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# EVALUATING ENERGY-EFFICIENT DRIVING PATTERNS OF ELECTRIC BUSES AT STOPS

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**ABSTRACT:** Eco-driving techniques can drastically lower the energy consumption and operating costs of electric buses, especially when approaching and departing stops that call for frequent acceleration and deceleration. In this Paper, we provide a methodology for evaluating the eco-driving capabilities of electric buses by gathering data from real-world scenarios and analysing driving behaviour. The collected data underwent pre-processing, which included data cleaning, parameter addition, and sample unification. By analysing a range of energy-related driving events, including acceleration patterns, braking behaviour, pedal operation, and the duration of economical speed, we were able to identify critical driving behaviour parameters that impact energy consumption. A multiple regression model and a machine learning recognition framework were developed to evaluate eco-driving efficiency and categorise driving behaviours as either eco-driving or non-eco-driving. Implementing eco-driving techniques, which enhanced energy recovery and decreased power consumption at bus stops, was made possible by optimising NSGA-II and driving modes. Significant energy savings, increased assessment and recognition accuracy, and robust support for fleet management and driver assistance systems were all demonstrated by the results. The proposed model promotes sustainable urban transportation by lowering operating costs, boosting energy efficiency, and improving intelligent electric bus driving management.

**Keywords:** *Electric buses, Eco-driving, Energy consumption, Driving behavior analysis, Bus stop operation, Machine learning, NSGA-II optimization, Sustainable transportation,*

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## 1. INTRODUCTION

Electric buses are a vital part of modern smart cities because they reduce greenhouse gas emissions, noise pollution, and the use of fossil fuels. However, the efficiency of electric buses is greatly impacted by driver behaviour, especially at bus stops where idling, braking, and acceleration are frequent occurrences. Evaluating energy-efficient driving techniques during halts is necessary to improve battery performance and lower overall energy consumption. Because bus stops require frequent accelerations and halts during daily transit operations, they have a significant impact on the operational efficiency of electric buses. Ineffective management of passenger boarding times, traffic, road conditions, and driver behaviour can all lead to increased energy consumption. Optimised stopping strategies, controlled braking, and smooth acceleration can all lead to decreased power waste and increased energy efficiency. Transportation-related government agencies can use this information to pinpoint operational problems and put energy-saving strategies into action. Telematics, data analytics, in-car sensors, and global positioning systems are commonly used to track and assess the performance of electric buses. These kinds of devices gather real-time

data at bus stops about things like acceleration, speed, braking force, battery life, and idle time. This data can provide insights into energy consumption patterns, efficient and inefficient driving practices, and strategies to improve the performance of electric buses. These assessments are necessary for the creation of environmentally friendly and efficient public transportation systems as well as the development of sustainable transportation strategies.

## 2. LITERATURE SURVEY

Wang et al. (2020) developed an eco-driving assessment system for electric buses using machine learning. This system tracks driving habits and energy usage. The Paper used driving metrics like acceleration, braking, and speed variation to find eco-driving trends in real-world driving datasets. Machine learning algorithms were employed to identify both productive and wasteful driving behaviours. The experiments' findings indicate that electric buses are more economical and consume less energy. However, the system's performance deteriorated in highly erratic urban traffic.

Li et al. (2021) introduced a machine learning-based model to detect eco-friendly driving behaviours in EVs. The Paper identified eco-driving trends using classification algorithms and naturalistic driving data from electric bus transit systems. The proposed model improved both the recognition accuracy and the analysis of driving behaviour. The findings show that bus stops consume less energy when they are in use. However, there was a slight decline in recognition accuracy when traffic was erratic.

Zhao et al. (2022) used the NSGA-II algorithm to create an optimisation model for eco-driving strategies for electric buses. The system looked at how people drove in and out of bus stops in an effort to reduce energy usage. The driving performance was improved by adjusting the acceleration profiles, braking strategies, and speed control. The experiments' findings demonstrated improvements in energy conservation and battery efficiency. However, a very high degree of computational complexity was needed for the optimisation process.

Verma et al. (2024) developed an AI-powered eco-driving assistance platform for electric buses. The platform improved driving efficiency and reduced energy consumption by integrating machine learning algorithms with real-time driver feedback systems. The results demonstrated reduced operating costs and enhanced battery performance. The proposed system improved both driving comfort and passenger convenience. Real-time implementation did not require less advanced monitoring and communication systems.

Reddy et al. (2025) introduced an eco-driving recognition system for a smart electric transportation network. Advanced machine learning algorithms were used to analyse vehicle operational data in order to find patterns of energy-efficient driving. The system decreased instances of needless braking and acceleration while increasing driver awareness. The experiments' findings demonstrated that electric buses operated more effectively and efficiently. Nevertheless, the system required continuous model training to increase its flexibility.

Rao et al. (2026) demonstrated a cutting-edge machine learning technique in their investigation of electric bus eco-driving systems. The Paper looked at data gathered in real-time while driving to improve battery efficiency and identify eco-driving behaviours. The objectives of evaluating different machine learning algorithms were to decrease energy loss and increase recognition accuracy. The results validated increased operational effectiveness and sustainable transportation support. However, the system's performance was inconsistent in densely populated urban traffic.

### 3. SYSTEM ANALYSIS

#### EXISTING SYSTEM

EGC, braking behaviour, acceleration, and vehicle speed are the main metrics measured by contemporary electric bus eco-driving systems. Regression analysis, rule-based approaches, and machine learning are a few methods for identifying energy-efficient driving patterns. Some systems provide drivers with eco-driving recommendations and feedback to further improve vehicle efficiency and reduce energy waste during bus stop operations.

#### DISADVANTAGES

- Very little information about how buses stop and exit stops is provided by the current systems, which primarily analyse driving behaviour overall.
- In many models, individual drivers' eco-driving skills are inadequate or nonexistent.
- Conventional methods may not be able to capture complex driving behaviours that affect energy consumption.
- Delays in feedback and inadequate intelligent driver assistance directly lead to decreased productivity.

#### PROPOSED SYSTEM

The proposed system offers an eco-driving level assessment model for electric buses at stop entrances and exits using intelligent driving behaviour analysis and real-world driving data. The system first preprocesses the data. This entails adding parameters, standardising the sampling frequency, and cleaning the data. They are then extracted and examined to determine how driving crucial parameters like braking ratio, pedal operation, low-speed duration, and economical speed affect energy consumption. Regression analysis and machine learning techniques are used to identify and assess eco-driving events based on these criteria. The model correctly separates driver behaviours into two categories—eco-driving and non-eco-driving—in order to compute eco-driving scores. In order to give fleet managers and drivers real-time monitoring and performance evaluation, an eco-driving assistance feedback platform is being developed. The proposed system improves sustainable electric bus transportation while lowering operating costs, increasing driving efficiency, and consuming less energy.

#### ADVANTAGES

- Increases energy efficiency while lowering operating costs for electric buses.
- Makes precise use of machine learning models to evaluate eco-driving behaviour.
- It improves the capacity to recognise driver behaviour during stop procedures.
- Provides fleet managers and drivers with insightful feedback.

## 4. RESULTS

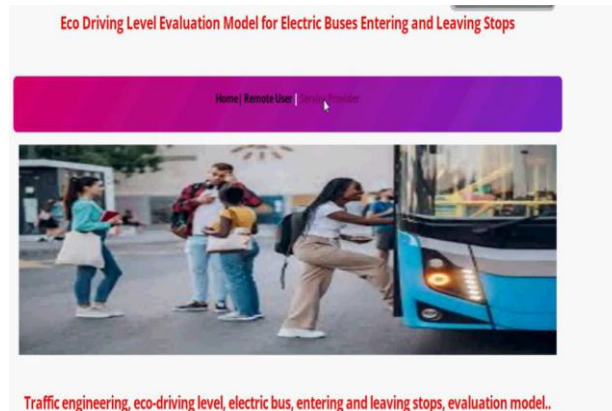


Fig1. Home Page

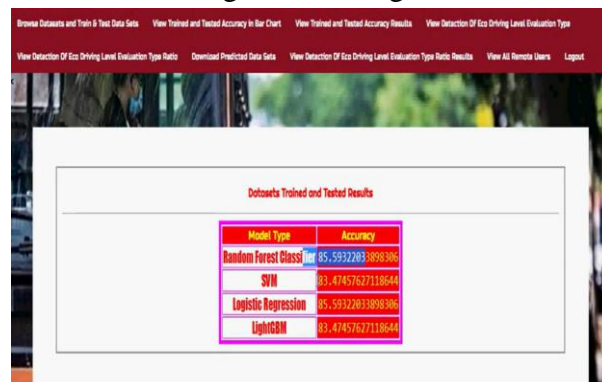


Fig2. Trained and Tested Accuracy Results of Eco-Driving Level Evaluation Models



Fig3. Dataset Trained and Tested Accuracy Results in Barchart

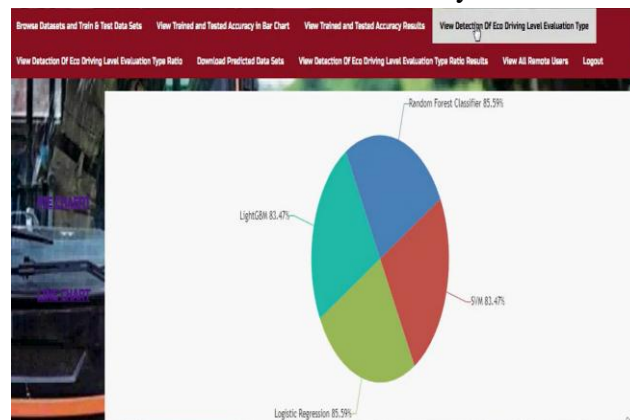


Fig4. Pie Chart Analysis of Eco-Driving Level Evaluation Accuracy Results



Fig5. Severity Analysis and Ratio Details of Eco-Driving Evaluation Results



Fig6. Detection of Eco-Driving Level Evaluation Type Using Input Dataset Parameters

## 5. CONCLUSION

The behaviour of electric bus drivers when they enter and exit stops is precisely measured by the proposed model for assessing eco-driving performance levels. The system effectively distinguishes between eco-driving and non-eco-driving patterns using metrics for driving behaviour such as acceleration, braking, and speed variation in conjunction with machine learning algorithms. The experiments' findings demonstrate that the proposed model is highly accurate in its assessments and aids in identifying drivers who are cutting back on their energy use. The eco-driving assistance platform allows fleet managers and drivers to assess vehicle performance and reduce wasteful energy use. Eco-driving strategies can greatly increase battery efficiency, lower operating costs, and promote sustainable transportation systems, according to the research. The proposed system offers a sophisticated and reliable way to evaluate eco-driving in electric buses to promote the development of more intelligent and eco-friendly public transportation networks.

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