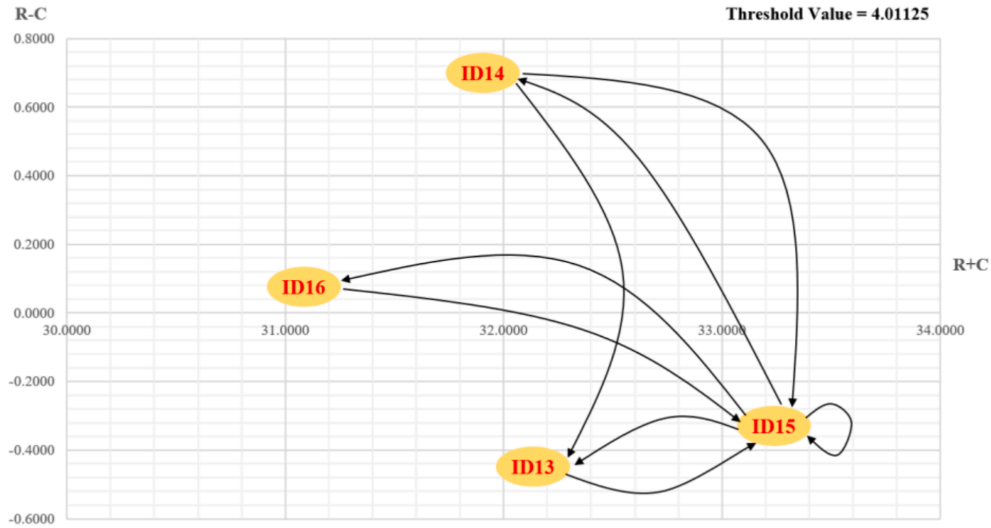

Fig. 8. The causal-effect relationships and impacts of indicator questions influencing Product (D5).

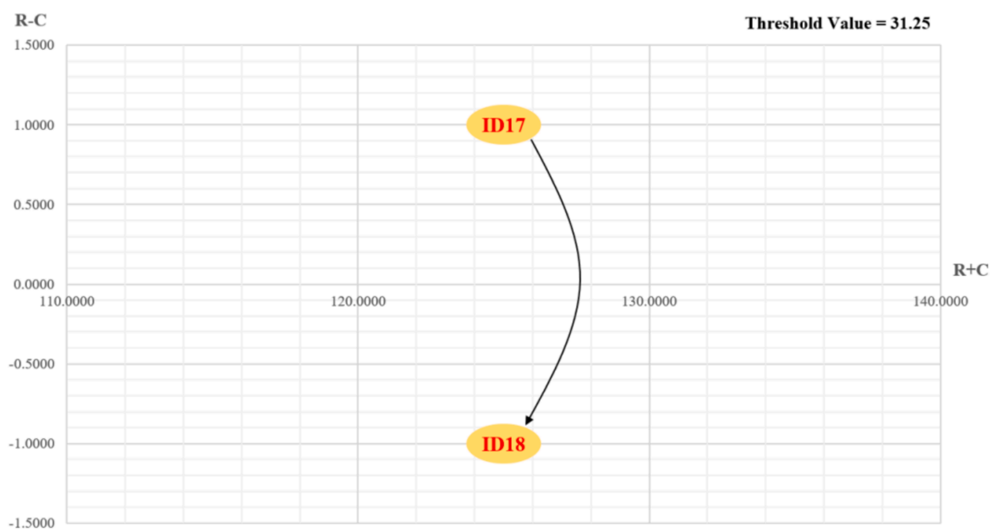

Fig. 9. The causal-effect relationships and impacts of indicator questions influencing Service and Attributes (D6).

Table 13
Ranking of the factors related to policies that affect user decisions to purchase and use EVs.

Ranking	$(r_i + c_j)$	Factor
1	20.5929	Purchasing Incentive Policies (P4)
2	19.5988	Driving Incentive Policies (P1)
3	18.9124	Charging Incentive Policies (P2)
4	17.8736	Registering Incentive Policies (P3)

Table 14
Causal-effect relationships of factors related to policies that affect user decisions to purchase and use EVs.

Relation	$(r_i - c_j)$	Factor
Cause	0.3294	Charging Incentive Policies (P2)
Cause	0.2868	Driving Incentive Policies (P1)
Effect	−0.1661	Purchasing Incentive Policies (P4)
Effect	−0.4501	Registering Incentive Policies (P3)

policies of various forms so that more potential users can be convinced to purchase and use EVs.

Regarding the indicator questions, we find that *IP14* (Government incentives for EV purchases), *IP13* (EV purchase tax exemption), and *IP15* (EV insurance discount) hold the highest levels of importance — in which *IP13* and *IP14* are cause indicators, while *IP15* is an effect indicator. Fig. 11 depicting the causal-effect relationships of indicators influencing Purchasing Incentive Policies (*P4*) indicates the importance of *IP14* as the most significant indicator. This implies that government incentives for EV purchases is one of the most critical instruments in the development of purchasing incentive policies that effectively stimulate users to purchase and use EVs in Thailand. This is in line with the results of other research, including Kang and Park (2011), Kuo et al. (2022), Lai et al. (2015), Zhang et al. (2011), and Kuntawong et al. (2022), demonstrating that government assistance — such as financial subsidies or tax reductions — could effectively incentivize users to purchase and drive EVs.

Conclusions

EVs are a considerably new technology in emerging markets like Thailand. In order to implement a smooth transition from conventional

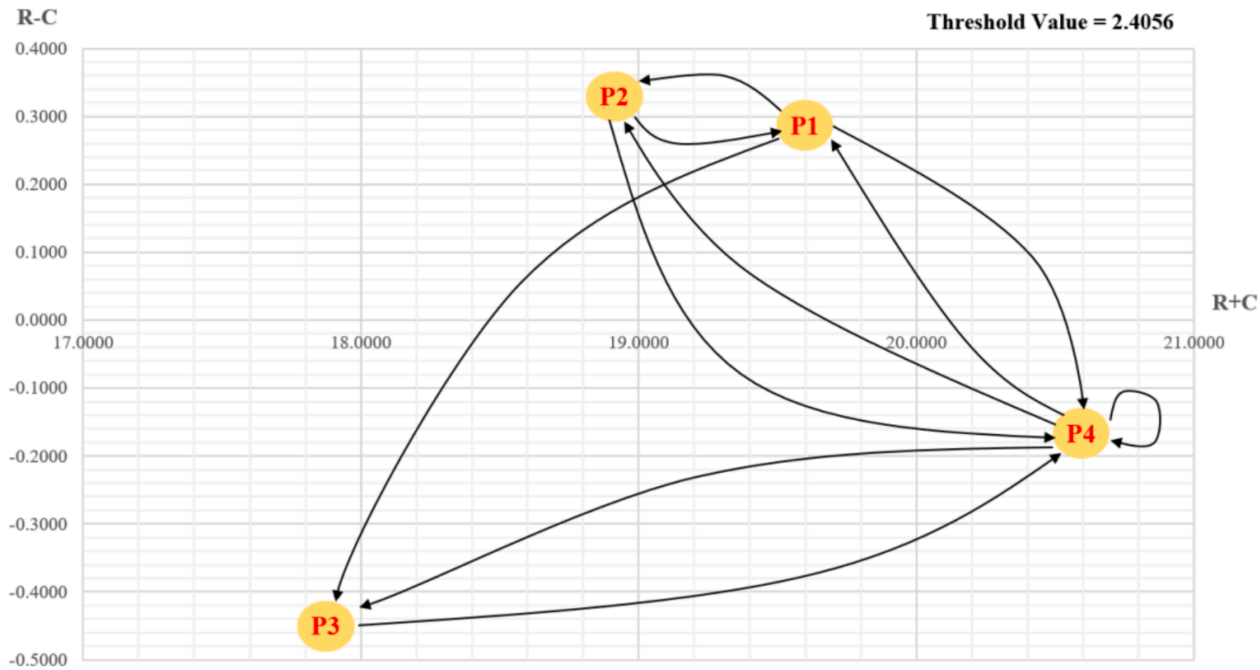

Fig. 10. The causal-effect relationships and impacts of factors influencing the policies that affect user decisions to purchase and use EVs.

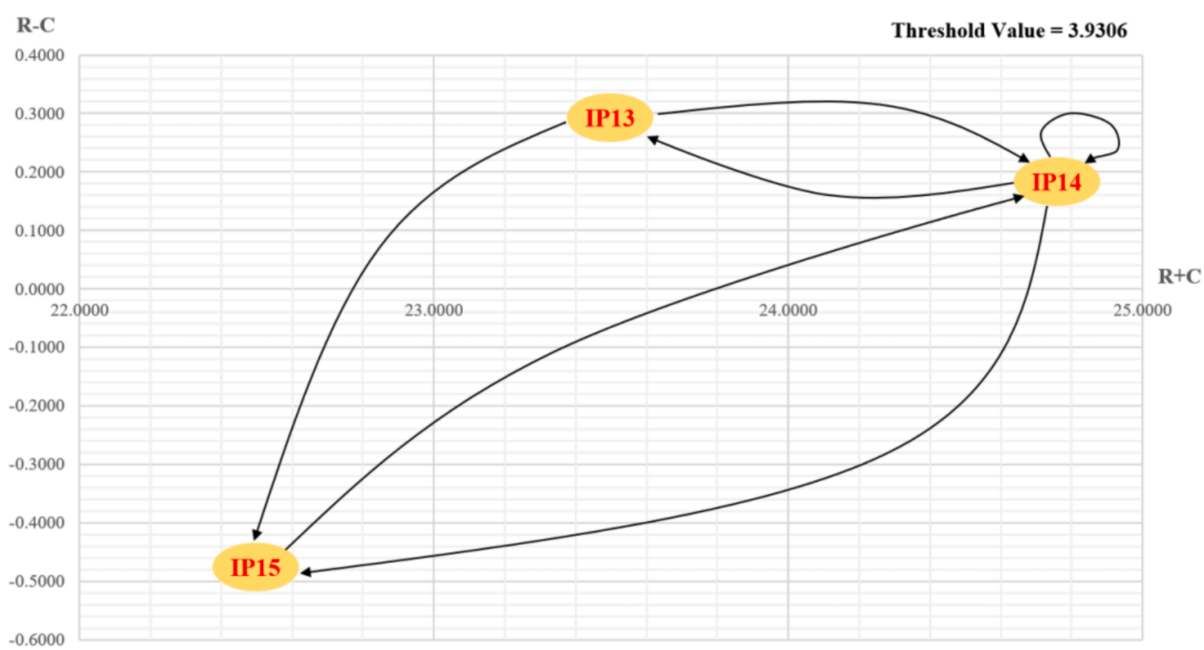

Fig. 11. The causal-effect relationships and impacts of indicator questions influencing Purchasing Incentive Policies (*P4*).

combustion vehicles to EVs — with an overall goal to achieve a net-zero society by 2050 — the Thai government needs to comprehend not only the factors influencing the acceptance of EV technology but also those affecting decisions to purchase and use EVs within the country. This research reveals such factors in a systematic fashion by thoroughly investigating factors in three different perspectives — namely, (*i*) acceptance of EV technology, (*ii*) decisions to purchase and use EVs, and (*iii*) policies that affect user decisions to purchase and use EVs — with two different data-utilizing approaches. Specifically, the factor analysis approach is first applied to the dataset of general EV users in order to group factors with high correlations together, while eliminating factors with weak dominance. Then, the DEMATEL approach is applied to the dataset of the expert group in order to identify prominent factors with greater impacts — and thus their causal-effect relationships. This information, in turn, allows us to prioritize factors and make informed decisions more efficiently than before regarding EV development and policy improvements, including taxation, subsidies, privileges, infrastructure development to support EV usage, and sales strategies to meet customer demands.

In terms of EV technological acceptance, Attitude Toward Using EVs (*A3*) is regarded as the most important factor, along with indicators *IA12* (Overall, do you think using EVs would result in more benefits than drawbacks?) and *IA14* (The increasing efficiency levels of EVs create more motivation for you to use EVs). These findings show that it is essential to prioritize customer attitudes toward EV usage in order to increase public acceptance of EV technology within the country. This could be achieved by raising user awareness and providing more accurate information about EVs to potential users, especially information related to the financial and environmental aspects.

In addition to Attitude Toward Using EVs (*A3*), Subjective Norms (*A2*) are crucial to the acceptance of EV technology. Indeed, this factor is considered the most influential and pivotal in impacting other factors. Based on this finding, the EV industry should accordingly ensure that the EVs are reasonably priced according to their performance and features.

Regarding decisions to purchase and use EVs, Product (*D5*) and Service and Attributes (*D6*) are important, along with the indicators *ID15* (Performance and reliability of electric vehicle brands and batteries) and *ID17* (The EV dealership has knowledgeable and experienced sales staff). As such, to better promote decisions to purchase and use EVs in Thailand, emphasis should be placed on product and service aspects. This could be achieved by offering highly efficient EVs with aesthetic appeal that fit customers' expected price ranges. In addition to these considerations, the EV brand's image is also crucial for instilling confidence in user decisions to buy and use EVs.

Finally, Purchasing Incentive Policies (*P4*), together with the indicators *IP14* (Government incentives for EV purchases) and *IP13* (EV purchase tax exemption), are the most prominent factors and indicators revealed by the DEMATEL approach. This finding stresses the need for supportive government policies to stimulate potential users to purchase and use EVs. Examples of these policies include subsidies for first-time EV buyers and tax incentives for EVs.

While this study comprehensively covers a wide range of factors capable of influencing the adoption of EVs in Thailand, new unidentified factors may potentially arise due to the dynamics of the EV industry (*e.g.*, changes in EV technology, evolving lifestyles, and new regulations or incentive policies implemented by government and private sectors to further stimulate customer adoption decisions). As such, it is advisable to refine the measurement questions in future studies to cover such aspects so that they remain comprehensively up to date. Clearly, with a more relevant set of questions, more informative results would be expected — but no modification of the framework is needed. Considering the detailed insights that our proposed framework offers — *i.e.*, the dominant factors and their respective causal-effect relationships — our study would serve as a stepping stone for the development of informed decisions that help enhance the public use of EVs in the long run, not only for an emerging country like Thailand but also for other countries.

CRediT authorship contribution statement

Thadathibesra Phuthong: Writing – original draft, Validation, Methodology, Investigation, Formal analysis. **Tanarat Borisuth:** Writing – original draft, Methodology, Investigation, Formal analysis. **Zaili Yang:** Writing – review & editing, Validation, Formal analysis. **Pisit Jarumaneeroj:** Writing – review & editing, Validation, Supervision, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A

Tables A1–A3 show all identified factors and indicator questions of EV Technology acceptance, decisions to purchase and use EVs, and policies influencing decisions to purchase and use EVs, from the literature.

Table A1
Identified factors and indicator questions for EV technology acceptance from the literature.

Factors	Indicator Questions
Interpersonal Influence	Accept 1. Members of your family think you should use an EV. Accept 2. Your friend or coworker thinks you should use an EV. Accept 3. The person you have been in touch with thinks that using an EV is a good idea.
Personal Innovativeness	Accept 4. Do you have knowledge and understanding of EV innovations and technology? Accept 5. You are willing to give advice on the use of EVs to others. Accept 6. The increasing efficiency levels of EVs create more motivation for you to use EVs.
Price Acceptance	Accept 7. You would use an EV if the maintenance costs are lower than those of a gasoline-powered car. Accept 8. You would use an EV if the price of electricity for charging is lower than the price of fuel for a gasoline-powered car. Accept 9. The price range of EVs of 500,000–1,000,000 THB is acceptable to you. Accept 10. The price range of EVs of 1,000,000–2,000,000 THB is acceptable to you. Accept 11. The EV price of more than 2,000,000 THB is acceptable to you. Accept 12. The price range for changing the battery of an EV is acceptable to you. Accept 13. The acceptable price for charging the battery of an EV is approximately 300–600 THB per full charge, which can cover a range of about 300–600 Km per charge cycle. Accept 14. The acceptable range of expenses for EV insurance is approximately 18,000 THB to 30,000 THB for standard personal liability coverage.
Subjective Norms	Accept 15. Your friend is mostly interested in using EVs. Accept 16. Members of your family are mostly interested in using EVs. Accept 17. The person you contact is mostly interested in using EVs.
Compatibility	Accept 18. Do you think EVs are suitable for you (price, aesthetics, and technology)? Accept 19. Do you think EVs are compatible with urban driving in communities? (sufficient charging and service centers, smooth road surfaces, high maneuverability). Accept 20. Do you think EVs align well with your lifestyle? (comfortable lifestyle use, ease of learning, and convenient charging).

(*continued on next page*)

Table A1 (*continued*)

Factors	Indicator Questions
Compatibility	Accept 21. You would use an EV if it helps reduce air pollution or improves air quality. Accept 22. You would use an EV to help reduce environmental problems. Accept 23. You would use an EV if the EV is energy-efficient. Accept 24. Do you have a positive attitude toward the use of EVs?
Environmental Concerns	Accept 21. You would use an EV if it helps reduce air pollution or improves air quality. Accept 22. You would use an EV to help reduce environmental problems. Accept 23. You would use an EV if the EV is energy-efficient.
Attitude Toward Using	Accept 24. Do you have a positive attitude toward the use of EVs? Accept 25. In this era, EVs are considered essential. Accept 26. Overall, do you think using EVs would result in more benefits than drawbacks?
Perceived Ease of Use	Accept 27. You can easily and quickly learn how to use an EV. Accept 28. Allocating time for charging can be done and is appropriate for your schedule (6–8 h for regular charging or 30–40 min for fast charging). Accept 29. EVs are suitable for your daily tasks.
Perceived Usefulness	Accept 30. Using an EV can enhance the quality of your daily life. Accept 31. Using an EV can help reduce monthly expenses. Accept 32. Using an EV will make your life more convenient and comfortable. Accept 33. Having an EV in your possession contributes to a positive image of yourself in society. Accept 34. People around you perceive using an EV as a positive thing. Accept 35. The importance of choosing a vehicle that can attract attention from others matters to you.

Table A2
Identified factors and indicator questions for decisions to purchase and use EVs from the literature.

Factors	Indicator Questions
Attributes and Performance	Decide 1. Comfortable driving experience. Decide 2. High-quality overall performance. Decide 3. Safety features. Decide 4. Appropriate size. Decide 5. Attractive exterior and interior design. Decide 6. Adequate driving range on a single charge. Decide 7. Good driving capabilities.
Financial	Decide 8. Price of the EV. Decide 9. Annual maintenance costs. Decide 10. Charging expenses. Decide 11. Cost of EV parts and maintenance. Decide 12. The resale value of used EVs.
Technology	Decide 13. Performance and reliability of the EV and battery brand. Decide 14. Maximum driving range on electric power. Decide 15. Charging time for the battery. Decide 16. Safety technology of the EVs.
Infrastructure Readiness	Decide 17. Number of electric charging stations covering all areas. Decide 18. Special parking or traffic lanes for EV users. Decide 19. Residential accommodations that facilitate electric charger installation. Decide 20. Availability of skilled technicians and service centers at various distances.
Values	Decide 21. EVs are environmentally friendly and have a lower impact on natural resources and environmental energy compared to traditional fuel-powered vehicles. Decide 22. Regulations and laws regarding environmental issues in the automotive industry have positive impacts on society. Decide 23. Government participation in environmentally friendly incentive policies has a positive impact on society.
Experience	Decide 24. Have you heard about the benefits of EVs? Decide25. Have you heard about the risks or challenges associated with EVs? Decide 26. Have you studied or learned about the mechanics of EVs?
Environment	Decide 27. EVs can operate without or reduce the amount of traditional fuel used for driving Decide 28. EVs can contribute to a decrease in emissions of pollutants and greenhouse gases. Decide 29. EVs can reduce noise pollution from the engine, as they tend to operate more quietly than conventional vehicles.

(*continued on next page*)

Table A2 (*continued*)

Factors	Indicator Questions
Promotion	Decide 30. The EV dealership advertises and promotes its products through various media channels. Decide 31. An EV dealership conducts test drives. Decide 32. The EV dealership employs knowledgeable and experienced sales staff to provide services. Decide 33. The EV dealership offers promotions, such as special discounts, exclusive financing conditions for EV loans, and complimentary installation of electric chargers as part of their promotional activities. Decide 34. The EV dealership collaborates with presenters, influencers, ambassadors and bloggers to promote its products. Decide 35 The EV dealership engages in buying and selling used EVs.

Table A3
Identified factors and indicator questions for policies influencing decisions to purchase and use EVs from the literature.

Factors	Indicator Questions
Purchasing Incentive Policies	Policy 1. Government financial incentives for purchasing EVs. Policy 2. Tax exemptions for the purchase of EVs. Policy 3. Discounts on car insurance for EVs.
Charing Incentive Policies	Policy 4. The ability to use electric charging receipts for tax deductions. Policy 5. Financial incentives for the installation of private electric charging stations. Policy 6. Discounts or subsidies for electric charging costs.
Driving Incentive Policies	Policy7. Discounts on parking fees for electric vehicles. Policy 8. Special parking spaces exclusively for EVs. Policy 9. Exemptions from toll fees for EVs on expressways.
Registering Incentive Policies	Policy 10. Exemptions or reductions in annual vehicle tax and property tax. Policy 11. Special license plates for EVs. Policy 12. Exemptions from driver's license fees for EVs.
Other Incentive Policies	Policy 13. Expansion of the number of electric charging stations. Policy 14 Extended warranty coverage for EV batterie. Policy 15. Government incentives for vehicle maintenance and repairs.

Appendix B

Tables B1–B3 show the results of vector calculations, by rows and columns of total relation matrix (T) in all three main perspectives.

Table B1
The results of vector calculations for the EV technological acceptance.

	A1	A2	A3	A4	A5	A6	A7	A8	r_i	c_j
A1	0.835	1.003	1.059	0.848	0.838	0.863	0.972	0.936	7.3542	7.1747
A2	0.996	0.919	1.108	0.890	0.886	0.902	1.014	0.987	7.7023	7.5561
A3	0.998	1.040	0.958	0.884	0.874	0.884	1.005	0.974	7.6173	7.9568
A4	0.797	0.850	0.882	0.630	0.729	0.724	0.797	0.774	6.1823	6.4509
A5	0.837	0.892	0.931	0.781	0.666	0.785	0.849	0.825	6.5671	6.4160
A6	0.900	0.961	1.012	0.829	0.835	0.728	0.913	0.887	7.0662	6.5220
A7	0.940	0.969	1.036	0.813	0.808	0.843	0.816	0.899	7.1244	7.2333
A8	0.872	0.921	0.970	0.775	0.781	0.792	0.866	0.748	6.7262	7.0303

Table B2
The results of the vector calculations for decisions to purchase and use EVs.

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	r_i	c_j
D1	0.582	0.709	0.678	0.688	0.769	0.727	0.667	0.721	0.709	0.701	0.723	0.689	8.3622	8.8034
D2	0.739	0.745	0.800	0.820	0.909	0.872	0.746	0.855	0.831	0.805	0.838	0.803	9.7642	9.6672
D3	0.748	0.828	0.737	0.831	0.918	0.884	0.775	0.866	0.848	0.822	0.856	0.817	9.9291	9.3991
D4	0.727	0.826	0.798	0.736	0.902	0.875	0.749	0.843	0.832	0.808	0.837	0.801	9.7325	9.5740
D5	0.785	0.858	0.842	0.849	0.852	0.907	0.789	0.892	0.867	0.842	0.875	0.840	10.1971	10.5828
D6	0.756	0.845	0.819	0.848	0.924	0.807	0.772	0.864	0.862	0.833	0.867	0.829	10.0265	10.1887
D7	0.719	0.749	0.735	0.742	0.827	0.801	0.638	0.777	0.772	0.755	0.786	0.738	9.0385	8.9380
D8	0.762	0.840	0.821	0.821	0.922	0.874	0.763	0.779	0.849	0.816	0.858	0.812	9.9174	9.9422
D9	0.750	0.827	0.798	0.822	0.905	0.871	0.767	0.853	0.759	0.810	0.848	0.803	9.8123	9.7993

(*continued on next page*)

Table B2 (*continued*)

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	r_i	c_j
D10	0.735	0.790	0.766	0.793	0.868	0.847	0.742	0.813	0.808	0.712	0.817	0.788	9.4777	9.5163
D11	0.758	0.835	0.804	0.810	0.891	0.865	0.770	0.848	0.844	0.800	0.765	0.799	9.7908	9.9005
D12	0.744	0.813	0.802	0.815	0.895	0.859	0.761	0.831	0.819	0.812	0.830	0.723	9.7047	9.4413

Table B3
The results of vector calculations for factors related to policies that affect user decisions to purchase and use EVs.

	P1	P2	P3	P4	r_i	c_j
P1	2.315	2.458	2.422	2.747	9.9428	9.6560
P2	2.480	2.157	2.321	2.663	9.6209	9.2915
P3	2.227	2.146	1.925	2.413	8.7117	9.1619
P4	2.633	2.531	2.494	2.555	10.2134	10.3795

References

Aasness, M.A., Odeck, J., 2015. The increase of electric vehicle usage in Norway—incentives and adverse effects. Eur. Transp. Res. Rev. 7 (4) https://doi.org/10.1007/s12544-015-0182-4.

Adamson, K., 2005. Calculating the price trajectory of adoption of fuel cell vehicles. Int. J. Hydrogen Energy 30 (4), 341–350. https://doi.org/10.1016/j.ijhydene.2004.07.004.

Agarwal, R., Prasad, J., 1997. The role of innovation characteristics and perceived voluntariness in the acceptance of information technologies. Decis. Sci. 28 (3), 557–582. https://doi.org/10.1111/j.1540-5915.1997.tb01322.x.

Ajzen, I., 1991. The theory of planned behavior. Organ. Behav. Hum. Decis. Process. 50 (2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-t.

Asadi, S., Nilashi, M., Iranmanesh, M., Ghobakhloo, M., Samad, S., Alghamdi, A., Almulihi, A., Mohd, S., 2022. Drivers and barriers of electric vehicle usage in Malaysia: A DEMATEL approach. Resour. Conserv. Recycl. 177, 105965 https://doi.org/10.1016/j.resconrec.2021.105965.

Bhattacherjee, A., 2000. Acceptance of e-commerce services: the case of electronic brokerages. IEEE Trans. Syst. Man Cybern. 30 (4), 411–420. https://doi.org/10.1109/3468.852435.

Bjerkan, K.Y., Nørbech, T.E., Nordtømme, M.E., 2016. Incentives for promoting Battery Electric Vehicle (BEV) adoption in Norway. Transp. Res. Part D: Transp. Environ. 43, 169–180. https://doi.org/10.1016/j.trd.2015.12.002.

Carley, S., Krause, R.M., Lane, B.W., Graham, J.D., 2013. Intent to purchase a plug-in electric vehicle: A survey of early impressions in large US cites. Transp. Res. Part D: Transp. Environ. 18, 39–45. https://doi.org/10.1016/j.trd.2012.09.007.

Chiu, Y.J., Chen, H., Tzeng, G.H., Shyu, J.Z., 2006. Marketing strategy based on customer behaviour for the LCD-TV. Int. J. Manag. Decis. Mak. 7 (2/3), 143. https://doi.org/10.1504/ijmdm.2006.009140.

Christian, T., Andrea, A., Gabriella, S., Alyona, Z., Guzay, P.K., 2012. Attitude of European car drivers towards electric vehicles: a survey. Publ. Off. Eur. Union. https://doi.org/10.2790/68984.

Davis, F.D., 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. Manag. Inf. Syst. Q. 13 (3), 319. https://doi.org/10.2307/249008.

Frewer, L.J., Scholderer, J., Bredahl, L., 2003. Communicating about the risks and benefits of genetically modified foods: the mediating role of trust. Risk Anal. 23 (6), 1117–1133. https://doi.org/10.1111/j.0272-4332.2003.00385.x.

Garanad, P. 2019. Factors that Affecting the Intention to Purchase of Electric Vehicle of Customer in Nonthaburi. Strategic Planning and Management for Entrepreneur Graduate School Thai-Nichi Institute of Technology.

Guo, X., Sun, Y., Ren, D., 2023. Life cycle carbon emission and cost-effectiveness analysis of electric vehicles in China. Energy Sustain. Dev. 72, 1–10. https://doi.org/10.1016/j.esd.2022.11.008.

Hair, J.F., 2010. Multivariate data analysis : a global perspective. https://ci.nii.ac.jp/ncid/BB03463866.

Hardman, S., Chandan, A., Tal, G., Turrentine, T., 2017. The effectiveness of financial purchase incentives for battery electric vehicles – A review of the evidence. Renew. Sustain. Energy Rev. 80, 1100–1111. https://doi.org/10.1016/j.rser.2017.05.255.

Haugneland, P., Hauge, E., 2015. Norwegian electric car user experiences 2014. World Electric Vehicle J. 7 (4), 650–658. https://doi.org/10.3390/wevj7040650.

Huang, C.Y., Shyu, J.Z., Tzeng, G., 2007. Reconfiguring the innovation policy portfolios for Taiwan's SIP Mall industry. Technovation 27 (12), 744–765. https://doi.org/10.1016/j.technovation.2007.04.002.

Jalajas, D., Bommer, M., 1999. A comparison of the impact of past and the threat of future downsizings on workers. J. Soc. Behav. Pers. 14 (1), 89.

Jin, L., Searle, S., Lutsey, N., 2014. Evaluation of State-Level U.S. Electric Vehicle Incentive. International Council on Clean Transportation. https://theicct.org/sites/default/files/publications/ICCT_state-EV-incentives_20141030.pdf.

Kabir, M.R., Habiba, U.E., Khan, W.U., Shah, A., Rahim, S., Farooqi, Z.U.R., Iqbal, M., Shafiq, M.N., 2023. Climate change due to increasing concentration of carbon dioxide and its impacts on environment in 21st century; a mini review. J. King Saud Univ. – Sci. 35 (5), 102693 https://doi.org/10.1016/j.jksus.2023.102693.

Kaiser, H.F., 1958. The varimax criterion for analytic rotation in factor analysis. Psychometrika 23 (3), 187–200. https://doi.org/10.1007/bf02289233.

Kang, M.J., Park, H., 2011. Impact of experience on government policy toward acceptance of hydrogen fuel cell vehicles in Korea. Energy Policy 39 (6), 3465–3475. https://doi.org/10.1016/j.enpol.2011.03.045.

Kim, J., Kim, N., Moon, H., Lee, S., Jeong, S.Y., Díaz-Pulido, G., Edwards, M.S., Kang, J., Kang, E.J., Oh, H., Hwang, J., Kim, I., 2020. Global warming offsets the ecophysiological stress of ocean acidification on temperate crustose coralline algae. Mar. Pollut. Bull. 157, 111324 https://doi.org/10.1016/j.marpolbul.2020.111324.

Konstantinou, T., Gkritza, K., 2023. Examining the barriers to electric truck adoption as a system: A Grey-DEMATEL approach. Transp. Res. Interdisc. Perspect. 17, 100746 https://doi.org/10.1016/j.trip.2022.100746.

Kuntawong, P., Suwannoi, T., Sukhaparamate, S., Jantarakolica, K., Jantarakolica, T., 2022. The technology acceptance, financial benefit, and environment influencing customers' decision making to electric vehicles in Bangkok and Metropolitan Area. J. Human. Soc. Sci. Nakorn Pranom Univ. 12 (1). https://so03.tci-thaijo.org/index.php/npuj/article/download/252010/172993/963938.

Kuo, T., Shen, Y., Sriwattana, N., Yeh, R., 2022. Toward Net-Zero: the barrier analysis of electric vehicle adoption and transition using ANP and DEMATEL. Processes 10 (11), 2334. https://doi.org/10.3390/pr10112334.

Lai, I.K.W., Liu, Y., Sun, X., Zhang, H., Xu, W., 2015. Factors influencing the behavioural intention towards full electric vehicles: an empirical study in Macau. Sustainability 7 (9), 12564–12585. https://doi.org/10.3390/su70912564.

Lane, B.R., Potter, S., 2007. The adoption of cleaner vehicles in the UK: exploring the customer attitude–action gap. J. Clean. Prod. 15 (11–12), 1085–1092. https://doi.org/10.1016/j.jclepro.2006.05.026.

Leurent, F., Windisch, E., 2011. Triggering the development of electric mobility: a review of public policies. Eur. Transp. Res. Rev. 3 (4), 221–235. https://doi.org/10.1007/s12544-011-0064-3.

Li, W., Long, R., Chen, H., Dou, B., Chen, F., Zheng, X.L., He, Z., 2020. Public preference for electric vehicle incentive policies in China: a conjoint analysis. Int. J. Environ. Res. Public Health 17 (1), 318. https://doi.org/10.3390/ijerph17010318.

Liang, Y., Wang, H., Zhao, X., 2022. Analysis of factors affecting economic operation of electric vehicle charging station based on DEMATEL-ISM. Comput. Ind. Eng. 163, 107818 https://doi.org/10.1016/j.cie.2021.107818.

Likert, R., 1932. A technique for the measurement of attitudes. https://psycnet.apa.org/record/1933-01885-001.

Lin, C., Tzeng, G., 2009. A value-created system of science (technology) park by using DEMATEL. Expert Syst. Appl. 36 (6), 9683–9697. https://doi.org/10.1016/j.eswa.2008.11.040.

Liou, J.J.H., Tzeng, G., Chang, H., 2007. Airline safety measurement using a hybrid model. J. Air Transp. Manag. 13 (4), 243–249. https://doi.org/10.1016/j.jairtraman.2007.04.008.

Malima, G., Moyo, F., 2023. Are electric vehicles economically viable in sub-Saharan Africa? The total cost of ownership of internal combustion engine and electric vehicles in Tanzania. Transp. Policy 141, 14–26. https://doi.org/10.1016/j.tranpol.2023.07.014.

Mersky, A.C., Sprei, F., Samaras, C., Qian, S., 2016. Effectiveness of incentives on electric vehicle adoption in Norway. Transp. Res. Part D: Transp. Environ. 46, 56–68. https://doi.org/10.1016/j.trd.2016.03.011.

Mourato, S., Saynor, B., Hart, D.M., 2004. Greening London's black cabs: a study of driver's preferences for fuel cell taxis. Energy Policy 32 (5), 685–695. https://doi.org/10.1016/s0301-4215(02)00335-x.

Murugan, M., Marisamynathan, S., 2022. Analysis of barriers to adopt electric vehicles in India using fuzzy DEMATEL and Relative importance Index approaches. Case Stud. Transp. Policy 10 (2), 795–810. https://doi.org/10.1016/j.cstp.2022.02.007.

Panson, T., 2018. Behavioral Acceptance of Electric Vehicles in Bangkok. Chulalongkorn University Theses and Dissertations (Chula ETD). https://doi.org/10.58837/chula.the.2018.1204.

Parker, N., Breetz, H.L., Salon, D., Conway, M.W., Williams, J.C., Patterson, M., 2021. Who saves money buying electric vehicles? Heterogeneity in total cost of ownership. Transp. Res. Part D-Transp. Environ. 96, 102893 https://doi.org/10.1016/j.trd.2021.102893.

Sang, Y., Bekhet, H.A., 2015. Modelling electric vehicle usage intentions: an empirical study in Malaysia. J. Clean. Prod. 92, 75–83. https://doi.org/10.1016/j.jclepro.2014.12.045.

Schmalfuß, F., Mühl, K., Krems, J.F., 2017. Direct experience with battery electric vehicles (BEVs) matters when evaluating vehicle attributes, attitude and purchase intention. Transport. Res. F: Traffic Psychol. Behav. 46, 47–69. https://doi.org/10.1016/j.trf.2017.01.004.

Schulte, I., Hart, D.M., Van Der Vorst, R., 2004. Issues affecting the acceptance of hydrogen fuel. Int. J. Hydrogen Energy 29 (7), 677–685. https://doi.org/10.1016/j.ijhydene.2003.09.006.

Segal, R., 1995. Fore casting the market for electric vehicles in California using conjoint analysis. Energy J. 16 (3), 89–111. https://repository.upenn.edu/.

Shi, J., Liu, Z., Feng, Y., Wang, X., Zhu, H., Yang, Z., Wang, J., Wang, H., 2024. Evolutionary model and risk analysis of ship collision accidents based on complex networks and DEMATEL. Ocean Eng. 305, 117965 https://doi.org/10.1016/j.oceaneng.2024.117965.

Shieh, J., Wu, H., Huang, K., 2010. A DEMATEL method in identifying key success factors of hospital service quality. Knowl. Based Syst. 23 (3), 277–282. https://doi.org/10.1016/j.knosys.2010.01.013.

Sinsap, P., 2023. Investigation on factors and growth assessment of electric vehicles in Thailand. https://doi.org/10.58837/chula.is.2019.94.

Slovic, P., Finucane, M.L., Peters, E., MacGregor, D.G., 2004. Risk as analysis and risk as feelings: some thoughts about affect, reason, risk, and rationality. Risk Anal. 24 (2), 311–322. https://doi.org/10.1111/j.0272-4332.2004.00433.x.

Sumrit, D., 2013. Using DEMATEL Method to analyze the causal relations on technological innovation capability evaluation factors in Thai technology-based firms. Int. Trans. J. Eng., Manage., Appl. Sci. Technol. https://tuengr.com/V04/081-103.pdf.

Tangphet, W., 2017. Factors Affecting Customer's Battery Electric Vehicle Purchase Intention for Gen X and Gen Y in Bangkok. Faculty of Commerce and Accountancy Thammasat University.

Tangtaku, A. (2015). Willingness to Pay for Purchasing Electric Vehicle: A Case Study of Bangkok. Faculty of Economics, Thammasat University.

Taylor, S., Todd, P., 1995. Understanding information technology usage: A test of competing models. Inf. Syst. Res. 6 (2), 144–176. https://doi.org/10.1287/isre.6.2.144.

Tu, J.C., Yang, C., 2019. Key factors influencing customers' purchase of electric vehicles. Sustainability 11 (14), 3863. https://doi.org/10.3390/su11143863.

Turner, R.C., Carlson, L.A., 2003. Indexes of Item-Objective congruence for multidimensional items. Int. J. Test. 3 (2), 163–171. https://doi.org/10.1207/s15327574ijt0302_5.

Viardot, E., 2004. Successful Marketing Strategy for High-Tech Firms, seconded. Artech House. Artech House, Boston, Boston, Mass.

Wang, S., Li, J., Zhao, D., 2017. The impact of policy measures on customer intention to adopt electric vehicles: Evidence from China. Transp. Res. Part A-Policy Pract. 105, 14–26. https://doi.org/10.1016/j.tra.2017.08.013.

Wang, S., Li, C., Yang, L., 2018. Decoupling effect and forecasting of economic growth and energy structure under the peak constraint of carbon emissions in China. Environ. Sci. Pollut. Res. 25 (25), 25255–25268. https://doi.org/10.1007/s11356-018-2520-2.

Wang, J., Zhou, W., 2019. Factors Influencing the Purchase Willingness towards Electric Vehicles in China. Uppsala University. http://uu.diva-portal.org/.

Williams, L., Magee, G. D., & Suzuki, Y. (1998). A Multidimensional View of EDI: Testing the value of EDI participation to firms. J. Busin. Logist. https://trid.trb.org/view/512546.

Yamane, T. (1973). Statistics: An Introductory analysis. https://digilib.umsu.ac.id/index.php?p=show_detail&id=24636.

Yang, Y., Shieh, H., Leu, J., Tzeng, G., 2008. A novel hybrid MCDM model combined with DEMATEL and ANP with applications. Int. Oper. Res.

Yang, Z., Slowik, P., Lutsey, N., Searle, S., 2016. Principles for effective electric vehicle incentive design. Int. Council Clean Transp. https://doi.org/10.13140/RG.2.2.30952.26883.

Yang, Z., Poo, M.C.P., Galatioto, F., Dimitriu, D., Qu, Z., Rushton, C., Lee, P.T., Guan, B., Woodward, N., 2020. Key green performance indicators (KGPIs) for vehicle cleanliness evaluation: A buyer choice. Transp. Res. Part D: Transp. Environ. 87, 102505 https://doi.org/10.1016/j.trd.2020.102505.

Zhang, Y., Yu, Y., Zou, B., 2011. Analyzing public awareness and acceptance of alternative fuel vehicles in China: The case of EV. Energy Policy 39 (11), 7015–7024. https://doi.org/10.1016/j.enpol.2011.07.055.