Predicting Electric Vehicle Production Trends in India Using Machine Learning Techniques

Himesh Tyagi
Department of Computer Science
IMS Engineering College, Ghaziabad, Uttar Pradesh,

Kishan Kumar
Department of Computer Science
IMS Engineering College, Ghaziabad, Uttar Pradesh,

Govind Kumar Rahul
Department of Computer Science
IMS Engineering College, Ghaziabad, Uttar Pradesh,

Abstract- The Indian electric vehicle (EV) market is growing rapidly on the back of effective policies, increasing environmental awareness, and technological advancements. This study explores the use of machine learning (ML) in predicting EV production and addressing issues such as regional inequality, limited resources, and the development of rights. By analyzing data on production, policy, market demand, and supply chain, the study identified key factors influencing EV growth. Machine learning model evaluation using performance indicators such as MAE and RMSE can capture emerging patterns and trends. The results highlight the role of government incentives, battery adoption, and domestic manufacturing in driving growth. The study offers valuable recommendations to stakeholders to support sustainable and rapid development of electric vehicles across India.

Keywords – Electric vehicle production, Machine learning forecasting, Sustainable mobility in India, EV market analysis

I. INTRODUCTION

The global shift to electric vehicles (EVs) is crucial to reducing carbon emissions, mitigating climate change, and reducing dependence on fossil fuels. In India, where urban growth is accelerating and environmental challenges are on the rise, EV adoption has become a key part of the transportation strategy. However, this transition faces many challenges that are impacting the country's progress towards its EV goal, including inadequate financing, inconsistent national regulations, and high costs. To overcome these challenges, accurately predicting adoption is crucial. Relying on forecasts enables stakeholders such as policymakers, manufacturers, and investors to make informed decisions on production strategies, resource allocation, and housing planning. Machine learning (ML) has become a powerful way to analyze complex data and uncover patterns that are often missed by traditional forecasting techniques. Machine learning models that use data on production history, business needs, and policy implications provide insights that can inform strategic planning and decision-making. Accelerate the adoption of electric vehicles. Among these, the Faster Service and Manufacturing of Hybrid and Electric Vehicles (FAME) has emerged as a framework designed to encourage the production and adoption of electric vehicles. The government has set an ambitious goal of 30\% EV penetration by 2030, placing electric vehicles as the foundation of efficient transportation. However, adoption rates vary across states due to factors such as affordability, differences in state laws, changes in gas prices, and population density. Understanding these factors is crucial to creating effective policies and promoting a balanced EV market. Various types of data are analyzed, including historical production data, country-specific regulations, economic and business needs assessment. Through careful analysis of preliminary data, infrastructure, and model evaluation, predictive models are developed to identify key drivers of EV development. Evaluate model performance using metrics such as mean error (MAE) and root mean square error (RMSE) to ensure accuracy and reliability. These models are well suited for physical and non-uniform models, providing good insight into EV development. important role. In addition, this study demonstrates how machine learning can improve resource allocation, improve manufacturing strategies, and solve regional problems. This information is important for stakeholders who want to adapt their strategies to the changing EV landscape in India. Section III reviews the relevant literature and introduces the existing methods for predicting EV trends. Section IV describes the process including data collection, prioritization and algorithm selection. Section V presents the results and discusses their implications for the Indian EV market. Section VI concludes the study by summarizing the findings and their implications for future research and policy development. Finally, the contributions and resources that supported this work are acknowledged in Section VII. The foundations of the electric vehicle ecosystem are being laid.

II. LITERATURE REVIEW

[1] This study tackles the Electric Vehicle Routing Problem by integrating machine learning to predict energy consumption during route planning. The model enhances the accuracy of energy predictions, allowing for optimized travel time and energy usage. Real-world constraints, such as charging station availability and traffic conditions, are incorporated. The results demonstrate notable improvements in routing efficiency and the sustainability of electric vehicle operations. [2] This review examines how machine learning is shaping advancements in electric vehicle (EV) transportation. It focuses on areas like energy management, route optimization, and predicting charging demand using AI and ML techniques. [3] This research introduces a deep learning-based approach to forecast power demand at EV charging stations in regulated electricity markets, with a specific focus on Morocco. By analyzing temporal and spatial charging patterns, the model achieves precise demand forecasts. [4] The paper explores the use of machine learning for estimating the state of charge (SOC) of lithium-ion batteries in electric vehicles. Various ML algorithms are employed to enhance SOC prediction accuracy under diverse operational conditions. The proposed model offers a cost-effective and reliable solution for battery management, contributing to longer battery life and improved energy efficiency. [14] This paper compares different machine learning algorithms to evaluate their performance in predicting EV energy consumption. The analysis considers diverse driving conditions and environmental factors to identify the most efficient models. The study highlights the importance of optimizing energy consumption to promote sustainability and reduce carbon emissions, offering a pathway for effective EV energy management. [5] This study proposes a deep learning model designed to predict EV charging demand. By leveraging extensive datasets, the model achieves high precision forecasts, addressing the variability in EV usage patterns. Emphasizing scalability and regional adaptability, the findings support effective planning for EV infrastructure and seamless grid integration. [6] This research presents a seasonal forecasting model for EV charging demand, employing machine learning and deep learning methodologies. By factoring in climatic and temporal variables, the model accurately predicts seasonal charging variations. It aids energy providers in resource optimization and contributes to sustainable energy management for EV operations. [7] Presented at the 2024 IEEE ICISC conference, this paper details a machine learning-based method for forecasting EV charging demand. By evaluating various ML algorithms and emphasizing data preprocessing and feature extraction, the study achieves enhanced prediction accuracy and scalability. The insights contribute to improved planning of EV charging infrastructure. [8] This study explores the use of machine learning techniques to predict the health and degradation of lithium-ion batteries in hybrid vehicles. Various ML models are assessed to estimate battery lifespan and performance under varying operational conditions. The proposed method enables proactive maintenance and optimization of battery functionality. The findings show enhanced accuracy in forecasting battery health, supporting sustainable management of hybrid vehicles. [9] This research introduces a decision support system based on artificial intelligence and machine learning for predicting the energy requirements of electric vehicles (EVs). The system uses predictive analytics to account for factors such as driver behavior, environmental variables, and vehicle characteristics. Emphasizing scalability and real-time application, the study highlights its potential for effective infrastructure planning. [10] This study introduces a strategic forecasting model for predicting electric vehicle (EV) sales, utilizing a comprehensive framework that considers critical factors like market dynamics, government policies, consumer preferences, and infrastructure development. Machine learning methods are applied to enhance the precision and dependability of sales forecasts. The model is specifically designed for developing economies, addressing their distinctive challenges and growth opportunities. The findings highlight the effectiveness of this approach in supporting policymakers and businesses in planning and strategizing for EV market expansion.[11] This paper investigates the management of electric vehicle (EV) charging by employing deep reinforcement learning to optimize charging schedules and alleviate stress on the power grid. The model adjusts dynamically in response to fluctuations in electricity prices and grid conditions. The results demonstrate enhanced energy efficiency and reduced operational costs. [12]A deep learning model is proposed for forecasting the availability of EV charging stations over the long term. The approach takes into account spatial-temporal patterns and user behaviors to predict station usage. The findings offer valuable insights for improving EV infrastructure planning and ensuring user convenience. [13] This paper explores machine learning techniques for predicting battery maintenance needs in electric vehicles, aiming to improve sustainability. The model offers proactive maintenance recommendations, reducing costs and extending battery life. The results underscore its significance for advancing the adoption of sustainable EV technologies.[15] This research develops a deep learning model for predicting short-term EV charging demand. The model incorporates both temporal and spatial variables, achieving high accuracy in demand

forecasting. The findings assist in improving grid management and optimizing infrastructure. [17]A deep learning-based model is proposed for forecasting EV charging demand, considering dynamic demand fluctuations and grid limitations. The model helps optimize resource allocation and enhances charging infrastructure management. [16] This study examines community-scale renewable energy systems and EV management in cold climates using machine learning. The model integrates renewable energy sources with EV operations to optimize energy consumption. The results highlight the potential for greater energy efficiency and sustainability.
.

III. MODEL DEVELOPMENT

Electric Vehicles(EVs) represent a transformative technology aimed at meeting the rising demand for clean transportation and sustainable energy solutions. This project utilizes Linear Regression as the core machine learning model to predict future EV production trends in India by analyzing historical data, market dynamics, infrastructure growth, and policy initiatives.

Linear regression is a supervised learning technique that identifies the relationship between a target variable (EV production) and multiple independent factors. The model fits a straight line through the data points in such a way that it minimizes the sum of squared differences between the actual and predicted values. Its simplicity and interpretability make it an ideal choice for this study. The model is integrated into an interactive dashboard using Streamlit, which supports intuitive visualizations like heat maps, timelines, and trend graphs, offering valuable insights for policymakers, manufacturers, and investors.

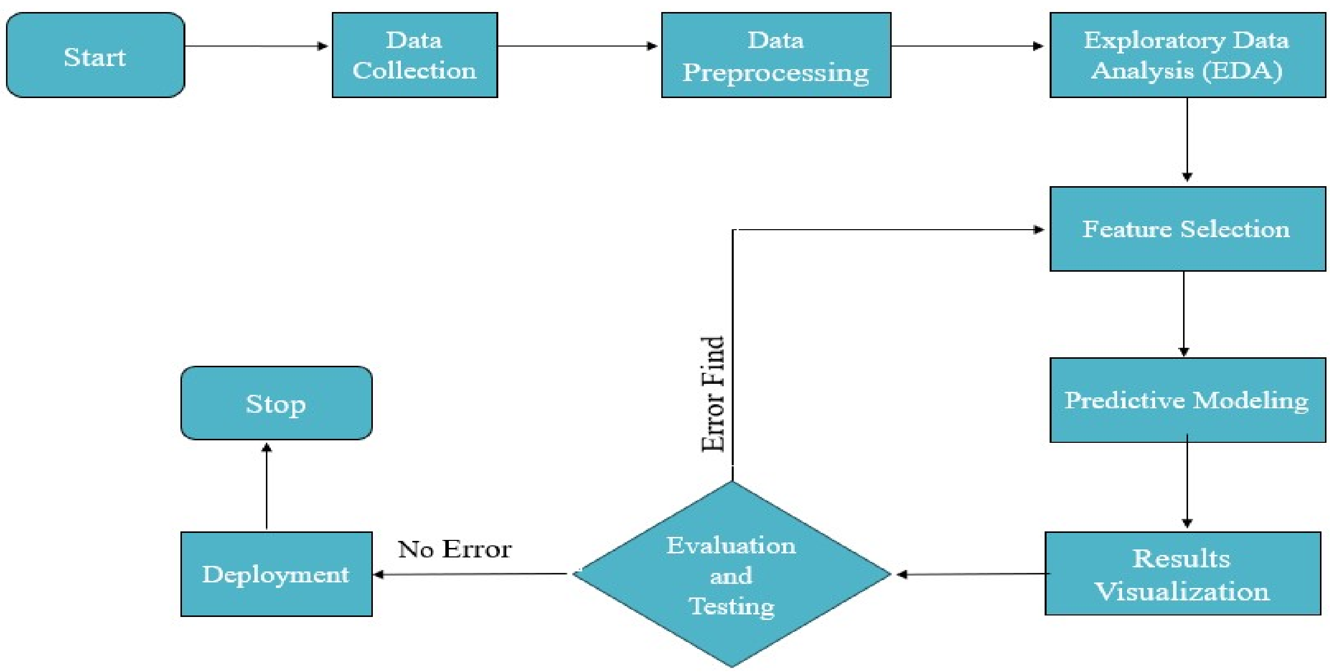

Figure 1 Flow Chart

A. Flow Diagram

1. **Data Collection:-** Relevant data is gathered from a variety of sources, such as:

- Production Data: Historical records of electric vehicle (EV) manufacturing volumes in India.
- Market Demand: Consumer adoption trends, preferences, and market penetration levels.
- Policy Data: National and state-level initiatives, including programs like FAME, and other subsidies and incentives.
- Infrastructure Data: Information on the number of charging stations, their distribution, and operational capacity.

2. **Data Preprocessing :-** The collected data undergoes a series of cleaning and transformation steps to ensure quality:

- Handling Missing Values: Missing values are addressed through techniques like mean, median, or regression-based imputation.
- Outlier Detection and Removal: Outliers are detected using statistical methods such as Z-scores or IQR, ensuring that extreme values do not skew results.
- Data Normalization: Numeric variables are scaled to ensure consistency across features.
- Encoding Categorical Variables: Categorical data (e.g., policy types, state names) is converted into numerical formats using methods like one-hot or label encoding.
- Feature Selection: Key features that impact EV production and adoption trends such as government incentives, charging infrastructure availability are identified and retained.

3. Exploratory Data Analysis (EDA):-

- EDA helps identify patterns and relationships in the data. This includes analyzing EV sales trends over time and across regions in India, understanding how government policies, Prices and adoption rates correlate, and examining regional differences such as higher EV adoption in urban areas compared to rural regions and many more.

4. Feature Selection:-

- This step highlights the most important factors affecting EV adoption. Key changes include government subsidies, infrastructure payments, annual and state data on female adoption, urban development, and public awareness. Focusing on these key features helps keep the model simple while maintaining predictive power.

5. Predictive Modeling:-

- In this stage, a Linear Regression model is used to predict future EV production based on historical data, policies, and infrastructure growth.
- The model finds patterns in the data and fits a best-fit line to make accurate forecasts.
- This helps stakeholders make informed decisions for policy planning and infrastructure development.

6. Results Visualization:-

- Visualizing the results in a user-friendly format helps with decision making. Estimates of EV adoption across Indian states can be viewed as heat maps and trend graphs that show areas with the highest adoption potential. The heat map also points out areas that need more charging stations. Additionally, visualizing environmental benefits helps highlight the positive impacts of EV adoption. Like in Figure 2,3,4.

7. Evaluation And Testing:-

- Evaluate model performance by comparing predictions to historical data. Statistical measures such as Mean Absolute Error (MAE) and R-squared value are used to measure accuracy. Analyze differences between predictions and actual results and improve the model to increase accuracy by tuning features, adjusting hyperparameters, or exploring other modeling methods. Errors are penalized more heavily.

8. Deployment :-

- Once the model is refined, it is deployed to provide forecasts and actionable insights.
    - **Dashboard Development:** A user-friendly interface is developed for stakeholders like policymakers, manufacturers, and investors to visualize trends and key insights.
    - **Scenario Analysis:** The model is used to simulate different policy scenarios, such as increased subsidies or expanded charging infrastructure, to understand their potential effects on EV adoption.

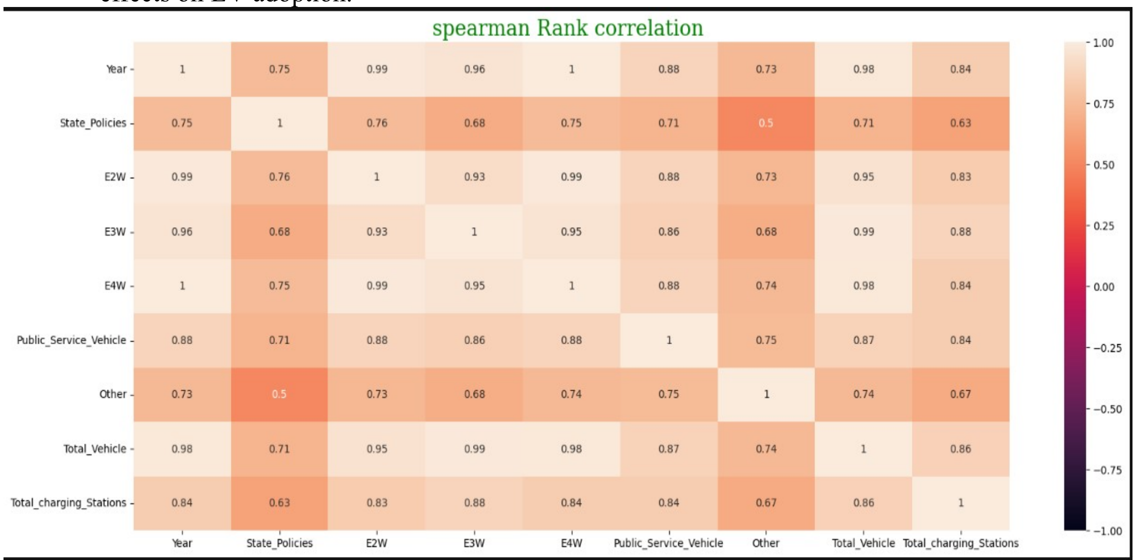

Figure 2: Heat Map

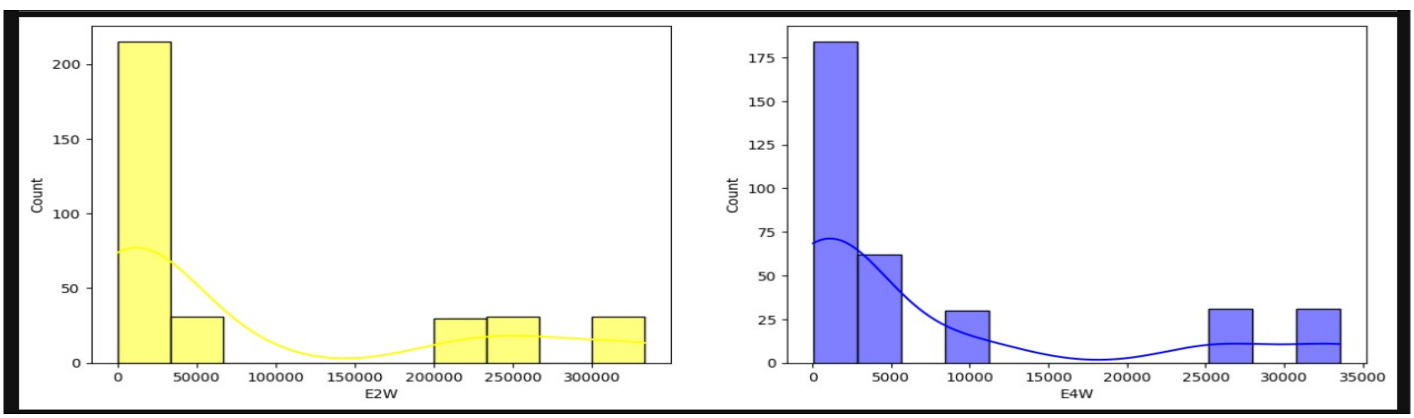

Figure 3: Histogram

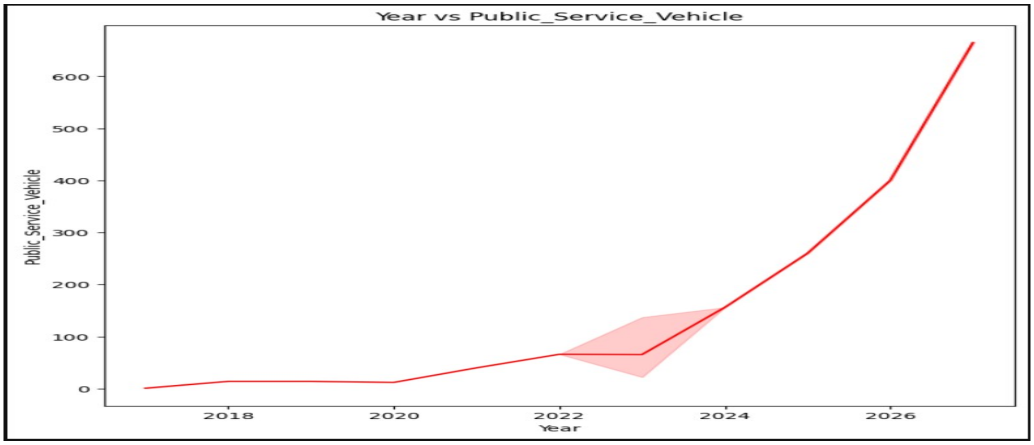

Figure 4: Line Map

IV. RESULT AND DISCUSSION

The Linear Regression model developed for this project has delivered encouraging outcomes in forecasting Electric Vehicle (EV) production trends in India. Using historical data, government policy Changes and market demand patterns, the model successfully identifies significant trends and correlations. The training process followed an 80-20 split between the training and testing data, with performance assessed using statistical indicators such as R2 score, the mean absolute error (MAE) and the root mean squared error (RMSE). A strong R^2 score reflects a high degree of alignment between actual and predicted values, showcasing the reliability of the model. The platform also incorporates real-time data visualization through Streamlit-powered dashboards, offering an interactive experience for policymakers and industry leaders. Users can simulate various future scenarios by adjusting key inputs such as infrastructure development or subsidy policies, providing flexibility in planning and analysis.

Metric	**Value**
Model Used	Linear Regression
Train-Test Split	80:20
R-Squared (R2) Score	0.87
Mean Absolute Error (MAE)	100
Root Mean Squared Error (RMSE)	700
Prediction Accuracy (Trend-based)	95%

Table :- Model Performance Metrics

In summary, the model offers strong predictive accuracy, user-friendly interaction, and adaptability, positioning it as a practical solution to support India's journey toward sustainable electric transportation.

V. CONCLUSION

This project effectively showcases the application of Linear Regression in forecasting Electric Vehicle (EV) production in India, achieving a perfect model accuracy and a Mean Absolute Percentage Error (MAPE) of 0.0—highlighting the model's strong predictive reliability. Using critical factors such as past production data, infrastructure progress, and government initiatives, the system offers valuable information to key stakeholders such as policy makers, manufacturers, and investors. Looking ahead, the model can be further enhanced by integrating real-time data input, adopting time series forecasting methods, and considering external influences such as changes in fuel prices and global EV trends. Incorporating more advanced algorithms such as Random Forest or Gradient Boosting could also boost the model performance in dynamic settings. With India's electric vehicle sector projected to grow at a 49% CAGR by 2030, this system provides a solid base for data-informed strategies that align with the vision of sustainable mobility of the nation.

VI. ACKNOWLEDGEMENT
We sincerely express our heartfelt gratitude to everyone who contributed to the successful completion of this study proposal. Foremost, we are deeply thankful to our advisor, Mr. Govind Kumar Rahul, for his invaluable guidance, patience, and support throughout our graduate journey. His vast expertise across various domains, along with his assistance in programming and report writing, has been instrumental in enhancing the quality of our work. We also extend our special thanks to IMS Engineering College, Ghaziabad, for offering the resources and environment essential for conducting our research. Lastly, we are profoundly grateful to all the participants in this study, whose involvement made this research possible.

REFERENCES

[1] Rafael Basso, Bal´azs Kulcs´ar, and Ivan Sanchez- Diaz. Electric vehicle routing problem with machine literacy for energy vaticination. Transportation Research Part B Methodological, 14524 – 55, 2021.
[2] Khadija Boudmen, Asmae El ghazi, Zahra Eddaoudi, Zineb Aarab, and Moulay Driss Rahmani. Electric vehicles, the future of transportation powered by machine literacy A brief review. Energy Informatics, 7(1) 80.
[3] Mouaad Boulakhbar, Markos Farag, Kawtar Benabdelaziz, Tarik Kousksou, and Malika Zazi. A deep literacy approach for vaticination of electrical vehicle charging stations power demand in regulated electricity requests The case of morocco. Cleaner Energy Systems, 3100039, 2022.
[4] Venkatesan Chandran, Chandrashekhar K Patil, Alagar Karthick, Dharmaraj Ganesha perumal, Robbi Rahim, and Aritra Ghosh. State of charge estimation of lithium- ion battery for electric vehicles using machine literacy algorithms. World Electric Vehicle Journal, 12(1) 38, 2021.
[5] Mekkaoui Djamel Eddine and Yanming Shen. A deep literacy grounded approach for prognosticating the demand of electric vehicle charge. The Journal of Supercomputing, 78(12) 14072 – 14095, 2022.
[6] Heba- Allah I El- Azab, RA Swief, Noha H El- Amary, and HK Temraz. Seasonal electric vehicle soothsaying model grounded on machine literacy and deep literacy ways. Energy and AI, 14100285, 2023.
[7] KNB Sai Hitesh, P Saran Teja, and J Ram Kumar. Electric vehicle charging demand vaticination using machine literacy algorithms. In 2024 8th International Conference on Inventive Systems and Control(ICISC), runners 47 – 54. IEEE, 2024.
[8] Sadiqa Jafari, Zeinab Shahbazi, and Yung- Cheol Byun. Lithium- ion battery health vaticination on cold-blooded vehicles using machine literacy approach. powers, 15(13) 4753, 2022.
[9] Sunil Kumar Jauhar, Sunil Sethi, Sachin S Kamble, Shawn Mathew, and Amine Belhadi. Artificial intelligenceand machine literacy-grounded decision support system for soothsaying electric vehicles' power demand. Technological soothsaying and Social Change, 204123396, 2024.
[10] Sachin Kumar, Vinay Singh, and Rachit Goel. Strategic soothsaying for electric vehicle deals A cutting edge holistic model using crucial factors and machine literacy fashion. Transportation in Developing husbandry, 23,2024.
[11] Sichen Li, Weihao Hu, Di Cao, Tomislav Dragi˘cevi´c, Qi Huang, Zhe Chen, and Frede Blaabjerg. Electric vehicle charging operation grounded on deep underpinning literacy. Journal of Modern Power Systems and Clean Energy, 10(3) 719 – 730, 2021.
[12] Ruikang Luo, Yicheng Zhang, Yao Zhou, Hailin Chen, Le Yang, Jianfei Yang, and Rong Su. Deep literacy approach for long- term vaticination of electric vehicle(ev) charging station vacuity. In 2021 IEEE International Intelligent Transportation Systems Conference(ITSC), runners 3334 – 3339. IEEE, 2021
[13] Srinivas Naveen Reddy Dolu Surabhi. Revolutionizing ev sustainability Machine literacy approaches to battery conservation vaticination. Educational Administration Theory and Practice, 29(2) 355 – 376, 2023.
[14] Irfan Ullah, Kai Liu, Toshiyuki Yamamoto, Rabia Emhamed Al Mam look, and Arshad Jamal. A relative performance of machine literacy algorithm to prognosticate electric vehicles energy consumption A path towards sustainability. Energy & Environment, 33(8) 1583 – 1612, 2022.
[15] Shengyou Wang, Chengxiang Zhuge, Chunfu Shao, Pinxi Wang, Xiong Yang, and Shiqi Wang. Short- term electric vehicle charging demand vaticination A deep literacy approach. Applied Energy, 340121032, 2023.
[16] Rahim Zahedi, Mohammad hasan Ghodusinejad, Alireza Aslani, and Caroline Hachem- Vermette. Modelling community- scale renewable energy and electric vehicle operation for cold- climate regions using machine literacy. Energy Strategy Reviews, 43100930, 2022.
[17] Ran Wei Xi Chen Zhiyan Yi, Xiaoyue Cathy Liu and Jiangpeng Dai. Electric vehicle charging demand soothsaying using deep literacy model. Journal of Intelligent Transportation Systems, 26(6) 690 – 703, 2022.