Factors Influencing Consumer Adoption of Electric Vehicles Replacements: A Case Study in Eastern Economic Corridor, Thailand

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ABSTRACT

The aim of this research was to examine the factors influencing the choice of electric vehicle service among car users in the Eastern Economic Corridor (EEC) who intend to transition to electric vehicles as part of Thailand's energy policy. This study employed quantitative research, using a one-time survey instrument for data collection, analyzed with both inferential and descriptive statistics. The results revealed that the choice of electric vehicle charging stations by EEC car users is consistent with marketing mix factors. Five factors, namely price, product, marketing promotion, distribution channel, and service, significantly affect the choice. Furthermore, the Physical factor (PH4, sig = 0.198) also had a 95% confidence level significance, primarily due to the issues of heavy rainfall and recurring flooding problems in some areas, which were inconsistent and impacted the decision-making of EEC car users who sought to use electric vehicle charging station services without attendant service in the future.

1. INTRODUCTION

In the Eastern Economic Corridor (EEC) region, which is densely populated and a significant contributor to Thailand's economy, it serves as a hub for industrial manufacturing facilities in the country. The region witnesses a substantial reliance on internal combustion engine vehicles for various mobility needs such as commuting to work and leisure travel, leading to air pollution concerns [1]. These circumstances have expedited the transition in the traditional automotive industry, which utilizes internal combustion engines, contributing to carbon dioxide (CO_2) emissions from vehicle operations, primarily resulting from the combustion of fossil fuel. Such emissions are a major source of air pollution and a key driver of global warming. Given the foreseeable depletion of fossil fuel reserves, many automobile manufacturers have begun developing electric vehicle technology and have actively introduced electric cars into the market. Consequently, the global electric vehicle market has witnessed a rapid growth rate, surpassing earlier expectations [2]. It is projected that electric vehicles will hold a 1-in-3 market share by the year 2025 and more than half, or 51%, by the year 2030. Within this share, electric vehicles powered by batteries and plug-in hybrid vehicles (PHV) are expected to account for approximately 25% each [3].

As previously discussed, both the impact of mitigating air pollution in the Eastern Economic Corridor (EEC) region and aligning with the expanding network of electric vehicle (EV) charging stations in the EEC area necessitate the objective of investigating the selection of EV charging stations by prospective users transitioning to electric vehicles in the future. This research is conducted employing a survey-based data collection methodology and analyzed using descriptive and inferential statistics. It involves examining the following marketing-related factors: 1. Product-related factors, 2. Service quality-related factors, 3. Pricing factors, 4. Distribution channel factors, 5. Marketing promotion factors, and 6. Physical characteristics. factors. Shown in Fig. 1. The dependent variable in this context is the decision to choose an EV charging station. This study aims to elucidate the decision-making behaviors in selecting EV charging stations that are likely to emerge in the future. This insight will serve as a strategic guide for designing new facilities soon to be opened, renovating existing locations, selecting business partners, and ensuring alignment with the future needs of electric vehicle users in the EEC region [4]-[6], [13]-[20].

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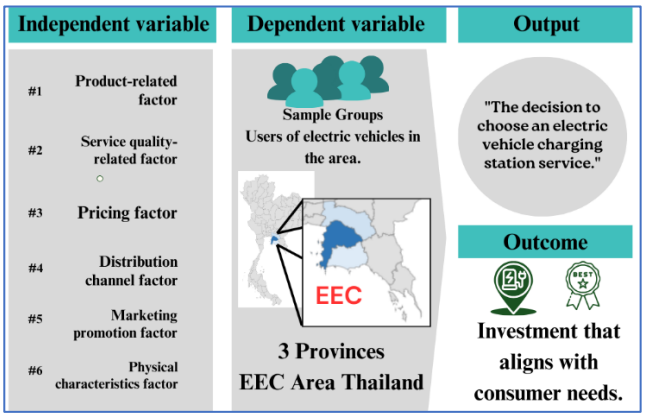


Fig. 1. Conceptual Framework.

2. LITTERATURE AND RELATED WORK.

2.1 Electric Vehicle Charging Stations (EVCS)

In preparation for the anticipated rapid expansion of the EV industry, it is imperative that critical infrastructure, such as EV charging stations, be adequately developed to accommodate future demands. Currently, there is a discernible trend in the deployment of charging stations in locations extending beyond residential areas. These diverse locations encompass gas stations, shopping malls, government facilities, and community malls, among other settings. As per the 2023 report published by the Electric Vehicle Association of Thailand, the country boasts a total of 1,479 charging stations, with the following distribution: (The characteristics of electric vehicle charging stations in Thailand, as depicted in the illustration, showcase service availability both during daytime and nighttime, as shown in Fig. 2).

1. MEA EV Charger Station: Comprising 34 stations with 138 charging heads, these stations are strategically located in Bangkok and its environs.

2. PEA VOLTA: Managed by the Provincial Electricity Authority (PEA), the PEA VOLTA network includes 264 stations featuring a total of 528 charging heads, incorporating 440 DC and 88 AC charging heads.

3. EleX by EGAT: This service is accessible at PT gas stations, with a current count of 50 branches, and it welcomes prospective long-term investors and landowners interested in establishing EV charging stations.

4. EVAT: The Electric Vehicle Association of Thailand (EVAT) offers a comprehensive online map showcasing the locations of all EV charging stations in Thailand, encompassing both public and private charging facilities.

5. PTTOR: The state-owned enterprise, PTT Public Company Limited, manages 362 EV Station PluZ charging stations across various regions, including Northern, Central, Northeastern, and Southern Thailand. Payment methods include credit cards and Blue Card loyalty points.

6. EA Anywhere: EA Anywhere, a service offered by the Provincial Electricity Authority (PEA), provides high-powered EV charging for Plug-in Hybrid Electric Vehicles (PHEVs) and Battery Electric Vehicles (BEVs) at a rate of 44 kW. The service integrates the 2C2P payment platform.

7. MG EV Charger Station: MG SUPER CHARGE is an application designed to assist users in locating and reserving MG electric vehicle charging stations, ensuring efficient and punctual charging services.

8. Tesla: Tesla offers an application for locating its Supercharger stations as well as other compatible charging stations on a global scale.

9. BMW EV Charger: This service, established in collaboration with BMW and Evolt, extends discounts to BMW PHEV and BEV owners when utilizing the BMW Charging Station network.

10. BYD: Rêver Automotive is an application tailored to collect vehicle data and facilitate the booking of charging stations located at nearby dealerships.

a) Example of EVCS Service in the Area (Midday).

b) Example of EVCS Service in the Area (Midnight).

Fig. 2. Example of EVCS.
Remark : Very thank you for the illustration provided by the PTT gas station (a) and the PT gas station (b).

Steps for Charging an Electric Vehicle are as follows:

1. Download and register in the respective service provider's app.

2. Plug the charging head into your vehicle.

3. Launch the app and scan the QR code on the charging head you wish to use.

4. Check the charging head and payment details upon completing the transaction.

5. Begin charging by pressing the 'Start Charging' button.

6. Press the 'Stop Charging' button when you want to end the charging.

7. Recheck the charging service summary.

8. Unplug the charging head from your vehicle and return it to the charger.

2.2 7Ps Marketing

The 7Ps of marketing is an extension of the traditional 4Ps marketing mix, which includes Product, Price, Place, and Promotion. The 7Ps add three more elements to better address the service-based industry and the overall customer experience. Here are the 7Ps of marketing shown in Fig.3 [7].

Fig. 3. 7Ps Marketing for EVCS uses evaluation.

The 7Ps Marketing framework encompasses various elements crucial for effective marketing strategy. The product, whether tangible or a service, forms the core offering, emphasizing the importance of aligning it with customer needs. Pricing involves a strategic assessment considering production costs, competition, and perceived value. Place, or distribution, pertains to the channels through which customers access the product or service. Promotion involves marketing and advertising strategies to raise awareness, encompassing advertising, public relations, and social media. People, particularly in-service industries, play a vital role, emphasizing the significance of employee attitude, competence, and training for customer satisfaction. Process involves the company's procedures and systems in delivering the product or service, with an efficient process positively impacting customer satisfaction. Physical evidence in service industries refers to tangible elements aiding customers in evaluating the service, such as the physical environment and appearance of employees.

2.2 Main objective and contributions

Ihis study, an examination of factors influencing consumers' decisions to use electric vehicle services as they transition to electric cars in the Eastern Economic Corridor (EEC) region of Thailand, a significant economic area of the country, was conducted. The research utilized a questionnaire-based survey to analyse seven distinct market-related factors. Notably, factors related to individuals (i.e., consumers) were excluded from the analysis, as electric vehicle users are typically self-service chargers.

2.3 Rerated work

The rerated work delves into significant subjects: 1. Elderly views on assistive device leasing, focusing on device attributes. 2. Photovoltaic EV charging's role in the smart grid with a dynamic pricing model. 3. An effective strategy aligning Plug-in EV charging with Fast Charging Station deployment, minimizing distribution system upgrades and highlighting FCS management and profitability as follow:

Article [8] explored elderly individuals' sentiments toward leasing assistive devices via a product service system and discerned the pivotal determinants influencing this choice. Employing logistic regression analysis, the investigation established that the utility of the "key attributes of leased assistive devices" profoundly affects their willingness. These findings offer valuable policy guidance and industry insights for crafting rental approaches for the elderly.

Article [9] emphasizes the growing importance of Electric Vehicles (EVs) within the smart grid, emphasizing the necessity of Photovoltaic (PV) charging stations to optimize domestic power consumption and advance sustainability. It proposes a dynamic pricing approach utilizing a Stackelberg game model for PV-equipped EV charging stations. The model considers EV user preferences and constraints associated with power consumption variability. The research establishes the existence and uniqueness of the Stackelberg Equilibrium, offering a distributed algorithm for its determination. Simulation outcomes validate the scheme's capacity to lower charging station expenses and augment profitability.

Article [10] presents an economically efficient method for coordinating Plug-in Electric Vehicle (PEV) charging demand with Fast Charging Station (FCS) deployment in the distribution system. It involves two phases. The first evaluates distribution system capacity to fulfill PEV charging needs, accounting for various charging types. The second phase optimally matches growing public PEV demand with FCS capacity, considering economic and service quality aspects. The findings suggest that substantial

distribution system upgrades are unnecessary to accommodate public PEV demand up to a 30% penetration level. Furthermore, the paper highlights FCS's role in managing PEV demand and offers tools for assessing FCS profitability.

In articles [11, 12], Electric Vehicles (EVs) are increasingly advocated for their potential to mitigate carbon emissions in urban settings. Fast charging stations play a pivotal role in replenishing EV batteries, requiring strategic placement to ensure accessibility within driving ranges. This paper proposes an analytical approach to determine optimal locations and sizes of fast-charging stations in Muang district, Nakhon Ratchasima, Thailand, considering various cost factors. It emphasizes the importance of developing public transport systems with EV integration to reduce fossil fuel consumption and air pollution. Additionally, it discusses the feasibility and challenges of fast charging stations in Nakhon Ratchasima, including infrastructure requirements and power system considerations to maintain stability amidst high-energy demands.

3. METODOLOGY

3.1 Sample population

The study's sample group was selected from a survey of Thai car drivers aged 18-65, holding valid driver's licenses, and expressing an inclination to transition to electric vehicles by the year 2030. The sample comprised 400 individuals. Sample size determination followed W.G. Cochran's formula (1953), with a non-probability convenience sampling approach. (Equation 1.)

$$n = \frac{\mathrm{P}(1-\mathrm{P})Z^2}{d^2} \quad (1)$$

$$n = \frac{0.5(1-0.5)(1.96)^2}{0.05^2}$$

$$n = 380.25,$$

where, n is the population size, P represent the signifies the proportion of the population that the researcher intends to sample (specified as 50% of the population), Z is corresponds to the confidence level predetermined by the researcher, with a value of 1.96 at a 95% confidence level (a significance level of 0.05) and d is the stands for the margin of error (used at a 5% margin of error).

3.2 Steps and Methods of Evaluation

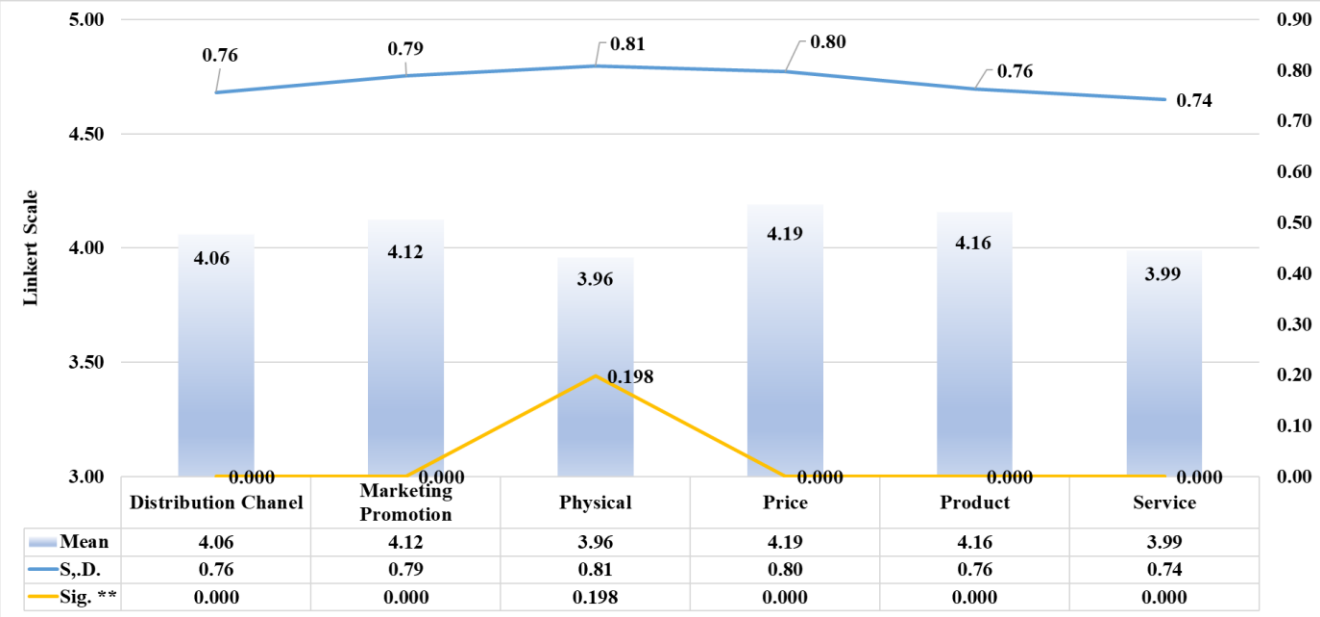
This study employs quantitative research methods and an online questionnaire created using Google Forms. The questionnaire comprises four sections:

1. Preliminary questions for screening.

2. Personal demographic information, with four multiple-choice questions.

Table 1. The details of the questions related to independent variables

Factors	Code	Description
Product	D1	The quality standards of EV chargers are superior when compared to other stations?
	D2	There are multiple types of chargers to choose from, such as standard chargers and fast chargers, among others?
	D3	The charger brands are reliable?
Service	S1	The charging stations offer convenient and fast services, including features like reservation and payment options?
	S2	The charging stations have various payment methods, and they may differ from other charging stations?
Price	P1	The price of electric car charging cheaper than that of competitors or not?
	P2	The price of electric vehicle is charging varies by time, such as during the day, at night, or not?
	P3	Is there a cost associated with booking an electric vehicle charger in advance?
Distribution Chanel	C1	Is there an adequate number of electric vehicles charging stations for service?
	C2	Is the number of charging stations greater than the competitors or not?
	C3	Charging stations are located within the community, making it easy to access without wasting time searching?
Marketing Promotion	M1	Does the application have a system for accumulating member points for redeeming rewards?
	M2	Sales promotions in collaboration with banks, such as receiving cashback when making payments with a credit card, are available.
	M3	Is there any public relation through advertisements or social media?
Physical	PH1	Is the electric vehicle charging station aesthetically pleasing and clean?
	PH2	Is there sufficient lighting and clear signage at the entrance at night?
	PH3	Is the restroom clean and adequately maintained?
	PH4	There is a roof to provide service during electric vehicle charging, whether it rains or not?
	PH5	Do electric vehicle charging stations have sufficient parking and convenient access points?



*Remark : Sig.** is α = 0.05*

Fig. 4. Graph illustrating the analysis of factors for choosing electric vehicle charging station services.

3. Questions about factors influencing the choice of using electric vehicle charging station services, consisting of 19 questions across 6 factors shown in Table 2. These questions utilize a Linkert Scale to measure responses on a 5-point interval scale: 0-1.49 = Least, 1.5-2.49 = Low, 2.5-3.49 = Moderate, 3.5-4.49 = High, 4.5-5 = Highest.

4. Questions regarding the decision-making process for choosing electric vehicle charging station services, comprising 6 questions. These questions also employ a Linkert Scale to measure responses on a 5-point interval scale: 0-1.49 = Least, 1.5-2.49 = Low, 2.5-3.49 = Moderate, 3.5-4.49 = High, 4.5-5 = Highest.

4. RESULT

This study involved gathering data through 413 survey questionnaires, which served as the research instrument to examine the factors impacting consumer adoption of electric vehicle replacements in a case study conducted within Thailand's Eastern Economic Corridor. Subsequently, the collected data underwent analysis and processing using inferential statistics.

4.1 Marketing mix components

Factors Influencing Consumer Adoption of Electric Vehicle Replacements: A Case Study in the Eastern Economic Corridor, Thailand, delved into six distinct marketing mix elements. The data was portrayed using measures of central tendency and dispersion. The findings demonstrated that price, product-related factors, and marketing and public relations aspects are the primary determinants affecting the selection of electric vehicle charging stations, as illustrated in Fig. 4.

Based on the findings depicted in Fig. 4, the study elucidates the hierarchy of factors influencing consumers. The foremost determinant is associated with pricing, specifically denoted as (P2), followed by (P3). The second-ranked determinant influencing consumers pertains to the product domain, with (D2) emerging as the primary consideration, followed by (D3) and (D1). The third-ranked determinant affecting consumers encompasses marketing and promotional aspects, delineated as (M3), (M2), and (M1) in descending order. In summation, consumers contemplating the adoption of electric vehicle charging stations prioritize factors such as unregulated pricing, a preference for enhanced marketing promotions, and apprehensions regarding the services offered by electric charging station operators. These concerns encompass issues related to quality, installation standards, and the stability of electrical power, potentially impacting the experience of electric vehicle users.

4.2 Marketing mix components

From the study of the marketing mix factors and their prioritization in influencing the choice of electric vehicle charging stations, as presented in Table 2.

Fig. 5. reveals a discernible correlation between the distribution of survey respondents within the designated area and the demographic composition of electric vehicle users. The foremost provinces, arranged in descending order based on their prevalence, include Chonburi, Chachoengsao, and Rayong.

Table 2. summarize the ranking of the importance of each question

Factors / Question Code	$\bar{x}$	S. D.	Ranking of Importance
Distribution Chanel	4.06	0.76	4
C1	4.16	0.72	6
C2	4.05	0.80	11
C3	3.96	0.74	17
Marketing Promotion	4.12	0.79	3
M1	4.05	0.74	14
M2	4.06	0.80	9
M3	4.25	0.83	1
Physical	3.96	0.81	6
PH1	4.25	0.76	3
PH2	4.16	0.72	6
PH3	4.05	0.80	11
PH4	3.28	1.00	19
PH5	4.05	0.74	14
Price	4.19	0.80	1
P1	4.06	0.80	9
P2	4.25	0.83	1
P3	4.25	0.76	3
Product	4.16	0.76	2
D1	4.25	0.76	3
D2	4.16	0.72	6
D3	4.05	0.80	11
Service	3.99	0.74	5
S1	3.96	0.74	17
S2	4.02	0.74	16
All Factor	**4.07**	**0.78**	**High**

4.3 One-way ANOVA analysis

The one-way ANOVA analysis with a normal distribution was conducted to find overall confidence in all 19 questions from the entire sample group of 413 sets. It revealed significant relationships in the same direction for all 18 questions except for the question where sig = 0.00 in the physical factor (PH4). The test results showed that the sig value for each question was greater than (α = 0.05) (PH4 found that sig. = 0.198). This implies that one of the factors influencing the choice of using electric vehicle charging stations is the need for stations to have rain protection, as the EEC area experiences heavy rainfall.

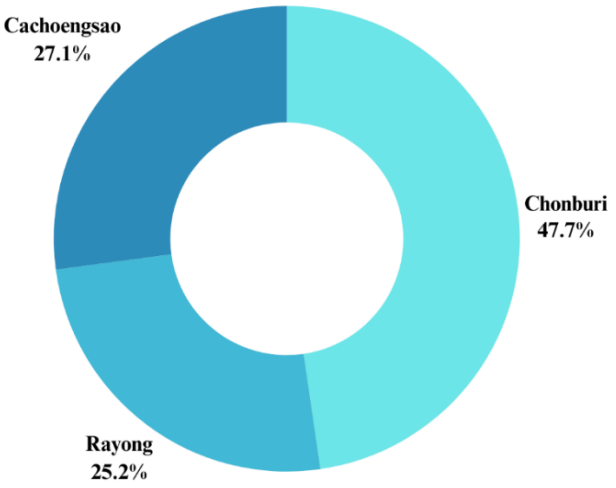


Fig. 5. the percentage of data for each province by users of electric vehicles in the EEC area.

5. 5. CONCUSSION

Through a comprehensive analysis of the marketing mix elements, it is discerned that all six factors exert a notable influence on the determinants of electric vehicle charging station service utilization within the Eastern Economic Corridor (EEC), as ascertained through survey-based investigations. The six pivotal factors that exhibit significant correlations with the adoption of electric vehicle charging station services are, in sequential order: price, product quality, marketing promotional activities, distribution channel accessibility, service quality, and physical infrastructure. Each of these factors substantively impacts the decision-making process regarding the utilization of electric vehicle charging station services. It is noteworthy that the EEC region is strategically envisioned as a Smart City, encompassing comprehensive developmental plans, namely the high-speed rail system (EECh), digital industry and innovation initiatives (EECd), the holistic medical industry growth strategy (EECmd), the industrial advancement schemes of the Eastern Economic Corridor (EECi), and the promotion of aviation-centric urbanization within the Eastern Economic Corridor (EECa). In light of the research findings, the alignment of urban planning with these forthcoming developmental blueprints is deemed imperative. Moreover, an elevation in service quality assumes significance as a source of competitive advantage for business entities operating in this context

In the context of prioritizing factors for enhancement, it becomes evident that the physical aspects claim precedence. This prioritization is underscored by the meteorological circumstances prevailing in the Eastern Economic Corridor, typified by recurrent heavy rainfall and subsequent flooding incidents. In response to these climatic exigencies, consumers assert that the provision of roofing structures at electric vehicle charging stations is a requisite, further underlining the need for flood risk mitigation

strategies. Notably, certain survey respondents emphasize the value of locating charging stations within shopping mall premises, as these indoor settings provide shelter from inclement weather conditions, thereby facilitating convenient electric vehicle charging procedures.

Nevertheless, it is imperative to note that in the course of conducting this quantitative inquiry, data collection is advocated through the use of structured interviews, encompassing diverse sample groups to accommodate the potential variation in service usage behaviors among stakeholders within the EEC region. Additionally, it is vital to recognize that beyond the identified factors, there may exist additional variables that exert influence on the decision-making process concerning electric vehicle charging station services. Consequently, an exploration of the self-service dynamics, particularly within the context of Thai cultural preferences that often involve service by attendants, assumes significance in understanding its relationship with service adoption.

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