

Bikezy: The Bike Rental System

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Abstract: *The Bike Rental System app provides a convenient, digital platform for short-term bike rentals aimed at simplifying access to affordable transportation. Designed for use by commuters, tourists, and recreational users, the app enables users to browse, rent, unlock, and pay for bikes directly from their smartphones. Key features include real-time bike availability, GPS-based tracking, secure payment processing, and user-friendly navigation. By integrating third-party services like map and payment gateways, the app automates inventory management and enhances user experience while offering business insights through rental data analytics. This platform leverages React Native for cross-platform compatibility on iOS and Android, along with a robust backend infrastructure, to ensure performance, scalability, and security. The app supports business growth by streamlining operations, providing data-driven insights, and delivering a reliable, user-focused solution for bike rentals..*

Keywords: Shared transportation, sustainable urban mobility, active transportation, bike rental system, LOGIT model

I. INTRODUCTION

As urban areas grow and the need for sustainable, cost-effective transportation options rises, bike-sharing systems have gained popularity as an accessible solution for short-distance travel. A bike rental app provides a digital solution that enhances the traditional bike rental experience by allowing users to locate, book, unlock, and pay for bikes via their smartphones. This system is designed for various user types, including daily commuters seeking an alternative to public transport, tourists exploring new cities, and recreational riders enjoying outdoor activities.

The Bike Rental System app aims to make bike rentals seamless and user-friendly, enabling users to rent bikes efficiently without waiting in lines or completing extensive paperwork. Key features of the app include real-time bike availability, GPS tracking to locate nearby bikes, secure payment options, and a history of rentals for user reference.

Through the integration of advanced technologies and third-party services, such as Google Maps for navigation and Stripe for secure payments, the app aims to create a reliable, secure, and scalable solution that improves operational efficiency and user satisfaction.

This app not only benefits users but also provides business operators with tools to manage inventory, monitor real-time rentals, and analyze usage patterns. The platform contributes to the growing trend toward environmentally friendly and shared transportation while supporting business growth through data insights and streamlined operations. By bringing bike rentals to users' fingertips, this system promotes sustainable urban mobility and offers a convenient alternative to traditional bike rentals.

Key Objective:

The Bike Rental System app aims to achieve the following key objectives:

- **Enhance User Convenience :** Provide a simple, intuitive app interface that allows users to locate, rent, unlock, and pay for bikes quickly and easily, minimizing the need for in-person interactions and paperwork.
- **Streamline Rental Operations :** Automate core processes like inventory management, bike availability updates, and payment handling to improve operational efficiency, reducing the need for manual interventions by staff.
- **Enable Real-Time GPS Tracking :** Integrate GPS tracking to help users locate nearby bikes, navigate routes, and check real-time availability, making the rental process faster and more efficient.

- **Ensure Secure and Seamless Payments:** Implement a secure payment system with various payment options, including credit cards, digital wallets, and in-app payment methods, to ensure smooth transactions and data protection.
- **Provide Business Insights:** Collect and analyze rental data to generate insights into usage patterns, peak times, and user preferences, helping operators make data-driven decisions for better resource allocation and revenue growth.
- **Promote Sustainable Urban Mobility:** Encourage eco-friendly transportation by making bike rentals easily accessible, thus reducing reliance on cars and promoting a more sustainable mode of travel.
- **Deliver a Scalable and Reliable Platform:** Build a robust backend that supports growth and can handle increasing numbers of users and transactions

II. LITERATURE REVIEW

The bike is reappeared in the last years with a phenomenal development on almost all continents after a long disappearance. Nowadays, the shared bike, represent an alternative solution to motorized mobility [19]. Since the launching of the first system in the 1960s in the Netherlands, four generations of bike sharing can be considered [4], [17], [10]. The first generation is known as Witte Fietsen “white bikes” This service is characterized by bikes randomly placed in a certain areas for free usage [17]. Unfortunately, this experience had failed, because bikes were simply harmed either thrown into channels or adapted for private use [4]. A second generation appeared in the early 1990 years, in Farsø, Grenå, and Nakskov to face the problems encountered during the first generation by integrating a financial fee to encourage users to bring the borrowed bike into a station to recover their deposit [2]. The third generation start in the beginning of 1996, the bike sharing system became more popular. This generation is characterized by a variety of technological enhancements, including the electronic locking barriers, telecommunication systems, smart cards or magnetic stripe cards, mobilephone access and embedded computers [3]

In May 2009, BIXI is the first shared fourth generation bike system appeared in Canada with its solar powered mobile stations [15]. Other innovations emerged with the fourth generation including mobile stations, solar energy stations, electrical assistance bikes and the setting up of self-regulation policy using smartphones applications [9]. In 2014, approximately 855 bike sharing programs was counted in almost every region of the world with about 946,000 bikes [12]. However, in the African continent, only two shared bike programs have been set up. The first is located in Marrakech in 2016 with 350 bikes and a dozen stations. The second was set up in Egypt in 2017 with 100 bicycles and 5 stations. In Tunisia, preparations are in progress in Sfax, Kairouan, and Tunis. This system has multiple environmental, economic and social benefits. Bike share is a sustainable practice with minor negative impacts and even without any negative impacts compared to other transportation methods. The increased use of bikes can solve problems of congestion, fuel expenses, and greenhouse gas emissions [13]. A 312 000 km/day course by the users of Vélib’ represents a reduction of about 57 720 kg of CO₂ per day compared with the same usage by car [17]. Shared bike systems contribute to reduce air and noise pollution, as well as preserve urban spaces. Moreover, requested space for bike facilities is smaller than the infrastructures required for cars [6]. Furthermore, using bikes help to reduce stress and make users more healthy [18]. Some literature reviews, highlight a lot of variety of researches done on shared bike systems [12] [20], some of them was done with deep analysis to check if it is possible to implant similar system.

Others study done by focusing on the environmental, socio-economic, geographic and psychological factors that influence the probability to use the bike. However, few studies have explored the characteristic of bike sharing users and the factors that encourage and discourage them to use it [21]. In our study, we will particularly focus on this innovative system.

III. METHODOLOGY

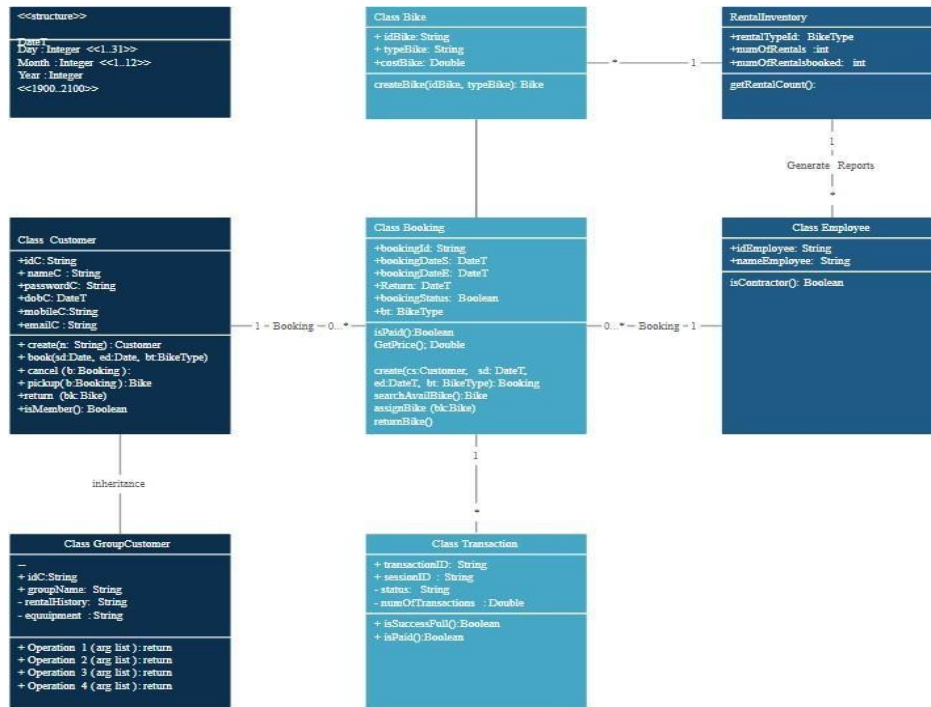


Fig1. Class Diagram[10]

Technical Architecture:

The technical architecture of the Bike Rental System app includes a combination of frontend, backend, database, and third-party integrations to deliver a seamless user experience and support efficient administrative operations. Below is an in-depth look at each component of the architecture:

1. Frontend Development

- **Technology:** React Native for cross-platform mobile app development, ensuring compatibility with both iOS and Android devices. This choice allows for code reusability and a consistent user experience across platforms
- **User Interface (UI):** Designed to be intuitive and user-friendly, focusing on easy navigation, real-time map views, and a simple booking flow.
- **User Experience (UX):** Emphasis on smooth navigation and minimal steps to complete rentals. The app UI will incorporate Google Maps or Mapbox for easy bike tracking and location-based features.
- **Security:** Implement Secure Sockets Layer (SSL) for encrypted communication between the client app and backend API.

2. Backend Development

- **Technology Stack:** Node.js with Express.js framework for the backend server, chosen for scalability and efficient handling of API requests.
- **Architecture:** RESTful API architecture that allows for easy integration with the frontend and third-party services.
- **Microservices Approach:** Modular approach with separate services for user management, booking, payment processing, and notifications to support scalability and maintainability.

- **Authentication & Authorization:** Use OAuth 2.0 or JWT (JSON Web Token) to manage secure user login and access permissions.
- **API Security:** Enforce authentication on all endpoints and include rate limiting to prevent abuse.
- **Business Logic:** Manages key processes such as bike reservations, inventory updates, payment validation, and user notifications.

3. Database Layer

Database Choice:

- MongoDB for flexibility in storing diverse data types like bike details, user profiles, rental records, and transaction data.
- PostgreSQL as an alternative for relational data needs if more complex relationships between entities are required

Data Management:

- Real-time database updates for bike availability, rental statuses, and user accounts.
- Regular backups and replication for data redundancy and disaster recovery.

Data Security:

- Encrypted storage of sensitive information (e.g., user credentials, payment records).
- Access control mechanisms to restrict data access based on roles (e.g., users, admin staff).

4. Third-Party Integrations

- **GPS and Mapping Services:** Integration with Google Maps API or Mapbox to support GPS-based tracking of bike locations and route navigation.
- **Payment Gateway:**
 - Stripe or PayPal to handle payment processing securely.
 - PCI-DSS compliance to ensure secure handling of credit card information.
- **Push Notifications:** Firebase Cloud Messaging (FCM) to send real-time notifications for booking confirmations, rental reminders, and promotional alerts.
- **QR Code or Bluetooth Integration:** Enable contactless bike unlocking through QR code scanning or Bluetooth (if supported by bike hardware).

5. Admin Web Portal

- **Frontend:** React.js for an interactive and responsive web-based admin dashboard.
- **Backend Integration:** Connected to the main backend API, providing access to real-time data on bike availability, user activity, and rentals
- **Dashboard Features:**
Inventory management, customer support, and reporting capabilities.
Data analytics on rental trends, revenue insights, and maintenance schedules.
- **Security:** Role-based access control to ensure only authorized personnel can access sensitive information.

6. Cloud Infrastructure & DevOps

- **Hosting:** AWS, Google Cloud Platform (GCP), or Microsoft Azure for scalable hosting solutions.
- **Load Balancing and Auto-Scaling:** To handle peak traffic times without compromising performance.
- **Continuous Integration and Continuous Deployment (CI/CD):** Set up with tools like Jenkins, GitHub Actions, or CircleCI to automate testing, deployment, and updates.

- **Monitoring and Logging:** Use Cloud Watch (AWS), Google Stack driver (GCP), or AzureMonitor for real-time monitoring, log analysis, and quick incident response.

7. Security Protocols

- **Data Encryption:** SSL/TLS for data in transit; database encryption for data at rest.
- **User Authentication:** OAuth 2.0 for secure authentication.
- **API Security:** Rate limiting, input validation, and sanitization to prevent abuse and attacks.
- **Regular Security Audits:** Conduct regular code reviews, vulnerability scanning, and penetration testing.

Technical Architecture Diagram (Overview)

- Client (Mobile App) ↔ API Gateway (Node.js, Express.js)
- Backend Services (User Service, Booking Service, Payment Service) ↔ Database(MongoDB/PostgreSQL)
- Third-Party Integrations: Maps, Payment Gateway, Push Notifications
- Admin Portal (React.js, API integration) ↔ Admin Backend (Node.js)

This architecture ensures that the Bike Rental System app is secure, scalable, and capable of handling a growing user base with minimal latency and high reliability. The structure also allows for future feature expansion and integration with new third-party services as the platform evolves.

IV. FUTURE SCOPE

The Bike Rental System app project covers the development of a mobile application and supporting web-based tools, focusing on providing users with a seamless bike rental experience. The scope includes the following elements:

1. Platform Development

- **Mobile App:** Create a cross-platform mobile app available on iOS and Android, accessible to all potential users including tourists, commuters, and recreational riders.
- **Admin Web Portal:** Develop a web-based admin portal for operators to manage bike inventory, rentals, and customer support.

2. Core Features

- **User Registration and Login:** Enable users to register and log in via email, phone number, or social media accounts for personalized access.
- **Bike Catalog and Availability:** Display a catalog of available bikes, with real-time updates on each bike's location, status, and specifications (e.g., type, battery level for e-bikes).
- **GPS-Based Tracking and Navigation:** Integrate GPS functionality to allow users to locate nearby bikes, navigate to selected bikes, and plan routes within the app.
- **Bike Rental Process:** Simplify the booking process, including reservation, unlocking through QR code scanning or Bluetooth, and returning bikes to designated areas.
- **Payment Integration:** Include secure payment options such as credit/debit cards, digital wallets, and in-app payment methods, with PCI-DSS compliance for transaction safety.
- **Rental History and Invoices:** Allow users to access a history of past rentals, receipts, and billing details within the app

3. Technical Infrastructure

- **Frontend Development:** Utilize React Native to develop a responsive, user-friendly mobile app interface that supports both iOS and Android devices.
- **Backend Development:** Use Node.js with Express for scalable backend services with a robust API layer to handle data interactions and business logic.

- **Database:** Implement MongoDB or PostgreSQL for storing user data, rental records, and bike inventory, with necessary data encryption for security.
- **Third-Party Integrations:** Maps and GPS Services: Integrate Google Maps or Mapbox for bike tracking and route navigation.
- **Payment Gateway:** Integrate a secure payment gateway such as Stripe or PayPal to manage transactions and ensure data security.
- **Push Notifications:** Use Firebase or similar services to send notifications for rental reminders, alerts, and promotions.

4. Admin Panel Capabilities

- **Inventory Management:** Allow admins to view, update, and manage bike inventory status (e.g., in use, available, under maintenance).
- **Real-Time Analytics:** Provide data on bike usage patterns, peak rental times, location-based demand, and revenue reports for informed decision-making.
- **Customer Support Interface:** Equip operators with tools to handle user queries, issue resolution, and provide a better support experience.
- **User Management:** Track and manage user profiles, permissions, and activity within the app.

5. Development Phases

- **Phase 1:** Requirement gathering, user research, and prototype design.
- **Phase 2:** Frontend and backend development with core functionality (user registration, bike).
- **Phase 3:** Integration of third-party services (maps, payment processing, notifications). **Phase 4:** Quality assurance, testing (unit, integration, and user testing), and bug fixes. **Phase 5:** Deployment to app stores and final launch.
- **Phase 6:** Post-launch support, updates, and feature enhancements.

6. Out-of-Scope

- Custom hardware development for bikes, such as locking mechanisms (assumed to be provided by bike providers).
- Long-term maintenance contracts (post-launch updates and maintenance are included only up to an initial period).
- The project aims to deliver a comprehensive, secure, and scalable solution that enhances bike rental accessibility and operational efficiency for both users and administrators.

Expected Outcomes:

The Bike Rental System app is expected to deliver the following outcomes upon successful development and deployment:

1. Enhanced User Accessibility and Convenience

- **Seamless Rental Experience :** Users will enjoy a hassle-free, digital platform for renting bikes without the need for physical paperwork or waiting in lines.
- **Real-Time Bike Tracking :** Users can quickly locate available bikes nearby, reserve them, and navigate to their locations using GPS integration.
- **Contactless Unlocking :** The app will enable users to unlock bikes via QR code scanning or Bluetooth, reducing friction in the rental process.

2. Increased Operational Efficiency

- **Automated Inventory Management:** The app will automate updates on bike availability and maintenance needs, enabling operators to manage the fleet effectively.
- **Reduced Manual Interventions:** Automated systems for booking, payment, and user verification will reduce the need for manual handling by staff, allowing them to focus on higher-level tasks.

3. Secure and Reliable Transactions

- **Secure Payment Processing:** Integration with PCI-DSS compliant payment gateways will ensure safe, encrypted transactions, increasing user trust and satisfaction
- **Data Protection:** Users' personal and payment data will be securely managed, meeting data privacy and security standards.

4. Business Insights through Analytics

- **Data-Driven Decision Making:** Analytics on user demographics, peak usage times, popular locations, and revenue will enable operators to optimize resources, expand services, and identify areas for improvement.
- **Rental Trend Analysis :** Tracking bike usage patterns will allow for demand forecasting, helping the business manage inventory and bike distribution efficiently.

5. Scalability and Long-Term Growth :

- **Robust Backend for Growth :** The app's scalable backend architecture will support an expanding user base and increasing transactions without compromising performance.
- **Future Integration Capabilities:** The modular architecture and third-party integration capabilities will allow easy expansion with new features, services, or hardware as the business evolves.

6. Contribution to Sustainable Urban Mobility:

- **Eco-Friendly Transportation Solution:** By providing easy access to bike rentals, the app will promote green transportation, reduce carbon emissions, and support sustainable urban mobility efforts.

7. Positive User Engagement and Retention:

- **User Satisfaction:** A smooth, user-friendly experience is expected to drive positive user reviews, encourage repeat use, and increase customer retention.
- **Increased Brand Loyalty:** A reliable service with seamless functionality and secure transactions will enhance brand reputation and user loyalty over time.

These outcomes will establish the Bike Rental System app as a reliable, scalable, and user-centric platform, supporting both user satisfaction and business growth in the long term

V. CONCLUSION

The development of the Bike Rental System app presents a comprehensive solution for modernizing bike rentals through a seamless digital platform. By enabling users to browse, rent, unlock, and pay for bikes with ease, the app enhances user convenience and accessibility, meeting the needs of various user groups such as commuters, tourists, and recreational riders.

Through the integration of GPS tracking, real-time bike availability, secure payment processing, and contactless unlocking, the app streamlines the entire rental process while maintaining robust data security and user privacy. The inclusion of a web-based admin portal allows operators to monitor and manage bike inventory, track rental activity, and access valuable analytics to optimize operations and drive data-informed decision-making.

With its scalable architecture and modular design, the app supports future growth and feature expansion, enabling it to adapt to evolving user demands and technological advancements. The system also contributes to sustainable urban mobility by encouraging eco-friendly transportation options.

Overall, the Bike Rental System app represents an effective, scalable, and user-focused solution that promotes a positive rental experience, enhances operational efficiency, and supports a greener, more connected urban environment.

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