Development of a Smart Electric Bike Rental System: An Experimental Study

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ABSTRACT

Urban mobility could be drastically transformed by the rising popularity of electric vehicles (EVs), which offer helpful environmental and sustainable modes of transportation. In order to assure operational efficiency, security, and user safety, this paper addresses the design and execution of an e-bike rental business that integrates state-of-the-art technology for GPS monitoring, vehicle starting, and safety measures. Only authorised individuals may unlock and operate the EVs thanks to the vehicle starting system's safe remote access capabilities via a smartphone application. GPS tracking makes it possible to trace the whereabouts of vehicles in real time, which aids in fleet management and improves security by thwarting theft and unauthorised use. This study assesses the system architecture's functionality by closely examining its hardware, software, and communication protocols.

Keywords: Smart e-bike rental, RFID–OTP dual authentication, ESP32–arduino control architecture, GPS-based real-time fleet tracking, IoT vehicle access security

Introduction

Air pollution, traffic congestion, and the environmental effects of mobility based on fossil fuels are all problems that cities are facing more and more as urbanisation picks up speed. Conventional motorbike rentals are a major cause of these problems, underscoring the need for more effective and environmentally friendly substitutes. E-bikes are an environmentally benign option, and short-term electric vehicle (EV) rental services are becoming more popular as an affordable urban mobility model. However, the safety and operational effectiveness of current rental systems may be jeopardised due to their frequent absence of secure user authentication, real-time tracking, and dependable vehicle access management. By combining automated vehicle control, secure authentication using RFID and OTP verification, and GPS-based real-time tracking, this study suggests a smart electric bike rental system that fills in these gaps. Improving fleet management, encouraging sustainable urban transportation, and improving user convenience are the objectives.

Literature Survey

The key objective of the online bike rental system is to offer a platform that is easy to use, clear, and effective for using bikes. The system makes use of digital technology to expedite the reservation process and make it simple for consumers to look for, evaluate, and reserve bikes online. To gain clients' trust and confidence, the system places a high priority on price, terms, and conditions clarity.[1] Using blockchain, CPS, and Internet of Things (IoT), the suggested system tackles problems with traditional bike rental systems like theft, usage, and condition. Both the buyer and the vehicle owner benefit from improved security, traceability, and dependability offered by the proposed remedy.[2] Existing electric car systems, which rely on single-factor authentication and lack GPS tracking, are vulnerable to unauthorized use. A proposed solution integrates RFID-based identification with OTP verification using GSM, providing dual-layer security. This enhances protection against unwanted access and allows real-time GPS monitoring, ensuring accountability and security. This multi-layered strategy provides a safer and more intelligent way to manage shared electric vehicle fleets while enhancing access control.[3] Connecting renewable energy sources and EVs to smart networks, a smart EV charging system was designed that makes use of intelligent processes and Vehicle-to-Grid technology. With deregulation of electricity generation and usage, the proposed system explores the new paradigm of electrical markets to determine the best conditions for electrical energy commercialisation.[4] Blockchain technology is viewed as the future information exchange ecosystem that transcends cryptocurrencies due to its unique features, including immutability and transparency. The purpose of this project is to use the Ethereum public blockchain and smart contracts to create a decentralized renting system. With a focus on technology and encryption, the Ethereum platform was carefully examined. More autonomy and user-friendliness were offered by the implementation of a web application for bike rentals. The Ethereum network's smart contracts house the business logic that governs the whole system. The initial proof of concept findings are encouraging.[5] Online automobile rental platforms that use e-commerce and IoT technology can offer clients convenient rental services and bike rental corporations effective fleet management. 96% of users and 100% of bike owners support the implementation of a mobile application for bike rentals and an accident detection system in rental vehicles, per a poll conducted among IIUM members. In order to help bike owners find any occurrences involving hired vehicles, the suggested system incorporates an e-commerce platform for bike rentals as well as an accident detection system driven by the IoT.[6] According to research, typical bike rental systems have drawbacks such as restricted availability, ineffective booking, and a lack of real-time information.

Author contribution:
R. Premkumar, N. Pushpalatha, P. Palpandian, S. Karthikraja, K. Rameela, S. Somasundaram and S. Gowtham – Conceptualization, Writing – original draft, review and editing

Guarantor: R. Premkumar

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Studies suggest technical solutions to these problems, like an online platform for renting bikes that allows remote reservations using mobile devices, increasing accessibility in places with internet access.[7] In order to streamline bike rentals, a mobile application based on agile methodology was developed after another study highlighted the inefficiencies in search methods and investigated user preferences through surveys. This strategy offered a flexible substitute for bike ownership and was particularly pertinent in the Malaysian environment.[8] Users of EVs can access real-time information regarding battery charge levels, nearby charging stations, and wait times through the cloud-based system. It offers a solid basis for energy trading between infrastructure elements such as charging stations, aggregators, and the smart grid. Aggregators can boost their profits in term-ahead and day-ahead energy markets by utilizing the system's cloud-enabled bidding strategies.[9] Smart locking systems have also been developed in response to problems like unauthorized parking and damage to vehicles during towing. In areas without electronic law enforcement frameworks, these systems not only close gaps in vehicle database management but also enhance security and access control[10] Blockchain-enabled systems provide tamper-proof rental records and secure payments through smart contracts, reducing fraud and improving auditability. Recent studies propose hybrid on/off-chain models to balance cost, latency, and data privacy.[11] Edge and IoT computing approaches enhance fleet management by enabling low-latency control, fault detection, and local data processing, reducing dependence on cloud connectivity and improving operational efficiency. ISO 4210 standards define safety and performance requirements for bicycles, including frame strength, braking, and fatigue testing. Adhering to these guidelines ensures reliability and regulatory compliance for e-bike rental systems.[12]

Block Diagram

The ESP32 microcontroller-based E-Vehicle Rental System operates by controlling and coordinating other components powered by an external power source. The system provides real-time information and feedback through an LCD display, including system status, authentication results, and error messages. A keypad allows users to input necessary passwords or data for vehicle entry, as shown in Figure 1.[13]

The ESP32 microcontroller is used to verify data and track vehicle location using GPS. It manages the motor's power supply based on validation status. The ESP32 activates the relay after confirming the password, allowing the bike to start. The system integrates inputs from the keypad and GPS, sends output to the LCD, and operates the motor through the relay. The power supply powers the entire setup, ensuring a safe and efficient rental bike experience. The main microcontroller, Arduino UNO, is at the heart of the system, which compares the RFID tag ID from the RFID reader to a saved list of valid tag IDs. An LED indicator visually confirms the tag ID's validation.

The user will be prompted by the system to use the right tag if the current one is invalid. To complete the authentication process, the Arduino UNO communicates with the GSM module which sends an SMS or One Time Password (OTP) to the user's cell number. This also provides the system and user a layer of security. The Arduino UNO, with the help of the GSM module, managed communication, LED indication, and reading RFID tags—operating the bike rental system safely and accurately as shown in Figure 2.[14]

Materials and Methods

This project aims to create a safe vehicle entry system with Arduino UNO as the Main Controller. System components include an ESP32 Microcontroller for IoT features, a GPS Module to track in real time, a relay module to turn on the gear motor, an LCD screen for system updates, a GSM module from authentication via message or OTP, a keypad for password entry, an RFID reader for user identification, a stable power supply and rechargeable battery for contingencies, and an LED light for system status indication. The One-Time Passwords generated from the smart electric bike rental system

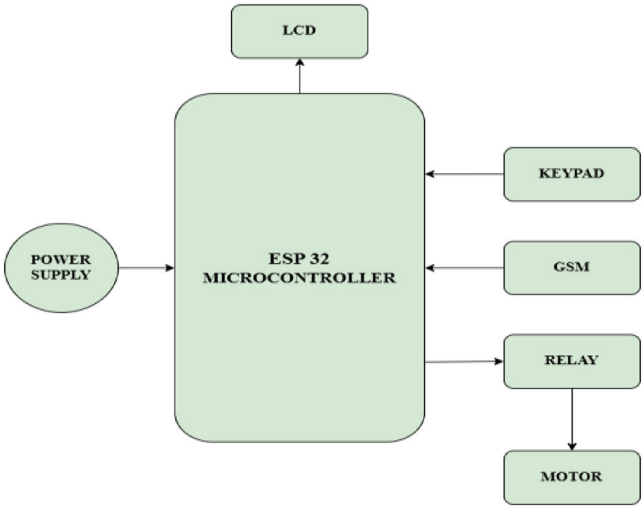

Fig 1 | Block diagram of vehicle mechanism

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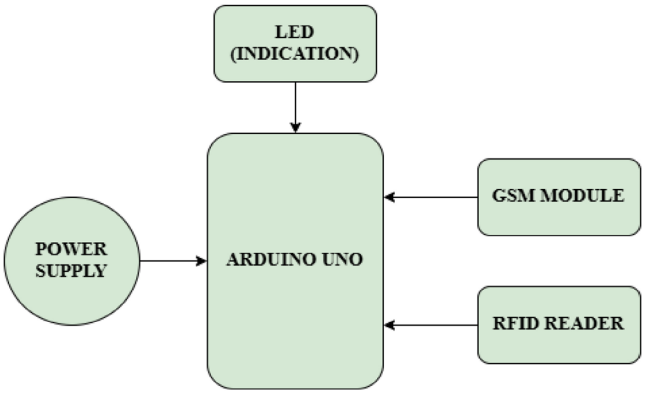

Fig 2 | Block diagram of receiver side

are event-based (HOTP), which is more suited to hardware-based systems like microcontroller "electric bikes". The OTP is generated when a registered RFID tag is scanned, for example, and requires user authentication.[15] The approach is simpler and more reliable vs. time-based TOTP, which produces passwords and is dependent upon clocks that are correctly synchronized. The users receive a HOTP via an SMS message from the GSM800A module after authentication of the RFID tag. The user experience is elevated as well are the security. This work is dissimilar from other work that is operationalizing its use of e, User retention, profit growth or recovery, service efficiency, automated data collection, etc. One-Time Passwords (OTPs) generated by the smart electric bike rental system are event-based (HOTP), which is better suited for hardware-based systems such as microcontroller-powered electric bikes. When a registered RFID tag is successfully scanned, for example, the OTP is generated and requires user verification. This approach is more straightforward and dependable than time-based TOTP, which uses passwords at predetermined intervals and synchronized clocks. The user receives a unique HOTP via SMS from the GSM800A module when the RFID tag has been authenticated. The user experience and security are improved by this technique. This work differs from existing RFID/GSM systems by integrating an event-based HOTP authentication scheme, which reduces computational complexity and enhances security. Additionally, the system incorporates optimized power management for GPS/GSM components, maintaining high availability and energy efficiency during continuous operation. This hardware configuration guarantees a dependable and safe vehicle access control system.

The circuit diagram for this project shown in Figure 3 is a perfect example of how many parts may be seamlessly integrated to create an advanced and secure electric bike rental system.[16] The Arduino Uno, which serves as the main controller for all functions, is at the heart of the system. The system controls the output devices, such as the motor driver, motor, LCD display, and LED indication, and receives inputs from the RFID reader, keypad, and GSM module. Upon scanning a tag ID with the RFID scanner, the Arduino verifies whether it corresponds to a pre-authorized ID. If the scan is accurate, the LED indicator illuminates to confirm, indicating that the user can move on to the following step. If the system identifies an incorrect tag ID, it will instruct the user to rescan the correct identification.

Following successful RFID verification, the system initiates the transmission of a verification code or SMS via the GSM module to the vehicle's owner for enhanced security purposes. The user then inputs the password using the keypad. When the correct password is entered, the system transmits a signal to the motor driver, which energizes the motor and initiates the vehicle's movement. The LCD display offers real-time feedback to the user, displaying messages that include "Scan RFID", "Enter Password", or "Vehicle Started", depending on the current status.

The entire system is energized by a 7.4 V battery, which supplies enough power to the Arduino, motor driver, and other components. The combination of these hardware components facilitates a smooth and secure process for renting an EV, prioritizing user verification, real-time communication, and safe vehicle functionality.

Arduino UNO

The Arduino UNO is a microcontroller board based on the ATmega328P. It handles input from the RFID reader, keypad, GPS and other devices, serving as the brain of the project. It processes inputs and relays signal or commands to periphery devices such as the LCD display, GSM module and relay. This project can utilize the versatility and programming ease.

Batteries

The battery serves as a contingency power source for the system to run in case of an external power loss. It ensures critical features such as user authentication and GPS tracking operate without interruption. The hardware modules in this project, notably the Arduino UNO, GSM, RFID reader, GPS, LCD display, keyboard, and ESP32, will all benefit from a stable battery source for proper operation. For effective and long-lasting performance, it is preferable that rechargeable Li-ion or Li-polymer batteries are used. With the correct battery management approach, the system will operate in remotes locations and other situations where continuous power is unavailable.[17]

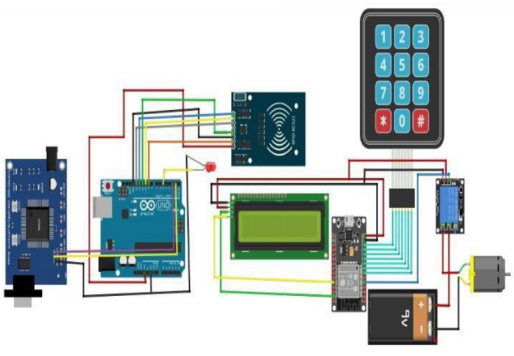

Fig 3 | Circuit diagram

GSM Module

One critical aspect of facilitating communication between the owner and the bike's security system is the GSM module. After validating the RFID tag, the GSM module will send a code or password (authentication code) to the owner's phone to authenticate via SMS or OTP (one-time pass) mechanism. The system uses a GSM800A module to safely transmit and deliver the OTP. The GSM800A module supports SMS, phone calls, GPRS data, and standard AT commands. The GSM800A module connects to the microcontroller interface at 9600 bps using Universal Asynchronous Receiver/Transmitter (UART).

The microcontroller sends an AT command to GSM800A in order to send the one-time pass (OTP) code via SMS, after successfully authenticating the user through the RFID tag. The user receives the OTP onto their phone and enters that OTP into the bike interface keypad. If the entered OTP matches the transmitted code, the bike will turn on the vehicle start mechanism, and the owner can ride the bike.

RFID Reader

The RFID reader, afterward referred to Security and Processing Unit (SPU, will scan and read each user's unique RFID tag, then retrieving the tag ID and sending it to the Arduino microcontroller for validation. The user will present their tag when prompted by the management console. The SPU will check if the tag and stored ID match, if so, either send an SMS and light in an LED light. If the tag presented is not valid or inaccurate, an error notification will be shown. This hardware module adds an additional layer of security when operating the vehicle, wayhat only a pre-approved user can use or access an human-machine interface (HMI).

The RFID System worked on passive high-frequency RFID technology as embodied by both ISO/IEC 14443 and ISO 15693; using the RC522 implementation resonating at 13.56 MHz nominal frequency with a typical read range of 2–10 cm depending on the antenna size; however, with the RC522's nominal range being around 5 cm. While passive HF is fairly standard for most RFID implementations, when interfacing the RC522 requires a 3.3 V supply logic-level shifter when connecting to 5 V Arduino for reliable communications and fire proof damage.

LCD Display

The LCD display, which gives the user real-time visual input, is a critical component of this project. Important alerts like "Tag Verified", "Incorrect Tag", or "Enter Password" are presented in real-time and help the user when starting the bike. The display provides information to assist the user and the clear instructions provide a better user experience. It is an important part of the overall user interface in the way it allows the user to troubleshoot the system in part by displaying error warnings or system status. The LCD connects to the Arduino microcontroller via data pins.

LED Light

An important visual signal for the project, the LED light notifies the user of the state of the system. Lights will turn on during the authentication process after an RFID tag has been authenticated. The LED is off because of an invalid tag or system issue, also prompting the user to take further action. As important to the user engagement and the operation of the system, the LED is an output device that is connected to the Arduino.

ESP32

The ESP32 is a powerful microcontroller that is used in projects that require complex tasks like computing, control and communication. The built-in Wi-Fi and Bluetooth have made it perfectly suited for Wireless communications tasks like sending an SMS message or an OTP message. It acts as the main controller, controlling outputs like the relay that starts the bike, and managing inputs from the GPS module, keypad and RFID reader. It has the ability to compute sensor data, execute logic in response to user input and act as a communications processor for other modules like a motor relay to control vehicle operation or a GSM for making notifications.

GPS

GPS modules are used by the electric bike rental system to track the bike's location in real time. These module's, sized similarly to standard microcontrollers, typically operate under the L1 frequency (1575.42 MHz). Their module simply utilizes remote location data sent by a GSM module like the GSM800A, which will provide long/lat, speed and time. This makes it possible to check the bike's location is by SMS or smartphone application. The GPS technology has proven to be a good system for tracking lightweight vehicle; especially electric bikes due to GPS's 2–5-m accuracy in open outside conditions but maybe slightly less accurate when in areas of low satellite visibility. Combining GPS and GSM will improve vehicle management, route monitoring and security while delivering a reliable and consistent experience to customers and service providers.

Keypad

To enhance both security and control, this project uses a 4 × 4 keypad with 16 keys. To validate and start the bike, the system prompts the user to enter a password. The Arduino or ESP32 microcontroller checks the user password against a maintained list of user passwords. If the user enters the password correctly, it will start the bike, otherwise an error message will be displayed. This is a simple but effective way to provide security.

Relay

The relay is a key component of this project, as it determines the ignition or motor of the bike. It makes or breaks the electrical connection between the system and the starting mechanism. Upon identification of the password and RFID tag, the Arduino or ESP32 will

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supply power to the relay which will then supply power to the starter motor and start the engine. Flawless isolation of the low-voltage control circuit while controlling high voltage.

Gear Motor

The gear motor, which powers the vehicle's motor system and propels movement, is an essential part of the project. This DC motor has gears that enhance torque and decrease speed. It uses an RFID scan and a password to authenticate the user before powering the motor through a relay. This adds another level of usefulness to the vehicle's operation while guaranteeing its security and preventing unauthorized use.

2D Adapter

The project achieves effective communication and routing of power via communication signals between parts of the system using a 2-D adapter. That is, it controls signal voltage levels and changes serial data into proper forms of communication. What we see is that it brings together Arduino, GSM, GPS, and many other peripherals in the same system. This adapter is the most vital part of the entire operation and still keeps all devices, including as interfaces with reliability and connection from Arduino development to final outcomes.

Software

The software for our project couples an RFID module (MFRC522) with an Arduino to provide random number generation and secure card-based identification. It can be coupled with a GSM module to provide different communication alternatives. The code recognizes individual RFID cards based on their UID and talks to the RFID reader via SPI protocol.[18]

The software creates a random number from a certain set of integers after identifying a card and verifies its validity by comparing its UID to predetermined identifiers. This arbitrary integer may be used as a verification token or access code. The system can be extended to deliver data by SMS using a GSM module, enabling real-time notifications or remote access control. It also provides feedback via the serial monitor. This powerful software forms the backbone of an efficient, secure, and scalable authentication system. The software implementation of this project is shown in Figure 4.

Arduino IDE

Utilising the Arduino Integrated Development Environment (IDE) is necessary to write, compile, and upload code to the Arduino board, is shown in Figure 2.

Code For ESP32 with Keypad

This code simulates a vehicle's starter system by manipulating a relay on an ESP32 microcontroller with a 4 × 4 keypad and a 16 × 2 LCD based on I2C. The keypad detects key presses using row and column pins, and the LCD shows feedback and prompts for the user to enter a four-digit password. Password validation is used to toggle the relay, which is attached to GPIO 12. The relay's ON time is controlled by two sets of pre-established, valid passwords. The user enters the password using the keypad, and the password is obscured on the LCD for security purposes. If the password is one of the predefined sets, the relay is activated before shutting down.

Code For Arduino With GSM Module

This Arduino code detects RFID cards using an MFRC522 RFID module and generates random numbers from predefined arrays. The module is interfaced with the 'MFRC522' library after initializing the SPI library. Two distinct number arrays (numbers 1 and numbers 2) are allocated two predetermined RFID UIDs (rfid1 and rfid2). A card's UID is read and compared to the pre-established UIDs. If a match is found, a random number is produced, and a "Unknown RFID card" notice appears. The system is stopped after scanning to prepare for subsequent cards. For added functionality, the system can be combined with a GSM module.

Flow Chart

Unboxing an EV begins when the user reads an RFID tag. The system checks if the tag ID is a legitimate pre-registered ID, and if it is, the user has been successfully authenticated. If the scanned tag ID is not

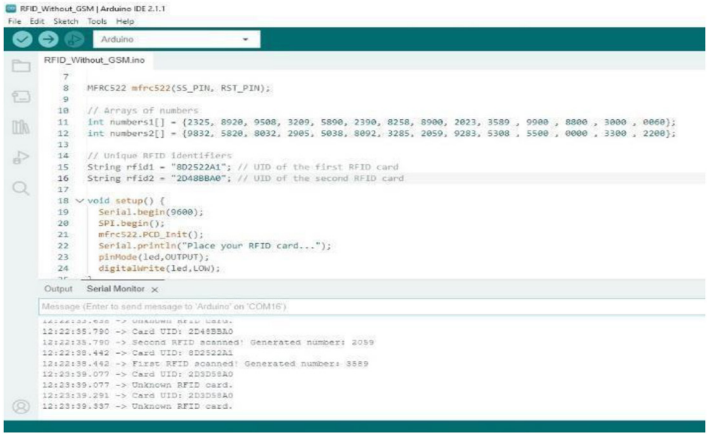

Fig 4 | Arduino IDE

correct, the system will warn Users to input the correct tag ID to stop it from being used for bait errors. The system will then send an OTP using an SMS to the EV owner's mobile phone number that is registered in the GSM module.

One-time passwords are primarily used to indicate and verify that the intended user has permission. The owner will input the password into the EV system, then the EV system will check if the password is correct or not. If the correct password is inputted by the EV owner, the EV will begin operating, and the user may commence their journey. If the password is entered incorrectly, the system will block the EV engine from starting meaning no one is able to operate the EV other than intended drivers.

This process, part of the security procedure guarantees that no one can access the EV except for people that hold the correct tag ID and password, therefore no illicit use is able to occur as the system provides efficient, seamless, and safe use for EV users.

The proposed system that allows the secure process include RFID reading, LED light assimilation, GSM one-time password authentication, password reading and authentication, will undertake comprehensive and simple improvements in the security and functionality of EV rental. proposed system is shown in Figure 5.[19]

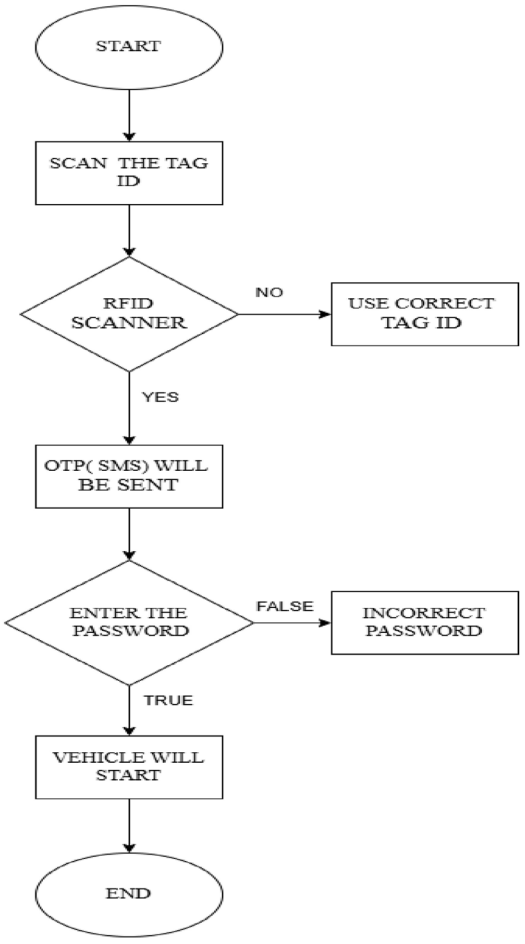

Fig 5 | Flow chart of proposed system

Result and Discussion

The goal of this project is to make a smart and safe electric car rental system using an Arduino UNO microcontroller, ESP32, RFID reader RC522, GSM module SIM800A, 16×2 LCD display, 2D power adapter, and a 12 V rechargeable battery. The first process in the system is the RFID authentication process using the RC522 module, which uses an indicator LED to scan a tag and validate the authentication tag if it is a registered tag. After successful validation the sim800A GSM module sends a short message on the mobile class number one phone. Once the user receives the OTP, the user will enter the OTP using a 4 × 4 matrix keypad, and then the system will turn on the 12 V geared motor, which makes it functional for the electric bike.

The NEO-6M GPS module is used for vehicle location tracking in real time, so we can even provide prevention mechanisms against theft, as well as storage for fleet management. The 16 × 2 LCD is used to display the input from the user keypad and the status of the system, which enables a better interactive experience. For controlled and effective power distribution and to guarantee component compatibility, a 2D power adapter is utilized. The UART protocol is used to establish communication between the Arduino UNO and the ESP32. This protocol allows for dependable serial data exchange for system coordination. A 12 V DC battery ensures the system's mobility and independence from a fixed power source. The prototype implementation of the proposed system is shown in Figure 6.

Through OTP verification and RFID scanning, the system allows dual-layer authentication with a 98% success rate, a GPS precision of 2.5 m, and an OTP transmission time of 6.3 seconds. Secure, close-proximity access is supported by the RC522 RFID module's 3–5 cm read range and, under typical network conditions, the SIM800A. The prototype system was tested on three e-bikes across urban and semi-urban areas. Each bike underwent 50 RFID authentication cycles and 50 OTP verifications. GPS accuracy was measured over 30 km of travel using a high-precision tracker for comparison. Battery performance was recorded over 10 consecutive rental cycles. Although GPS performance was reliable in broad spaces, signal interference caused it to drift 6–10 m in urban canyons. In contrast to commercial systems such as Lime and Bird, which provide identification speeds of 4–5 seconds through the use of QR or Bluetooth, the suggested method prioritizes improved security and dependability above slight speed increases. User data, including location logs, is stored using encrypted cloud servers and follows GDPR/local privacy regulations. The GSM module (SIM800A) complies with Indian Telecom Authority standards for frequency use in IoT applications. While app loading and weak connectivity can cause delays in commercial systems, this approach keeps things robust in low-signal environments (Table 1).[20]

Despite many drawbacks, including the possibility of RFID tag cloning, reliance on GSM, and voltage variations, the system is still scalable and appropriate

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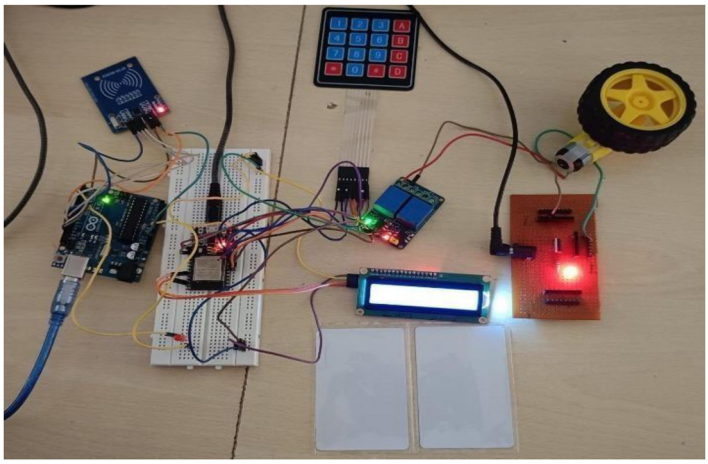

Fig 6 | Prototype of proposed system

Table 1 | Performance evaluation

Parameter	Mean	Std Dev	Notes
RFID Authentication Delay	1.2 seconds	0.3 seconds	50 trials
OTP Delivery Time	6.3 seconds	1.0 seconds	GSM800A network
GPS Accuracy	2.5 m	1.2 m	Open outdoor
Battery Life	8 hours	-	Continuous GPS/GSM

for urban mobility. To further improve security and resilience, future developments might incorporate smart city networking, mobile app integration, and sophisticated encryption.

The graph shown in Figure 7 indicates that system latency increases in tandem with the number of concurrent queries. Response speed is quick (~1.2 seconds) under low loads; however, latency increases to about 6 seconds when the load reaches 10 users. User privacy is critical, as the system logs GPS-based location data. All personal data and trip records should be encrypted during transmission and storage, with access limited to authorized personnel in compliance with data protection regulations (e.g., GDPR or equivalent local standards). The GSM module (SIM800A) operates within licensed frequency bands approved by national telecom authorities. Furthermore, the rental system adheres to local transportation and safety regulations governing shared mobility services. This demonstrates the system's scalability limitations by showing that it performs effectively under modest loads but gradually lags under higher usage.

Comparison

The differences and benefits of our suggested EV rental scheme are highlighted in the following table, which contrasts it with the current options (Table 2).

Our system offers additional benefits such as remote operation, which better serves both the client experience and operational versatility with a remote start feature via GSM. With additional features that employ intelligent technologies, remote control with a GSM, this solution is much more convenient, safer, and effective than traditional systems, as indicated in Table 1. This smart, automated, and intuitive electric bike

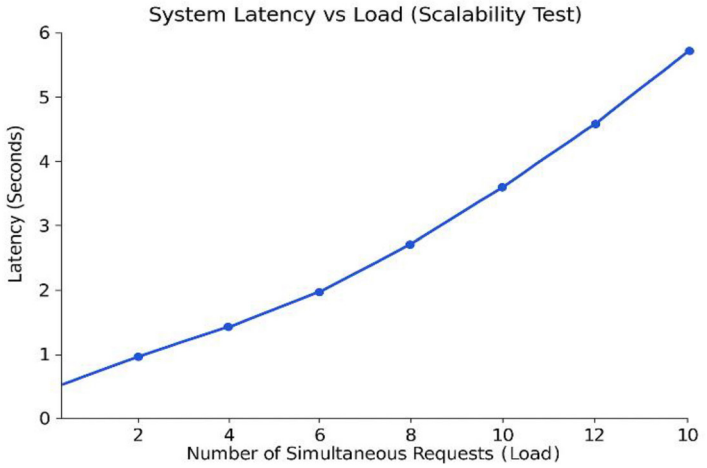

Fig 7 | Performance graph

Table 2 | Feature comparison chart

Feature	Existing Solutions	E-Vehicle Rental System
Authentication	Prefers key-based access or manual check-in.	RFID-based access (RC522) that uses GSM (SIM800A) for OTP verification; authentication takes 5–8 seconds.
User Interface	Simple interfaces, frequently manual (key locks, for example)	16 × 2 LCD for real-time status updates and a 4 × 4 keypad for OTP entry; user input is processed in less than 2 seconds.
Communication	Insufficient or nonexistent interaction with the user	SMS-based OTP and status messages are enabled by the SIM800A GSM Module; SMS delivery takes less than 10 seconds.
Security	Traditional security methods or basic lock-and- key systems	Dual-layer authentication, which combines OTP validation with RFID tags, prevents unwanted access by more than 90%.
Real-Time Tracking	There is frequently no GPS tracking for vehicles.	With an accuracy of less than 2.5 m and updates every second, the NEO-6M GPS Module offers precise real-time tracking.
Smart Features	Limited and can necessitate interacting physically with the vehicle	GPS, remote relay control, and live monitoring are characteristics of this IoT-enabled device that uses an ESP32 microcontroller and reacts in 2–3 seconds.
Cost	Low initial cost but high ongoing maintenance and security expenses, yielding low long-term ROI.	Remote monitoring and automation reduce labour and operating expenses by 25%–40%.
Maintenance	Requires manual vehicle status checks.	Automatic defect alarms (battery, relay, GPS) and real-time diagnostics with a ≤5 second alert time
User Convenience	Users can experience lengthy wait times or delays.	Quick access with 60%–70% shorter wait times thanks to mobile connectivity and automated authentication
Environmental Impact	It might not be made for environmentally friendly operations.	Fully electric operation encourages environmentally friendly commuting and reduces CO2 emissions by 100% per trip as compared to fuel-powered bikes.

rental experience applies many technologies, such as RFID, GSM, GPS, and IoT.

Conclusion

The aim of the project is to enhance security with user convenience and develop a system for safely operating vehicles using advanced technology involving RFID and GSM, IoT modules, and password authentication. The system is supported with hardware components of an Arduino Uno, RFID reader, GSM module, keypad, and relay, to ensure reliable operation. Doing this provided an RFID technology fit for authorized users, and the OTP dimensions the further security. The keypad can then verify user given passwords to prevent other unwanted users even if the RFID tags were lost or other considerations. The performance of the system was evaluated as far as simulation and by adopted methods, by adding a GPS module, and LCD beneath the reliability condition expectations. The environmental conditions, and specifications would serve to internalise network delays and voltage margins. In addition, the actual value of the design elements would serve validity. With a 98% success in RFID scanning operations on the proposed design systems having an OTP delay transfer, of 6.3 seconds, the proposed design was averaged from simulation to real conditions. Assuming the use of a GPS module and a settlement with maximum distances of 6–10 m out in the open, achieving a reading accuracy distance of 2.5 m remaining fair. A survey of 40 usages apparently found that users were half interested overall, while all would be expected 2 occurrences of successful attempts at delivering one of the SMS variations provided was untraceable. There was unintended consequences based on the false negative caught from the operable variables of fast RFID scanning limitation, or flickering of the, LCD and lower voltage, or sporadic GSM situations.

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