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Sustainable Pathways for Electric Vehicle Adoption in Chiang Mai, Thailand: Readiness Assessment and Key Challenges

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Electric vehicle (EV) adoption is critical for achieving low-carbon urban mobility and mitigating greenhouse gas emissions. This study assesses the readiness of Chiang Mai, Thailand, for EV deployment by integrating qualitative interviews with 10 key organizations and quantitative survey data from 400 participants (200 EV users and 200 potential users). Findings indicate that 82% of respondents identified environmental concerns – particularly reducing PM2.5 air pollution – as their top motivation for EV adoption. This was followed by expectations of long-term cost savings (78%) and confidence in EV performance standards (74%). In contrast, 67% of non-users indicated high upfront costs as the primary barrier, 62% reported inadequate access to charging infrastructure in suburban and rural areas, and 58% exhibited limited awareness of EV incentives and policies. Policy evaluation revealed critical gaps in the implementation of Thailand's "30@30" target, including delays in financial incentives and insufficient regional infrastructure planning. To address these challenges, the study recommends targeted financial support for middle-income households, strategic expansion of charging networks in underserved areas, and increased public-private collaboration. The integration of smart grid technologies and renewable energy sources is also proposed to enhance grid efficiency and reduce long-term operational costs. By linking EV adoption to measurable environmental and economic outcomes, this research provides actionable insights for policymakers and a replicable framework for secondary cities in Thailand and comparable global contexts.

Keywords: electric vehicles, sustainable mobility, renewable energy integration, charging infrastructure, Thailand.

Introduction

Electric vehicles (EVs) are a cornerstone of global efforts to transition towards sustainable mobility, offering a viable solution for reducing greenhouse gas emissions and improving urban air quality. As cities worldwide grapple with the dual challenges of climate change and worsening air pollution, EV adoption has become integral to achieving environmental sustainability goals (International Energy Agency, 2024). EVs not only reduce reliance on fossil fuels but also contribute to healthier urban living conditions by curbing pollution from internal combustion engines (Marwa Ben Ali, 2022; Pamidimukkala et al., 2023; Tokito and Nakamoto, 2025; Umair, 2024; Zaino et al., 2024). Despite their potential, the adoption of EVs varies significantly across regions due to differences in infrastructure (Adamashvili and Thrassou, 2024; Klungsida et al., 2024; Pamidimukkala et al., 2023; Zaino et al., 2024), policy (Pamidimukkala et al., 2023; Umair, 2024; Zaino et al., 2024), and socio-economic factors (Marwa Ben Ali, 2022; Umair, 2024). Region-specific studies are essential to understanding these variations and designing effective interventions. Thailand is an important country in Southeast Asia, with Chiang Mai being a key city in the northern region, located 696 kilometres from Bangkok. Covering an area of 20 107.057 square kilometres, Chiang Mai is the largest province in the north and the second-largest city. It is known for its high potential and serves as a gateway to neighbouring countries, playing a central role in economic, industrial, and tourism development. The province with a population of 1 746 840 people, 785 999 households, and a population density of 86.88 people per square kilometre presents a compelling case for such an investigation. Known for its unique blend of urban growth and environmental challenges (Insan et al., 2022; Sathyan et al., 2024; Souissi et al., 2024), including severe seasonal air pollution from agricultural burning and vehicular emissions, Chiang Mai serves as an ideal setting to explore the dynamics of EV adoption in a rapidly developing city. The city's efforts to balance economic growth with sustainability objectives highlight the importance of tailored strategies that address localised barriers and drivers of EV adoption.

This study aims to assess Chiang Mai's readiness for EV adoption by identifying key factors influencing current and potential EV users. It integrates qualitative and quantitative approaches to provide a comprehensive understanding of the barriers and enablers within the local context. Specifically, the research seeks to:

1 evaluate the motivations and preferences of current EV users and intended adopters;
2 identify critical challenges, such as limited charging infrastructure and financial barriers;
3 examine the effectiveness of existing policies, including Thailand's "30@30" initiative, and propose region-specific improvements.

By addressing these objectives, the study contributes to the broader discourse on sustainable urban mobility and provides actionable insights for policymakers, industry stakeholders, and community leaders. The findings aim to guide the development of targeted strategies that not only promote EV adoption but also enhance the quality of life for Chiang Mai's residents. Additionally, the research offers a framework that can be adapted to similar urban contexts, facilitating the global transition to cleaner transportation systems.

Chiang Mai's case underscores the need for a holistic approach to sustainable mobility – one that integrates technological innovation, robust policy frameworks, and active stakeholder engagement. By focusing on localised solutions, this study emphasises the critical role of regional insights in overcoming the barriers to EV adoption and achieving long-term environmental and societal benefits.

Electric vehicle adoption trends

EVs have emerged as a pivotal component of global strategies to combat climate change and promote sustainable transportation. Worldwide, EV adoption has experienced a rapid increase, driven by policy incentives, technological advancements, and growing consumer awareness of environmental issues. For instance, countries such as Norway and the Netherlands have pioneered EV adoption through comprehensive policy frameworks, including subsidies, tax exemptions, and extensive charging infrastructure. China and the United States also lead in EV market growth, supported by their robust manufacturing capabilities and strategic investments in renewable energy integration with EV infrastructure (International Energy Agency, 2024). However, disparities in EV adoption persist due to factors like economic development levels, policy readiness, and public acceptance.

In Thailand, the promotion of EVs as a sustainable transportation solution began in 2015 with the National Reform Council's resolution to advance EV adoption. The Energy Efficiency Plan (EEP) 2015–2036 set a national target of deploying 1.2 million EVs by 2036, complemented by the development of 690 EV charging stations nationwide (Techakanont et al., 2019). Despite these efforts, the local adoption rate remains modest, largely constrained by high vehicle costs, limited charging infrastructure, and public hesitancy.

Existing infrastructure and policy frameworks

Thailand's EV promotion policies include a three-phase Energy-Driven Mission Plan. Phase 1 (2016–2017) prioritized public transport electrification, focusing on infrastructure readiness. Phase 2 (2018–2020) expanded public transport operations and prepared the groundwork for private EV adoption by introducing charging station standards, adjusting tariff structures, and incentivizing private investment. Phase 3 (2021 onwards) targets scaling private EV adoption through enhanced infrastructure, smart charging systems, and vehicle-to-grid (V2G) integration.

In 2021, the National Electric Vehicle Policy Committee introduced the "30@30" policy, aiming for zero-emission vehicles (ZEVs) to comprise at least 30% of the total vehicle production by 2030, driving Thailand towards a low-carbon future (Energy Policy and Planning Office, 2021). Announced on May 12, 2021, the policy set production and usage targets, including 440 000 passenger cars and pickup trucks, 650 000 motorcycles, and 33 000 buses and trucks. It also outlined plans for 12 000 public fast-charging heads and 1450 battery-swapping stations for electric motorcycles. To support this transition, measures were introduced to boost Thailand's EV manufacturing sector and establish standards for vehicles and key components. Workforce development and business adaptation strategies were also included. As part of the policy's implementation, the third/2021 and first/2022 committee meetings approved various EV promotion measures. On February 15, 2022, the EV Tax Incentive Package was launched, leading to tariff reductions and customs duty exemptions for fully assembled battery electric vehicle (BEV), announced on April 22, 2022, by the Ministry of Finance and the Excise Department. Additionally, on March 21, 2022, the Industrial Works Department issued regulations to support EV adoption in cars and motorcycles. These initiatives aim to make BEV more competitively priced against conventional vehicles (Energy Policy and Planning Office, 2021).

Additionally, the EV3.5 scheme (2024–2027) offers financial incentives, such as subsidies between 5000 and 100 000 Thai Baht (THB) for imported EVs, reduced import duties, and excise tax reductions, conditional on manufacturers commencing local EV production by 2026 (Apisitniran, 2024). Complementing these measures is the Master Plan for Thailand's Smart Grid System (2015–2036), which supports energy management advancements essential for EV integration. The mid-term phase (2025–2034) focuses on deploying distributed energy resources (DERs), energy storage systems, and EV charging networks, crucial for meeting Thailand's carbon neutrality goals by 2050–2065.

Despite significant progress, gaps remain in integrating EVs within Thailand's existing urban infrastructure. Inconsistent policy implementation and insufficient collaboration between stakeholders – government, private sector, and consumers – pose challenges. For instance, Kamkate's feasibility study highlighted that financial and policy support are critical for the long-term sustainability of EV infrastructure investments (Techakanont et al., 2019). Furthermore, consumer surveys indicate that while financial incentives can increase EV adoption, they must be paired with accessible charging networks and regulatory clarity (Kongklaew et al., 2021).

Region-specific barriers: the Chiang Mai context

Recent trends indicate a growing shift from internal combustion engine vehicles to electric alternatives, including battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and hybrid electric vehicles (HEVs). Collectively, these are often referred to as xEVs (a term encompassing all types of electric vehicles). *Fig. 1* shows Thailand's current electric vehicle status as of February 2024, with the number of xEV registrations in 2024: PHEV 1834, HEV 26 134, and BEV 22 278. *Fig. 2* shows an accumulated number of xEV registrations in 2020–2024: PHEV 55 782, HEV 369 532, and BEV 154 027 (Electric Vehicle Association of Thailand, 2024). Chiang Mai, a major northern province and economic hub in Thailand, faces unique challenges in EV adoption. The city has experienced rapid urbanisation, population growth, and increasing vehicle ownership. From 2020 to 2023, vehicle registrations in Chiang Mai

grew from 1 534 472 to 1 777 237 – a monthly increase of approximately 7300 vehicles as shown in *Table 1* (Transportation Statistics Group Planning Division of Department of Land Transport, 2020, 2023a, 2023b, 2023c). This rise has exacerbated traffic congestion and air pollution, with PM2.5 levels frequently surpassing safe thresholds, particularly during the dry season. These environmental issues have ranked Chiang Mai among the world's most polluted cities multiple times between 2019 and 2024 (Bank of Ayudhya Public Company Limited, 2024; Energy Policy and Planning Office, 2021).

Fig. 1. *A new number of xEV registrations (Electric Vehicle Association of Thailand, 2024)*

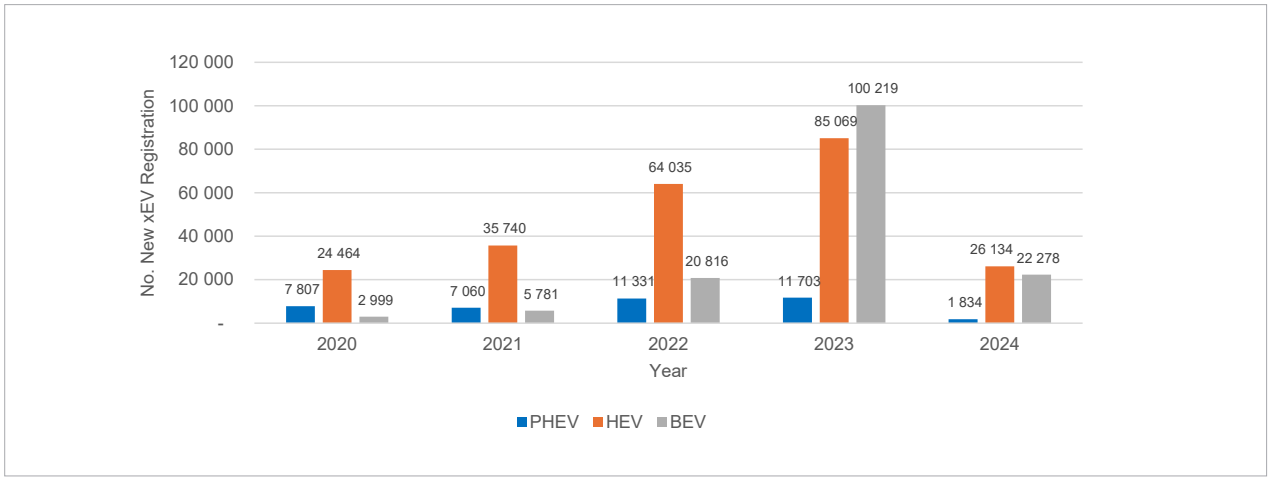
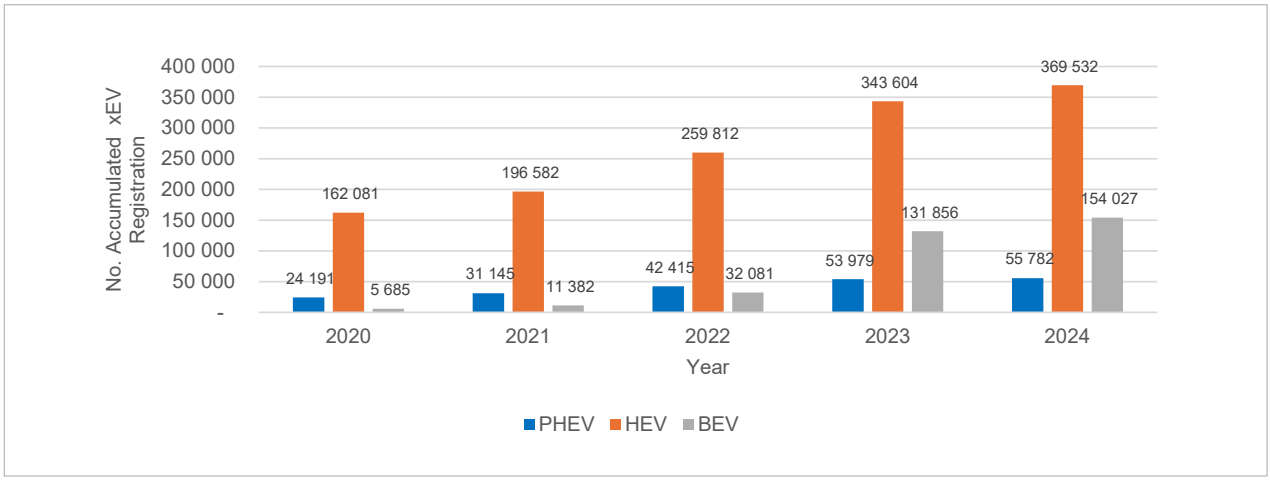


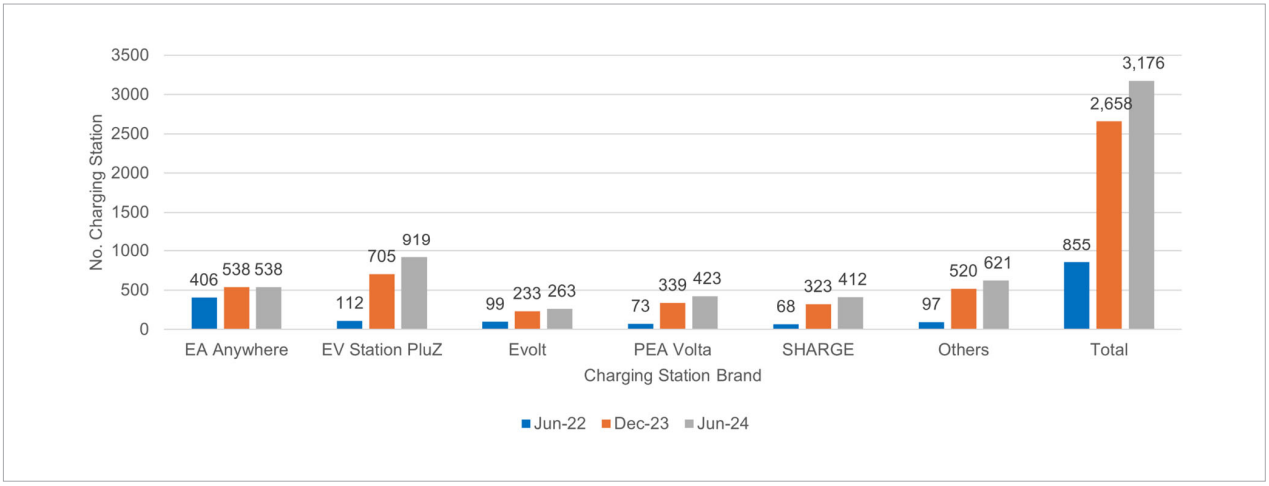
Fig. 2. *Accumulated number of xEV registrations (Electric Vehicle Association of Thailand, 2024)*



Although Chiang Mai has been designated a model city for EV promotion, several barriers hinder its progress. High upfront EV costs, limited availability of charging stations, and consumer concerns about battery range remain significant obstacles. By 2023, at least three service providers will provide permanent cross-network charging services (Electric Vehicle Association of Thailand, 2024).

Fig. 3 shows the number of public EV charging stations in Thailand. It rapidly grew from 855 stations in June 2022 to 2658 in December 2023 and 3176 in June 2024, not including public EV charging stations that serve only specific EV owners, e.g., Tesla Super Charger, MG Super Charge, etc. About 4% of total charging stations are in Chiang Mai (Energy Policy and Planning Office, 2024).

Fig. 3. *Number of public EV charging stations in Thailand (Energy Policy and Planning Office, 2024)*



Additionally, the local EV market is dominated by higher-income demographics, limiting widespread adoption. To address these issues, Chiang Mai requires targeted interventions, including expanded charging networks, financial incentives for lower-income groups, and enhanced public awareness campaigns.

Chiang Mai possesses significant renewable energy potential, particularly in solar photovoltaic (PV). With high solar irradiance averaging 5.0–5.5 kWh/m^2/day (DEDE, 2023) and based on this potential, an average PV array yield is 4.36–4.86 kWh/kW/day (Ketjoy et al., 2013). Chiang Mai has a 10% proportion of using renewable energy to total energy (Pongruengkiat et al., 2023); only a small fraction of this is linked to EV infrastructure. Therefore, there is significant potential for growth and expansion in the coming years for PV rooftop installations on public buildings, charging stations, and residential properties that can support decentralized EV charging. A feasible pathway involves solar-powered EV charging stations, combining rooftop PV with battery storage systems (Kitworawut et al., 2023). As confirmed by simulation studies (Sriboon et al., 2016), a decentralised solar-based EV charging system with battery storage shows how local energy generation can reduce strain on the national grid. This enhances energy resilience, particularly for rural or peri-urban areas where grid reliability is an issue. It empowers communities to take part in clean energy generation, reinforcing energy democracy. These insights support the advancement of sustainable, localised energy systems that are critical for the widespread adoption of EVs in secondary cities like Chiang Mai. Additionally, policies that encourage net metering and feed-in tariffs for EV-related solar generation could promote prosumer behaviour and reduce strain on the central grid (Krungsri Research, 2024; Leewiraphan et al., 2024a, 2024b). The synergy between renewable energy and EV adoption enhances environmental performance and increases local energy resilience, particularly important in a tourist-driven, mountainous region with logistical challenges.

Chiang Mai's strategic location as a tourism and economic hub offers significant potential for EV integration. The province hosts approximately 9.6 million tourists annually, generating significant revenue (Chiang Mai Provincial Office, 2019). Leveraging its tourism sector to promote EV adoption, such as implementing electric public transport or encouraging EV rental services, could yield substantial environmental and economic benefits.

Gaps in research on region-specific barriers

While global research has extensively covered EV adoption trends, region-specific studies, particularly in developing economies like Thailand, remain underexplored. Comparative research in environmentally progressive countries, such as Vassileva and Campillo's study in Sweden, demonstrated that policy incentives, renewable energy availability, and environmental awareness significantly influence EV adoption (Vassileva and Campillo, 2017). These findings highlight the importance of tailoring strategies to regional contexts.

In Thailand, existing studies focus predominantly on national-level policies and urban centres like Bangkok, neglecting the specific needs of secondary cities such as Chiang Mai. For instance, Sangaroon's survey in Bangkok emphasized the role of financial incentives and infrastructure in driving EV adoption but did not account for regional disparities in public acceptance or environmental challenges (Kongklaew et al., 2021). Similarly, while Kamkate's analysis provided insights into the economic feasibility of charging station investments, it did not explore localised barriers, such as consumer perceptions or geographic constraints (Techakanont et al., 2019).

Addressing these research gaps is critical for devising effective EV promotion strategies. Studies must examine the interplay of environmental challenges, consumer behaviour, and infrastructure readiness in secondary cities. In Chiang Mai, integrating EV adoption with air quality management and urban planning could provide a model for sustainable development. Moreover, understanding consumer hesitancy through behavioural studies could inform targeted interventions, such as subsidy schemes for middle-income groups or public-private partnerships to expand charging infrastructure.

EV adoption is integral to Thailand's transition to a sustainable and low-carbon society. While significant strides have been made at the national level, regional challenges, particularly in secondary cities like Chiang Mai, must be addressed to realise the full potential of EVs. Existing policies and infrastructure frameworks provide a solid foundation, but targeted interventions and region-specific research are essential to overcoming local barriers. By addressing gaps in infrastructure, enhancing public awareness, and tailoring policy measures to regional contexts, Thailand can accelerate EV adoption and achieve its sustainability goals.

Methodology

This study employs a mixed-methods approach, integrating qualitative interviews with key stakeholders and quantitative surveys targeting electric vehicle (EV) users in Chiang Mai. This methodology is designed to provide a comprehensive understanding of factors influencing EV adoption, encompassing infrastructure, stakeholder collaboration, and consumer perceptions. The mixed-methods approach ensures the triangulation of findings, enhancing the reliability and depth of the research.

Justification for selecting Chiang Mai

Chiang Mai was selected as the study site due to its unique combination of environmental challenges, urbanisation trends, and government-led sustainability initiatives. As a popular tourist destination and a regional hub, the city faces significant air pollution issues, particularly from PM2.5, which electric vehicles can help mitigate. According to a recent health impact assessment, long-term exposure to PM2.5 pollution in Thailand results in substantial public health risks (Mueller et al., 2021). Additionally, increasing ambient temperatures and reduced thermal comfort in urban outdoor environments have been documented in tropical regions, highlighting the compounded challenge posed by air pollution and heat stress (Sadakorn et al., 2025). Furthermore, Chiang Mai's strategic plans for integrating renewable energy and smart grid technologies align well with the study's focus on EV infrastructure and sustainable mobility. This setting provides a relevant and actionable context for exploring EV adoption in Thailand.

Data collection

The research employed two primary methods of data collection:

1. Qualitative interviews. Semi-structured interviews were conducted with representatives from government agencies, private sector organisations, and electricity service providers. The organisations were selected using purposive sampling to ensure their relevance to EV adoption efforts in Chiang Mai. The interviews aimed to gather insights into roles and responsibilities, infrastructure readiness, and challenges in promoting EV adoption. *Table 1* summarises the organisations involved in the interviews. Pre-determined questions facilitated active engagement, covering the following areas:
   - roles and responsibilities related to EV promotion;
   - readiness to support EV services and demand;
   - challenges and obstacles in developing EV infrastructure.

Table 1. *Sample organisations for interviews*

Sector	Organisations
Government	Chiang Mai Provincial Office, Chiang Mai Industrial Council, Chiang Mai Chamber of Commerce, Chiang Mai Municipality, Region 10 Energy Office, Chiang Mai Transport Office, Nakhon Ping Energy Research and Development Institute, Chiang Mai University
Private sector	FOMM Asia Co., Ltd., SCP Motorsport Co., Ltd. (Thailand), Basella Motors Chiang Mai Co., Ltd., Charoen Motor Benz Co., Ltd., MG Sales (Thailand) Co., Ltd., Thai Electric Vehicle Association
Electricity	Electricity Authority of Region 1 (Northern Region)

A total of 10 stakeholders were interviewed, and thematic coding was employed to analyse the qualitative data, identifying recurring themes and highlighting opportunities for stakeholder collaboration.

2. Quantitative surveys. Surveys were conducted randomly with 400 EV users and potential users residing in Chiang Mai province. Participants were identified through documentary and statistical data from the Department of Land Transport. The survey was designed to explore six key areas:

- general demographics;
- knowledge and understanding of EV technology;
- behaviour and decision-making processes;
- factors influencing EV adoption.
- challenges experienced by EV users;
- future trends and intentions regarding EV use.

The survey utilised a combination of Likert scales and open-ended questions, providing both quantitative and qualitative insights. Knowledge levels were categorised into three bands (low = 1.00–2.40, moderate = 2.41–3.40, and high = 3.41–5.00) based on a scoring framework derived from the Wadecharoen method (Wadecharoen, 2017). Data were statistically analysed using regression models to examine the impact of environmental awareness, financial incentives, and infrastructure availability on EV adoption. SPSS Statistics version 17.0 for Windows was employed for descriptive statistics and stakeholder response analysis

Data analysis

The study integrated qualitative and quantitative data to derive actionable insights:

- Qualitative analysis. Interview transcripts were thematically coded to identify patterns in stakeholder readiness, infrastructural challenges, and collaborative opportunities. The analysis highlighted critical barriers and enablers of EV adoption specific to Chiang Mai's context.
- Quantitative analysis. Survey data were subjected to statistical tests, including regression analysis, to evaluate the significance of key factors such as environmental awareness, financial incentives, and charging infrastructure availability. Results were used to test the study's hypotheses and assess the relative importance of each factor.
- Integration. Findings from both methods were synthesised to provide a holistic understanding of Chiang Mai's readiness for EV adoption. This approach enabled the formulation of targeted recommendations for stakeholders.
- The content validity of the in-depth interviews, analysed using the Item-Objective Congruence Index (IOC) based on the opinions of three experts, showed an index value of 0.78. The content validity analysis for the questionnaires intended for electric vehicle users resulted in an IOC value of 0.96. Likewise, the content validity analysis for the questionnaires aimed at individuals interested in using electric vehicles also yielded an IOC value of 0.96.
- Reliability was assessed using the Cronbach alpha coefficient. The reliability test for the questionnaire designed for electric vehicle users resulted in the Cronbach alpha value of 0.949. Similarly, the test for the questionnaire aimed at individuals interested in using electric vehicles yielded the Cronbach alpha value of 0.955.

Ethical considerations

The study adhered to rigorous ethical standards. Approval was obtained from the Human Subject Protection Committee (HSP) under the Naresuan University Institutional Review Board (IRB), COA No. 439/2021.

All research activities conformed to the Declaration of Helsinki, The Belmont Report, CIOMS Guidelines, and the International Conference on Harmonisation in Good Clinical Practice (ICH-GCP). Participants provided informed consent, and their data were anonymised to ensure confidentiality.

By combining qualitative and quantitative insights, this methodology provides a robust framework for assessing EV adoption in Chiang Mai, addressing both infrastructural and behavioural dimensions. The findings aim to guide policy and stakeholder strategies in advancing sustainable urban mobility in the region.

Results and Discussion

Stakeholder insights

Interviews with 10 key stakeholders revealed three major themes: (1) perceived benefits of EV adoption for reducing urban pollution, (2) infrastructure and policy challenges, and (3) the importance of public awareness and incentives. First, most stakeholders agreed that EVs offer a promising solution to air quality issues, especially concerning PM2.5 emissions. Several respondents referenced growing public concern over health impacts and environmental degradation. Second, challenges such as limited charging stations, unclear policy direction, and high upfront costs were frequently mentioned. Finally, stakeholders emphasised that public education campaigns and financial and non-financial incentives are critical for accelerating adoption. These insights are further elaborated below with representative quotes and observations from different stakeholder groups.

Infrastructure limitations. A consistent concern among stakeholders was the limited availability of charging stations, particularly outside Chiang Mai's central districts. While some progress has been made in establishing basic charging infrastructure, suburban and rural areas remain underserved, creating a significant barrier to widespread adoption. Stakeholders also noted the lack of advanced charging options, such as fast chargers, which limits convenience for EV users and raises concerns about range anxiety.

Policy and economic challenges. Stakeholders expressed concerns about inconsistencies in the implementation of EV-related policies. While national frameworks such as "30@30" provide high-level targets, the lack of clear, localised guidelines reduces their effectiveness. Moreover, delays in providing subsidies and tax incentives have discouraged investment in both EV infrastructure and consumer adoption. The high cost of EVs, driven largely by import duties and expensive components like batteries, was also identified as a major deterrent, particularly for middle-income groups.

Public awareness and perception. A recurring theme in the interviews was the low level of public understanding of EV technology. Stakeholders observed that many consumers lack awareness of the long-term benefits of EVs, such as lower operational costs and environmental advantages. Misconceptions about battery lifespan, maintenance costs, and the environmental impact of electricity generation further contribute to consumer hesitancy. Stakeholders emphasised the need for public education campaigns to address these gaps and build confidence in EV technology.

Opportunities for growth. Despite these challenges, stakeholders identified several opportunities to enhance EV adoption in Chiang Mai. Leveraging the city's tourism sector was highlighted as a potential driver for EV uptake, with incentives for EV use in tourism-related services, such as electric shuttles and rental cars, offering dual benefits of increasing visibility and reducing emissions. Furthermore, stakeholders emphasised the potential of public-private partnerships to accelerate infrastructure development. Collaborative efforts between government agencies, private investors, and energy providers could help distribute the financial burden of infrastructure expansion while ensuring accessibility in underserved areas.

Technology integration. Stakeholders also noted the importance of integrating emerging technologies to support the EV ecosystem. For instance, the adoption of vehicle-to-grid (V2G) technology and household solar rooftops were seen as promising solutions to enhance energy efficiency and reduce charging costs. Investments in local battery production and research and development for alternative battery technologies were also identified as long-term priorities to make EVs more affordable and accessible.

These insights reveal that while Chiang Mai faces significant challenges in its journey toward EV adoption, strategic initiatives and collaborative efforts among

stakeholders can address these barriers. Key areas for improvement include expanding charging infrastructure, streamlining policy implementation, and improving public awareness, all of which are crucial for creating a supportive ecosystem for EVs in Chiang Mai.

Quantitative survey results

Survey responses from 400 participants (200 EV users and 200 potential users) provided critical insights into consumer behaviour and preferences as follows.

Demographic trends. Fig. 4 shows that the majority of respondents were men (74.5%), and *Fig. 5* shows that the largest age group was 30–40 years (33.0%), followed by 41–50 years (28.5%). In *Fig. 6*, most were married (50.0%), while 47.0% were single. Regarding education, 62.0% held a bachelor's degree, 20.5% had lower qualifications, and 17.5% had higher degrees, as seen in *Fig. 7*. *Fig. 8* demonstrates that the largest occupational group consisted of private company employees (34.5%), followed by business owners (24.5%) and civil servants (15.0%). Income distribution in *Fig. 9* showed that 40.5% earned between 20 000 and 40 000 THB per month, 25.5% earned less than 20 000 THB, and 34.0% earned more than 40 000 THB. *Fig. 10* shows that most participants resided in Mueang Chiang Mai District (54.0%), while 39.0% lived in suburban districts within 15 km, such as Mae Rim, San Sai, and Hang Dong. Only 7.0% lived in outer districts more than 15 km away. Additionally, most users were using EVs for one to five years without encountering any issues.

Fig. 4. *Number of respondents classified by gender (author's survey, 2024)*

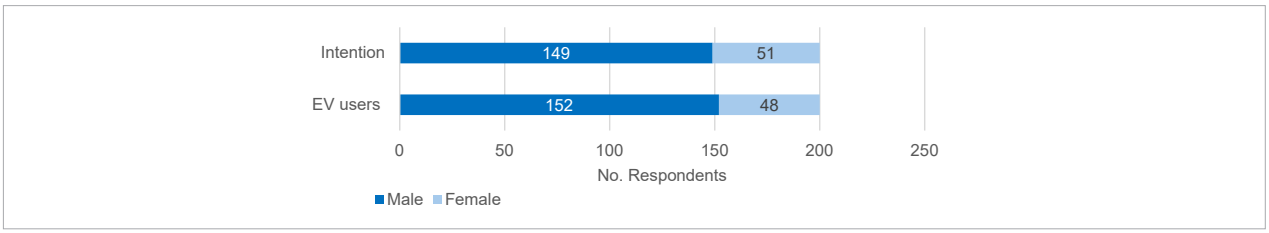


Fig. 5. *Number of respondents classified by age (author's survey, 2024)*

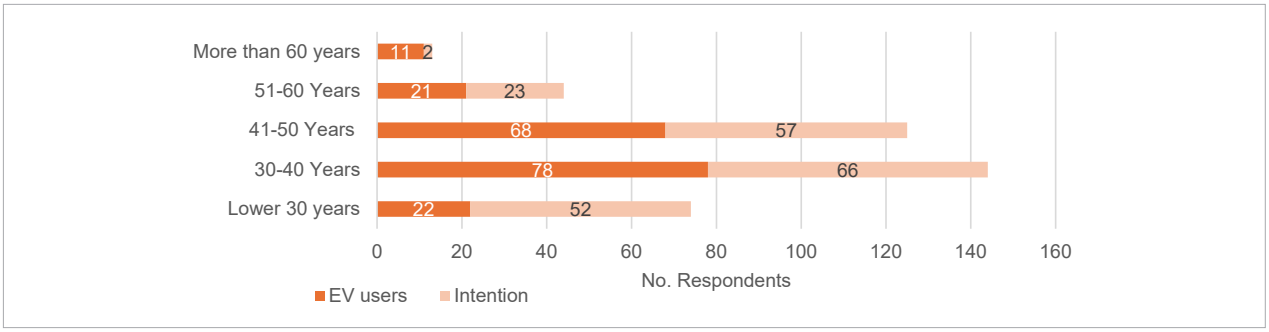


Fig. 6. *Comparison of EV users and Intentions classified by respondent status (author's survey, 2024)*

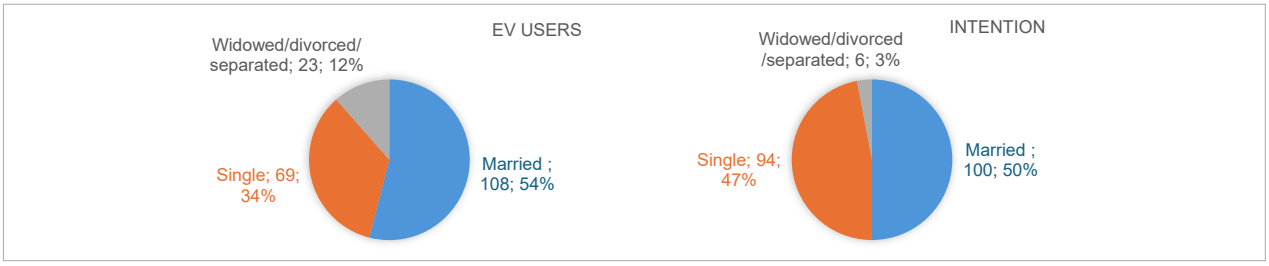


Fig. 7. *Percentage of respondents by education level (author's survey, 2024)*

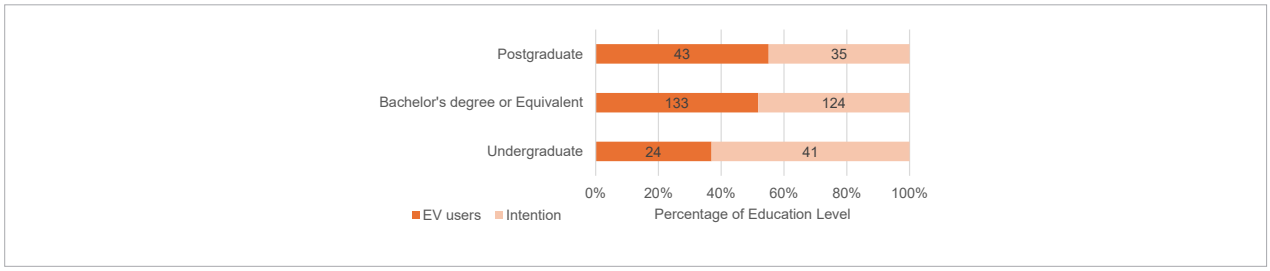


Fig. 8. *Percentage of respondents by occupation (author's survey, 2024)*

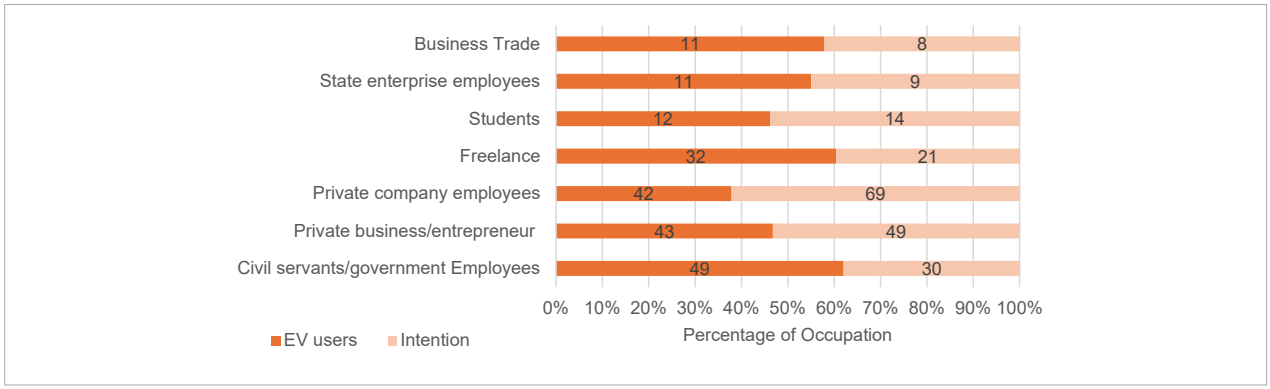


Fig. 9. *Comparison of EV users and Intentions classified by respondent's average monthly income (author's survey, 2024)*

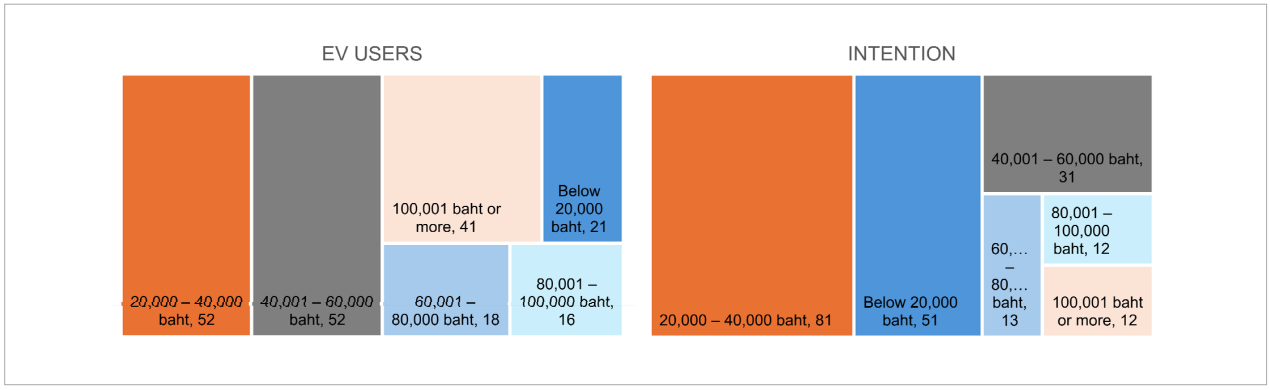
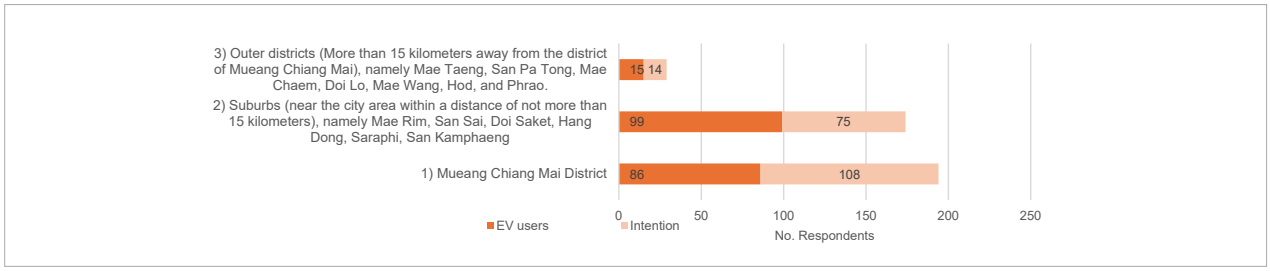


Fig. 10. *Number of respondents classified by residential area (author's survey, 2024)*



Key motivators. The study highlights several critical motivators for electric vehicle (EV) adoption among current users and potential adopters in Chiang Mai.

1 *Environmental concerns*. Environmental benefits, particularly the reduction of PM2.5 pollution and noise pollution, emerged as top motivators. Over 80% of respondents prioritised these factors, with mean scores of 4.04 for potential users and 3.97 for current users. The perception of EVs as environmentally friendly and a tool for improving Chiang Mai's air quality strongly influenced interest.
2 *Economic savings*. Fuel cost savings were rated as a major incentive, with mean scores of 4.05 for current users and 4.11 for potential adopters. Rising fuel prices have heightened interest in EVs, particularly as respondents recognised the long-term cost efficiency of EV ownership.

In addition to environmental motivations, economic incentives are crucial in influencing EV adoption decisions. In Thailand, BEV prices range between 700 000 to 1.8 million THB, depending on the model and battery size. Government incentives introduced in 2022–2023, including direct subsidies ranging from 70 000 to 150 000 THB per vehicle and import tax reductions, have lowered the effective purchase cost. When comparing long-term ownership, BEVs offer significant savings in fuel and maintenance. For example, an average user driving 15 000 km/year may save approximately 20 000–25 000 THB annually on fuel and 8000–10 000 THB on maintenance compared with a gasoline vehicle. Over a 10-year period, the total cost of ownership (TCO) for BEVs becomes competitive or lower than that of conventional vehicles, especially when subsidies and rising fuel prices are considered (Champeecharoensuk et al., 2025). However, high upfront costs and limited second-hand EV market options remain barriers. Additional local incentives – such as parking privileges, toll waivers, or income tax deductions – could further improve the economic attractiveness for end users.

3 *EV quality and standards*. The quality and reliability of EVs, including advanced manufacturing technology (mean: 3.99 for potential users, 3.88 for current users) and battery performance, were highly valued. Features such as battery lifespan, engine performance, and supported charging systems were crucial in building consumer confidence.

In addition to domestic policies and market incentives, international investments and collaborations, such as sister-city relationships and global trade agreements, are increasingly seen as essential drivers for promoting sustainable urban transitions, including electric vehicle (EV) adoption. These partnerships often facilitate knowledge exchange, joint pilot projects, and co-investment opportunities in infrastructure and technology. For example, recent findings highlight how Thailand's sister-city arrangements have not only strengthened diplomatic and cultural ties but have also supported environmental and smart city initiatives through technical cooperation and shared sustainability goals (Prasittisopin et al., 2024). Such collaborations can help local governments access external funding and expertise, thereby accelerating innovation in mobility and clean energy sectors.

Table 2. *Summary of survey-based factors affecting the choice of EV users and intention*

Factors	EV users			Intention		
		SD	Evaluation		SD	Evaluation
Policies and measures to promote the use of EVs	3.15	1.12	moderate	3.34	1.22	moderate
Awareness of pollution and environmental problems	3.97	1.07	high	4.04	0.92	high
Quality and standards of EVs	3.76	0.91	high	3.91	0.83	high
EV prices	3.42	0.87	high	3.66	1	high
Electric charging stations	3.34	0.98	moderate	3.52	1.14	high
Service from the manufacturer/ distributor/service centre	3.35	0.85	moderate	3.48	1.08	high
Overview	**3.5**	**0.79**	**high**	**3.66**	**0.82**	**high**

The collected scores represent stakeholder evaluations using a 5-point Likert scale (1 = very low, 5 = very high). Depending on the question category, the scores reflect perceptions of importance, feasibility, or agreement. The average scores indicate overall stakeholder consensus on each factor.

Table 2 shows the summarised stakeholder evaluation scores. It was revealed that the selection of EVs of the samples of EV users was at a high level, with an average of 3.50. When considering each side, it was found that the highest score was attributed to the factors in awareness of pollution and environmental problems, followed by quality and standards of EVs and automotive prices. It is crucial to select EVs at a considerable level. The total mean was 3.97, 3.76, and 3.42, respectively, while the factor of service from manufacturers / distributors / service centre electric charging stations and policies and measures to promote the use of EVs is important to the moderate selection of EVs. The total mean was 3.35, 3.34, and 3.15, respectively.

Barriers. Despite significant interest, the study identified several barriers impeding EV adoption in Chiang Mai:

1 High vehicle costs. The cost of EVs was a major barrier, particularly due to high import taxes and expensive components like batteries. Current users rated the cost factor at a mean of 3.42, while potential users rated it at 3.66. Affordability concerns were exacerbated by limited financial incentives and a lack of accessible financing options, such as leasing programs.

2 Limited charging infrastructure. Accessibility to charging stations remains insufficient, particularly in suburban and rural areas. While charging station safety and convenience were rated highly (mean: 3.70 for current users, 3.82 for potential adopters), the overall availability of charging facilities scored only moderately (mean: 3.34 for users, 3.52 for potential users). This gap contributes to range anxiety, a key deterrent to adoption.

3 Policy implementation challenges. Policies to promote EV adoption, such as tax reductions and public-private collaboration, were rated moderately effective, with mean scores of 3.15 for users and 3.34 for potential users. Stakeholders cited delays and inconsistencies in policy implementation as significant obstacles. The ambitious of "30@30" national strategy has led to policy instruments such as tax incentives, EV promotion packages (2022–2025), and industrial investment support via the Board of Investment (BOI). While these efforts have accelerated EV production and sales – especially in Bangkok and the Eastern Economic Corridor (EEC) – localised adoption in cities like Chiang Mai remains modest. Interviews revealed a gap between national goals and local capacity. Chiang Mai currently lacks a formal municipal EV strategy or regulatory roadmap aligned with the "30@30" agenda. Infrastructure readiness, especially public charging stations, is limited. Additionally, stakeholders expressed concerns over the lack of budget decentralisation and capacity-building programmes for provincial governments. Therefore, while the "30@30" policy sets a clear vision at the national level, its translation into subnational action requires stronger coordination, tailored incentives, and regional pilot programs. Enhancing provincial-level planning and encouraging public-private partnerships could help bridge this policy-implementation divide.

Awareness levels. The study revealed moderate awareness levels among respondents, with knowledge of EVs averaging 7.5 on a 13-point scale.

1 Current users. Current users demonstrated relatively higher awareness of EV technology, benefits, and functionality. They valued environmental and economic advantages but noted gaps in understanding long-term maintenance costs and charging infrastructure.

2 Potential adopters. Potential adopters expressed interest in EVs but highlighted limited knowledge as a barrier to purchase. Many were unfamiliar with the operational benefits, available incentives, and costs associated with EVs. This lack of information contributed to hesitancy, particularly among middle-income groups.

Environmental concerns, economic savings, and EV quality are the primary motivators for adoption in Chiang Mai. However, high costs, limited charging infrastructure, and moderate awareness levels remain significant barriers. Addressing these challenges through targeted educational campaigns, expanded charging networks, and pricing incentives will be crucial in boosting EV adoption. Enhancing consumer knowledge and addressing misconceptions about EVs can further

bridge the gap between interest and action, positioning Chiang Mai as a leader in sustainable mobility.

Barriers to adoption

Despite strong motivators for EV adoption, several significant barriers hinder its widespread uptake in Chiang Mai:

1 High vehicle costs. EVs are perceived as expensive, primarily due to high import taxes and costly components like batteries, which account for 30–40% of the vehicle price. The mean scores of 3.42 for current users and 3.66 for potential adopters highlight affordability as a key concern, particularly among middle-income groups. The lack of comprehensive subsidies or flexible financing options further exacerbates this issue, restricting EV accessibility to a narrower demographic. However, EV prices could become more affordable if Thailand establishes a battery production base or invests in the research and development of alternative battery technologies. Such efforts would require collaboration between the government, private sector, and stakeholders in the automotive industry. Increasing global awareness of EVs and the adoption of clean energy alternatives are already being actively promoted worldwide, driving positive outcomes in reducing environmental impacts (Lin and Tan, 2017). In Thailand, household solar rooftops are becoming increasingly cost-effective and accessible (Leewiraphan et al., 2024a, 2024b), representing a significant factor in transitioning from conventional fuel-powered vehicles to EVs. The adoption of innovative technologies and alternative energy solutions is expected to lower battery costs, reduce charging times, and make EVs more practical and affordable in the near future (Manjula et al., 2022; Manutworakit and Choocharukul, 2022; Mohammadreza, 2021). These advancements underscore the importance of enhancing Chiang Mai's capacity for effective EV planning and deployment. By aligning with these technological and economic shifts, Chiang Mai can address affordability barriers, support widespread EV adoption, and position itself as a leader in sustainable urban mobility.

2 Limited charging infrastructure. Inadequate charging station coverage, especially in suburban and rural areas, contributes to range anxiety and reduces the appeal of EVs. Current users rated charging station availability at a mean of 3.34, while potential users gave it 3.52. Key issues include the limited number of stations, uneven distribution, and insufficient support for various EV brands. Stakeholders also highlighted the need for fast-charging facilities to address user convenience.

3 Policy implementation gaps. Policies promoting EV adoption, such as tax incentives and public-private partnerships for charging infrastructure, are not fully effective due to delays and inconsistent local execution. The moderate mean scores of 3.15 for users and 3.34 for potential users reflect a lack of clarity and accessibility in these initiatives. Stakeholders reported challenges in aligning national strategies with regional needs and ensuring policy awareness among consumers.

4 Knowledge gaps and misconceptions. Limited consumer understanding of EV technology, benefits, and operational costs hinders adoption. Potential adopters cited concerns about battery performance, maintenance costs, and the environmental impact of electricity generation, which contributed to their hesitancy.

Oslo, Norway, is widely recognised as a global leader in electric mobility, where over 80% of new cars sold in 2023 were electric. Key drivers include generous incentives (e.g., tax exemptions, free parking, bus-lane access), a strong charging infrastructure network, and clear long-term policies (Budnitz et al., 2025). Importantly, Oslo's success emphasises consistency in policy direction and coordinated urban planning – elements that Chiang Mai can adopt at a smaller scale. Phuket, Thailand, a major tourism destination in southern Thailand, has recently launched a pilot electric public transport initiative through collaboration with private sector partners. The project includes electric tuk-tuks and shuttle buses in high-tourist-traffic zones, supported by targeted provincial subsidies and investment incentives. This showcases the potential of leveraging tourism-based demand and public-private partnerships – an approach also relevant to Chiang Mai.

These case studies demonstrate that effective EV adoption requires a combination of visionary policy, financial mechanisms, infrastructure planning, and stakeholder collaboration, all of which can be adapted and localized to suit Chiang Mai's socioeconomic and environmental context.

Recommendations

To address the identified barriers and promote sustainable EV adoption, the following recommendations are proposed:

1. Reduce EV costs
- Subsidies and incentives: introduce targeted subsidies for EV purchases and reduce import duties and taxes on EVs and batteries; focus on incentivising middle-income groups to broaden adoption.
- Flexible financing options: develop affordable leasing programmes and low-interest loans to reduce the financial burden of EV ownership.

2. Expand charging infrastructure
- Phased deployment: prioritise high-traffic areas in the initial phase, followed by suburban and rural zones; collaborate with local governments and private investors to ensure balanced coverage.
- Fast-charging stations: increase the availability of fast chargers at key locations to reduce charging time and enhance user convenience.
- Integration with renewable energy: promote solar-powered charging stations to improve sustainability and reduce operational costs.

3. Strengthen policy implementation
- Streamline incentives: simplify the process for accessing tax benefits and subsidies, ensuring clear guidelines for eligibility and application.
- Public-private collaboration: establish dedicated regional task forces to align national policies with local infrastructure needs and ensure seamless execution.
- Enhance electric vehicle affordability through pricing strategies, including tax and non-tax incentives. Measures may include personal income tax deductions, corporate tax reductions, registration tax benefits, and special expressway or highway privileges.
- Develop smart grid plans, integrating IT-based electricity networks and smart meters to enable efficient vehicle-to-home (V2H) support. This serves as an added incentive for consumers to switch from fuel-powered to electric vehicles.

4. Enhance consumer awareness
- Educational campaigns: launch awareness initiatives focusing on the economic and environmental benefits of EVs. Use air quality issues in Chiang Mai, particularly PM2.5 pollution, as a key theme to drive public interest.
- Knowledge hubs: develop online platforms and workshops to provide detailed information about EV technology, maintenance, and available incentives.
- Success stories: showcase testimonials from existing EV users to build trust and confidence among potential adopters.

5. Foster stakeholder collaboration
- Public-private partnerships: encourage partnerships between government agencies, private companies, and energy providers to share the financial and operational burden of infrastructure development.
- Capacity building: provide training for local officials and stakeholders to improve their understanding of EV technologies and policies.
- Given shifting consumer behaviour influenced by economic and societal factors, as well as varying access to and acceptance of EV technology, comparative studies across age groups are essential to understand EV adoption.
- The shift to a fully electric vehicle industry will affect oil service stations and fossil fuel-based businesses. Studying adaptation strategies is key to supporting industries linked to EVs.

By adopting these strategies, Chiang Mai can address high costs, infrastructure gaps, and moderate awareness levels, promoting sustainable EV adoption. These actionable insights offer a replicable framework for other cities facing similar challenges, advancing environmental, economic, and public health goals globally.

While this study focuses on Chiang Mai, many of the key findings, such as the importance of stakeholder engagement, infrastructure readiness, and cross-sector collaboration, are applicable to other cities facing similar challenges. For instance, Bangkok, as Thailand's capital, shares common issues with air pollution, traffic congestion, and the need for EV infrastructure. The strategies identified in this study, such as incentivising private sector investment and leveraging international partnerships, could be scaled to fit Bangkok's larger population and more complex governance structure. Similarly, Singapore offers a relevant comparison due to its emphasis on smart mobility, stringent environmental regulations, and regional leadership in EV adoption. Although Singapore operates under a different policy regime and urban scale, the emphasis on integrating EV adoption with broader urban sustainability goals is aligned. Lessons from this study could

inform city-level strategies in Bangkok and Singapore, particularly in tailoring public awareness campaigns, urban planning, and incentive structures to local socio-economic contexts.

To enrich the local findings, Chiang Mai's EV adoption readiness is compared with other secondary cities in Southeast Asia, namely Khon Kaen (Thailand) and Da Nang (Vietnam). Khon Kaen shares similar socioeconomic characteristics as a second-tier Thai city with a focus on smart city development (Chindaprasirt et al., 2024). While Chiang Mai is more advanced in tourism-driven EV adoption, Khon Kaen is ahead in integrating EVs into public transit systems, such as its Smart Bus project. Da Nang also faces seasonal air pollution and high tourism traffic. The Vietnamese government is supporting city-wide electrification through partnerships with international organisations (Van Dai, 2024). Da Nang's incentive structure and charging infrastructure planning can serve as a reference for Chiang Mai. These comparisons suggest that while Chiang Mai benefits from early adopter behaviours among tourists and certain public-private initiatives, the city could learn from peers in terms of public transit electrification, integrated EV urban planning, and leveraging international partnerships.

Conclusion

This study assessed the readiness for electric vehicle (EV) adoption in Chiang Mai, Thailand, through a mixed-methods approach combining stakeholder interviews and a survey of 400 EV users and potential adopters. The findings underscore Chiang Mai's considerable potential to transition toward sustainable urban mobility, while also highlighting the distinct regional challenges that must be addressed to accelerate EV uptake.

Three primary drivers of EV adoption emerged: heightened environmental awareness, particularly concerning PM2.5 air pollution and rising urban temperatures, economic savings from long-term ownership, and improvements in EV technology and quality standards. However, these drivers are counterbalanced by significant barriers: high upfront vehicle costs, limited charging infrastructure outside city centres, and moderate public awareness regarding EV benefits and incentives.

The study reveals a misalignment between national-level strategies, such as the "30@30" policy, and local implementation in Chiang Mai. Stakeholders noted gaps in municipal-level planning, decentralised budgeting, and access to supporting infrastructure. This limits the effectiveness of national initiatives in secondary cities and calls for tailored, region-specific policies and decentralised coordination mechanisms.

Importantly, the integration of renewable energy, particularly solar PV, with EV charging infrastructure was identified as a key opportunity to enhance environmental and economic sustainability. Chiang Mai's solar potential and growing tourism sector present unique opportunities for developing solar-powered charging stations and green transport solutions in high-traffic zones.

International examples, such as Oslo and Phuket, demonstrate the value of consistent policy frameworks, targeted incentives, and strong public-private collaboration. Drawing on these lessons, Chiang Mai can advance EV adoption through region-specific financial incentives, fast-charging network expansion, public awareness campaigns, and integration with renewable energy systems.

While this research is localised, its insights offer broader applicability to other urban areas facing similar environmental, infrastructural, and economic constraints. Future research should explore cross-regional comparisons and develop scalable, evidence-based models for sustainable transport in the context of rapidly urbanising secondary cities across Southeast Asia and beyond.

References

Adamashvili N., and Thrassou A. (2024) Towards Sustainable Decarbonization: Addressing Challenges in Electric Vehicle Adoption and Infrastructure Development. *Energies 17*(21): 5443. Available at https://www.mdpi.com/1996-1073/17/21/5443

Apisitniran L. (2024) Taking a closer look at the EV expansion. *Bangkok Post*. Available at https://www.bangkokpost.com/business/motoring/2755189/taking-a-closer-look-at-the-ev-expansion (accessed 12 Decmeber 2024).

Bank of Ayudhya Public Company Limited (2024) *Thailand Industry Outlook 2024-2026*. Available at https://www.krungsri.com/en/research/industry/summary-outlook/industry-outlook-2024-2026 (accessed 12 Decmeber 2024).

Budnitz H., Jaskólski M., Knapskog M., Lis-Plesińska A., Schmidt F., Szymanowski R., der Craats J. v., and Schwanen T. (2025) Multi-level governance and modal thinking: Tensions in electric mobility transitions in European cities. *Transport Policy 160*: 63-72. Available a https://doi.org/https://doi.org/10.1016/j.tranpol.2024.10.035

Champeecharoensuk T., Saisirirat P., Chollacoop N., Vithean K., Thapmanee K., Silva K., and Champeecharoensuk, A. (2025) Total cost of ownership (TCO) analysis of electric vehicle in ASEAN. *Energy for Sustainable Development 85*. Available at https://doi.org/https://doi.org/10.1016/j.esd.2024.101650

Chiang Mai Provincial Office. (2019) *Chiang Mai Province Information Year 2019*. Available at https://www.chiangmai.go.th/english/index.php/welcome/information (accessed 15 Decmeber 2024).

Chindaprasirt P., Klungboonkrong P., Jaensirisak S., Faiboun N., Long S., Tippichai A., and Taylor M. A. P. (2024) Integrated Urban Transport and Land-Use Policies in Reducing CO_2 Emissions and Energy Consumption: Case Study of a Medium-Sized City in Thailand. World Electric Vehicle Journal 15(8): 349. Available at https://www.mdpi.com/2032-6653/15/8/349

DEDE (2023) *Solar Radiation Map of Thailand from Setellite Data 2020*. Available at https://gis.dede.go.th/upload/20230302_135735.pdf

Electric Vehicle Association of Thailand (2024) *Thailand electric vehicle current status as of February 2024*. Available at https://evat.or.th/images/evinfo/current-status/2024-03/02-2567-EVAT.pdf (accessed 12 Decmeber 2024).

Energy Policy and Planning Office (2021) *EV policy meeting*. Available at https://www.eppo.go.th/index.php/th/component/k2/item/18418-news-260965-01 (accessed 10 Decmeber 2024).

Energy Policy and Planning Office (2024) *EPPO Dashboard EV Thailand* Available at https://public.tableau.com/app/profile/neic.dashboard.ev/viz/EPPODashboardEVThailand/Main?fbclid=IwY2xjawGxIaFleHRuA2FlbQIxMAABHVxrtcbUiDIVe-3jtr30nz6g5sUFoPbVwZ65t5eh5Iqsh4WVW5OJ5s6bEiA_aem_zkw6FuOLsiTLWDA7q92HPA (accessed 12 Decmeber 2024).

Insan D., Rakwichian W., Rachapradit P., and Thanarak P. (2022) The Business Analysis of Electric Vehicle Charging Stations to Power Environmentally Friendly Tourism: A Case Study of the Khao Kho Route in Thailand. *International Journal of Energy Economics and Policy 12*(6): 102-111. Available at https://doi.org/https://doi.org/10.32479/ijeep.13535

International Energy Agency (2024) *Global EV Outlook 2024*. Available at https://iea.blob.core.windows.net/assets/a9e3544b-0b12-4e15-b407-65f5c8ce1b5f/GlobalEVOutlook2024.pdf (accessed 21 Decmeber 2024).

Ketjoy N., Sirisamphanwong C., and Khaosaad N. (2013) Performance Evaluation of 10 kWp Photovoltaic Power Generator under Hot Climatic Condition. *Energy Procedia 34*: 291-297. Available at https://doi.org/https://doi.org/10.1016/j.egypro.2013.06.757

Kitworawut P., Ketjoy N., Suriwong T., and Kaewpanha M. (2023) Best Practice in Battery Energy Storage for Photovoltaic Systems in Low Voltage Distribution Network: A Case Study of Thailand Provincial Electricity Authority Network. *Energies 16*(5): 2469. Available at https://www.mdpi.com/1996-1073/16/5/2469

Klungsida N., Maneechot P., Butploy N., and Khiewwan K. (2024) Forecasting Energy Consumption from EV Station Charging Using RNN, LSTM and GRU Neural Network. *Journal of Renewable Energy and Smart Grid Technology 19*(1): 1-6. Available at https://doi.org/10.69650/rast.2024.254636

Kongklaew C., Phoungthong K., and Techato K. (2021) SWOT analysis for Electric Vehicles (EVs) in Thailand. *The International Journal of Integrated Engineering 13*(7): 20-26. Available at: https://doi.org/10.30880/ijie.2021.13.07.003

Krungsri Research (2024) *Thailand Industry Outlook 2024-2026*. Available at https://www.krungsri.com/en/research/industry/summary-outlook/industry-outlook-2024-2026 (accessed 12 Decmeber 2024).

Leewiraphan C., Ketjoy N., and Thanarak P. (2024a) An Assessment of the Economic Viability of Delivering Solar PV Rooftop as a Service to Strengthen Business Investment in the Residential and Commercial Sectors. *International Journal of Energy Economics and Policy 14*(2): 226-233. Available at https://doi.org/https://doi.org/10.32479/ijeep.15505

Leewiraphan C., Ketjoy N., and Thanarak P. (2024b) Business Perspectives of Distributed System Operators for Solar Rooftop-as-a-Service. *Energies 17*(1): 52. Available at https://doi.org/https://doi.org/10.3390/en17010052

Lin B., and Tan R. (2017) Estimation of the environmental values of electric vehicles in Chinese cities. *Energy Policy 104*: 221-229. Available at https://doi.org/https://doi.org/10.1016/j.enpol.2017.01.037

Manjula B. C., Shilpa B. S., and Sundaresh M. (2022) A Study on Barriers to Adoption of Electric Vehicles. *East Asian Journal of Multidisciplinary Research 1*(7): 1303-1316. Available at https://doi.org/https://doi.org/10.55927/eajmr.v1i7.802

Manutworakit P., and Choocharukul K. (2022) Factors Influencing Battery Electric Vehicle Adoption in Thailand—Expanding the Unified Theory of Acceptance and Use of Technology's Variables. *Sustainability 14*(14): 8482. Available at https://doi.org/https://doi.org/10.3390/su14148482

Marwa Ben Ali G. B. (2022) A Review of Factors Influencing the Adoption of Electric Vehicles in the World. 19th International Multi-Conference on Systems, Signals and Devices (SSD22),

Mohammadreza K. (2021) *Factors impacting consumer intention to purchase electric vehicles in the Bangkok* Mahidol University. Available athttps://archive.cm.mahidol.ac.th/

bitstream/123456789/4186/1/TP%20MM.024%202021.pdf (accessed 12 Decmeber 2024).

Mueller W., Vardoulakis S., Steinle S., Loh M., Johnston H. J., Precha N., Kliengchuay W., Sahanavin N., Nakhapakorn K., Sillaparassamee R., Tantrakarnapa K., and Cherrie J. W. (2021) A health impact assessment of long-term exposure to particulate air pollution in Thailand. *Environmental Research Letters 16*(5). Available at https://doi.org/10.1088/1748-9326/abe3ba

Pamidimukkala A., Kermanshachi S., Rosenberger J. M., and Hladik G. (2023) Evaluation of barriers to electric vehicle adoption: A study of technological, environmental, financial, and infrastructure factors. *Transportation Research Interdisciplinary Perspectives 22*. Available at https://doi.org/https://doi.org/10.1016/j.trip.2023.100962

Pongruengkiat W., Tippayawong K. Y., Aggarangsi P., Pichayapan P., Katongtung T., and Tippayawong N. (2023) Assessing sustainability of Chiang Mai urban development. *Discover Sustainability 4*(1). Available at https://doi.org/10.1007/s43621-023-00174-2

Prasittisopin L., Kitkuakul P., Chotchakornpant K., and Rugkhapan N. T. (2024) Implementing the Sister City Policy: Perspectives from Thailand. *Nakhara : Journal of Environmental Design and Planning 23*(2). Available at https://doi.org/10.54028/NJ202423413

Sadakorn W., Tetiranont S., Prasittisopin L., and Kaewunruen S. (2025) Assessing thermal comfort in hot and humid (tropical) climates: Urban outdoor and semi-outdoor conditions in waiting areas of railway stations. *Building and Environment 267*. Available at https://doi.org/https://doi.org/10.1016/j.buildenv.2024.112240

Sathyan S., Pandi V. R., Deepa K., and Sheik Mohammed S. (2024) Techno-Economic and Sustainable Challenges for EV Adoption in India: Analysis of the Impact of EV Usage Patterns and Policy Recommendations for Facilitating Seamless Integration. *International Journal of Sustainable Energy Planning and Management 40*: 75-95. Available at https://doi.org/https://doi.org/10.54337/ijsepm.8048

Souissi A. S. E., Kraiem H., Flah A., and El Madani A. (2024) Improving Electric Vehicle Autonomy in the Smart City Concept. *Engineering, Technology & Applied Science Research 14*(2): 13299-13304. Available at https://doi.org/https://doi.org/10.48084/etasr.6941

Sriboon T., Sangsritorn S., Tuohy P. G., Sharma M. K., and Leeprechanon N. (2016) *Simulation and analysis of renewable energy resource integration for electric vehicle charging stations in Thailand*. International Conference on Cogeneration, Small Power Plants and District Energy (ICUE 2016). Available at: https://doi.org/10.1109/COGEN.2016.7728973

Techakanont K., Launuan Y., and Chawiriyaphong N. (2019) *Strategies and Action Plans to Promote Small and Medium Enterprises in Electric Vehicle Industry*.

Tokito S., and Nakamoto Y. (2025) Differences in vehicle electrification policies and optimal transition periods across countries. *Journal of Industrial Ecology*. Available at https://doi.org/https://doi.org/10.1111/jiec.70028

Transportation Statistics Group Planning Division of Department of Land Transport (2020) *The Number of Cars which Registered from 1st January to 31st December 2019*. Available at https://web.dlt.go.th/statistics/

Transportation Statistics Group Planning Division of Department of Land Transport (2023a) *Number of newly registered cars Classified by fuel type (monthly report)*. Available at https://web.dlt.go.th/statistics/ (accessed 12 Decmeber 2024).

Transportation Statistics Group Planning Division of Department of Land Transport (2023b) *Number of newly registered vehicles by province*. Available at https://web.dlt.go.th/statistics/ (accessed 12 Decmeber 2024).

Transportation Statistics Group Planning Division of Department of Land Transport (2023c) *Statistics on the number of cars according to the law on automobiles Classified by fuel type Total nationwide as of 31 December 2022*. Available at https://web.dlt.go.th/statistics/ (accessed 12 Decmeber 2024).

Umair M., Hidayat N. M., Nik Ali N. H., M Nasir N. S., Hakomori T., Abdullah E. (2024) A Review of Malaysia's Current State and Future in Electric Vehicles. *Journal of Sustainable Development of Energy, Water and Environment Systems 12*(4): 1120521. Available at https://doi.org/https://doi.org/10.13044/j.sdewes.d12.0522

Van Dai P. (2024) Driving Change: How Vietnam's Private Sector Leads the Transition to Zero-Emission Vehicles. *Journal of Southeast Asian Economies 41*. Available at https://doi.org/10.1355/ae41-3f

Vassileva I., and Campillo J. (2017) Adoption barriers for electric vehicles: Experiences from early adopters in Sweden. *Energy 120*: 632-641. Available at https://doi.org/https://doi.org/10.1016/j.energy.2016.11.119

Wadecharoen W. (2017) *Research methods from concept, theory to practice*. SE-EDUCATION PUBLIC COMPANY LIMITED.

Zaino R., Ahmed V., Alhammadi A. M., and Alghoush M. (2024) Electric Vehicle Adoption: A Comprehensive Systematic Review of Technological, Environmental, Organizational and Policy Impacts. *World Electric Vehicle Journal 15*(8): 375. Available at https://www.mdpi.com/2032-6653/15/8/375