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Bicycle Renting System with IoT-Based Smart Tracker-Pick and Go

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***Abstract* - We are proposing a solution to the current transportation issue in our country. We are creating a system where people can rent bicycles and pay according to their travel distance. This system can embed to any current available bike renting company as part of their renting system. These bicycles can be rented from renting stations that are placed in public areas like railway stations and bus stands. This is a pick-and-ride system. They can either be pre-reserved or just come and pick up their bicycles. With this system, fuel shortage is no longer an issue, people don't have to buy bicycles for themselves, and it is also good for their health too. Most of the previous products that relate to our product mainly use smartphones and their inbuilt components for vehicle tracking and fitness tracking purposes. Measurements are not very accurate when using the phone to track. Renting systems are usually situated in a place and consumers have to go there and rent and return the bikes. Our systems overcome these issues with a pick-and-go renting system. We have bicycle stations, and anyone can pick up their bikes from those stations and a tracking device is placed in the bike. Measurements can be taken accurately, and consumers can pick up and drop off bicycles at their closest stations. The research focuses on developing an accident detection and notification system for timely response to incidents. It explores integrating demand prediction to optimize bicycle availability and repair processes. To engage and motivate riders, interactive elements are incorporated into rides through gamification. The research predicts upcoming bicycle issues through data analysis, enabling proactive maintenance and fewer breakdowns. A weather detection system provides timely weather updates, enhancing safety and planning. The combination aims to improve the overall riding experience while prioritizing safety, efficiency, and satisfaction.**

Keywords: GPS, Gamification, prediction, IOT, Microcontroller, Machine learning, Accident detection, MPU6050, Accelerometer, Gyroscope, Real-time, Emergency alert, User friendly, Random Forest, Android, API, Arduino, MySQL, Regression Model, Random tree, Weather prediction, Maintenance.

I. INTRODUCTION

With the economic crisis, fuel prices are increasing day by day. Demand for fuel also increased. People don't get enough fuel for their day-to-day tasks. People are suffering with public transportation. People are now tending to ride foot bicycles again with this fuel crisis. Because of that the prices of bicycles also increased sellers. We are proposing a solution to this transportation issue. We are creating a system where people can rent bicycles and pay according to their travel distance. There are currently many bicycle renting systems. They are either charged on a daily or anytime basis. Also, there is no proper tracking system for bicycles. We are designing a system that is more efficient and effective in many ways for the renters and users too. These bicycles can be rented from renting stations that are placed in public areas like railway stations and bus stands. This is a pick-and-ride system. They can either be pre-reserved or just come and pick up their bicycles. With this system, fuel shortage is no longer an issue, people don't have to buy bicycles for themselves, and it is also good for their health.

II. BACKGROUND STUDY

Our research is based on the Bicycle renting system and its relevant components. This is proposed as a solution to a fuel crisis in our country. There are lots of vehicle renting systems and research is available to find. Most of the systems are dependent on smartphones. Tracking bicycles' speed, distance and location, and everything is done by the smartphone itself. The measurements will take from smartphones are not very accurate. For example, if a rider stops the bicycle and went to some store, and walked in there with his phone in his pocket, that distance is counted as he rides the bicycle. But in our case, we are using a separate IOT device, and it will stay mounted to the bicycle.

And the measurement taken from the device is much more accurate than taking measurements using smartphone sensors. These accurate measurements can be used to calculate the fare of the trip very accurately. [1]

Also, there is research and the use of a dock to protect the bicycle. This lock has to be embedded in the wheel. It means

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that a separate modification has to be made to the bicycle. In this system, they have both dock and dockless bicycles to rent. Dockless bicycles have to be returned to the stations and docked models don't have to. But in this case, they charge additionally for the docked model. If a rider came to buy dock less model and even, though he is very comfortable with returning the bike to the station, he has to buy docked one if dockless were not available at the time. So, he has to pay additional anyway. [2]

Another research we found is bicycle usage in a smart city. In this research, they offer bicycles with various specs, and the cost depends. On specs, this is very good if the rider wants a high-spec bike. But if the rider just wants a regular bike and there is only a hi specs bike available, the rider has to pay additional for no reason. [3]

When considering the effects of gamification on driver behavior there is research on a gamification platform for that. They Encourage users to change their driving behavior to the eco-friendlier method by controlling Acceleration, Cruising, and Deceleration. But in modern days, many vehicle manufacturers are using various technologies. So, this gamification platform may not treat everyone equally. [4]

Regarding the accident detection system, previous research was mainly focused on accident prevention. One paper discussed a smart helmet that is attached to an alcohol detection sensor and IR sensor. But the helmet should be charged. It can be an unnecessary thing. The product also high price. [5] Some papers talked about accident detection but there is not a proper way to mitigate the danger of the accident. In the domain of bicycle repairing processes, previous research has highlighted only the repairing process of bicycles. But in our system, it can predict the upcoming issues of the bicycle. [6]

Previous studies in the field of weather detection systems for cyclists have underlined the value of giving cyclists real-time weather updates to improve safety and planning. However, other studies ignored the significance of localized and reliable weather data related to the cyclist's immediate surroundings and exclusively relied on stationary weather stations or weather forecasting APIs. This limitation makes it difficult to deliver accurate and timely weather information, which is essential for guaranteeing rider safety while traveling. [7]

III. METHODOLOGY

A variety of technologies were used in the development of the suggested system. Figure 1 depicts the thorough architecture of the recently developed system. The system is made up of four main modules: a weather prediction system for bicycle users; an accident detection and emergency notification system for bicycle riders; a platform for predicting customer interactions and gamification using machine learning; and an upcoming issues prediction in the bicycles and the repairing process for the bicycle rental system. The overall system diagram of the research project is shown in Figure 1.

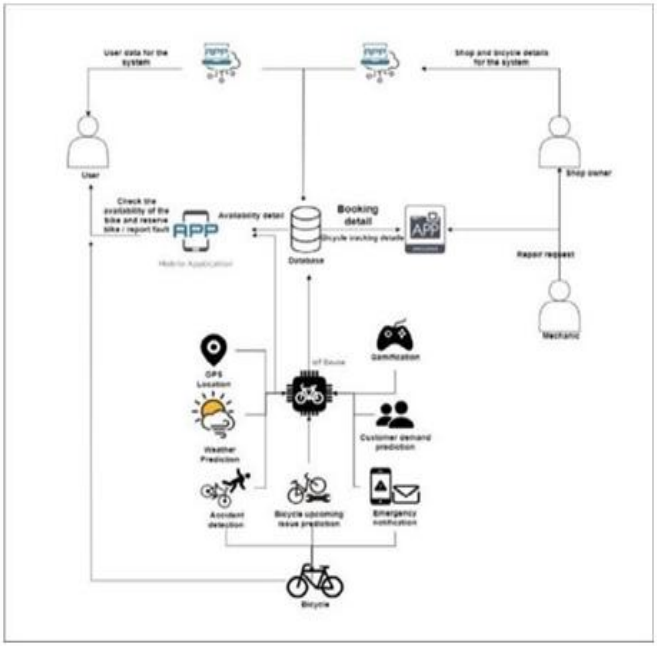

Figure 1: Overall System Diagram

A) Weather prediction system for bicycle riders

Our research project's IoT gadget uses a variety of hardware elements to allow weather identification and improve the bicycle rental system. These elements are essential to data collection and the use of real-time information delivery. The main hardware components used are listed below. The NodeMCU module, a flexible microcontroller board driven by the ESP8266 Wi-Fi chip, lies at the core of our IoT device. The IoT device and the API server may communicate with each other without interruption thanks to this module. Our IoT system's backbone allows the device to connect to a Wi-Fi network, share data, and receive commands.

GPS Module: The GPS module is a crucial component of our system and is in charge of precisely tracking the location of the bicycles. It gathers signals from several satellites and determines the specific location of the gadget, including its latitude, longitude, and altitude. Our solution offers up-to-date bicycle monitoring information using realtime GPS data, boosting user experience and guaranteeing effective rental operations.

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Raindrop Sensor: We have included a raindrop sensor to detect meteorological conditions associated with precipitation. This sensor is made up of conductive traces that, when they come into touch with raindrops, cause a voltage decrease. The sensor gauges the strength of the downpour by sensing this voltage fluctuation. Users may better plan their rides based on this information, which also increases their safety when it's bad outside.

MQ-135 Sensor: Monitoring air quality is essential for assuring user safety and well-being. So, an MQ-135 sensor is incorporated into our IoT gadget. This sensor measures the number of gases in the air, including dangerous chemicals like benzene, ammonia, and carbon dioxide. We can give customers useful information about the environment they will be cycling in by continually monitoring the air quality. Water Level Sensor: We have incorporated a water level sensor to handle the possible concerns related to water accumulation and floods. With the aid of this sensor, we can determine the meteorological conditions that increase the risk of flooding and water buildup. By integrating this sensor, we can alert customers in advance about places that are likely to flood, assuring their safety while riding bicycles.

LDR (Light Dependent Resistor): Our IoT gadget uses an LDR, sometimes referred to as a photo resistor, to determine the amount of light present in the environment. Based on the quantity of light hitting it, this sensor changes its resistance. We can give consumers pertinent information about day and night circumstances by tracking the light intensity. This aids in route planning and increases visibility and security.

Humidity Sensor: The humidity sensor monitors the amount of moisture in the atmosphere, which helps to identify the weather accurately. Our IoT gadget tracks relative humidity levels, giving users information about the surrounding wetness and empowering them to plan their rides wisely. This guarantees user comfort and security, especially in hot or dry weather.

Our IoT gadget collects essential information about weather conditions and bicycle tracking by utilizing the combined capabilities of these hardware elements. As the core processing unit, the NodeMCU module facilitates communication between the IoT device and the API server. The extra sensors enable the detection of meteorological characteristics, such as rainfall intensity, air quality, light intensity, and humidity, while the GPS module offers precise position data. Together, these hardware parts create a solid framework for our IoT-based bicycle rental system that improves user experience and encourages safety. [8] [9] [10] [11] Figure 2 is shown the Weather prediction system diagram.

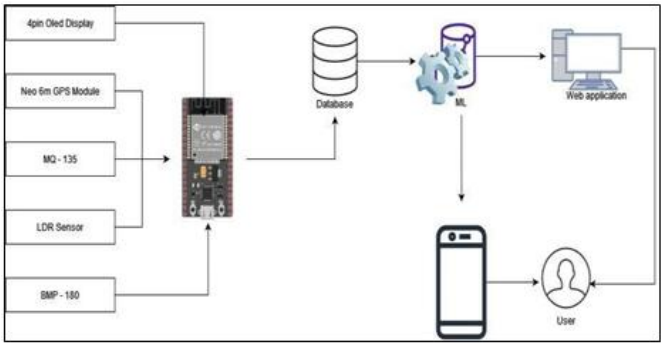

Figure 2: Weather prediction system diagram

B) Accident Detection and Emergency Notification System using IoT and Machine Learning

This part details building an innovative bicycle accident detection and emergency notification system. The system uses machine learning and Internet of Things (IoT) technologies to detect accidents in real-time and automatically send emergency alerts to a contact. An MPU6050 module acts as the accelerometer and gyroscope sensor collecting data. The main goal is to detect accidents and improve rider safety by providing immediate help during critical situations. The paper outlines the architecture, data collection and categorization, machine learning model creation, and integration of IoT components.

Experiments show the system accurately detects accidents and promptly notifies contacts. The system uses a mix of hardware and software. The hardware includes a Raspberry Pi 3 board, an MPU6050 sensor for measuring movement and rotation, a SIM800L GSM module, a NEO-6M GPS module, a buzzer, and a push button. The software includes data processing, machine learning, accident detection in realtime, and alerts. To create an accurate accident detection model, a large dataset of sensor data from accident and non accident situations was collected. The data was carefully organized into accident and non-accident categories based on facts. Many features were extracted from the sensor data to describe accident patterns well. These features were inputs for a random forest machine learning model trained to recognize and classify accidents. The system constantly analyzes incoming data from the sensors as it operates in realtime. When an accident is detected, the emergency notification process gets started. If a major accident is identified, a message with the accident location is automatically sent to a designated friend of the rider using GPS and cellular technology. In contrast, if the accident is deemed non-major, the rider has the option to press a button to prevent the notification from being sent and silence the alarm.

The extensive tests and evaluations show the system's effectiveness at detecting accidents and notifying people for

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help. The system achieves high accuracy, sensitivity, and specificity ensuring timely assistance for riders involved in accidents. It shows 98% accuracy. By properly distinguishing between major and minor accidents, the system minimizes false alarms and reduces unnecessary notifications.

The accident detection and notification system for bicycle riders is designed with a well-planned system architecture integrating hardware components and software algorithms. The hardware setup includes a Raspberry Pi 3 board, an MPU6050 accelerometer and gyroscope module, a SIM800L GSM GPRS module, a NEO-6M GPS module, a buzzer for alerts, and a push-button switch for user input. The Raspberry Pi acts as the central processing unit, collecting data, preprocessing it, and making decisions. The MPU6050 module captures accelerometer and gyroscope data processed and analyzed by machine learning algorithms running on the Raspberry Pi. The GSM GPRS module allows the system to send emergency notifications by SMS while the GPS module provides accurate location info in notifications. The buzzer alerts people nearby of an accident. The pushbutton switch lets the rider indicate if the accident is major or minor, controlling notifications and alarms. The software includes data processing algorithms, machine learning model implementation, real-time accident detection, and emergency notification generation. The system architecture ensures all components integrate seamlessly, enabling efficient accident detection and quick emergency response. The system architecture is shown in Figure 3 for the accident detection and emergency notification system.

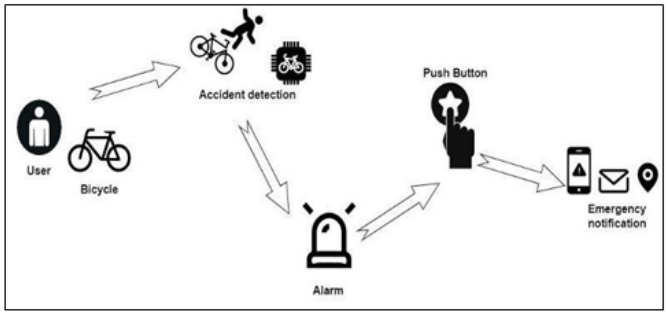

Figure 3: Accident Detection and Emergency notification system diagram

Proper data gathering and organization are essential for developing an accurate accident detection and emergency notification system for bicycle riders. To create a reliable machine learning model, a comprehensive data set of accelerometer and gyroscope data related to both accident and non-accident scenarios are assembled. The data collection process involves recording sensor data during controlled accident situations as well as regular riding conditions. Each data point is clearly labeled to indicate whether it corresponds to an accident or non-accident event. This labeled data set serves as the base for training the machine learning model.

Once the data set is compiled, the data undergoes a careful categorization process. The collected data is divided into two distinct classes: accident and non-accident. This categorization is based on the ground truth information obtained during data gathering. Careful attention is paid to ensure that the data set is well-balanced, representing a range of different accident scenarios and non-accident instances. This balance is critical for the machine learning model to accurately learn and distinguish between accident and non-accident patterns.

The machine learning model is a vital part of the accident detection and emergency notification system for bicycle riders. In this research project, a random forest algorithm was chosen as the underlying model because it's effective at handling classification tasks. There were some models checked and Random Forest is the best. The model is trained using the labeled and categorized dataset collected previously. To prepare, relevant features were identified from the sensor data to focus the model on the most informative aspects. This helps the model by reducing unnecessary details and highlighting what matters most. The machine learning model trained serves as the real-time accident detection part of the system. As new sensor data arrives from the MPU6050 module, the model applies the learned patterns and features to categorize the data as either an accident or non-accident. This immediate prediction enables the system to detect accidents quickly and start the proper emergency notification process.

After being implemented, the machine learning model continually and instantly evaluates the incoming sensor data. The system starts the emergency notification process when it notices an accident. The GSM GPRS and GPS modules automatically send a message with the accident location to a chosen buddy of the rider if the accident is deemed major. Alternatively, if the accident is assessed to be minor, the rider can deactivate the push-button switch to stop the alarm from sounding and prevent the notice from being sent.

To assess the system's effectiveness in accident detection and emergency alerting, numerous trials are conducted. The outcomes show a high degree of accuracy and promptness in accident identification, ensuring that riders receive assistance as soon as possible. The system successfully distinguishes between serious and minor incidents, resulting in reduced false alarms and useless messages. [12] [13] [14] [15] [16]

C) Upcoming issues prediction in the bicycles and the repairing process for the bicycle rental system fault

To satisfy customers and reduce downtime, bicycle rental systems must have effective maintenance management. However, tests based on periodic maintenance schedules may not be the best course of action, as bicycles may experience

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problems at varying levels of intensity depending on usage patterns, environmental conditions, and component quality, among other things. To reduce repair costs and boost customer satisfaction, a predictive maintenance system that can accurately predict upcoming bicycle issues is required.

As an example, when the rider booked the bicycle near to him and after booking, he goes to that booked bicycle location. When he goes to ride the bicycle, the bicycle may be faulty. Then the bicycle cannot be ridden anymore. As a rental system, the system needs to provide a proper solution for it. If it is not, the system does not work well and when the bicycle is faulty and there is no solution to repair, then the bicycle owner has to go to the bicycle located place and he has to repair his bicycle on his own. A bicycle rental system needs to provide a proper solution to it if not the rider is not satisfied with the service and the bicycle owner also is not satisfied with this system and the system will fail without a proper solution.

To solve this problem the rental system is provided with a new process for the bicycle repair process. Why does the system use customer feedback to detect the bicycle faulty? Because they practically cannot implement a device to detect the bicycle's fault by using IOT devices or sensors for the bicycle. It is a bicycle, and the sensor may be damaged, when the bicycle is riding, or the bicycle can fall to the ground then the sensors can be Brocken and a lot of sensors have to use each part of the bicycle.

If there is any issue that occurs with the bicycle while riding or when the riders go to the bicycle allocated place, the mobile application will provide a faulty submission form. Riders can easily submit the detected fault in the bicycle and riders can complete the ride with another bicycle. In that form, the system will take some details (rider name, bicycle number, fault on the bicycle) and update them in the database. Then the system automatically sends a notification to the bicycle owner and the notification includes faulty bicycle details. The system is registered, who have bicycle repairing skills, can register with the system. The system automatically sends a notification to the repair people and if they are available at that time, they can visit the bicycle location and repair it. After the bicycle is repaired, the bicycle will be allocated to the system, and it will show on the map. After repairing the bicycles, the repaired man has to submit a rectification form. Because the system needs a record for future proposes and it will use for the train the machine learning model to predict the upcoming issue in the bicycles.

To train the ML model the system needs a data set. Then it can be taken in the repairing history of the bicycle rental system. The implement the ML model, the system has to take the previous issues of each bicycle, the condition of the bicycles (high, low, med), and the usage of each bicycle. These variables are taken to train the ML model. For the implementation, the ML model system uses a random forest machine learning algorithm and for implementing the mobile application uses the flutter programming language.

Why the system uses random forest, it is a more accurate prediction because it combines multiple decision trees to make the predictions. It can work with a large number of data sets. These are some features of the random forest algorithm. This model is unique for each bicycle rental system because the bicycle issues are different in each bicycle system in other countries. Before using this model for the bicycle rental system. The model needs the rental system repair history records in a time range. Then the model can give more accrued predictions to the system. The implementation of a machine learning-based predictive maintenance system can significantly reduce repair costs and increase customer satisfaction by accurately forecasting the upcoming issues in bicycles rented in a bicycle rental system. [17] [18] [19] Figure 4 shows the upcoming issue issues prediction and repairing process system diagram.

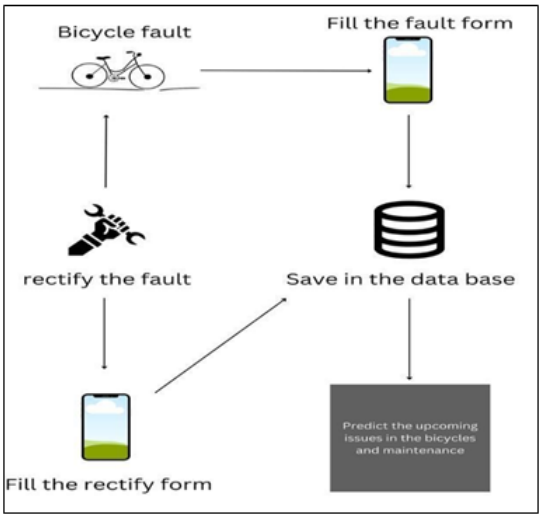

Figure 4: Upcoming issues prediction and repairing process system diagram

D) Billing system with Future customer interaction prediction and Gamification platform

The gamification platform is mainly focused on riders. It is designed to provoke riders to use Pick and Go more often. Here we maintain a leader board and give points to riders for each ride. The more you use, the more points you get. At the end of the month, ride records were collected and displayed on the leader board for the next month. The top scorers of the leader board get discounts for their next rides.

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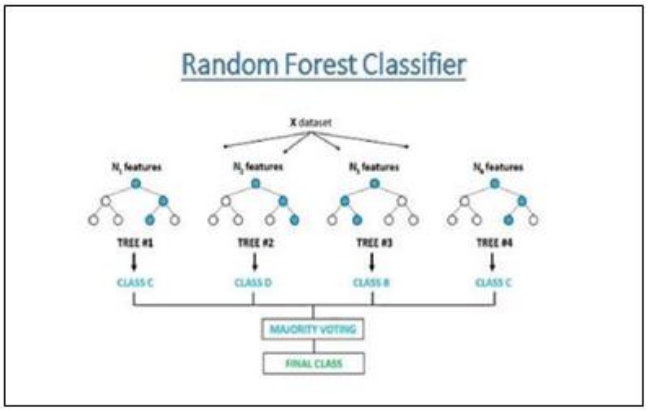

Figure 5: Random forest classifier

Customer interaction prediction and Gamification systems were designed to improve the user experience of the system for users. Interaction prediction was designed for the use of bicycle renters. Using this system, they can predict the estimated number of customers for each day. This helps renters to prepare and provide good service to the customers. This is done by analyzing past ride records.

Every rental and riding record was stored in the main database. To give the prediction, it analyzes the past months' data and gives the estimated number of customers that may come to rent bicycles. For example, the system gathers the past month's records and gets the total number of customers who interacted on Mondays. Then it takes an average value and displays the estimated number of customers. The regression model is used to implement the prediction and the random tree is the architecture used to implement the prediction (Random Forest regression model). As a supervised learning algorithm, Random Forest Regression does regression using the ensemble learning approach. With the use of the ensemble learning method, predictions from various machine learning algorithms can be combined to produce predictions that are more accurate than those from a single model. [20] [21] [22]

IV. RESULT AND DISCUSSION

The implementation of weather prediction combining machine learning models and bicycle location tracking using an Internet of Things device produced promising outcomes. The machine learning model demonstrated high precision in forecasting weather conditions based on past weather data and real-time sensor inputs. This enabled cyclists to receive timely weather updates specific to their current location, ensuring they could plan their rides properly and take suitable safety precautions. The integration of an Internet of Things device for bicycle location tracking further increased the accuracy of weather predictions, as it allowed for localized weather data to be collected and analyzed. Overall, this blend of machine learning and Internet of Things technologies significantly improved the safety and riding experience for cyclists.

The created accident detection and emergency notification system recognized accidents and responded to them successfully in real-time, giving bikers immediate aid in urgent situations. The IoT device's accelerometer and gyroscope data allowed the machine-learning model to distinguish between accident and non-accident patterns with great success. The system successfully detected accidents with high accuracy, sensitivity, and specificity, reducing false alarms, and assuring prompt emergency alerts. In the case of a significant accident, the integration of IoT components, including GPS and GSM modules, enabled precise location tracking and prompt communication with registered contacts. The system's capacity to distinguish between significant and minor accidents and the presence of a push-button switch for human input further enhanced its practicality and usability.

The implementation of predictive models for upcoming issue prediction in bicycles and the repair process for the bicycle rental system fault showcased significant improvements in proactive maintenance and repair strategies. By analyzing historical maintenance records and sensor data, the models accurately predicted potential issues in bicycles, enabling timely repairs and minimizing breakdowns. This proactive approach not only improved the overall performance and reliability of the bicycle rental system but also enhanced customer satisfaction and reduced operational costs. The integration of machine learning techniques facilitated the identification of underlying patterns and trends, allowing for more accurate predictions and effective repair processes.

The implementation of an invoicing system with future customer interaction prediction and a gamification platform was advantageous in improving customer involvement and fulfillment. Leveraging machine learning algorithms allowed the invoicing system to accurately predict customers' future interactions and preferences, enabling customized recommendations and customized services. This proactive approach enhanced the customer journey, increased customer loyalty, and optimized income generation. The gamification platform, with interactive elements and rewards, further motivated customer participation and fostered a sense of achievement. The combination of the invoicing system and gamification platform contributed to an enjoyable and immersive experience, promoting long-term customer involvement and retention.

In summary, the findings from this study show the usefulness and feasibility of combining machine learning and IoT technologies in many parts of bicycle rider safety, maintenance, customer engagement, and the overall riding

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experience. The mix of these elements not only enhances safety steps like accident identification and weather forecasting but also advances proactive upkeep, billing processes, and customer involvement. The successful execution of these systems creates the groundwork for a complete and integrated strategy to optimize bicycle riding experiences while prioritizing safety, effectiveness, and customer contentment.

V. CONCLUSION AND FUTURE WORK

The IoT and Machine Learning based research project on bicycle rental systems with GPS location tracking, the ability to predict a week's worth of cycling behavior, a gamification platform, and pre-ride bicycle inspection has the potential to completely change the way bicycle rental systems function. This project's goal is to make bicycle rental systems more effective, secure, and user-friendly. The efficiency, security, and user experience of bicycle rental systems could all be considerably enhanced by the research study on IoT-based bicycle renting systems. Following are some conclusions and potential research projects for this system:

Enhanced Efficiency: Renters can locate, reserve, and unlock bicycles much more quickly and easily by integrating GPS tracking, and predictive analytics. More improvements can be made to optimize bicycle distribution and availability as the system gathers more information on cycling habits and user behavior.

Increased User Experience: By encouraging renters to ride more frequently and offering prizes for safe and responsible riding behavior, the gamification platform can improve user experience. Further features including tailored cycling route suggestions, weather updates, and social sharing capabilities may be added in later works.

Environmental Benefits: An IoT-based bicycle rental program could lower carbon emissions and encourage environmentally friendly transportation. Future research might concentrate on measuring the system's environmental impact and improving it for maximum sustainability.

Cost-effectiveness: The cost of the bike rental system may increase with the inclusion of IoT devices, predictive analytics, and gamification platforms. Future research might concentrate on figuring out how to deploy and maintain the system affordably while guaranteeing that it continues to be profitable for the operators.

The weather prediction system enabled cyclists to receive accurate and timely weather updates specific to their location, enhancing safety and ride planning. The accident detection and emergency notification system provided real-time accident detection, differentiating between major and non major accidents, and promptly notifying emergency contacts, ensuring timely assistance. The upcoming issue prediction system optimized proactive maintenance strategies, reducing breakdowns and improving the reliability of the bicycle rental system. The billing system with future customer interaction prediction and gamification platform enhanced customer engagement, satisfaction, and revenue generation. In terms of the bicycle maintenance aspect, the integration of sensor-based systems for continuous monitoring and data collection can enhance the accuracy and timeliness of issue prediction. Additionally, exploring predictive maintenance techniques, such as anomaly detection and prognostics, can further optimize maintenance processes and minimize downtime.

In general, the bicycle rental system has the power to completely change how people rent and utilize bicycles. The system may be improved further to deliver a productive, safe, and interesting user experience as more data is gathered and analyzed.

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