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Future of Online Bike Rental Systems in Smart Cities

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Abstract- The rapid growth of urban mobility solutions has increased the demand for efficient and secure bike rental systems. This project proposes an automated bike rental system using RFID, GPS, and IoT technologies to enhance the rental experience. The system ensures accurate rentals, prevents unauthorized access, and optimizes bike availability through real-time tracking. The RFID-based scanning system enables automatic bike identification and authentication, reducing human error. Each bike has an RFID tag, while rental stations feature RFID readers for automated check-in and check-out, streamlining the rental process. GPS tracking provides real-time location monitoring, improving fleet management and user safety. Users can locate bikes, check availability, and plan trips efficiently. IoT integration connects bike locks, tracking modules, and the mobile app for seamless operation. Smart locks with RFID sensors automatically unlock bikes upon successful user verification. IoT ensures real-time updates on bike status, battery levels, and maintenance needs. The mobile application allows users to rent bikes, track rentals, and make payments securely. Secure communication protocols protect user data and prevent cyber threats. The system is scalable, supporting multiple locations and rental stations. Cloud management ensures efficient data handling and fleet coordination. By integrating automated management, real-time monitoring, and enhanced security, this system offers a reliable and safe bike rental solution for urban commuters.

Index Terms- bike rental, smart transportation

I. INTRODUCTION

An Online Bike Rental System offers a smart, eco-friendly, and cost-effective solution for urban mobility. Using digital platforms, users can locate, rent, and unlock bikes through mobile apps, promoting seamless urban mobility. By leveraging technology, this system provides users with an easy-to-access platform to rent bicycles for short or long durations, reducing traffic congestion and promoting a greener environment. The system integrates GPS tracking, mobile applications, and automated rental stations to ensure seamless user experiences. It caters to daily commuters, tourists, and fitness enthusiasts, making transportation more accessible and convenient. Additionally, it supports cashless payments, real-time bike availability updates, and data-driven decision-making for city planners to optimize infrastructure. This innovative approach to bike-sharing enhances urban mobility reduces carbon footprints.

With the increasing need for sustainable and smart transportation solutions, an Online Bike Rental System plays a crucial role in enhancing urban mobility. This system leverages IoT (Internet of Things). The system is built using key components such as: RFID Reader – Enables secure user authentication and bike access using RFID cards.16x2 LCD Display – Provides real-time information such as bike status, rental confirmation, and instructions. GPS NEO-6M Module – Tracks the real-time location of bikes, ensuring security and efficient fleet management. IoT ESP8266 MCU – Acts as the main controller, connecting all components and enabling communication with the cloud for remote monitoring and control. By integrating these technologies, the system offers seamless bike booking, tracking, and automated rental management through a mobile application or web interface. Users can unlock bikes with RFID cards, check real-time availability, and track their rides effortlessly. The use of GPS and IoT enhances security by preventing theft and optimizing bike distribution. This smart bike rental system not only promotes eco-friendly transportation but also reduces traffic congestion, supports cashless transactions, and provides real-time data analytics for better city planning. It is a step toward sustainable urban mobility, improving convenience and accessibility for commuters, tourists, and fitness enthusiasts alike.

As cities become smarter and more connected, the demand for efficient and eco-friendly transportation solutions has grown. An Online Bike Rental System provides a sustainable and technologically advanced alternative for urban mobility. This system integrates IoT and smart components to enable

seamless bike rentals, ensuring convenience, security, and real- time monitoring for users and city administrators alike The system is built using key components such as an RFID reader, which allows secure user authentication and bike access through RFID cards, and a 16x2 LCD display, which provides users with important information such as rental status and instructions. A GPS NEO-6M module is incorporated to track the real-time location of bikes, enhancing security and optimizing fleet management. The entire system is controlled by the ESP8266 IoT microcontroller unit (MCU), which facilitates communication between components and enables cloud-based remote monitoring.

II. LITERATURE REVIEW

Ali Mustafa et describes a smart real-time positioning system that uses GSM and GPS technology to monitor and track objects or vehicles. The system is intended to give real time location updates and status information, hence increasing security and management efficiency. GSM/GPS technology provides large area coverage and dependable communication, making the system suited for a variety of applications such as logistics and personal security. Branimir Škugor et presents a technique for estimating city bus mass using GPS and CAN (Controller Area Network). The system's objective is to enhance vehicle efficiency and operational planning in public transportation networks through the analysis of tracking data obtained from various sources. Nalina V et details a cloud-based solution for monitoring and securing multiple vehicles. The system enables real-time observation and remote locking functions. This approach enhances the security and management of fleet operations through centralized oversight and control. Kei Kakinuma investigates a collaborative tracking approach in which multiple vehicles work together to monitor pedestrians in areas lacking GPS signals. This system utilizes inter-vehicle communication and sensor information to ensure precise tracking. Fatima Nadhim Ameen explores strategies for reducing expenses in GPS-GSM based vehicle tracking systems by refining hardware and communication protocols. It investigates affordable hardware alternatives and effective data transmission methods to decrease operational costs. The aim is to strike a balance between cost reduction and preserving high performance and reliability in vehicle tracking systems. Egor Kulik evaluates vehicle trajectories through GPS and accelerometer data to determine the needs for hybrid electric powertrains. By analyzing driving patterns and behavior, it establishes the specifications required for effective powertrain design. This method focuses on enhancing the performance and energy efficiency of hybrid electric vehicles. Abadal-Salam T. Hussain et al [7] details a vehicle positioning system that utilizes GPS for location tracking and GSM for communication purposes. This combined method enables real-time status on vehicle locations and statuses. It improves fleet management and security by offering continuous monitoring and data accessibility. Puji Valen Crisgar et al [8] describes a vehicle tracking and theft detection system using GPS combined with Google Cloud IoT and Firebase. By employing GPS for location tracking and cloud- based platforms for data handling and notifications, the system offers real-time monitoring and prompt theft alerts. This method improves vehicle security and management through cloud-based solutions. Prashant A. Shinde et al [9] describes a real-time vehicle monitoring and positioning system that uses an embedded Linux board along with an Android app. The Linux board handles processing tasks, while the Android app provides the user interface and data visualization. This configuration allows for ongoing vehicle tracking and monitoring, offering users real-time updates and control through a mobile application. Ning Li et al [10] introduces vehicle detection and tracking system which integrates, GPS/IMU, MMW radar and 3D Lidar data to function in unstructured environments.

By merging these technologies, the system achieves precise real-time vehicle detection and tracking, even in difficult conditions. This multi-sensor strategy improves the system's reliability and effectiveness in dynamic and unpredictable scenarios. K. Jeevitha et al [11] introduces a vehicle theft detection and tracking system utilizing GPS location tracking and biometric authentication. By incorporating biometric methods like fingerprint recognition, the system enhances vehicle security. It enables real-time tracking of the vehicle’s position and facilitating quick response and recovery during any event of theft. K. Mukherjee et al [12] details a system for preventing vehicle theft through GPS tracking and remote immobilization. This system enables owners to track their vehicle’s position in real-time and remotely disable it if theft occurs. The goal is to improve vehicle security and increase the chances of recovery. X. Jiang et al [13] describes a system which uses the IoT to monitor and prevent theft of port commodity vehicles by tracking their movements. This system provides real-time vehicle tracking and enhances security through IoT technology. The main goal is to increase the efficiency and safety of vehicle management in port settings.

III. METHODLOGY

The system begins by initializing essential modules such as the GPS for location tracking, the IoT module (ESP8266) for real-time data updates, and the RFID reader for user authentication. Secure Real-Time Bike Rental and Authentication Algorithm and the first step is the Initialization Start the system and initialize all components: ESP32 microcontroller, GPS module (NEO-6M), RFID reader (EM18 module), IoT module (ESP8266), LCD display (16×2), and power supply unit.The second step is the RFID Authentication Prompt the user to scan their RFID card. The RFID reader

(EM18 module) verifies the card against stored credentials.If authentication is successful, proceed to the step three, If authentication fails, prevent bike ignition is location Tracking., Activate the GPS module (NEO-6M) to determine the bike's real-time location, collecting latitude and longitude data. The fourth step is the IoT Communication is to transmit authentication status and location updates to the Arduino IoT Cloud app using the ESP8266 IoT module. Simultaneously, display the status on the 16×2 LCD screen. The fifth step is the Bike Ignition Control If authentication is successful, the ESP32 microcontroller enables bike ignition. Otherwise, the system remains locked, preventing unauthorized access. The sixth step is Continuous Monitor for unauthorized access attempts. If an invalid RFID card is detected multiple times, trigger security alerts via the Arduino IoT Cloud app. The seventh step is the Remote Access and Control which allow remote monitoring of the bike's status via the Arduino IoT Cloud app. Enable remote access features, such as location tracking and ignition control.

The Hardware Requirements includes the ESP32 Microcontroller – The core processing unit managing authentication, communication, and bike ignition. RFID Reader (EM18 Module) – Reads user RFID cards for authentication. GPS Module (NEO-6M) – Determines real-time location by receiving satellite data. IoT Module (ESP8266 with Built-in WiFi) – Sends authentication status and GPS data to the Arduino IoT Cloud app. 16×2 LCD Display – Provides real-time status updates to the user. Relay Module – Controls the bike's ignition system based on authentication status. Power Supply Unit – Supplies necessary voltage to all components. The Software Requirements includes Arduino IDE – Used for coding and programming the ESP32 microcontroller. RFID Library for Arduino GPS Library for Arduino IoT (ESP8266) Library for Arduino.

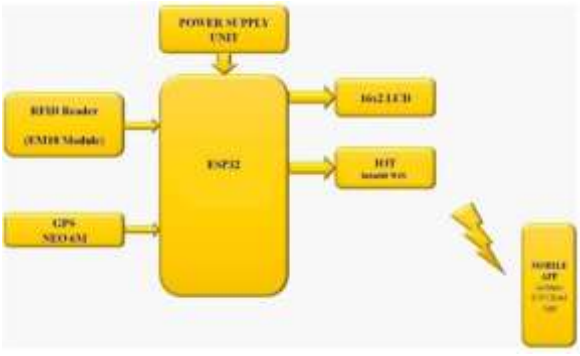

Fig.1 Block Diagram

Here, the ESP32 microcontroller serves as the main processing unit, handling the RFID authentication via the EM18 module GPS location tracking using the NEO-6M module IoT communication through the ESP8266 module. Real-time status updates displayed on a 16×2 LCD screen. All interactions between these components ensure secure bike access and efficient rental management, making the system robust and reliable. This System Initialization power on the system will initialize ESP32, GPS module (NEO-6M), RFID reader (EM18 module), IoT module (ESP8266), relay module, LCD display, and power supply unit. RFID Authentication. User scans their RFID card If the card is valid, proceed to location tracking and If the card is invalid, trigger buzzer and halt system. GPS Location Tracking Retrieve GPS coordinates Send location data via IoT (ESP8266) to Arduino IoT Cloud App Relay and Ignition Control Check ignition status. If authenticated, activate relay to enable ignition. Remote Monitoring and Alerts. Monitor bike status remotely. Send alerts if unauthorized access is detected illustrates the operational sequence of the Bike Rental and Security System. The system begins by powering on and initializing all components, including the ESP32 microcontroller, GPS module (NEO-6M), RFID reader (EM18), IoT module (ESP8266), LCD display, relay module, and power supply unit. The ESP32 serves as the central processing unit, managing all system interactions.

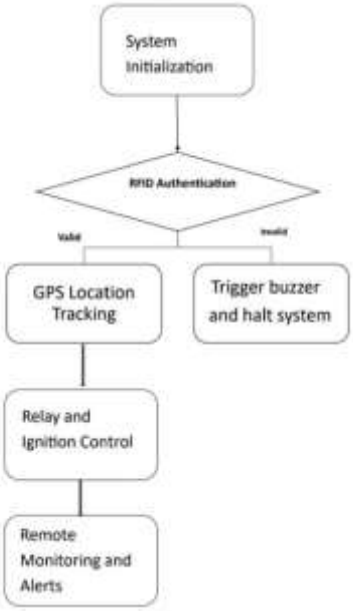

Fig.2 Flowchart

Upon startup, the system prompts the user to scan their RFID card. The RFID reader (EM18 module) reads the card and verifies its authenticity against stored credentials. If the card matches a registered user, the system proceeds to the next step. If the authentication fails, the system triggers a buzzer alert and prevents further actions, ensuring unauthorized individuals cannot access the bike. Once authenticated, the GPS module (NEO-6M) activates to determine the bike's real-time location. The acquired latitude and longitude data are processed by the ESP32 and prepared for transmission. The

IoT module (ESP8266) sends the data to the Arduino IoT Cloud App, allowing remote monitoring of the bike's location. This step ensures real-time tracking, providing an added layer of security. Following successful authentication, the relay module controls the bike's ignition system. The ESP32 sends a signal to activate the relay, allowing the bike to start. However, if authentication fails, the relay remains inactive, preventing ignition. The system continuously monitors the bike's status. If unauthorized access attempts are detected, immediate alerts are sent via the Arduino IoT CloudApp.

The bike rental and security system integrates an IoT-based authentication mechanism with RFID and GPS tracking to enhance vehicle security. The hardware architecture consists of a power supply unit, ESP32 microcontroller, RFID reader, GPS module, relay module, LCD display, buzzer, and an inbuilt WiFi module (ESP8266). The RFID reader (EM18 module) is linked to the ESP32 for user authentication, while the GPS module (NEO-6M) is connected to track the bike's real-time location. The IoT module with WiFi ensures seamless data communication, displaying authentication status and location details on both the 16×2 LCD display and the Arduino IoT Cloud App. The relay module controls bike ignition, allowing access only upon successful authentication. The software implementation is based on Embedded C, utilizing libraries for RFID, GPS, and IoT cloud communication. During the initialization phase, the ESP32 configures all peripherals, enabling the RFID system to verify user credentials. Upon a valid authentication, the relay moduleactivates, allowing the bike to start. If authentication fails, the buzzer is triggered, and access is denied. Simultaneously, the GPS module acquires latitude and longitude data, which is transmitted via the IoT cloud module to a designated server or mobile application for monitoring. If unauthorized access is detected, the system sends alerts through the cloud, and the buzzer provides an immediate warning signal. Additionally, remote access through the Arduino IoT Cloud App enables real-time monitoring of the bike's status, including ignition control and security alerts. By integrating RFID authentication, GPS tracking, and IoT-based monitoring, the system ensures a secure and efficient bike rental service, preventing unauthorized usage and enhancing anti-theft protection. This version better aligns with your ESP32-based system while keeping the format intact.

The Online Bike Rental System can be enhanced further by integrating advanced technologies to improve security, user experience, and operational efficiency. Mobile App Integration is a dedicated mobile application can be developed for users to rent and unlock bikes using their smartphones instead of RFID cards. The app can display real-time bike availability, GPS tracking, rental history, and payment options, making the system more user-friendly. Biometric Authentication is used instead of RFID cards, fingerprint or facial recognition can be implemented to enhance security. This would prevent the unauthorized access and eliminate the need for carrying physical cards. AI-Based Theft Detection in Artificial Intelligence (AI) algorithms can be integrated to analyze real- time movement patterns and suspicious activities. If unauthorized movement is detected, alerts can be sent to the owner along with live location tracking. Geo-Fencing and Auto Locking to Geo-fencing technology can be used to define virtual boundaries for bike movement. If the bike moves out of the predefined rental zone, the system can automatically disable ignition and alert the owner. Solar-Powered Charging System a solar-powered charging system can be integrated into electric bikes to ensure sustainability and reduce dependence on external power sources. Voice Command and AI Assistance Integration of voice commands using AI-based virtual assistants (such as Google Assistant or Alexa) can allow users to unlock bikes, check battery levels, and get real-time assistance without manual input.

Blockchain for Secure Transactions technology can be implemented for secure and transparent rental transactions, ensuring tamper-proof records and seamless payments without third-party intermediaries. Predictive Maintenance Using IoT sensors can be used to monitor bike health parameters such as battery levels, tire pressure, and engine performance. Predictive maintenance alerts can help in reducing breakdowns and improving bike longevity. These enhancements can significantly improve the efficiency, security, and usability of the Online Bike Rental System, making it more scalable and adaptable for future demands. The Online Bike Rental System utilizes RFID-based access control and IoT communication to offer a secure, efficient, and user-friendly rental experience. Central to this system is the ESP32 microcontroller, which coordinates an array of modules—including an RFID reader, GPS module, IoT module with built-in WiFi, and a 16×2 LCD display—to ensure that only verified users can operate the bike while simultaneously enabling real-time monitoring through cloud connectivity. User access is initiated via RFID authentication. Each prospective renter is provided with a personalized RFID card. When a user presents this card to the EM18 RFID reader, the system cross-references the card details with a pre-registered database. Upon a successful match, the microcontroller triggers the relay module, thereby allowing the bike to be started. In the event of an authentication failure, access is promptly denied to prevent unauthorized use. Following the authentication process, the system immediately relays the status update to both local and remote interfaces. This dual-mode feedback mechanism ensures transparency and enhances the overall user experience.

The ESP8266 IoT module sends the authentication results and other relevant data to the Arduino IoT Cloud application, while the 16×2 LCD display presents a clear message—such as "Access Granted" or "Invalid Card"— directly to the user. This dual-mode feedback mechanism ensures transparency

and enhances the overall user experience. Once the bike rental is activated, the NEO-6M GPS module begins continuous location tracking. This module gathers real-time geographic coordinates and transmits them to the cloud platform, enabling remote monitoring of the bike's whereabouts. Such real-time tracking not only assists in fleet management but also acts as a deterrent against theft, as the bike's location can be easily pinpointed if it is moved without authorization. For secure ignition control, the ESP32 microcontroller governs a relay module connected to the bike's starting mechanism. If the RFID verification is successful, the relay is activated, allowing the bike to be started. Conversely, if the RFID check fails, the relay remains inactive, ensuring that the bike cannot be started without proper authentication. This controlled ignition process is a critical aspect of the system's security framework. The system further enhances security through integrated remote monitoring and alert features. In cases where unauthorized access is attempted, the system promptly generates alerts that are transmitted via the IoT module to the Arduino IoT Cloud. These alerts, which include GPS coordinates and timestamps, enable administrators to take immediate action in response to potential security breaches. In conclusion, the Online Bike Rental System seamlessly integrates RFID authentication, GPS tracking, and IoT-based cloud communication to create a robust, secure, and efficient rental process. The strategic use of the ESP32 microcontroller, paired with real-time status updates via the ESP8266 IoT module, ensures comprehensive control and monitoring of the system. This integrated approach not only safeguards the bike rental process but also offers users a reliable and convenient experience through immediate feedback and remote oversight. The Online Bike Rental System is engineered to deliver a secure, efficient, and user- friendly rental experience by leveraging RFID-based access control and IoT communication. At the core of this system is the ESP32 microcontroller, which orchestrates a network of peripherals including an RFID reader, a GPS module (NEO- 6M), an IoT module with built-in WiFi (ESP8266), and a 16×2 LCD display. This integrated hardware setup not only authenticates users but also provides real-time monitoring and remote management capabilities through a cloud-based platform. RFID Authentication and User Verification begins with the presentation of a personalized RFID card. The EM18 RFID reader captures the card's unique identifier, and the ESP32 microcontroller cross-references this data against a pre-populated database of authorized users. Upon a successful match, the system enables the ignition by activating a relay module, thereby allowing the bike to be started. In contrast, if the RFID card fails to authenticate, the system immediately halts further operations to safeguard against unauthorized usage. This step is critical in ensuring that the rental process remains secure and that only validated users can access the service.

Real-Time Data Communication and Feedback Mechanisms: Once authentication is confirmed, the system promptly updates the user through dual feedback channels. The ESP8266 IoT module transmits status messages and location data to the Arduino IoT Cloud application, facilitating remote monitoring and control. Concurrently, the 16×2 LCD display provides on- site, real-time visual feedback, displaying messages such as "Access Granted" or "Invalid Card." This immediate feedback loop enhances user confidence and ensures transparency throughout the rental process. GPS Tracking for Enhanced Security of NEO-6M GPS module plays a pivotal role in tracking the bike's location post-rental. As soon as the bike is activated, the module continuously gathers and transmits real- time geographic coordinates to the cloud platform. This functionality not only assists in fleet management by providing precise location data but also acts as a deterrent against theft, as any unauthorized movement of the bike can be quickly detected and acted upon. Ignition Control and System Integration of the ignition process is governed by the coordinated actions of the ESP32 and a relay module. Following successful RFID verification, the microcontroller sends a signal to activate the relay, thereby closing the circuit required for the bike's ignition. If the authentication fails, the relay remains disengaged, ensuring that the bike remains locked. This tightly controlled ignition mechanism is cornerstone of the system's overall security.

IV. RESULTS AND DISCUSSION

The system's software, developed in Embedded C, is designed with modularity and scalability in mind. Custom libraries for RFID communication, GPS data parsing, and IoT connectivity have been implemented to streamline interactions between hardware components. The code structure is organized into clearly defined modules, each responsible for a specific functionality, such as authentication, data transmission, or alert generation. Rigorous testing routines are embedded within the software to validate each module's performance, ensuring that the entire system functions cohesively under various operational scenarios. System Calibration and Testing prior to full deployment, extensive calibration is conducted to ensure all hardware components operate within desired parameters. The RFID reader is tested for optimal read range and accuracy, while the GPS module is calibrated to achieve precise location tracking. In parallel, the IoT module's data transmission reliability is assessed through simulated network conditions to verify that real-time updates are consistently relayed to the cloud. Each test phase includes stress testing and error handling scenarios to ensure the system remains robust even under adverse conditions. Remote Monitoring and Alert Systems in addition to on-site feedback, the system is equipped with remote monitoring capabilities that allow administrators to oversee the status of each bike via the Arduino IoT Cloud app. This remote access is further enhanced by automated alert mechanisms, which generate

notifications in response to any anomalies such as unauthorized access attempts or sudden changes in location.

Fig.3 Authentication message

The User Experience and System Maintenance to ensure a seamless user experience, the system is designed with simplicity and clarity in mind. The intuitive user interface provided on the LCD display and mobile app minimizes user training requirements, while comprehensive logging of rental transactions and security events aids in routine maintenance and troubleshooting. Scheduled firmware updates and regular system diagnostics are planned to keep the system up-to-date and responsive to emerging security challenges. The Scalability and Future-Proofing which is looking forward, the system architecture has been developed with scalability as a priority. Future enhancements can include the integration of additional sensors, such as environmental or performance monitors, to provide even more detailed insights into bike usage and condition. The modular nature of both hardware and software components ensures that the system can be easily upgraded or expanded to meet the demands of a growing fleet or evolving user requirements. In summary, the Online Bike Rental System integrates RFID authentication, GPS tracking, and IoT cloud communication to create a robust and secure. rental service. Through carefully designe hardware integration, modular software architecture, and comprehensive testing protocols, the system offers a reliable, user-friendly, and secure solution for bike rentals.

Its scalability and potential for future enhancements make it a forward-thinking platform capable of adapting to the evolving landscape of smart transportation and secure vehicle management. This extended methodology provides an in-depth look at the system's design, functionality, and future potential, covering all essential aspects in a detailed and structured manner. Alerts include critical information such as GPS coordinates and timestamps, enabling swift intervention and reinforcing the system's overall security posture.

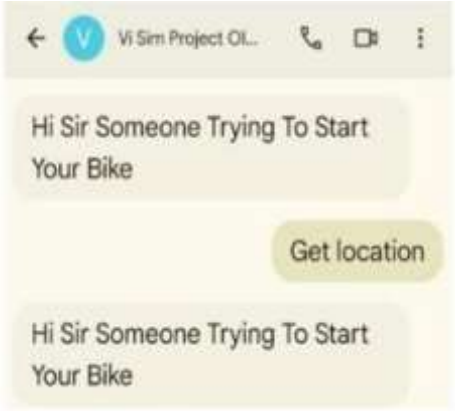

Fig.4 Message Notification

Fig.5 Live Tracking

V. CONCLUSION

Integrating GSM and GPS modules with fingerprint authentication creates a robust vehicle tracking and security system. This advanced system enhances vehicle protection through real-time monitoring, unauthorized access prevention, and efficient anti-theft management. By combining GPS tracking, GSM communication, and biometric verification, it provides comprehensive security, ensuring only authorized personnel can have access to the vehicle while allowing remote control and monitoring capabilities. The coordinated hardware and software components result in a reliable and effective solution that can quickly respond to potential threats and unauthorized access attempts. The efficiency of the model is 90 % as there was delay in sending and receiving messages. For personal vehicles, it protects against theft and unauthorized use with real-time tracking and recovery features. In fleet management, it improves the monitoring, coordination, and security of multiple vehicles. Rental and car-sharing services benefit from ensuring that only verified

users can start vehicles, aiding in both management and security. Additionally, logistics and delivery services can optimize delivery routes and secure valuable goods in transit through real- time tracking and anti-theft measures. The implementation of an online bike rental system in smart cities can significantly enhance urban mobility, reduce traffic congestion, and promote sustainable transportation options. By leveraging technology to provide users with easy access to bicycles through mobile applications, such systems contribute to improved air quality and a healthier urban environment.

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