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# Forecasting battery electric vehicle growth and charging infrastructure needs in Thailand: A macroeconomic and statistical modeling approach

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**Abstract:** The rapid advancement of electric vehicle (EV) technology over recent years has significantly transformed the global transportation landscape. Many nations have implemented supportive policies aimed at fostering environmental sustainability and decreasing reliance on fossil fuels. Thailand has actively participated in this global shift, experiencing a notable increase in EV imports, heightened consumer interest, and an expanding need for comprehensive infrastructure to facilitate widespread adoption. This study endeavors to project the future number of electric vehicles in Thailand and to estimate the demand for EV charging stations through the application of various statistical models, including the Exponential Curve Projection, Linear Regression, and a predictive model incorporating gross domestic product (GDP) and population metrics. The analysis utilizes historical registration data sourced from the Department of Land Transport, complemented by national GDP and demographic data to develop scenario-based forecasts. Data processing, modeling, and simulation were conducted using advanced tools such as Microsoft Excel and MATLAB. The findings offer valuable insights into short- and medium-term EV growth trajectories and highlight critical infrastructure gaps. These results are intended to support policymakers and industry stakeholders in making informed decisions regarding EV adoption strategies, infrastructure development, and environmental policy formulation in Thailand, thereby promoting sustainable transportation initiatives and economic growth.
***Keywords:*** *Automotive technology, Electric vehicles forecasting, Environmental innovation, Sustainable transport.*

## 1. Introduction

The global transportation sector is undergoing a historic transformation, driven by pressing environmental imperatives, rapid technological advancements, and shifting societal norms. As concerns over climate change, air pollution, and the depletion of fossil fuels intensify, governments and industries worldwide are under growing pressure to transition toward cleaner, more sustainable mobility systems [1]. Central to this transition is the widespread adoption of electric vehicles (EVs), which offer a promising path to decarbonize the transport sector, reduce greenhouse gas emissions, and decrease reliance on petroleum-based energy sources. Unlike conventional internal combustion engine (ICE) vehicles, EVs operate on electric propulsion systems powered by rechargeable batteries, making them significantly more efficient and environmentally friendly [2].

At the global level, this shift is not only an environmental necessity but also a strategic opportunity. Major economies are leveraging EV transitions to strengthen energy security, reduce vulnerability to volatile oil markets, and boost economic competitiveness through innovation-driven industrial policies. Countries such as China, the United States, and several European Union members have integrated EV deployment targets into their national sustainability frameworks, coupling consumer incentives with regulatory mandates and significant investment in charging infrastructure. These actions have yielded robust EV adoption growth and catalyzed private-sector investments in clean mobility technologies


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[3]. However, achieving such outcomes requires not only policy ambition but also precise, data-driven forecasting tools to align vehicle growth with infrastructure expansion and market readiness.

Moving to the regional level, Southeast Asia presents a dynamic yet challenging environment for electric mobility. Rapid urbanization, rising energy demand, and worsening air quality in major metropolitan areas have placed transport-related emissions at the center of policy discourse. Yet, many countries in the region, including Thailand, face significant institutional, infrastructural, and economic barriers to full EV adoption. Despite growing public interest and government support, the EV transition remains uneven, constrained by limitations in infrastructure coverage, consumer awareness, and the availability of localized production [4]. The region's success in shifting to electric mobility thus hinges on well-informed, integrated strategies that align investment priorities with socio-economic and technological conditions.

At the national level, Thailand has emerged as a key player in Southeast Asia's electric mobility efforts. The government has announced ambitious targets to make Thailand a regional EV manufacturing hub, supported by the National Electric Vehicle Policy Committee (NEVPC) and the Board of Investment (BOI). Measures include tax incentives for manufacturers and consumers, subsidies for EV purchases, and promotion of public-private partnerships in charging infrastructure development [5]. These efforts have stimulated notable progress in the production and sale of EVs, especially Battery Electric Vehicles (BEVs), and increased awareness among consumers regarding the benefits of cleaner mobility options. Nonetheless, Thailand still faces a critical planning gap: while targets for vehicle production and market share have been publicized, there is limited evidence-based forecasting to determine the required scale and timing of supporting infrastructure, such as EV charging stations.

A major shortfall lies in the methodology of current projections. Most estimates are based on linear extrapolations of historical sales or registration data without consideration of macroeconomic variables such as GDP growth, urbanization rates, population density, and behavioral trends. This approach lacks sensitivity to real-world conditions and risks producing inaccurate forecasts, which could lead to either underinvestment (resulting in infrastructure bottlenecks and consumer dissatisfaction) or overinvestment (leading to inefficient capital deployment and idle capacity). Additionally, there is often insufficient spatial analysis of where infrastructure is most urgently needed, particularly in areas outside Bangkok and major economic corridors. This deficiency in granular, demand-driven modeling severely limits the effectiveness of national planning and private investment strategies.

At the infrastructure level, the challenge becomes even more acute. The development of EV charging networks must be synchronized with the pace of BEV adoption to avoid range anxiety and to support long-distance travel and commercial operations. Thailand's current charging station network, although growing, remains highly concentrated in urban areas and lacks the density needed to support nationwide adoption. According to projections from the Energy Policy and Planning Office (EPPO) [6] the country will require tens of thousands of additional charging points by 2028 to meet rising EV demand. However, the absence of comprehensive demand forecasting models makes it difficult for public agencies, utilities, and private investors to allocate resources efficiently and develop viable business models for infrastructure deployment.

From a microeconomic perspective, this problem also affects consumers and businesses. Without reliable access to charging infrastructure, potential EV buyers may be discouraged from switching to electric vehicles, thereby slowing market growth. Similarly, fleet operators and logistics providers, key drivers of electrification in many countries, are unlikely to invest in BEVs unless infrastructure scalability and grid readiness are assured. Inaccurate or incomplete forecasting models thus create a vicious cycle where uncertainty in infrastructure planning dampens adoption, and slow adoption discourages infrastructure investment.

In this context, the need for a comprehensive, multi-level, and data-driven forecasting model becomes imperative. Such a model must incorporate historical vehicle registration data, demographic indicators, economic growth rates, and regional variations to project both the adoption of BEVs and the corresponding demand for charging stations. Without this level of analysis, Thailand risks falling short of its EV targets and missing the opportunity to lead the region in sustainable mobility development.

*1.1. Research Objectives*

The study aims to achieve the following objectives:

1. To estimate the future number of electric vehicles (EVs), specifically Battery Electric Vehicles (BEVs), in Thailand based on historical registration data and statistical forecasting models.
2. To predict the number of charging stations required in Thailand in the coming years, ensuring alignment with projected EV adoption.
3. To assess the reliability of different forecasting methods (Exponential Curve Projection, Linear Trend Model, and GDP-Population Model) for application in the Thai automotive context.
4. To provide recommendations for infrastructure development and policy planning based on the research findings.

## 2. Literature Review

*2.1. Global Outlook on Electric Vehicles*

The global automotive industry is undergoing a paradigm shift toward electrification, primarily driven by mounting environmental concerns, stricter emission regulations, and technological advancements. According to the International Energy Agency (IEA) [1] global stock of electric vehicles (EVs) reached 10 million units in 2020, with battery electric vehicles (BEVs) comprising approximately two-thirds of this figure. The agency projects that under existing policies, the global EV stock will grow to 145 million units by 2030, representing around 15% of all vehicles on the road. In a more ambitious sustainable development scenario, aligned with global net-zero carbon targets, the EV fleet could exceed 230 million units, accounting for over 30% of the global stock. This exponential growth is supported by major policy interventions across developed economies, including the European Union, China, and the United States. These governments have introduced a mix of subsidies, tax incentives, fuel economy standards, and zero-emission vehicle (ZEV) mandates to stimulate adoption. Moreover, technological advances in lithium-ion batteries, such as improved energy density, longer lifecycle, and lower cost, have substantially improved the affordability and practicality of EVs [7]. However, one critical area lagging behind vehicle adoption is charging infrastructure development. The International Energy Agency (IEA) [1] cautions that without a parallel increase in both public and private charging networks, range anxiety and charging bottlenecks could hamper EV growth. Globally, achieving the projected targets will require not only over 250 million charging points by 2030 but also coordinated policy, utility support, and private investment.

*2.2. Regional Forecast and Policy Impacts in Southeast Asia*

In Southeast Asia, the EV transition is still in its early stages compared to global leaders. Nonetheless, several countries are making strategic moves to position themselves as regional hubs. Thailand, in particular, has emerged as a frontrunner, capitalizing on its well-established automotive manufacturing base. According to McKinsey & Company [8] over 350 EV models are expected to be available globally by 2025, reflecting intense competition and rapid innovation. Thailand's proactive policies are aligned with this trend, with its National Electric Vehicle Policy Committee (NEVPC) setting a target to make 30% of all domestic vehicle production electric by 2030. The Thai government has introduced a multi-pronged approach involving fiscal incentives, import duty exemptions, and corporate income tax breaks to attract foreign EV manufacturers, particularly from China and Japan. According to the Thailand Board of Investment (BOI) [9] approved investments in the EV sector have already exceeded 50 billion baht, with leading companies such as BYD, Great Wall Motors, and MG establishing production facilities in the country. However, regional EV demand still trails supply-side growth. While Thailand aims to become a manufacturing hub, domestic adoption remains relatively low due to factors such as high vehicle costs, limited model availability, and inadequate infrastructure. Thus, government efforts must balance production incentives with strategies to stimulate local consumption, including subsidies for buyers, charging network expansion, and public awareness campaigns [4].

### *2.3. EV Adoption and Charging Infrastructure in Thailand*

The adoption of EVs in Thailand has gained momentum in recent years, but challenges remain. According to the Office of Energy Policy and Planning (EPPO) [10] Thailand is expected to register over 138,000 EVs by 2025, with a long-term target of surpassing 1 million units by 2028. BEVs, in particular, are receiving focused support through tax reductions and government fleet integration. Nevertheless, Thailand's EV ecosystem faces a significant constraint in its charging infrastructure. As of 2022, the country had only about 1,000 public charging stations, primarily concentrated in Bangkok and major urban areas. To meet the projected demand by 2028, more than 47,000 charging points would need to be installed nationwide [10]. Assuming a service ratio of one charger per three BEVs, this figure is consistent with global planning standards. However, the geographical distribution and deployment speed of these chargers remain unclear, raising concerns about range anxiety, particularly for rural and intercity users. Several private sector entities, including PEA, MEA, and EA Anywhere, have entered the charging market, but their coverage and business models are still evolving. Without reliable forecasting, both over-investment (resulting in underused stations) and under-investment (leading to congestion and lost consumer confidence) are likely risks. Addressing this challenge requires data-driven infrastructure planning that aligns charger rollout with projected BEV adoption.

### *2.4. Forecasting Models for EV Adoption*

Various approaches have been employed in academic and policy research to forecast EV growth. The most common include trend extrapolation, linear regression, logistic growth models, and econometric models incorporating macroeconomic variables. One notable example is the work of Gomonwattanapanich and Jansa [11] who developed an energy end-use demand model for Thailand's transport sector. Their methodology included GDP growth, population dynamics, and fuel price elasticity, demonstrating that incorporating macroeconomic variables leads to more reliable long-term forecasts. Other studies have employed scenario-based modeling, combining economic and policy variables to produce multiple outcomes. For instance, the International Energy Agency (IEA) [1] uses conservative, policy-driven, and sustainable development scenarios to assess the implications of different regulatory pathways. Scenario modeling is particularly useful in dynamic policy environments where assumptions may shift rapidly. Statistical methods such as Exponential Curve Projection are also popular, especially when historical growth exhibits non-linear trends. In Thailand's case, BEV registration growth from 2017 to 2022 has shown exponential characteristics due to policy shifts and declining vehicle costs. However, using exponential models without considering market saturation or economic variables may result in over-forecasting.

Similarly, Linear Regression Models are simple and intuitive but risk underestimating growth if future trends diverge from past patterns. Therefore, multi-model approaches that combine regression techniques with economic indicators are increasingly recommended for EV forecasting [1, 11].

### *2.5. Gaps in Current EV Forecasting Research*

Despite the growing interest in EV forecasting, several critical gaps persist in the literature, especially within the Thai context. First, many forecasts are based on aggregate national data and lack granular, region-specific projections, which are essential for planning localized charging infrastructure. Second, most models rely on historical sales trends without integrating behavioral factors such as consumer preferences, fuel price sensitivity, or charging habits [1]. Moreover, while macroeconomic factors like GDP and population are included in some studies, few attempts have been made to combine these variables with advanced statistical models such as exponential smoothing, multivariate regression, or system dynamics modeling. The absence of real-time data integration further limits the responsiveness of these models to sudden policy or market changes. In Thailand specifically, there is a dearth of research that connects national BEV registration data with charging infrastructure needs through quantitative modeling. Government plans often rely on rough benchmarks, such as one station per three vehicles, without sensitivity analysis or scenario testing. As a result, policy and investment decisions may be based on incomplete or outdated assumptions. Furthermore, existing studies rarely address infrastructure readiness in relation to consumer adoption thresholds. Research suggests that perceived lack of infrastructure is a major deterrent to EV adoption, particularly in emerging markets. Without targeted analysis, charging expansion efforts may fail to alleviate public concerns, thus slowing EV market growth despite favorable policies. This review reveals a growing global and regional consensus on the importance of EV adoption for environmental sustainability and energy security. While Thailand has made significant strides in EV policy and production capacity, major challenges remain in aligning vehicle adoption with infrastructure development. Current forecasting models are limited in their ability to predict long-term demand and infrastructure requirements with high accuracy.

To address these gaps, this study proposes a multi-model forecasting approach that combines statistical techniques, such as Exponential Projection and Linear Regression, with macroeconomic indicators like GDP and population. By leveraging historical BEV registration data and incorporating scenario-based assumptions, the study aims to provide evidence-based projections for BEV growth and associated charging infrastructure demand in Thailand through 2028. This approach offers greater flexibility, robustness, and relevance for policymakers, planners, and private investors seeking to navigate the rapidly evolving EV landscape.

## 3. Research Framework

The conceptual framework of this research is structured around three main components:

### *3.1. Input Data*

- EV registration statistics from the Department of Land Transport (2012–2022)
- National GDP and population data
- Existing charging station statistics

### *3.2. Forecasting Methods*

- Exponential Curve Projection
- Linear Regression Model
- GDP and Population-Based Demand Model

### *3.3. Outputs*

- Forecast of the number of BEVs in Thailand (2023–2030)
- Estimated demand for EV charging stations
- Comparative analysis of model accuracy ($R^2$ values)

This structured approach ensures a comprehensive analysis grounded in data and contextual understanding.

## 4. Research Methodology

### *4.1. Data Collection*

- Vehicle Data: EV registration data was sourced from the Department of Land Transport (DLT), segmented by fuel type and year.
- Economic Data: GDP data was retrieved from the National Economic and Social Development Council (NESDC), and population data from the National Statistical Office (NSO).

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- Tools Used: Microsoft Excel for data organization and initial modeling; MATLAB for regression-based coefficient estimation.

*4.2. Forecasting Models*

- Exponential Curve Projection

$$P_{t+n} = P_t(1+r)^n$$

This model assumes compounded growth based on historical trends.

- Linear Model (Straight Line Forecasting)

$$P_{t+n} = P_t + bn$$

This model is suitable for short-term forecasts where growth trends are linear.

- GDP-Population Based Model

$$N_{j,k} = e^a \cdot GDP^b \cdot e^{Tc} \cdot POP$$

This formula is derived from regression models where **a**, **b**, and **c** are estimated constants using MATLAB.

*4.3. Data Processing Steps*

To ensure the reliability and robustness of the forecasting results, a systematic approach was employed for data processing, trend analysis, and model implementation. The following steps detail the methodology used to process the data and generate forecasts for electric vehicle (EV) adoption and corresponding charging infrastructure demand in Thailand:

Step 1: Compilation and Categorization of Historical EV Registration Data

The first stage involved the collection and organization of historical EV registration data sourced from the Department of Land Transport (DLT). Data were compiled on an annual basis, disaggregated by electric vehicle type, specifically focusing on Battery Electric Vehicles (BEVs), which are fully electric and do not rely on hybrid systems. This granular classification ensured that the forecasting models addressed the most relevant segment of the EV market with respect to charging infrastructure demand. Data from the past 10–12 years were compiled to identify reliable historical patterns.

Step 2: Calculation of Year-on-Year Growth Rates and Trend Visualization

Next, year-on-year growth rates were computed to evaluate the pace and consistency of BEV adoption over time. These growth metrics were visualized using time-series plots to identify whether the underlying adoption trend was linear, exponential, or irregular. By plotting these trends graphically, initial assumptions regarding the nature of the adoption curve were tested. This visual inspection also served to detect anomalies or outlier years that may require adjustment or further contextual analysis (e.g., policy changes, global economic disruptions).

Step 3: Model-Based Forecasting for Future EV Adoption

Three different forecasting models were then applied to project future BEV adoption over a 5- to 10-year horizon (up to 2028). These models included:

- Linear Regression Model, which assumes a constant rate of increase over time.

- Exponential Growth Model, suitable for capturing the compounding nature of early-stage technology adoption.
- Econometric Model, which incorporates macroeconomic variables such as Gross Domestic Product (GDP) and population growth to reflect broader national development trends.

Each model was calibrated using the historical data, and forecast outputs were generated to predict the number of BEVs expected to be registered in future years. Forecasts from all three models were compared to evaluate consistency and sensitivity to model assumptions.

Step 4: Evaluation of Model Accuracy Using Coefficient of Determination ($R^2$)

To determine the goodness-of-fit for each model, coefficient of determination ($R^2$) values were calculated. $R^2$ measures the proportion of variance in the dependent variable (BEV registration) that is explained by the independent variable(s) in the model. A higher $R^2$ value indicates a better model fit. This step was critical in selecting the most reliable model for policy recommendation purposes. In cases where multiple models showed high $R^2$ values, additional criteria such as residual analysis and future policy alignment were considered.

Step 5: Estimation of Charging Infrastructure Demand

After forecasting the total number of BEVs, the next step involved calculating the required number of public charging stations. This was done by applying a standardized service ratio, which assumes that one public charging station can serve approximately three BEVs. This ratio is commonly referenced in EV infrastructure planning literature and is used by agencies such as the IEA and EPPO. While this assumption provides a baseline, future work may consider variable ratios depending on urban density, travel behavior, and private charging availability.

$$\text{Required Chargers} = \frac{\text{Projected BEVs}}{3}$$

By applying this calculation to each year's projected BEV count, an annual estimate of infrastructure demand was produced. This enables stakeholders to plan charging station deployment in line with actual vehicle growth, minimizing both over- and under-investment.

Step 6: Synthesis and Interpretation for Strategic Planning

Finally, results from all models and calculations were synthesized into comparative charts and tables. The study evaluated key implications for policy design, infrastructure investment, and regulatory support based on the projected mismatch between vehicle adoption and charger availability. These findings were prepared for further discussion in the results and recommendation sections.

## 5. Research Findings

### *5.1. Forecasting Models*

- Forecast Results Using Exponential Curve Projection

The exponential model predicted aggressive growth in BEV adoption over the next several years. Using a compound annual growth rate derived from historical data (approx. 40% for BEVs), the following forecasts were obtained:

**Table 1**.
Forecast Results Using Exponential Curve Projection.

| Year | Estimated BEVs (Exponential) |
|---|---|
| 2023 | 262,225 |
| 2024 | 367,130 |
| 2025 | 514,002 |
| 2026 | 719,632 |
| 2027 | 1,007,525 |
| 2028 | 1,410,591 |

While this model showed promising trends, its $R^2$ value (goodness-of-fit) was relatively low due to sensitivity to past volatility and extreme growth assumptions. Table 1 illustrates the projected number of Battery Electric Vehicles (BEVs) from 2023 to 2028 using an exponential curve projection. Beginning at 262,225 BEVs in 2023, the number is forecasted to grow sharply each year. By 2024, the figure rises to 367,130 and reaches 514,002 in 2025. The growth continues at an accelerating rate, reaching 719,632 in 2026, then over one million in 2027 with 1,007,525 BEVs. The projection for 2028 peaks at 1,410,591 units. This trend reflects a compound annual growth rate of approximately 40%, consistent with historical BEV adoption patterns. The exponential growth model used in this forecast highlights the potential for rapid BEV adoption over the next several years. The dramatic increase each year reflects not only growing consumer acceptance but also anticipated improvements in technology, infrastructure, and policy support for electric vehicles. However, while the projections demonstrate strong upward momentum, the model has limitations. Its relatively low $R^2$ value indicates a weaker statistical fit, suggesting that the model may not fully account for year-to-year variability or potential saturation points in the market. Exponential models tend to overestimate long-term growth, especially in industries subject to technological disruption, policy shifts, or market constraints. Therefore, while the results suggest an optimistic future for BEV adoption, they should be interpreted with caution and supplemented with other forecasting methods for more balanced planning.

*5.1.1. Forecast Results Using Linear Model*

The linear model yielded more conservative and steady growth projections based on the average annual increase from previous years:

**Table 2**.
Forecast Results Using Linear Model.

| Year | Estimated BEVs (Exponential) |
|---|---|
| 2023 | 298,107 |
| 2024 | 408,918 |
| 2025 | 519,729 |
| 2026 | 630,540 |
| 2027 | 741,351 |
| 2028 | 852,162 |

The linear model had a better $R^2$ value for short-term forecasting but became less reliable for longer horizons, as it failed to account for accelerating adoption influenced by policy or technological breakthroughs. Table 2 presents the projected number of Battery Electric Vehicles (BEVs) from 2023 to 2028 using a linear growth model. The forecast begins at 298,107 BEVs in 2023 and increases by approximately 110,811 units each year. The projections for subsequent years are as follows: 408,918 in 2024, 519,729 in 2025, 630,540 in 2026, 741,351 in 2027, and 852,162 in 2028. This linear progression reflects a consistent, steady growth pattern based on the average annual increase observed in historical data. The linear model offers a more conservative and stable forecast compared to the exponential model, suggesting moderate growth in BEV adoption. Its higher $R^2$ value indicates a better fit for short-term predictions, making it useful for near-future planning. However, the model's main limitation lies in its inability to capture the accelerating nature of BEV adoption that can result from factors such as technological innovation, government incentives, or infrastructure expansion. By assuming a constant annual increase, the linear model may underestimate long-term growth potential, especially in a dynamic and rapidly evolving sector. Therefore, while the linear model provides reliable short-term forecasts, it may not fully represent the disruptive forces shaping the future of the BEV market. Combining linear projections with more adaptive models may offer a more comprehensive outlook.

*5.1.2. Forecast Results Using GDP and Population-Based Model*

This model, which integrates macroeconomic variables (GDP and population growth), produced the most realistic forecasts, showing a strong correlation ($R^2 \approx 0.92$) between economic expansion and EV adoption.

**Table 3.**
Forecast Results Using GDP and Population-Based Model.

| Year | Estimated BEVs (GDP/POP Model) |
|---|---|
| 2023 | 275,000 |
| 2024 | 390,000 |
| 2025 | 560,000 |
| 2026 | 780,000 |
| 2027 | 1,050,000 |
| 2028 | 1,400,000 |

Table 3 presents BEV (Battery Electric Vehicle) adoption forecasts from 2023 to 2028 based on a model that incorporates macroeconomic variables, Gross Domestic Product (GDP) and population growth. The model estimates 275,000 BEVs in 2023, with figures increasing steadily to 390,000 in 2024 and 560,000 in 2025. The trend continues with 780,000 in 2026, surpassing one million in 2027 (1,050,000), and reaching 1,400,000 units in 2028. This forecast shows a consistent and accelerating pattern of growth, aligning with expected economic and demographic trends. The GDP and population-based model provides the most balanced and realistic projection of BEV adoption among the three models discussed. With a high $R^2$ value of approximately 0.92, it demonstrates a strong statistical correlation between economic growth, population expansion, and EV uptake. This model effectively captures the influence of broader socioeconomic factors on BEV adoption, such as rising consumer purchasing power, urbanization, and increased demand for sustainable transportation solutions. Unlike the exponential model, which may overstate future growth, and the linear model, which may understate it, this approach adjusts growth expectations based on tangible macroeconomic indicators. As such, it offers a credible and policy-relevant forecasting framework for long-term planning in both the public and private sectors.

*5.2. Projected Charging Station Demand*

According to the forecast data, the number of Battery Electric Vehicles (BEVs) in Thailand is expected to reach approximately 66,275 units by the year 2028. This projection was derived using time-series data and statistical forecasting methods, including Exponential Curve Projection and GDP- and population-adjusted models, to estimate the future growth of BEV adoption in Thailand. To evaluate the necessary infrastructure to support this growth, the report assumes a standard charging station-to-vehicle service ratio of 1:3, meaning one charging station can effectively serve three BEVs. This ratio is reasonable based on typical charging behavior, dwell times, and current station utilization rates in urban and suburban settings. Using this assumption, the estimated number of charging stations required in 2028 can be calculated as:

$$\frac{66{,}275 \text{ BEVs}}{3 \text{ BEVs/Station}} = 22{,}092 \text{ Charging Stations}$$


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Therefore, approximately 22,092 charging stations will be needed in 2028 if one station serves three BEVs. For the interpretation and implications, it is found out that:

*5.2.1. Infrastructure Gap*

As of the latest data, Thailand has significantly fewer than 22,092 charging stations nationwide. This implies a substantial infrastructure gap that needs to be addressed within the next few years to support the projected EV adoption.

*5.2.2. Urban vs. Rural Distribution*

The demand for charging stations is likely to be concentrated in urban centers, where BEV adoption is higher and average daily driving distances are shorter. However, expansion into rural areas is critical to eliminate range anxiety and ensure equitable access.

*5.2.3. Policy and Investment Requirements*

To meet the projected demand, government support in the form of incentives, subsidies, or public-private partnerships will likely be necessary. Infrastructure development should also align with national strategies on energy, transport, and emissions reduction.

*5.2.4. Scalability and Technology*

While the 1:3 station ratio is useful for estimation, future advancements, such as faster charging speeds, smart grid integration, or battery swapping technology, may alter these needs. Planning should remain flexible to accommodate such innovations.

*5.2.5. Grid Impact*

The expansion of charging infrastructure must be accompanied by investment in the electrical grid, especially in terms of capacity and stability. Unplanned charging station deployment could lead to localized grid stress.

In conclusion, the forecast of approximately 22,092 charging stations needed in 2028 represents a critical milestone for Thailand's transition toward electric mobility. Strategic planning, investment, and technology adoption will be key in bridging the gap between projected BEV growth and supporting infrastructure. Failure to meet this demand could result in slowed adoption rates and diminished public confidence in EV viability.

## 6. Conclusion

This study set out to estimate the future number of electric vehicles (EVs), particularly battery electric vehicles (BEVs), in Thailand and assess the corresponding infrastructure requirements using statistical models. Through analysis of historical vehicle registration data, national GDP, and population growth figures, three forecasting methods—Exponential Curve Projection, Linear Model, and a GDP-Population-based model—were applied. All three models predicted a steep upward trend in EV adoption. However, the GDP-Population model proved most reliable due to its incorporation of macroeconomic drivers, aligning with global forecasting best practices and producing a high coefficient of determination ($R^2 \approx 0.92$). According to this model, Thailand could expect over 1.4 million BEVs on the road by 2028. At a service ratio of 1 public charger per 3 EVs, this forecast implies the need for over 460,000 public charging stations nationwide—an enormous leap from the approximately 1,000 chargers currently available. This projection highlights a significant infrastructure gap and underscores the urgency for coordinated action by government agencies, utility providers, private investors, and automakers. The success of Thailand's EV transition depends not only on production capabilities and vehicle affordability but also on the timely expansion of charging infrastructure, the integration of renewable energy sources, and public trust in the reliability and convenience of EV usage.

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Moreover, the findings suggest that relying solely on historical trends or production-side policies is insufficient. Without adequate infrastructure and consumer-side incentives, high EV production may not translate into widespread adoption. To bridge this gap, policymakers must implement a holistic approach that includes spatial planning for charger deployment, localized demand analysis, and integration with national energy and climate strategies. In addition, this study contributes to the academic discourse by demonstrating that forecasting models incorporating macroeconomic variables (e.g., GDP and population) offer a more grounded and adaptable framework for national EV planning, especially in emerging markets like Thailand. The study also identifies gaps in current forecasting practices, particularly the lack of regional specificity and behavioral data integration, which should be addressed in future research. In conclusion, while Thailand's ambitions to become a regional EV hub are both commendable and achievable, they require a shift from aspiration to execution. Meeting the projected demand of over 1.4 million BEVs by 2028 will require a coordinated, data-driven, and multi-sectoral strategy to build the necessary charging infrastructure, enhance supply chain resilience, and drive consumer adoption. Failure to do so may jeopardize national goals related to decarbonization, energy security, and industrial competitiveness in the global electric mobility transition.

## 7. Discussion

The results of this study reveal a strong and consistent upward trend in Battery Electric Vehicle (BEV) adoption in Thailand across all forecasting models. However, the degree of accuracy and policy relevance varied significantly. The exponential model projected the most aggressive growth, aligning with global EV expansion scenarios projected by the International Energy Agency (IEA) [1] yet it proved volatile and overly optimistic for localized application. The linear model, by contrast, provided conservative and steady growth aligned with historical averages, suitable for short-term planning but limited in scalability, especially in a policy-driven environment. The GDP and population-based model emerged as the most realistic and robust, demonstrating a high $R^2$ value (~0.92) and aligning with macroeconomic growth patterns. This supports prior findings from Gomonwattanapanich and Jansa [11] who emphasized the value of integrating economic and demographic variables for reliable long-term transport energy forecasts. In the global context, the study's exponential projection mirrors the International Energy Agency (IEA) [1] global sustainable development scenario, which anticipates that EV stock could exceed 230 million by 2030, accounting for over 30% of all vehicles. This suggests that exponential growth is feasible under aggressive policy and innovation environments. However, as the IEA cautions, such growth is contingent upon infrastructure readiness, specifically, the deployment of more than 250 million charging points worldwide. Without this, issues such as range anxiety and bottlenecked charging availability could stall progress. This is consistent with the study's finding that Thailand's exponential forecast is unrealistic without equivalent infrastructure investment.

Regionally, Thailand is positioning itself as a Southeast Asian EV leader, supported by strong industrial policy and investment incentives [8, 9]. The National Electric Vehicle Policy Committee (NEVPC) targets 30% electrification of domestic vehicle production by 2030, which aligns with the GDP-population forecast reaching 1.4 million BEVs by 2028. However, domestic adoption continues to lag behind manufacturing output, primarily due to high vehicle prices, limited model options, and, most critically, underdeveloped charging infrastructure [4]. As of 2022, Thailand had approximately 1,000 public charging stations, with a projected need for over 47,000 by 2028 to meet service ratios of one charger per three BEVs [10]. The study reinforces this gap, noting that charging station deployment must not only accelerate but also be spatially coordinated to prevent congestion in urban areas and shortages in rural and intercity routes. Moreover, the infrastructure shortfall highlights a key limitation in Thailand's current policy focus. While production incentives have attracted leading manufacturers like BYD and Great Wall Motors, consumption-side strategies remain underdeveloped [9]. The findings align with global concerns that charging infrastructure is lagging vehicle deployment [1] and with regional literature emphasizing the need to balance supply- and demand-side policies [4]. Without accessible and reliable charging infrastructure, consumer hesitation may persist, slowing adoption despite generous incentives.

The forecasting model comparison further reflects broader methodological insights from the literature. As noted by the International Energy Agency (IEA) [1] and Gomonwattanapanich and Jansa [11] models incorporating macroeconomic variables offer more realistic projections than simple extrapolations. Exponential and linear models, while useful in certain scenarios, risk either overestimating or underestimating future growth, especially in rapidly evolving markets. Therefore, this study supports the emerging consensus that hybrid forecasting approaches, combining statistical trends with policy, economic, and behavioral variables, provide more actionable insights for EV planning. In addition, gaps identified in the literature remain apparent in the Thai context. Many existing forecasts rely on aggregate national data and lack regional differentiation, which is essential for infrastructure planning [1]. This study's findings suggest that while forecasting BEV registrations is critical, it must be paired with dynamic, data-driven infrastructure models to guide investment and avoid both overcapacity and congestion. Furthermore, current Thai forecasting practices do not integrate behavioral data, such as consumer attitudes toward charging or fuel price elasticity, which could improve predictive accuracy and public engagement. In conclusion, while Thailand has made commendable strides in establishing itself as a regional EV manufacturing hub, its long-term success will depend on the alignment of vehicle adoption with infrastructure development. The GDP-population-based model offers the most grounded and economically responsive forecast. However, achieving these projections will require a multi-pronged strategy involving: accelerated deployment of public charging networks, integration of renewable energy into charging infrastructure, localized supply chain development, and demand-side incentives and consumer education. To move from ambition to realization, Thailand must adopt forecasting and planning practices that mirror those of global leaders, data-driven, scenario-based, and regionally nuanced.

## 8. Recommendation

Based on the findings and analysis of the projected demand for electric vehicles and charging infrastructure in Thailand by 2028, several strategic recommendations are proposed to key stakeholders. For the government and policymakers, there is an urgent need to accelerate the deployment of charging infrastructure by implementing both national and regional plans focused on expanding coverage, particularly in high-density urban areas and along major transport corridors. Additionally, the government should continue and enhance fiscal incentives, including tax reductions, subsidies, and low-interest financing options for both electric vehicle consumers and manufacturers, to stimulate market growth. Encouraging public-private partnerships (PPPs) is also critical, as collaborative efforts can help mobilize capital and operational expertise needed to scale infrastructure development effectively.

For industry stakeholders, the emphasis should be on investing in research and development, as well as promoting localization of production, particularly for EV components, batteries, and software. This will not only reduce dependence on imports but also strengthen the domestic EV ecosystem. Moreover, the industry must implement dynamic demand forecasting and monitoring systems to remain responsive to market changes and adjust production, logistics, and investment strategies accordingly.

Lastly, for the research community, there is a clear need to refine existing forecasting models by integrating real-time data inputs, consumer behavioral patterns, and regional demand differences. Such enhancements will improve the precision of long-term infrastructure and policy planning. Additionally, researchers should explore the integration of EV infrastructure with renewable energy systems, such as solar and wind power, and evaluate the potential impacts on grid stability and sustainability. These research directions will help ensure that the growth of electric mobility aligns with national goals for clean energy and climate resilience.

## 9. Research Contribution

This research contributes to the field in the following ways:

- Data-Driven Forecasting: It applies three statistical models using real registration, GDP, and population data to yield actionable forecasts.
- Infrastructure Planning: The findings highlight a quantitative infrastructure gap, aiding policymakers in long-term resource allocation.
- Model Comparison: It offers a comparative evaluation of forecasting techniques for EV adoption, providing methodological guidance for future studies.
- Application of Macroeconomic Integration: The GDP-Population model demonstrates how integrating economic indicators improves forecast reliability, which could be adapted for other sectors like energy, logistics, and public transport.

## Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.



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