# Exploring Interoperability Factors Influencing Personal Electric Vehicle Adoption in Chiang Mai, Thailand

Krisana Yindee [1], Nipon Ketjoy [2] and Prapita Thanarak [3,*]

[1] School of Renewable Energy and Smart Grid Technology (SGtech), Naresuan University, Phitsanulok 65000, Thailand
[2] School of Renewable Energy and Smart Grid Technology (SGtech), Naresuan University, Phitsanulok 65000, Thailand
[3] School of Renewable Energy and Smart Grid Technology (SGtech), Naresuan University, Phitsanulok 65000, Thailand

*Corresponding Email : prapitat@nu.ac.th

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**Abstract.** *The transportation industry stands on the brink of a transformative revolution as the number of electric vehicles (EVs) continues to rise. However, the potential limiting factor of charging station availability looms large. This research, conducted in Chiang Mai province in northern Thailand, delved into the plans and decision-making processes of stakeholders in this transportation revolution, as well as the factors influencing the choice of EVs by users and potential users. The data, collected from 200 EV users and 200 potential buyers, was analyzed using structural equation modeling analysis. The findings underscore the need for cooperation among government agencies, private sector organizations, and electricity-producing entities to propel Chiang Mai towards a smart city, with a focus on pollution-free EV travel. Environmental concerns and fuel cost savings emerged as key factors influencing the decision to purchase an EV. The choice of an EV was also influenced by brand quality and standards. However, the most significant factor affecting the potential purchase decision was the availability of electric charging stations. To effectively support the use of EVs and meet environmental pollution standards, it is imperative that governmental, municipality, and private organizations concentrate on developing a sufficient power supply and network of charging stations.*

## Keywords:

Personal electric vehicles, Interoperability factors, Charging infrastructure, Regulatory frameworks, Consumer perceptions, Structural equation model, Confirmatory factor analysis

## 1. Introduction

Electrical Vehicles (EVs) reduce fossil fuel consumption, eliminate vehicle emissions, and produce minimal noise pollution. These advantages have garnered significant interest in the global automotive market. Consequently, promoting EVs has become a policy priority, aiming to replace the current internal combustion engine (ICE) vehicles [1, 2]. According to the International Energy Agency (IEA) global report on EVs in 2017 [3], many governments worldwide promote EV utilization. For instance, the United States has announced a national policy to encourage the use of renewable energy, which is a driving factor in expanding the EV industry in the country. The government supports the interoperability platform of domestic EVs, such as advanced battery technology, propulsion systems, and lightweight structures.

Additionally, importance is given to the infrastructure for electric charging, including relevant standards and grid integration. The government also disseminates knowledge to consumers, provides financial support for EV purchases, and sets an example by procuring EVs for public agencies. In this regard, the United States has set targets for battery technology development by 2022, including a battery cost of $125 per kilowatt-hour, specific energy of 250 watt-hours per kilogram, energy density of 400 watt-hours per liter, and particular power of 2,000 watts per kilogram [3, 4]. Japan has set practical plans to reduce carbon dioxide emissions by 26% in 2030 and aims to have plug-in hybrid and battery electric vehicles (BEV) account for 15-20% of total accumulated vehicles by 2020 and 20-30% by 2030. In addition, the Japanese government has expedited measures to prepare the infrastructure for electric charging. They have ready direct (fast charging) and alternating (slow charging) charging stations in residential areas, such as condominium parking lots, office buildings, public spaces, shopping centers, gas stations, and convenience stores. Various initiatives have been implemented to encourage increased usage of EVs. For example, a subsidy of approximately ¥400,000 is provided to EV buyers (the amount may vary by model). Some local governments also offer an additional subsidy of ¥50,000, and EV buyers can receive a further reduction of approximately ¥120,000 in automobile taxes [5]. While China aims to develop the EV industry as one of the ten target industries leading to the "Made in China 2025" vision, the Chinese government provides budget support and tax benefits to over 500 Chinese start-up companies that manufacture EVs and components (including batteries). In marketing and promoting EVs, the Chinese government employs a semi-mandatory strategy and creates price differentiation between EVs and ICE vehicles. The main policy is restricting the number of gasoline-powered vehicles in major cities by not allowing the registration of new vehicles, except through competitive bidding and exchanging old vehicles. This leads to high prices for new vehicle registration in major cities like Shanghai, which can exceed 300,000 Thai baht, although the actual vehicle price does not exceed 600,000 baht. However, the Chinese government allows immediate issuance of EV registration plates without additional costs. Furthermore, they promote using EVs in public transportation, such as buses and taxis, by replacing them with EVs instead of ICE, such as in Shenzhen's electric taxi fleet [6, 7].

For Thailand, the promotion of the EV interoperability platform as a sustainable form of transportation began in 2015 with the resolution of the National Reform Council on March 3, 2015. This resolution approved the Energy Reform Commission's proposal regarding the "Promotion of Electric Vehicles in Thailand." Subsequently, the Ministry of Energy, with the approval of the National Energy Policy Council, developed the Energy Efficiency Plan (EEP) 2015, covering the period from 2015 to 2036. This plan included measures to promote EVs as part of the energy conservation strategy in the transportation sector. The target was set to promote and encourage energy conservation through the use of EVs, aiming for 1.2 million EVs, 25% of the total vehicle production in the country, by 2036. The plan also included establishing EV charging stations throughout the country, with a target of 690 stations [2].

Furthermore, in 2021, Thailand announced the "30@30" policy, which sets a target to produce at least 30% Zero Emission Vehicles (ZEVs) of the total vehicle production by 2030 or 2027, aiming to drive Thailand towards a low-carbon society in the future [8]. In addition, the government has announced measures to promote investment in the production of BEVs, including passenger cars, pickups, and buses, as well as EV components such as traction motors, electric air conditioning systems, battery management systems (BMS), drive control units (DCU), on-board chargers, battery charging cables with connectors, DC/DC converters, inverters, portable EV chargers, electrical circuit breakers, smart EV charging systems, front, and rear suspension systems for electric buses, and more. Furthermore, there are measures to reduce the excise tax for domestically produced EVs from the standard expected average rate to 2% from the previous rate of 10%. Additionally, there are incentives to support investment in EV charging stations by exempting import duties on machinery and equipment for installing charging stations and providing a 5-year corporate income tax exemption. The government is also promoting the use of EVs in government agencies, state enterprises, and public transportation services. For example, the Bangkok Mass Transit Authority (BMTA) introduced 200 BEV passenger buses for service in 2017. Government agencies and state enterprises are encouraged to purchase BEVs, accounting for 20% of their annual new vehicle procurement budget.
Moreover, BEVs are encouraged to be used for tourism in large-scale historical parks [9]. However, the policy is concentrated on providing support only to manufacturers, entrepreneurs, and car companies that import cars [10]. From various government policies aimed at promoting the use and production of EVs in the country, Thai automotive entrepreneurs and stakeholders in the industry have become aware of and interested in becoming part of the growing EV industry. As a result, the expansion of EVs has continuously increased, according to the vehicle statistics in 2023 from the Department of Land Transport [11-15]. Table 1 shows the 100,219 registered BEVs; 79,402 were newly registered. This significant growth is over 30 times that in 2020 when only 2,999 were newly registered EVs. This remarkable leap indicates that consumers increasingly prioritize using BEVs. Furthermore, when examining the types of EVs, motorcycles are the majority, followed by cars and passenger vehicles, respectively.

**Table 1** Cumulative and Newly Registered BEVs nationwide from 2020 to 2023

| Years | | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|
| accumulate (vehicle) | Thailand | 8,684 | 14,573 | 35,390 | 100,219 |
| | Chiang Mai | 163 | 333 | 909 | 3,617 |
| new register (vehicle) | Thailand | 2,999 | 5,889 | 20,817 | 79,402 |
| | Chiang Mai | 141 | 170 | 576 | 2,708 |

In terms of promoting the use of EVs by regional power authorities, it has been found that there has been a continuous expansion of electric charging stations at the regional level from 2015 until 2022. A total of 263 charging stations have been opened, covering 75 provinces, and there are plans to open an additional 190 stations within 2023. Furthermore, in the power sector, various organizations such as the Electricity Generating Authority of Thailand (EGAT), Provincial Electricity Authority (PEA), Metropolitan Electricity Authority (MEA), PTT Oil and Retail Business Public Company Limited, AVL Technology Company Limited, Gridwiz (Thailand) Limited, Mahanakorn Power Company Limited, G. Green (Thailand) Limited, CHOSEN Energy Limited, and The Fifth Element Innovation Co., Ltd. have started testing the cross-network charging system, also known as the charging consortium. This is a collaborative project among network-related organizations to provide services to all EV users who must have an RFID card, a debit or credit card, or a mobile smartphone application. When users access the charging stations, the usage fees will be calculated and sent for payment at their homes.

This payment method can be used at all charging stations, costing 2.63 baht per kWh. The charging consortium will have a main application system to collect user data, create a unified standard for EV users, and enhance the service's convenience. The charging consortium project began in early 2023 in the Bangkok metropolitan area. It will expand to major cities such as Chiang Mai and Chonburi, covering the country with 944 stations.

Furthermore, in the private sector, companies such as EA Anywhere have been installing electric charging stations throughout Bangkok and its metropolitan area and in major cities across Thailand, such as Hua Hin, Pattaya, and various provinces. Currently, there are charging stations in Phitsanulok, Ratchaburi, Chiang Mai, Phuket, Hat Yai, Hua Hin, Chumphon, and more, totaling more than 1,000 stations nationwide. Other private companies collaborate with multiple EV manufacturers, such as Charge Now, a charging station network. For example, BMW has installed up to 50 electric charging stations throughout Bangkok. Mercedes-Benz has expanded its charging stations under the EQ brand, completing 50 stations in 2021 and reaching a target of 63 stations in 2022. Their goal for 2025 is to expand to 200 stations nationwide.

Chiang Mai, Thailand, is an essential city in the northern region, located 696 kilometers away from Bangkok. It covers an area of 20,107.057 square kilometers, making it the largest province in the north region and the second largest in the country. It is considered the top model city in the north of the region under Thailand's promotion plan for EVs. Chiang Mai is known for its high potential and serves as a gateway to neighboring countries, contributing to its central role in various aspects of development. This includes the economy, industry, and tourism. The province has a population of 1,746,840 people and 785,999 households, with a population density of 86.88 people per square kilometer. Additionally, Chiang Mai attracts many visitors, with approximately 9,623,958 tourists annually, generating a total income of 90,137.28 million baht. The tourism sector has grown annually at 3.64% [11].

In terms of expanding the use of EVs in Chiang Mai, it was found that in 2023, there were 2,708 new BEV registrations, with a cumulative total of 3,617 vehicles in Table 1. Compared to 2018, which had a cumulative total of 66 EVs, there has been a growth of over 10 times. This indicates a continuous increase in the use of EVs, especially in larger cities at the regional level. Furthermore, analyzing the data for 2022, most vehicles were personal cars, totaling 331 vehicles, followed by motorcycles with 245 vehicles [12-15]. Chiang Mai is an important area where the use of EVs has been continuously expanding. Therefore, developing a service system to support EVs is necessary. However, considering the context of Chiang Mai, which is still facing challenges in urban expansion, along with an increasing population and the number of private vehicles, as reported, the cumulative number of vehicles in 2020 was 1,534,472, in 2564, it reached 1,610,071, and in 2020 it increased to 1,691,411. On average, there is an increase of 1,777,237 vehicles per year, 7,300 vehicles per month, or 245 vehicles per day [14, 15]. Due to the expansion of the city, the increasing population, and the continuous growth of the number of vehicles, Chiang Mai has faced air pollution problems. The increased traffic congestion and vehicle emissions have contributed to severe air pollution, particularly during the dry season (January to May). The problem of delicate particulate matter (PM 2.5) exceeding the standard limit has ranked Chiang Mai as the world's top polluted city for several consecutive days. From 2019 to 2022, during the dry season, Chiang Mai experienced several days with PM 2.5 levels exceeding the standard limit: 74, 71, 42, and 35 days, respectively. In consecutive years, the average 24-hour maximum PM 2.5 levels were recorded at 241, 193, 189, and 176 ($\mu g/m^3$), indicating a significant impact on public health [16-19]. The problem of delicate PM 2.5 exceeding the standard in Chiang Mai is a significant issue at the national level. The government and various public and private sectors have tried to address this issue through policies, plans, activities, and legal measures for continuous air pollution management.
However, sustainable solutions and effective air pollution reduction have yet to be fully achieved, particularly in changing people's behavior to recognize the importance of using EVs to reduce emissions and minimize the particulate matter caused by combustion engines. Based on the regression analysis, the main findings confirmed that environment and incentive policies have an insignificant influence on individuals’ intention to adopt electric vehicles [20-23]. Additionally, the current widespread impact of the COVID-19 pandemic, including the newly emerged coronavirus variant, has affected Thailand, including Chiang Mai, and has led to delays and changes in the implementation of projects and activities related to the interoperability platform of EV infrastructure and services. EV charging stations that power environmentally friendly tourism support ownership investment's feasibility [24]. Most research in Thailand [20-25] has been conducted primarily in Bangkok, but the local context differs in other regions. For instance, Chiang Mai, which faces PM 2.5 challenges and emphasizes smart city development, has not yet been studied regarding EV interoperability. Therefore, the interoperability platform of EV models or service formats of PEVs aligns with the needs and interests of users and potential users of EVs in Chiang Mai is needed. This research is beneficial in informing government policies and plans and promoting public behavior that prioritizes the use of environmentally friendly electric energy, which helps reduce long-term air pollution. It also serves as a guide for manufacturers' interoperability platform of PEV products and the establishment of electric charging stations that meet consumer demand, leading to changes in consumer behavior towards adopting environmentally friendly PEVs. These efforts contribute to the overall development of the economy and society, not only in Chiang Mai but throughout Thailand.

## 2. Conceptual Framework

This research developed key interoperability factors for PEV adoption in Chiang Mai, Thailand, and employed qualitative and quantitative research methods. The study was approved by Human Subject Protection (HSP) by the declaration of Helsinki, The Belmont Report, the CIOMS Guideline, and the International Conference on Harmonization in Good Clinical Practice (ICH-GCP) under the Naresuan University Institution Review Board (IRB). The research methodology can be summarized as shown in Figure 1. The tools for data collection were categorized according to the following research formats:

Qualitative Research: Utilizing documentary research and in-depth interviews as research methods, including documentary research and in-depth interviews for groups of government agencies, the private sector, and electricity producers. The researcher conducted semi-structured interviews and prepared pre-determined questions, allowing interviewees to participate actively, exchange opinions, and express their thoughts fully. This approach aimed to gather in-depth information that effectively addresses the research objectives.

Quantitative Research: The researchers have developed questionnaires to collect data about general information about BEV users from the sample group of EV users and interested individuals in Chiang Mai, Thailand. It includes gender, age, marital status, education level, occupation, average monthly income, and current residential area/district. Knowledge and understanding of BEV, behavior, and decision-making in purchasing BEVs, factors Influencing the decision to use BEVs, problems and challenges in the BEV use, and trends in the future use of BEVs.

The assessment of content validity for the questionnaire analyzed through the Item-Objective Congruence Index (IOC) based on the opinions of the three experts indicated an index value of 0.96. The reliability test results of Cronbach's Alpha value of 0.949. The field data collection involves the researcher conducting on-site studies using various data collection methods, including in-depth interviews with government agencies, private sector organizations, and electric vehicle manufacturers. Additionally, data is collected through questionnaires administered to 200 EV users and those 200 interested in using EVs in Chiang Mai. The data collection period spans from October 2021 to October 2022.

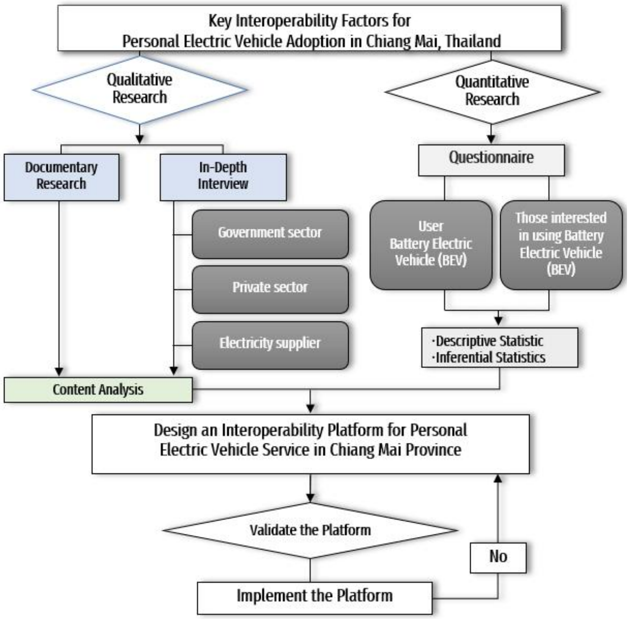


**Fig. 1** Conceptual framework of the research

Quantitative data analysis involves analyzing data from questionnaires of EV users and enthusiasts in Chiang Mai. Descriptive statistics are used to present and describe general data of questionnaire respondents, behavior, decision-making processes, and factors influencing the decision to use EVs among users and potential users in Chiang Mai. Inferential statistics are used to analyze the collaborative usability patterns of PEVs that align with the needs of users and enthusiasts. The key steps include model validation and assessing the data's goodness of fit using statistical indices such as the chi-square test, chi-square/degrees of freedom, goodness of fit index (GFI), adjusted goodness of fit index (AGFI), comparative fit index (CFI), and root mean square error of approximation (RMSEA). These statistical indices measure the model's goodness of fit and evaluate the overall fit. Specific parameter values may sometimes not be statistically significant [25].

The researcher performed Confirmatory Factor Analysis (CFA) using Structural Equation Modeling (SEM) with Analysis of Moment Structures (AMOS). This involved verifying the fit and assessing the goodness of fit of each variant in the structural equation model [26-28]. The analysis examined the relationships between observed and latent variables shown in Table 2. The CFA was conducted to test these relationships. This analysis of the SEM contributes to developing a model that represents the collaborative usability patterns of PEVs aligned with the needs of users and enthusiasts in Chiang Mai, as outlined in the researcher's model.

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**Table 2** The meanings of latent variables and observed variables.

| Variant | Meaning |
|---|---|
| Latent Variant | |
| Factors_BEV | Factors affecting the choice of EVs |
| Future_pro | Trends in the use of EVs in the future |
| Observed Variant | |
| Policy | Policies and measures to promote the use of EVs |
| Awareness | Awareness of pollution and environmental problems |
| Quality | Quality and standards of EVs |
| Price | Automotive price |
| Station | Electric charging station |
| Service | Service from the manufacturer/distributor/center |
| Advise | Referring to others to the use of battery EVs |
| Buy | Buying more battery EVs in the future |
| Willing | Willingness to pay for the purchase |
| Concern | Concerns about the use of EVs in the future |

## 3. Analysis and Results

The majority of respondents for both groups were male, aged between 30-50 years old, married, graduated with a bachelor's degree or equivalent, and had a monthly income between 20,000 - 40,000 baht who almost stayed in Mueang Chiang Mai district. The researcher adjusted the model based on recommendations for parameter adjustments in the model using Model Modification Indices (MI). It was found that the circular consistency index showed a good fit between the model and the empirical data as the model of factors affecting the choice of EV is related to the future use of battery electric vehicles by EV users. In Table 4, the MI values were adjusted. It was found that the critical indices were used to determine the coherence between the empirical hypothesis models, which consisted of index values such as CMIN/DF equal to 2.602 < 3, p-value equal to 0.064 > 0.05, GFI value equal to 0.952 > 0.90, AGFI value equal to 0.993 > 0.90, CFI value equal to 0.969 > 0.90 and RMSEA value equal to 0.061 < 0.07. Models and empirical data are consistent.

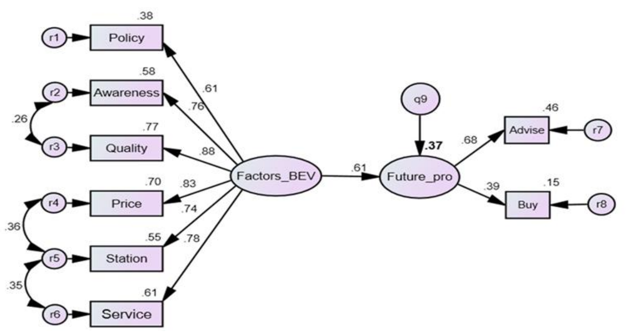
**Table 3** Data of the respondents of users and those interested in using EV in Chiang Mai

| Category | EV users Number (%) | Interested in using EV Number (%) |
|---|---|---|
| Gender | | |
| Male | 152 (76.0) | 149 (74.5) |
| Female | 48 (24.0) | 51 (25.5) |
| Age | | |
| Lower 30 years | 22 (11.0) | 52 (26.0) |
| 30-40 Years | 78 (39.0) | 66 (33.0) |
| 41-50 Years | 68 (34.0) | 57 (28.5) |
| 51-60 Years | 21 (10.5) | 23 (11.5) |
| More than 60 years | 11 (5.5) | 2 (1.0) |
| Marital status | | |
| Married | 108 (54.0)) | 100 (50.0) |
| Single | 69 (34.5 | 94 (47.0) |
| Widowed/divorced/separated | 23 (11.5) | 6 (3.0) |
| Highest level of education | | |
| Undergraduate | 24 (12.0) | 41 (20.5) |
| Bachelor's degree or Equivalent | 133 (66.5) | 124 (62.0) |
| Postgraduate | 43 (21.5) | 35 (17.5) |
| Occupation | | |
| Civil servants/government Employees | 49 (24.5) | 30 (15.0) |
| Private business/entrepreneur | 43 (21.5) | 49 (24.5) |
| Private company employees | 42 (21.0) | 69 (34.5) |
| Freelance | 32 (16.0) | 21 (10.5) |
| Students | 12 (6.0) | 14 (7.0)8 |
| State enterprise employees | 11 (5.5) | 9 (4.5) |
| Business Trade | 11 (5.5) | 8 (4.0) |
| Average monthly income | | |
| Below 20,000 baht | 21 (10.5) | 51 (25.5) |
| 20,000 – 40,000 baht | 52 (26.0) | 81 (40.5) |
| 40,001 – 60,000 baht | 52 (26.0) | 31 (15.5) |
| 60,001 – 80,000 baht | 18 (9.0) | 13 (6.5) |
| 80,001 – 100,000 baht | 16 (8.0) | 12 (6.0) |
| 100,001 baht or more | 41 (20.5) | 12 (6.0) |

**Table 4** Model consistency index for EV users and interested in using EVs

| Index | Criterion | Statistics | | Consideration |
|---|---|---|---|---|
| | | Users | Interested | |
| CMIN/DF | < 3 | 2.602 | 1.568 | qualify |
| P | > 0.05 | 0.064 | 0.080 | qualify |
| GFI | > 0.90 | 0.952 | 0.973 | qualify |
| AGFI | > 0.90 | 0.993 | 0.932 | qualify |
| CFI | > 0.90 | 0.969 | 0.990 | qualify |
| RMSEA | < 0.07 | 0.061 | 0.053 | qualify |

The goodness of fit index of the model of factors affecting the interest of EV is related to the future use of BEV. It was found that the critical index was used to determine the coherence between the empirical hypothesis models, which consisted of index values such as CMIN/DF equal to 1.568 < 3, p-value equal to 0.080 > 0.05, GFI value equal to 0.9732 > 0.90, AGFI value equal to 0.932 > 0.90, CFI value equal to 0.990 > 0.90 and RMSEA value equal to 0.053 < 0.07, so it can be said that Models and empirical data are consistent, in Table 4.




CMIN=41.629, DF=16, P=.064, CMIN/DF= 2.602GFI=.952, AGFI=.993, CFI=.969, RMSEA=.061

**Fig. 2** Factors influencing the adoption of EVs and their relationship to future EV usage trends

The test for the regression coefficient of latent variables after the model adjustment for harmonization found that the correlation weights (standardized regression weights) of latent variables affected the choice of EV (Factors_BEV) between 0.614 – 0.876, presented in Figure 2. The heaviest factor is quality and standard of electric vehicles (Quality) (weight component equal to

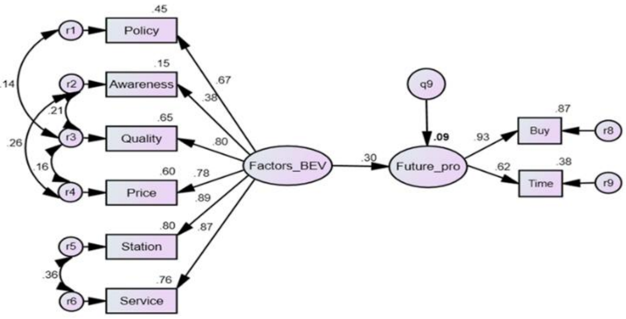
0.876), followed by automotive price (Price) (weight component equal to 0.835), service from manufacturers/distributors/service centers (Service) (weight component equal to 0.781), awareness of pollution and environmental problems (Awareness) (weight component equal to 0.761), stations (weight component equal to 0.740) and policies and measures to promote the use of motor vehicles. Electricity (Policy) (The weight of the element is 0.614). As for the future use of BEV by electric vehicle users, it was found that the variable with the heaviest component was recommending others to use BEV (Advice) (Weight component = 0.678) and future purchase of battery electric vehicles (Buy) (Weight component = 0.389). The relationship between factors affecting the choice of EV (Factors_BEV) and the use of electric vehicles in the future (Future_pro) is also considered. They were affecting the use of electric vehicles in the future with squared multiple correlations (R2) equal to 0.37 or 37 %, meaning the importance of factors affecting the choice of electric vehicles of automotive users' electricity. There is an opportunity to influence electric vehicle users to recommend more people to use electric vehicles. This includes the tendency to affect EV users to choose to buy and continue to use EVs, 37%. (Standardized regression weights). The first three are the quality and standard of the EV (Quality), followed by the price of the vehicle (Price) and the service from the manufacturer/distributor/service center (Service), detailed in Table 5.

Key interoperability factors revealed that the relevant agencies, both government and private sectors, and entrepreneurs must develop the quality and standards of EVs. Both develop engine performance and EV systems with an increasing average running distance per full charge. Is there a faster or shorter charging time per battery? How much is the automotive price? There should be a reduction or preferential treatment in terms of price. To attract motor vehicle users to use more EVs and services from manufacturers, distributors, and service centers that should cover all areas, making it more convenient for them to access the system check service or other services, etc.

**Table 5** Regression Coefficient Test of Latent Variables for EV Users

| Variant | | | Regression Weights | | | | Standardized Regression Weights Estimate |
|---|---|---|---|---|---|---|---|
| | | | Estimate | SE. | CR. | P | |
| Future_pro | <--- | Factors_BEV | .187 | .036 | 5.204 | *** | .609 |
| Awareness | <--- | Factors_BEV | 1.180 | .141 | 8.369 | *** | .761 |
| Quality | <--- | Factors_BEV | 1.162 | .126 | 9.242 | *** | .876 |
| Price | <--- | Factors_BEV | 1.054 | .116 | 9.062 | *** | .835 |
| Advise | <--- | Future_pro | 1.000 | - | - | - | .678 |
| Buy | <--- | Future_pro | .484 | .155 | 3.121 | *** | .389 |
| Station | <--- | Factors_BEV | 1.047 | .126 | 8.294 | *** | .740 |
| Policy | <--- | Factors_BEV | 1.000 | - | - | - | .614 |
| Service | <--- | Factors_BEV | .968 | .111 | 8.691 | *** | .781 |

Note: *** means p-value < 0.001 is close to zero or equal to 0.000




CMIN=21.949, DF=14, P=.080, CMIN/DF= 1.568, GFI=.973, AGFI=.932, CFI=.990, RMSEA=.053

**Fig. 3** Factors influencing the interest in EVs related to the trend of using EVs in the future

In Figure 3, the test for the regression coefficient of latent variables after the model adjustment for harmonization found that the correlation weights (Standardized regression weights) of latent variables affected the choice of electric vehicles. (Factors_BEV) of people interested in using EV is between 0.348 and 0.894. Table 6 shows the heaviest component is electric charging stations (Station) (weight component equal to 0.894), followed by services from manufacturers/ distributors/service centers (Service) (weight component equal to 0.870), quality and standards of electric vehicles (Quality ) (weight component equal to 0.804), price of vehicles (Price) (weight component equal to 0.775), policies and measures to promote the use of electric vehicles (Policy) (weight component equal to 0.669), and awareness of pollution problems and Environment (Awareness) (weight component equal to 0.384), respectively. As for the future use of BEV by EV users, it was found that the variable with the heaviest component was the future purchase of battery electric vehicles (Buy) (component weight equal to 0.933) and time to switch to electric vehicles (Time) (component weight equal to 0.619). When considering the relationship between factors affecting the choice of EV (Factors_BEV) Moreover, the use of EV in the future (Future_pro) of people interested in using EV Affecting the use of EVs in the future, with squared multiple correlations (R2) of 0.09 or 9%, that is, the importance of factors affecting the choice of EV of those interested in using EV. There is an opportunity for people to become interested in using EVs. If they decide to buy, and there is a time to buy an EV in the near term, 9%. When considering the factors that affect the choice of EV, it was found that the component that weighed the most in the first three standardized regression weights are EV stations (Station), followed by manufacturers/ distributors/service centers (Service) and quality and standards of EVs (Quality). Build confidence for the public or people interested in using EVs to decide to buy more. Related agencies should develop EV stations to cover all areas. There are sufficient and thorough service points for electric charging stations. Next is the service from the manufacturer/distributor/service center. With several showrooms and EV service centers covering all areas able to facilitate access to EV showrooms/service centers of service users, the quality and standards of EVs with the development of a faster battery charging system and an average running distance per full charge have increased. Such factors will increase the confidence of those interested in using electric vehicles and help them decide to use more electric vehicles in the future.

**Table 6** Regression Coefficient Test of Latent Variables for EV interested user

| Variant | | | Regression Weights | | | | Standardized Regression Weights Estimate |
|---|---|---|---|---|---|---|---|
| | | | Estimate | SE. | CR. | P | |
| Future_pro | <--- | Factors_BEV | .129 | .034 | 3.748 | *** | .304 |
| Awareness | <--- | Factors_BEV | .435 | .088 | 4.930 | *** | .384 |
| Quality | <--- | Factors_BEV | .821 | .079 | 10.430 | *** | .804 |
| Price | <--- | Factors_BEV | .948 | .101 | 9.410 | *** | .775 |
| Buy | <--- | Future_pro | 1.000 | | | | .933 |
| Station | <--- | Factors_BEV | 1.246 | .134 | 9.273 | *** | .894 |
| Policy | <--- | Factors_BEV | 1.000 | | | | .669 |
| Service | <--- | Factors_BEV | 1.154 | .127 | 9.098 | *** | .870 |
| Time | <--- | Future_pro | 3.451 | 1.125 | 3.067 | *** | .619 |

Note: *** means p-value < 0.001 is close to zero or equal to 0.000

## 4. Conclusion and Discussion

Considering the relationships between the factors influencing the selection of EVs and the future use of EVs, it was found that giving importance to the factors affecting the selection of EVs significantly increased the likelihood of EV users recommending others to use EVs. Furthermore, there is a tendency for EV users to continue purchasing and using EVs, with 37% indicating their intention to do so. When considering the factors influencing the selection of EVs, the top three components with the highest standardized regression weights are the quality and standards of EVs, followed by the price of EVs and the service from manufacturers, dealers, or service centers. When considering the relationship between the factors influencing the selection of EVs and the future use of EVs among EV enthusiasts, it was found that giving importance to the factors affecting the selection of EVs significantly increased the likelihood of EV enthusiasts making the decision to purchase electric vehicles and having a shorter timeframe for making the purchase, with 9% indicating their intention to do so. When considering the components of the factors influencing the selection of EVs, the top three components with the highest standardized regression weights are electric charging stations, followed by service from manufacturers, dealers, or service centers, and the quality and standards of EVs.

From the results of developing collaborative usability features for EVs specifically tailored to the needs and preferences of potential users, an SEM analysis revealed that prioritizing factors influencing the choice of EVs could significantly increase the likelihood of users recommending EVs to others. Moreover, there is a trend indicating that users of EVs are more likely to consider purchasing and using EVs shortly. The top three factors influencing the choice of EVs are the quality and standards of EVs, followed by the price of EVs and the services provided by manufacturers/dealers/service centers. Therefore, it is crucial for relevant entities, including government agencies, private sectors, and businesses, to focus on enhancing the quality and standards of EVs. This includes developing the engine/system capabilities of EVs, increasing the average distance covered per full charge, reducing the battery charging time, and establishing legislation, regulations, and rules related to EVs in Thailand.

Regarding the charging infrastructure, factors influencing the choice of EVs include wired charging stations, services from manufacturers/dealers/service centers, and the quality and standards of EVs. Establishing more charging stations, especially in various districts of Chiang Mai, is essential to ensure convenient access to services for EV users, similar to the suggestion of Sathyan et al. [29] in India. Moreover, in terms of the price of EVs, reducing taxes or providing special privileges could attract more consumers to choose EVs. This is particularly important as the high prices of imported EVs remain significant for consumers.

Additionally, service aspects, such as showrooms and service centers for EVs, must be diversified and expanded to cover all areas. This is especially relevant for new or popular EV brands in the Thai market. Furthermore, organizing EV exhibitions, mainly held in Bangkok, should be extended to major cities to meet the growing demand for information about and experience with EVs. In conclusion, to develop user-friendly collaborative features for personalized EVs in line with user preferences, it is imperative for relevant agencies and stakeholders, both in the public and private sectors, to enhance the quality and standards of EVs. This includes focusing on EVs' engine/system capabilities, ensuring convenient access to charging stations, and providing diversified services in showrooms and service centers. These efforts will build confidence among the general public and potential EV users, encouraging them to choose EVs in the future.

A review of international research indicates that developing interoperability for PEVs to meet the needs and demands of consumers requires establishing policies and plans that prioritize the quality and standards of EVs [1]. Research on the environmental impact assessment of EVs in four major cities in China, namely Beijing, Shanghai, Guangzhou, and Shenzhen, revealed that most of the sample population, consisting of high-income individuals with private cars, believed electric vehicles could improve air quality. They also expressed willingness to pay more for EVs if they could replace conventional cars and contribute to reducing air pollution while still being affordable and meeting safety standards in line with the studies of factors affecting EV purchasing in Bangkok [20-23]. Therefore, to meet the demands of EV users, relevant organizations involved in environmental and EV policymaking should prioritize providing information and clarifying the environmental friendliness of EVs. It is worth noting that these four major cities in China have all experienced air pollution issues that have raised concerns about their health impacts. The adoption of electric vehicles is considered a significant strategy for reducing pollution. Appropriate infrastructure development should also be implemented to support the increasing use of EVs in urban areas. Moreover, providing financial support for continuous research and development of EV technology is crucial.

## 5. Recommendations

Based on the research findings, it is revealed that Chiang Mai is well-prepared to support the use of EVs, mainly through the collaboration of the government, private sector, electricity producers, entrepreneurs, and other stakeholders in driving the smart city strategy of Chiang Mai. The EVs database may need to be organized and utilized to design an appropriate Chaing Mai smart mobility [30]. The research revealed that the users and potential users of EVs have a positive perspective on choosing EVs, especially as a new technology that helps reduce environmental problems and air pollution. The trend of selecting EVs is highly likely to replace fossil fuel-powered cars. However, several elements currently hinder the widespread adoption of EVs, such as the high selling price, inadequate charging station coverage, long charging time, limited driving range, and limited service provided by manufacturers/dealers/service centers, mainly concentrated in the Bangkok metropolitan area. Meanwhile, the variety of service centers is limited in significant cities, especially in Chiang Mai.

### *5.1. Policy Recommendations*

The provincial government and central government agencies should focus on and prioritize the promotion and establishment of policies, measures, and plans related to the use of EVs, as follows:

- Promoting the affordability of EVs for the public through appropriate pricing measures, including tax incentives and non-tax measures. This can be achieved by implementing tax reductions for EV purchases, such as personal income tax deductions, annual corporate tax reductions, tax benefits for registration renewal, special expressway privileges, and special highway privileges.
- Promoting the use of EVs within government agencies by establishing measures and regulations for procuring EVs and batteries. This includes rules for procurement and centralized pricing by government agencies, ensuring compliance with the law and aligning with the objectives of the 30@30 policy. This initiative aims to build public confidence in EV usage and enhance the government's image as a leading organization in adopting all EVs.
- Develop infrastructure to support the use of EVs by implementing measures to install electric charging stations in public parking areas. These locations may include government premises, state agencies, residential buildings, condominiums, commercial buildings, and highway service areas.
- Establish a policy to systematically promote electricity production from solar energy and utilize electricity as the power source for EVs in a comprehensive cycle. This may involve promoting each household to generate electricity from solar energy installed on rooftops to charge EVs [31, 32].
- Establish plans for developing and promoting smart grid technologies, such as creating an information technology-based electricity network connected through smart meters, to enable EVs to support the Vehicle-to-Home (V2H) system efficiently in the future. This is an additional incentive for consumers using fuel-powered vehicles to transition to EVs.
- Promoting the capacity of entrepreneurs to develop technologies related to EVs is crucial. The government should have a research and development support plan to elevate entrepreneurs in the EV industry and components, particularly in high-performance EV batteries. Additionally, there should be mutual understanding and collaboration between the government and entrepreneurs regarding the continuously changing consumer behavior, preparing together to adapt to significant energy transitions. This includes plans to encourage entrepreneurs to adapt to the shift towards EVs and plans related to developing human resources and workforce.
- Accelerating the establishment of EV standards suitable for usage in Thailand and testing agencies that can provide comprehensive services in EVs.
- Like electronic waste management, establishing measures to control and manage end-of-life EVs and batteries may have future environmental implications.

Therefore, there should be specific management and control following international standards.

### 5.2 Practical Recommendations

Government agencies at the regional, provincial, and local levels, private sector, state enterprises (electricity producers), entrepreneurs, and stakeholders involved in promoting the use of electric vehicles in Chiang Mai should aim to enhance collaboration and drive the full implementation of EV utilization. This will serve as a model area for EV usage, promoting clean energy and reducing air pollution, including PM2.5 delicate particulate matter. The following activities should be carried out:

- Establish a plan to expand the network of charging stations that covers all areas in Chiang Mai and foster cooperation between service stations, retail stores, and restaurants to set up charging stations to attract consumers to utilize these services. Currently, charging stations are necessary, and the charging time is still relatively long.
- Drive local administrative organizations to become exemplars in EVs, allowing the public to learn and become aware of the benefits of using EVs.
- Coordinate cooperation with educational institutions and national and international EV organizations to establish regional learning centers. Develop an EV curriculum to produce and enhance qualified EV professionals. Collaborate in research on EVs that can be adapted and developed to suit the context of Thailand. Additionally, organize innovation competitions to provide opportunities for students and personnel to showcase their EV capabilities.

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