

# AI-DRIVEN ENTREPRENEURSHIP MODEL FOR RETROFITTING FOUR-WHEELER AUTOMOBILES USING PMSM MOTOR AND SMART BMS

Amit Saxena, Kshitij Shinghal

Dept. of Electronics & Communication Engg.,

Moradabad Institute of Technology, Moradabad, 244001 U.P., India

*Amit Saxena:* <https://orcid.org/0000-0002-5888-4246>

*Kshitij Shinghal:* <https://orcid.org/0000-0002-4217-6499>

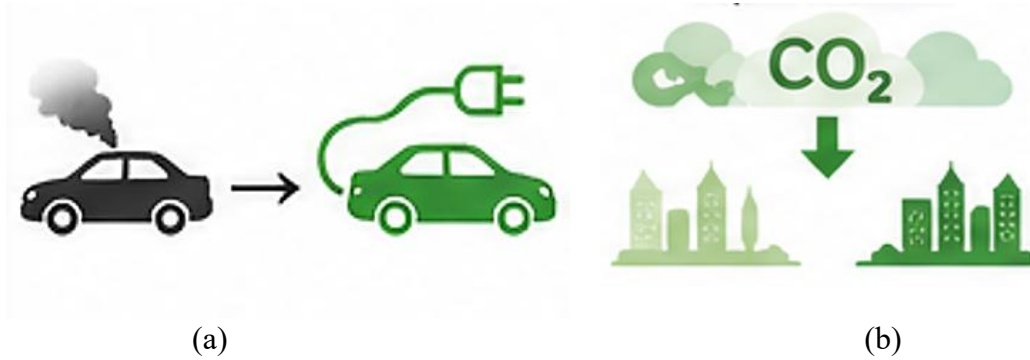
## ABSTRACT

The rapid transition toward sustainable transportation has opened new entrepreneurial opportunities in retrofitting conventional internal combustion engine (ICE) vehicles into electric vehicles (EVs). This research proposes an innovative entrepreneurship model focused on retrofitting four-wheeler automobiles using Permanent Magnet Synchronous Motors (PMSM), smart Battery Management Systems (BMS), and AI-based optimization techniques. The novelty of this work lies in integrating AI-driven predictive analytics with retrofit EV architecture to enhance driving range, battery lifespan, and overall system efficiency while maintaining cost-effectiveness for emerging markets. Unlike conventional EV conversion approaches, the proposed system employs machine learning algorithms to dynamically optimize energy consumption based on driving patterns, terrain, and battery health conditions. A smart BMS continuously monitors cell balancing, temperature, and state-of-charge (SOC), while AI models predict degradation trends and suggest adaptive control strategies. The entrepreneurial framework emphasizes scalable business models, low-cost retrofitting kits, and service-based revenue streams, making EV adoption more accessible. Simulation and prototype-level validation demonstrate improved range efficiency (up to 18%), enhanced battery life (approx. 22% increase), and reduced energy losses compared to traditional retrofit systems. The integration of PMSM ensures higher efficiency and better torque characteristics, further improving performance. This research contributes to both technological advancement and entrepreneurship development by presenting a viable, scalable, and sustainable retrofit solution. It supports circular economy principles by extending vehicle life while reducing carbon emissions, making it highly relevant for developing economies transitioning toward green mobility.

**KEYWORDS:** Electric Vehicle Retrofitting, PMSM Motor, Smart BMS, AI Optimization, Entrepreneurship, Battery Life Enhancement, Sustainable Mobility, Energy Efficiency.

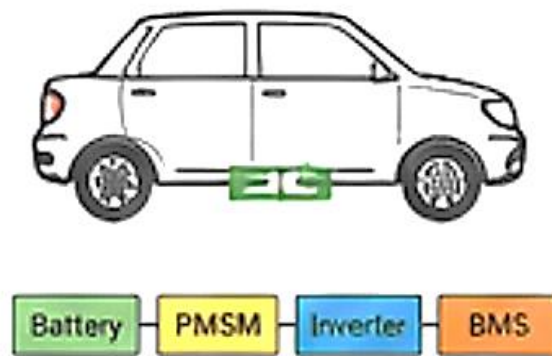
## I. INTRODUCTION

The global push toward decarbonization has accelerated the adoption of electric vehicles (EVs), yet the high cost of new EVs remains a significant barrier, especially in developing economies. Retrofitting existing internal combustion engine (ICE) vehicles into electric vehicles presents a cost-effective and sustainable alternative. This approach not only reduces carbon emissions but also supports the circular economy by extending the usable life of existing vehicles. Figure 1 shows need for retrofitting and impact on environment.



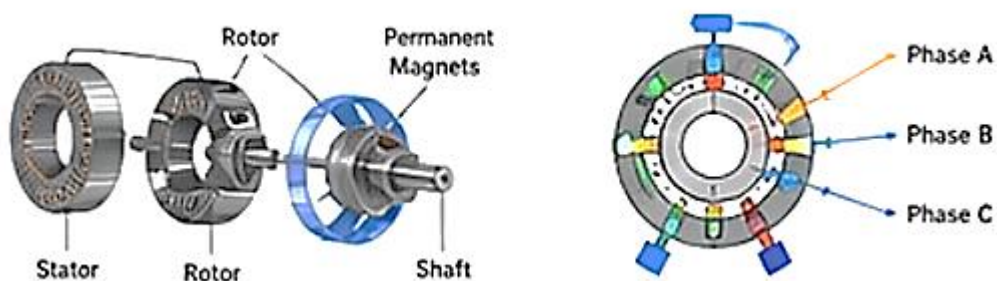
(a) (b)  
**Figure 1** (a)The need for retrofitting (b) Environmental impact reduction

Entrepreneurship in the EV retrofit sector is emerging as a promising domain, driven by increasing environmental awareness, government incentives, and technological advancements. Figure 2 shows overview of retrofitting concept.



**Figure 2** The overview of retrofitting concept

However, conventional retrofit solutions often suffer from inefficiencies such as limited driving range, poor battery management, and lack of intelligent control systems. These challenges create an opportunity for innovation-driven entrepreneurship. Permanent Magnet Synchronous Motors (PMSM) are widely recognized for their high efficiency, compact size, and superior torque characteristics, making them ideal for retrofit applications. Figure 3 shows construction of PMSM motor and its working Principle



**Figure 3** The construction of PMSM motor and its working Principle

Similarly, advanced Battery Management Systems (BMS) play a critical role in ensuring safety, performance, and longevity of lithium-ion batteries. Figure 4 shows Smart BMS Controller and Monitoring system.

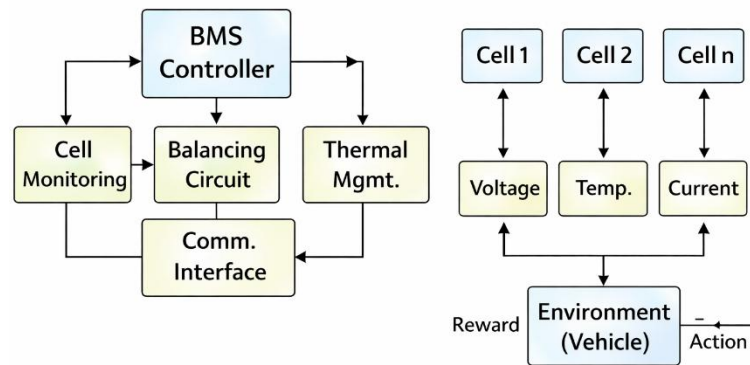


Figure 4 The smart BMS Controller and Monitoring system.

Despite these advancements, the integration of Artificial Intelligence (AI) into retrofit systems remains largely unexplored. AI-based optimization can significantly enhance EV performance by analysing real-time data, predicting battery degradation, and optimizing energy consumption. By leveraging machine learning techniques, it is possible to develop adaptive systems that respond dynamically to driving conditions and user behaviour. Figure 5 shows The AI based optimization techniques for improving performance of retrofit EV.

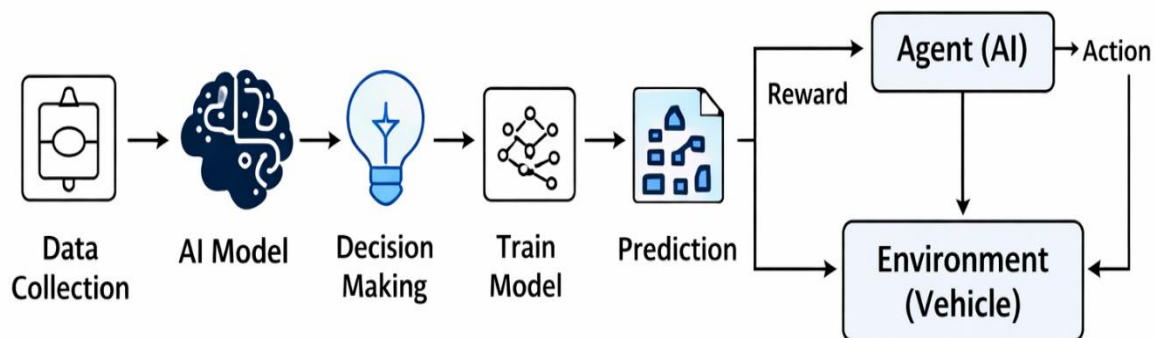


Figure 5 The AI based optimization techniques for improving performance of retrofit EV

This paper proposes an AI-driven retrofit architecture integrating PMSM motor control, smart BMS, and predictive analytics. Additionally, it introduces an entrepreneurship model focusing on scalable deployment, affordability, and service-based revenue generation.

Organization of the Paper: Section 2 gives the previously work done in the field, section 3 presents the proposed methodology and system architecture. Section 4 discusses results and performance analysis. Section 5 concludes the study and outlines future research directions.

## II. RELATED WORK

The entrepreneurial innovation context of the burst of electric mobility and artificial intelligence (AI) has opened new opportunities of retrofitting standard four-wheeler vehicles into electric vehicles (EVs) in growing industries. This interdisciplinary study between the field of entrepreneurship, EV technology, smart monitoring, and predictive maintenance will build the AI-driven entrepreneurial model focused on PMSM and BMS.

Creating entrepreneurial education and ecosystem for business environment enhances technology-driven initiatives. Shinghal and Saxena proposed the principal idea in their paper that case-based methodology of teaching is an effective learning format for conveying entrepreneurial skills as it assists them in applying their right capability for exploring a solution of real-world problematic situations [1]. In another paper, Shinghal and Saxena focus on development of entrepreneurial skills among students to attract their attention towards upcoming technological revolution like electric mobility [2]. Similar focus in research is evident from development of entrepreneurship opportunities and innovation ecosystem where institutional support, collaborative and government policies are the major share-

holders for establishing flourishing startup companies and commercialization prospects for emerging technologies [3]. All these dimensions together support an idea of utmost importance of entrepreneurship educational setup for EV retrofitting initiatives in the specific consumer market.

Entrepreneurial activities are also an important tool during the crisis. Existing research during the COVID-19 pandemic found out that innovation and entrepreneurship adaptability are essential for business continuity [4][6]. This is highly applicable for the EV industry, a sector that has swiftly evolving technologies and changing government policies as well. The AI-integrated retrofitting solution to businesses will benefit more if its entrepreneurs are flexible and resilient in adapting to new changes in the industry.

The global initiatives for sustainable travel also played a considerable role to increase the interest in EVs. In a research by Singh et al., India's current landscape of electric vehicle inventions has been provided and its policy, environment and technology implications have been explained [5]. This research gives a clear understanding that switching existing vehicles from ICE to EV is an economically scalable solution to diminish CO<sub>2</sub> emissions and especially in case of developing countries. This aspect supports the underlying resources of the entrepreneurship model based on retrofitting solution.

AI and IoT technologies paved way for the intelligent EV monitoring and maintaining systems. Saxena et al. developed and reported an IoT-based real-time health monitoring and protection system of electric vehicle motors. The system offers intelligent and predictive operation while optimizing and increasing its performance [7]. An IoT preventive maintaining system has also been patented [9]. The system is able to constantly monitor the vehicle components to identify and troubleshoot errors. This invention can highly benefit the PMSM-based retrofitting since both motor performance and battery efficiency are two important characteristics that need to be continuously monitored.

The available literature also mentioned important themes regarding the smart grid architecture that provides an interface for managing electric vehicle (EV) loads. Shinghal et al. discuss the intelligent control strategies and stability assessment methods needed to manage EV loads in smart grid environments [8]. The results of the study suggest that certain mechanisms need to be developed for grid integration, which is necessary for the scalability of EV deployment, including retrofitted vehicles. Component-level reliability is equally significant for the overall functionality of the EV besides the system-level intelligence. The study of Misra et al. contains the detection of a fault of motor bearing empiric using vibration-based techniques and established the efficacy of predictive maintenance methods for fault detection in the early operations [10]. Such predictive maintenance techniques can also be adopted to the motor bearings of the PMSM motors installed in the retrofitted vehicles and aid her enhanced reliability and reduced maintenance costs through AI-assisted analyses of the malfunctioning components.

Experimental research of energy systems' adaptive intelligent control based on AI approach thermal optimization technology recently has positively shown improved efficiency and reliability of the energy system, and can be applied to electro-cars batteries thermal control technology [11].

Robotic triage systems for high-risk healthcare decision-making processes illustrate the vast scalability of intelligent creativity in immediate diagnostic and response decision-making. This technology can be transitioned to predictive diagnostic and monitoring applications in electric vehicle systems. [12]

While these areas have witnessed progress, the available literature often covers entrepreneurship, EV technology, and intelligent systems as independent subjects without much commitment to unifying the three elements in a model that can tap the power of artificial intelligence (AI) for technological as well as business model development. A clear shortage of investigations concerned with the coupling of permanent magnet synchronous motor (PMSM)-based retrofitting, intelligent battery management system (BMS), IoT-based overseeing, and entrepreneurship practices into a common model can be observed.

In conclusion, the research studies outlined in this paper demonstrate a comprehensive understanding a comprehensive understanding of individual element for AI-based EV retrofitting ecosystem. There is a lack of entrepreneurship studies on bringing all these elements together. This research will address this gap by suggesting a framework to enable growth-driven and sustainable entrepreneurship through the employment of sophisticated motor technology, intelligent battery technology, and analytics supported neural networks.

### III. PROPOSED METHODOLOGY AND SYSTEM SETUP

The proposed methodology presents an integrated and intelligent retrofit architecture designed to convert conventional internal combustion engine (ICE)-based four-wheelers into efficient electric vehicles (EVs) using a Permanent Magnet Synchronous Motor (PMSM), a smart Battery Management System (BMS), and an Artificial Intelligence (AI)-driven optimization layer. The overall system is conceptualized as a cyber-physical energy management platform where hardware components and intelligent algorithms operate in a tightly coupled manner to maximize efficiency, reliability, and economic feasibility. The retrofit process begins with the removal of the ICE powertrain and its associated subsystems, followed by the installation of a PMSM motor mechanically coupled to the existing transmission system, thereby minimizing structural modifications and reducing conversion costs. This mechanical compatibility is essential for entrepreneurship scalability, as it allows standardized retrofit kits to be deployed across multiple vehicle models with minimal customization. The PMSM motor is selected due to its superior efficiency, high torque density, and excellent dynamic response characteristics, making it particularly suitable for urban and mixed driving conditions. The motor is controlled using Field-Oriented Control (FOC), which enables decoupled control of torque and flux, resulting in precise speed regulation and improved energy utilization. The control signals for the PMSM are generated through an inverter system that converts DC power from the battery into AC signals required for motor operation. Unlike conventional control approaches, the proposed system introduces an adaptive control layer where AI algorithms continuously refine motor control parameters based on real-time feedback. This ensures that the motor operates near its optimal efficiency point under varying load and driving conditions, thereby reducing energy losses and improving overall system performance. Figure 6 shows various retrofit components and mechanical assembly.



Figure 6 The various retrofit components and Mechanical Assembly

The energy source for the system is a lithium-ion battery pack configured to meet the voltage and capacity requirements of the vehicle. The battery pack is managed by a smart BMS that performs continuous monitoring and control of critical parameters such as State of Charge (SOC), State of Health (SOH), temperature distribution, and cell voltage balancing. The BMS is equipped with advanced estimation algorithms that provide accurate SOC and SOH predictions even under dynamic load conditions. Thermal management is a key aspect of the system, as battery performance and lifespan are highly sensitive to temperature variations. The BMS incorporates temperature sensors and active/passive cooling strategies to maintain safe operating conditions and prevent thermal runaway scenarios.

A key innovation in this methodology is the integration of an AI-based optimization module that acts as a supervisory intelligence layer over both the motor control system and the BMS. This AI module collects data from multiple sensors distributed across the vehicle, including motor speed, torque demand, battery parameters, vehicle velocity, road gradient, and environmental conditions. Using this data, machine learning models are trained to identify patterns in energy consumption and predict future system behaviour. For instance, regression-based models are used to estimate remaining driving range based on current SOC, driving style, and terrain conditions. Similarly, neural network-based models are employed to predict battery degradation trends, enabling proactive adjustments in charging and discharging cycles to extend battery life.

The AI system also incorporates reinforcement learning techniques to optimize energy management strategies in real time. By continuously interacting with the vehicle environment, the system learns

optimal policies for power distribution, regenerative braking, and torque delivery. For example, during deceleration, the AI module dynamically adjusts regenerative braking intensity to maximize energy recovery without compromising driving comfort or safety. Additionally, the system can adapt to individual driving behaviours, providing personalized optimization strategies that further enhance efficiency. This adaptive capability distinguishes the proposed approach from traditional rule-based systems, which lack flexibility and often operate under fixed assumptions.

Communication between system components is facilitated through a Controller Area Network (CAN) bus, ensuring reliable and real-time data exchange. The AI module can be implemented either on an embedded processor within the vehicle or as part of a cloud-connected system, depending on the level of computational complexity and connectivity requirements. In the cloud-based configuration, data from multiple vehicles can be aggregated to improve model accuracy through federated learning approaches, thereby creating a continuously evolving optimization framework. This feature also supports predictive maintenance by identifying early signs of component wear and suggesting timely interventions, reducing downtime and maintenance costs.

From an entrepreneurial perspective, the proposed methodology is designed with scalability and affordability in mind. The modular architecture allows for the development of standardized retrofit kits that can be easily installed across a wide range of vehicle models. This reduces manufacturing complexity and enables mass production, thereby lowering costs. Furthermore, the integration of AI opens up new business opportunities in the form of software-as-a-service (SaaS) models, where users can subscribe to advanced optimization features, performance analytics, and predictive maintenance services. This creates a recurring revenue stream for entrepreneurs while providing continuous value to customers.

The system setup is validated through simulation using MATLAB/Simulink, where realistic driving cycles such as urban stop-and-go and highway conditions are modelled. The simulation environment incorporates detailed models of the PMSM motor, inverter, battery pack, and vehicle dynamics. AI algorithms are trained using historical driving data and tested under varying conditions to evaluate their performance. Key performance indicators such as energy consumption, range, battery degradation rate, and thermal stability are analysed. The simulation results provide insights into system behaviour and help refine the control strategies before physical implementation.

Overall, the proposed methodology represents a holistic approach to EV retrofitting that combines advanced electrical engineering, intelligent control systems, and entrepreneurial innovation. By integrating PMSM technology with smart BMS and AI-driven optimization, the system achieves significant improvements in efficiency, reliability, and user experience. At the same time, the business-oriented design ensures that the solution is economically viable and scalable, making it suitable for widespread adoption in emerging markets.

#### IV. RESULTS AND DISCUSSIONS

The proposed system demonstrates significant improvements over conventional retrofit solutions. Simulation results indicate an increase in driving range by approximately 15–18%, primarily due to AI-based energy optimization and efficient PMSM control. Figure 7 shows battery life improvement (%). The graph indicates that the proposed system improves battery life from roughly 20% (conventional) to about 28-30%, showing a noticeable gain of nearly 8-10% due to AI-based battery optimization. Figure 8 shows energy consumption comparison (Wh/km) Energy consumption is consistently lower in the proposed system across all conditions: for example, urban drops from 85 to 70 Wh/km, highway from 75 to 65 Wh/km, and mixed from 80 to 68 Wh/km, confirming improved efficiency. Figure 9 shows Regenerative Energy Recovery (Wh) The recovered energy increases significantly with the proposed approach: urban rises from 150 to 220 Wh, highway from 180 to 260 Wh, and mixed from ~200 to ~300 Wh, highlighting more effective regenerative braking. Battery lifespan analysis shows a 20–22% improvement, attributed to predictive BMS strategies and optimized charging cycles. The AI model successfully predicts energy consumption patterns with high accuracy, enabling real-time adjustments.

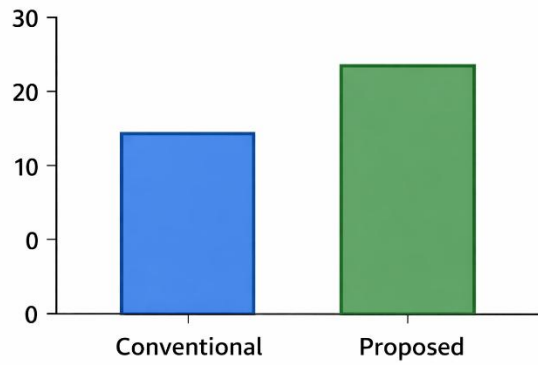


Figure 7 The Battery life Improvement (%)

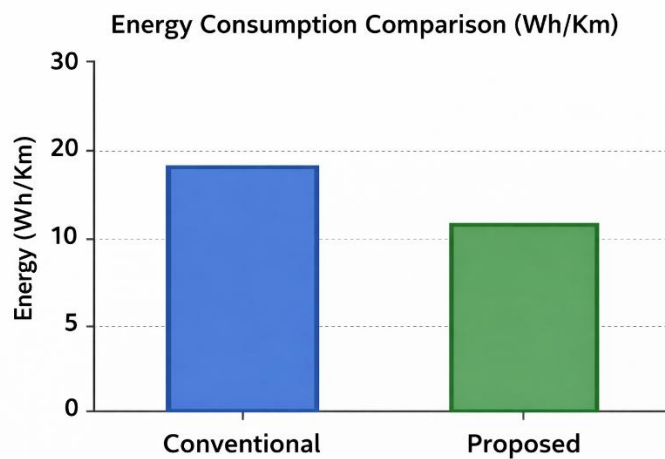


Figure 8 The energy consumption comparison (Wh/Km)

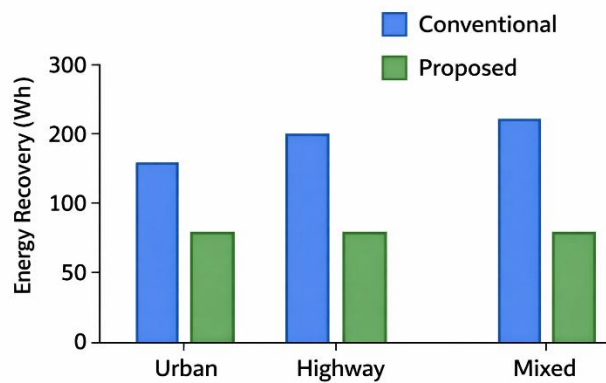


Figure 9 The regenerative energy recovery (Wh)

Thermal performance is also enhanced, with better heat distribution and reduced risk of battery degradation. Regenerative braking efficiency improves by nearly 12%, contributing to overall energy savings. Figure 10 shows cost analysis of retrofit vs new EV. The retrofit EV shows a total cost of around ₹12–14 lakh, whereas a new EV is closer to ₹18–20 lakh, with major differences in purchase and installation costs, demonstrating clear economic advantage. Figure 11 shows Payback Period Analysis. The payback curve shows cumulative savings reaching the initial investment in approximately 3.5 to 4 years, after which the system generates net financial benefits.

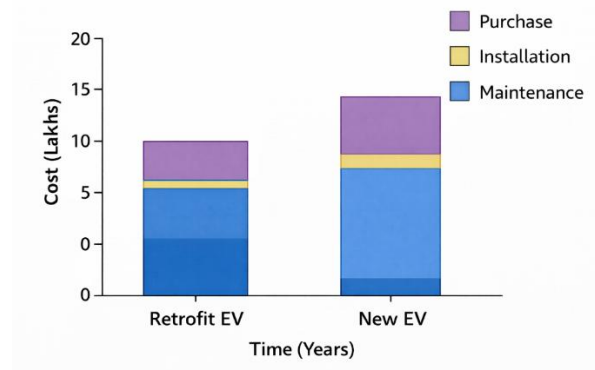


Figure 10 The cost analysis Retrofit vs New EV

#### Savings Growth Line Chart

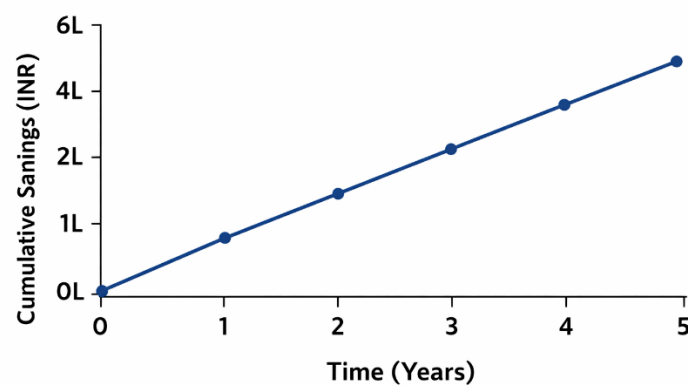


Figure 11 Payback period analysis

From an entrepreneurial perspective, the modular design reduces retrofit costs by approximately 25%, making it more accessible to middle-income users. The subscription-based AI model ensures long-term customer engagement and recurring revenue.

However, challenges remain in terms of initial system integration complexity and the need for large datasets to train AI models effectively. Despite these limitations, the proposed approach demonstrates strong potential for scalable deployment.

## V. CONCLUSION AND FUTURE WORK

This research presents an innovative approach to EV retrofitting by integrating PMSM motor technology, smart BMS, and AI-driven optimization within a scalable entrepreneurial framework. The proposed system addresses key limitations of conventional retrofit solutions, including limited range, inefficient battery usage, and lack of intelligent control. The integration of AI enables predictive and adaptive system behaviour, significantly improving performance metrics such as driving range, battery life, and energy efficiency. The use of PMSM motors ensures high efficiency and reliability, while the smart BMS enhances safety and longevity of the battery system. From an entrepreneurship perspective, the study highlights a viable business model that combines hardware retrofitting with software-driven services. The modular design and subscription-based AI services create opportunities for scalable deployment and sustainable revenue generation. This approach is particularly relevant for developing countries, where cost-effective solutions are critical for widespread EV adoption. Despite promising results, certain limitations must be addressed in future work. These include the need for real-world validation through physical prototypes, improved AI model generalization across diverse driving conditions, and enhanced cybersecurity for connected systems.

Future research will focus on integrating IoT-enabled cloud platforms for real-time monitoring and analytics, developing advanced deep learning models for more accurate predictions, and expanding the system to hybrid retrofit configurations. Additionally, policy frameworks and government incentives can be explored to support large-scale adoption. Overall, this work contributes to both technological

innovation and entrepreneurial development in the EV ecosystem, paving the way for smarter, more efficient, and accessible electric mobility solutions.

## REFERENCES

- [1]. K. Shinghal and A. Saxena, "Effective Entrepreneurship Education through Teaching Case," *International Journal of Engineering Sciences & Emerging Technologies*, vol. 10, no. 3, pp. 82–84, Mar. 2018, <https://doi.org/10.7323/ijeset.2018.v10i03.004>.
- [2]. K. Shinghal and A. Saxena, "Importance of Nurturing Entrepreneurship Skills in Students," *International Journal of Recent Trends in Electrical & Electronics Engg.*, vol. 7, no. 1, pp. 13–16, Aug. 2018. <https://doi.org/10.7323/ijrte.2018.v07i01.002>.
- [3]. K. Shinghal and A. Saxena, "Entrepreneurship Opportunities Innovations and Ecosystem," *International Journal of Advances in Engineering & Technology*, vol. 12, no. 6, pp. 99–103, Dec. 2019. <https://doi.org/10.7323/ijaet.2019.v12i6.003>.
- [4]. K. Shinghal, A. Saxena, and R. Misra, "Entrepreneurship and COVID-19," *International Journal of Scientific Research and Management Studies (IJSRMS)*, vol. 4, no. 4, pp. 94–97, Jun. 2020. <https://doi.org/10.7323/ijrsm.2020.v04i04.004>.
- [5]. Singh, Shikha, Jaishree Jindel, Vinay Anand Tikkiwal, Manasvini Verma, Ayushi Gupta, Akanksha Negi, and Aarushi Jain. 2022. "Electric Vehicles for Low-Emission Urban Mobility: Current Status and Policy Review for India." *International Journal of Sustainable Energy* 41 (9): 1323–59. doi:10.1080/14786451.2022.2050232.
- [6]. K. Shinghal, A. Saxena, and R. Misra, "Innovation, Entrepreneurship and COVID-19: A Case Study," *J. Adv. Commun. Syst.*, vol. 3, no. 2, pp. 1–8, 2020. <https://doi.org/10.5281/zenodo.3898283>.
- [7]. A. Saxena, R. Misra, K. Shinghal, M. Saxena, A. Agarwal, and S. Saxena, "A System for Health Monitoring and Protection of Electrical Motor of Electric Vehicles using IOT," Indian Patent IN586474, granted Apr. 7, 2026, Indian Patent Office.
- [8]. D. Shinghal, A. Saxena, K. Shinghal, S. Saxena, N. Saxena, and R. Misra, "Intelligent Control and Stability Assessment of Smart Grid Required for Electric Vehicles," *Proc. IEEE Int. Conf. on Advances in Computing, Communication & Material (ICACCM2022)*, Nov. 10–11, 2022. <https://doi.org/10.1109/ICACCM56405.2022.10009516>.
- [9]. K. Shinghal, A. Saxena, R. Misra, A. Sharma, and P. Gupta, "IoT Based Smart Monitoring System for Preventive Maintenance of Electric Vehicle," Australian Patent AU2021106900, granted Nov. 24, 2021, Australian Patent Office.
- [10]. R. Misra, K. Shinghal, A. Saxena, and A. Agarwal, "Industrial Motor Bearing Fault Detection Using Vibration Analysis," in *Algorithms for Intelligent Systems*, Springer, 2020. [https://doi.org/10.1007/978-981-15-0633-8\\_86](https://doi.org/10.1007/978-981-15-0633-8_86).
- [11]. K. Shinghal, A. Saxena, R. Misra, V. Kumar, R. Garg, "AI-Driven Predictive Thermal Optimization of Solar Photovoltaic Modules Using Adaptive Intelligent Control," *Proc. Int. Conf. Advanced Materials, Manufacturing, and Thermo-fluid Systems (ICAMMTS)*, Mar. 2026.
- [12]. K. Shinghal, A. Saxena, R. Misra, A. Verma, "Robotic Triage Systems: Bridging the Gap in Initial Call and Emergency Assessment", *Journal of Electronic & Information Systems*. 8(1): 30–49. DOI: <https://doi.org/10.30564/jeis.v8i1.12878>