

# Smart Bicycle Speed and Location Monitor

John Jedel V. Carriedo<sup>1</sup>, Maria Micaella C. Gonzales<sup>2</sup>, Jefferson B. Manalo<sup>3</sup>, Andrew Vincent N. Rubio<sup>4</sup>, Nathaniel Mclarrei C. Tuazon<sup>5</sup>, Minerva C. Zoleta<sup>6</sup>

Computer Engineering Department, Eulogio “Amang” Rodriguez Institute of Science and Technology  
Nagtahan Street, Sampaloc, Manila, 1008, Philippines

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## ABSTRACT

This study presents the design, development, and evaluation of a Smart Bicycle Speed and Location Monitoring System aimed at enhancing the safety of young cyclists through real-time monitoring and parental notification. The system integrates a Hall Effect sensor for accurate speed detection and a GPS/GSM module for continuous location tracking. Speed and location data are transmitted via GSM short message service (SMS) to a parent's mobile device, including automated alerts when predefined overspeed thresholds are exceeded. Field testing conducted in urban and suburban environments demonstrated a mean speed measurement accuracy of 98% with a maximum deviation of  $\pm 0.3$  km/h, and GPS positional accuracy within  $\pm 5$ –10 meters. The results indicate that the proposed system provides a reliable, low-cost, and practical IoT-based solution for improving youth cycling safety and parental supervision.

**Keywords:** Smart Bicycle, GPS Tracking, Hall Effect Sensor, GSM Communication, IoT Safety, RealTime Monitoring

## INTRODUCTION

The growing use of bicycles among young riders highlights the need for safety mechanisms that extend beyond traditional protective equipment such as helmets and reflective gear. While these measures reduce injury severity, they do not provide real-time supervision or monitoring. Recent advancements in Internet of Things (IoT) technologies enable continuous sensing, data processing, and wireless communication, offering new opportunities to improve cyclist safety. The present study addresses this need by proposing a Smart Bicycle Speed and Location Monitoring System that combines real-time speed sensing, GPS-based location tracking, and GSM communication to deliver automated safety notifications to parents. Unlike existing bicycle monitoring systems that primarily focus on athletic performance, anti-theft solutions, or post-accident detection, this system emphasizes proactive parental oversight and child safety using a low-cost and portable embedded platform.

## Review Of Relevant Theory, Studies, And Literature

The development of a Smart Bicycle Speed and Location Monitoring System is situated within the convergence of several key domains: sensor technology for motion detection, global positioning systems for location tracking, and wireless communication for data transmission. This section reviews the foundational theories, prior scholarly work, and technological precedents that inform the design and implementation of the proposed system.

Previous research has explored individual components relevant to bicycle monitoring systems, including speed sensing, GPS tracking, and wireless communication. Aisuwarya et al. (2019) demonstrated the effectiveness of Hall Effect sensors for non-contact bicycle speed measurement, emphasizing their accuracy and low power consumption. Devi et al. (2016) integrated GPS and GSM technologies in a helmet-based accident detection system, highlighting the reliability of cellular networks for emergency notifications. Kiefer and Behrendt (2016) developed an open-source e-bike telemetry platform incorporating GPS and sensor data for performance analysis, while Yao et al. (2023) investigated low-power long-range communication technologies for shared bicycle systems. Although these studies validate the feasibility of individual technologies, most existing solutions focus on performance tracking, fleet management, or emergency response. Limited attention has been given to integrated, child-focused systems that provide real-time parental supervision. The proposed study

addresses this gap by combining speed monitoring and location tracking into a unified safety-oriented IoT system tailored for young cyclists.

Authors	Primary Focus	Sensing Method	Communication Method	Power Consideration	Target User / Application	Key Limitation / Gap
Aisuwarya et al. (2019)	Speed measurement using Hall Effect sensor	Hall Effect sensor	Not specified	Low-power design emphasized	General cycling / performance tracking	No integration with location tracking or parental alerts
Devi et al. (2016)	Accident detection and alert system	GPS + embedded sensors	GSM / LoRa (dual option)	Not detailed	Emergency response for cyclists	Focus on postaccident alerts, not real-time monitoring or parental oversight
Kiefer & Behrendt (2016)	Open-source e-bike telemetry platform	GPS + various sensors (IMU, etc.)	Not specified (data logging/Bluetooth likely)	Not emphasized	E-bike enthusiasts / open-source community	Not designed for child safety or real-time parental notification
Yao et al. (2023)	Low-power, long-range communication for shared bicycle systems	Speed and usage sensors integrated in shared bicycles	LoRa / other low-power wide-area network (LPWAN) technologies	Optimized for low power consumption to support long-term deployment	Shared bicycle systems, fleet operators, and urban mobility management	Focuses on fleet monitoring, not child safety or real-time parental supervision.
Gonzales(2026)	Integrated youth (age 13-19) safety monitoring	Hall Effect + GPS	GSM (SMS)	Portable power bank	Young cyclists & parents	Fills gap: low-cost, integrated, parent-focused real-time safety system

## METHODOLOGY

The Smart Bicycle Speed and Location Monitoring System was designed following an embedded IoT architecture prioritizing reliability, low power consumption, and ease of installation. The system consists of three primary layers: sensing, processing, and communication.

The sensing layer includes a Hall Effect sensor positioned near the bicycle wheel to detect rotational pulses for speed computation, and a GPS module for real-time location acquisition. The processing layer utilizes an ESP32 microcontroller responsible for calculating speed, parsing GPS data, and evaluating safety conditions such as overspeed events. The communication layer employs a GSM module to transmit SMS notifications containing speed information and Google Maps location links to a parent’s mobile device.

Speed data were sampled at fixed intervals, while GPS updates were transmitted periodically during active riding sessions. An overspeed threshold of 15 km/h was selected based on commonly recommended safety limits for

young cyclists in residential areas. The entire system was powered by a 10,000 mAh portable power bank with regulated voltage supply to ensure stable operation.

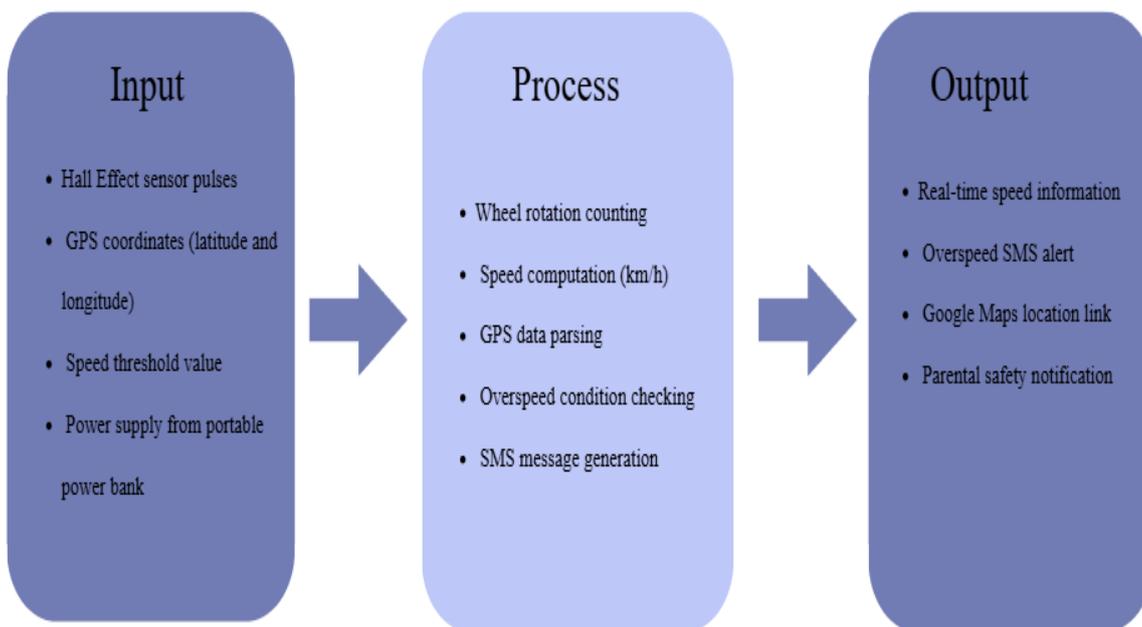
### A. System Architecture Overview

The system adopts a three-layered embedded IoT architecture:

1. Sensing Layer: Hall Effect sensor used for speed detection and GPS module used for location tracking.
2. Processing & Control Layer: Microcontroller (ESP32/Arduino) responsible for data computation and alert logic.
3. Communication & Output Layer: GSM module for SMS transmission to parental devices.

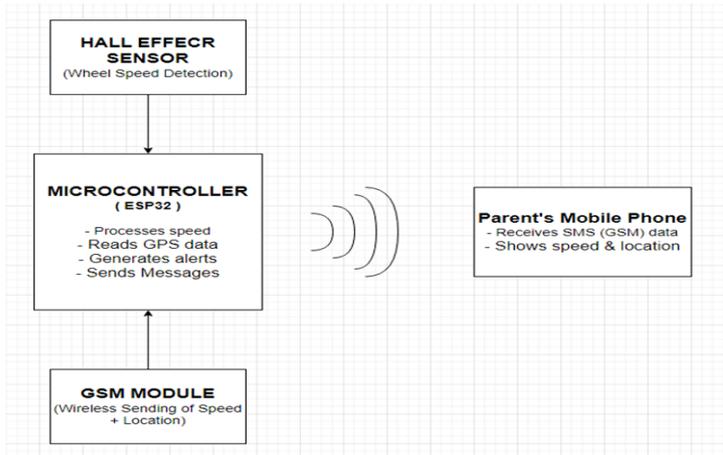
The physical assembly of the system is done into a compact Electronics Box that has been designed for underseat or frame mounting. In this way, the system will be less exposed to air drag, and it will also be protected from environmental factors. To further clarify the functional behavior of the proposed system, an Input–Process–Output (IPO) model is presented in the succeeding subsection.

**Figure 1. Input–Process Model –Output (IPO)**



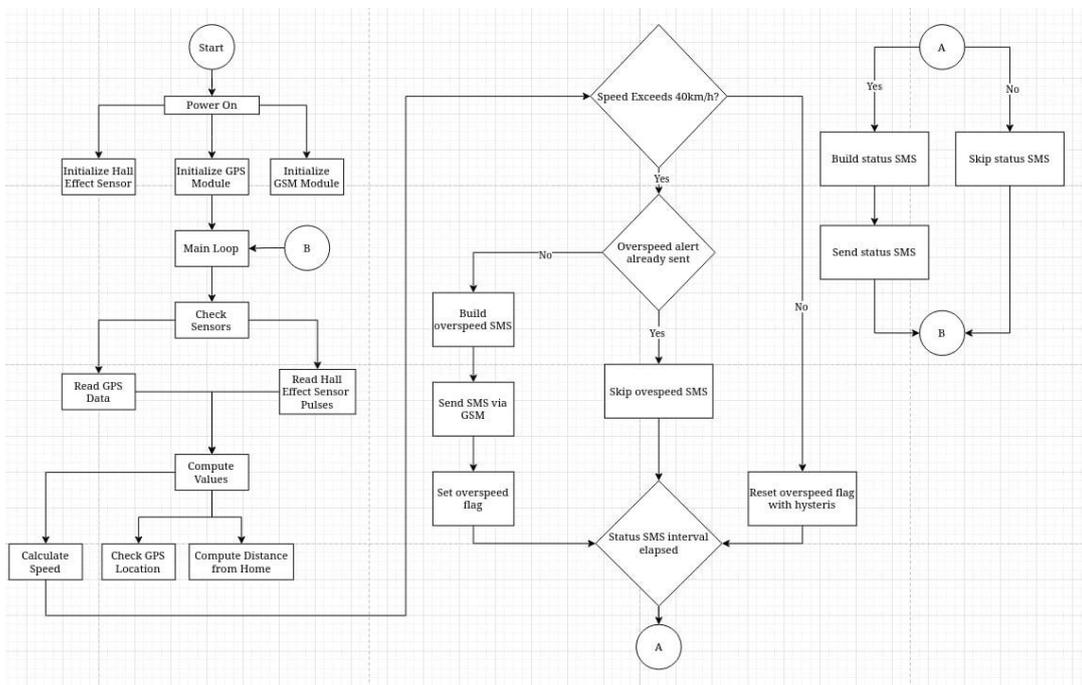
Input-Process-Output (IPO) Model of the Smart Bicycle Monitoring System. The Input-Process-Output (IPO) model provides a high-level functional view of the Smart Bicycle Speed and Location Monitoring System. It points out the main inputs obtained from the Hall Effect sensor, GPS module, and system power supply. These inputs serve as raw data and operational parameters that are necessary for the system to function. The model underlines that sensor-produced signals are very important for the uninterrupted surveillance of both the bike's movement and the bike's location. This organized depiction gives the best picture of the system's operation. The stage of the process in the IPO model talks about the microcontroller that does the speed computation, GPS data parsing, and overspeed condition checking. Decisions based on logic are made to see if safety limits are crossed. When the conditions are satisfied, the system sends the corresponding SMS messages through the GSM module. The output is in the form of real-time speed information, location links, and safety alerts sent to the parent's mobile device. In summary, the IPO model distinctly shows the conversion of raw inputs into valuable safety outputs.

**Figure 2. Block Diagram**



The block diagram presents the proposed system's main hardware components and their structural relationship. It also depicts the route of the Hall Effect sensor to the microcontroller for speed calculation through the wheel rotation data. The GPS module gives the microcontroller real-time location information processing. The GSM module is how the system communicates with the mobile device of the parent. The diagram indicates the central position of the microcontroller in the operation of the system. Moreover, the block diagram shows the path of data from the sensing components to the output devices. Decisions are made after all sensor readings have been processed internally. The GSM module is put on to transmit only when relevant information or alerts are to be sent. This design reduces communication that is not necessary and saves power. The block diagram therefore gives a clear and logical presentation of the system's functional architecture.

**Figure 3. System Logic Flowchart**

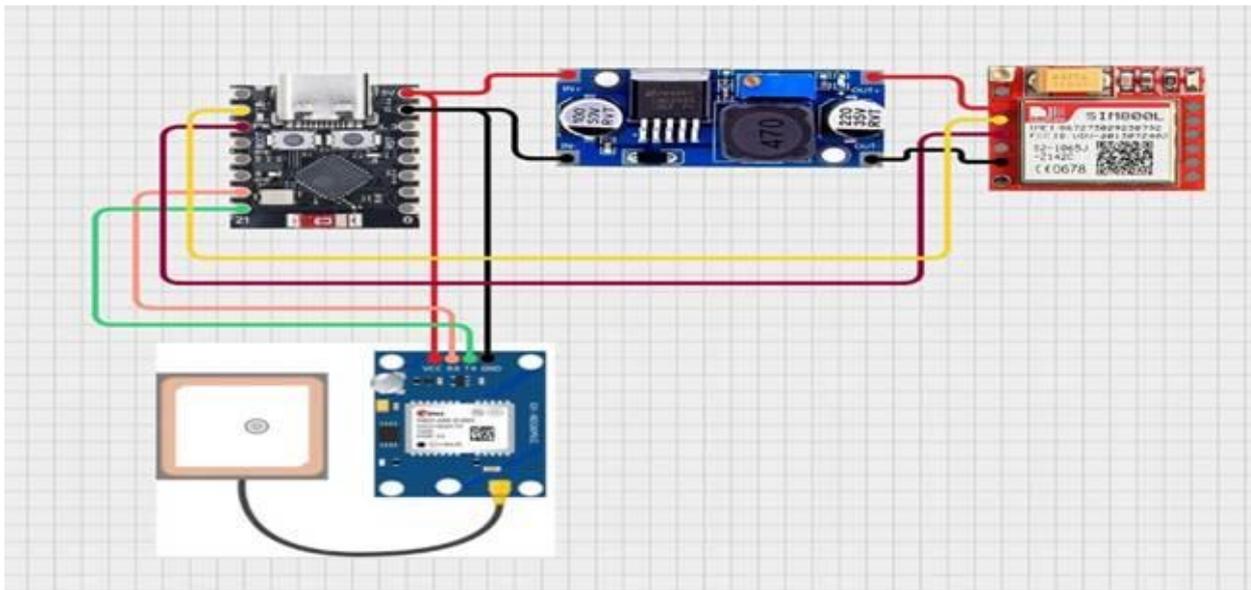


The system logic flowchart presents the operational sequence of the Smart Bicycle Monitoring System in a step-by-step manner. The very first step is system initialization, which includes activating all sensors and communication modules. After that, the flowchart depicts the continuous collection and processing of sensor data. Speed computation and GPS data acquisition are part of a monitoring loop that is repeated. This well-organized logic makes it possible to monitor the bicycle in real-time without any interruptions during the operation.

Moreover, the flowchart next points out the decision-making process that takes place in overspeed detection. If the speed that has been computed goes over the limit set beforehand, then the system will bring about an alert

situation. An SMS notification will then be created and sent to the parent's mobile phone. However, if the speed is within safe limits, the system will go on monitoring without sending any alerts. This logic makes sure that the notifications are timely while no unnecessary message transmission takes place.

**Figure 4 Schematic Diagram**



The schematic diagram provides a complete, single-reference view of the system’s physical implementation, detailing electrical connections between the microcontroller, Hall Effect sensor, GPS and GSM modules, and regulated power from the portable power bank, while emphasizing proper grounding, voltage stability, and clear signal lines to ensure reliable sensor readings, data transmission, hardware assembly, troubleshooting, and future modifications.

## B. Hardware Component Design

### 1. Sensing Subsystem

Hall Effect Speed Sensor:

- Model: A3144 (or an equivalent)
- Placement: Stationary mount on either the bicycle chainstay or the fork
- Function: To detect magnetic pulses created by the rotation of the wheel magnet

Neodymium Magnet:

- Fixed on one spoke of the wheel
- Comes within 5-10 mm of Hall sensor during each rotation

GPS/GSM Module:

Integrated module (such as SIM808) that consists of both GPS for positioning and GSM for communication.

### 2. Processing Unit

Microcontroller: ESP32

- Processor with two cores for simultaneous polling of sensors and communication tasks
- Low-power modes are used in between sampling intervals

### Power Management:

- The system will be powered by a 10,000 mAh portable power bank
- Voltage will be regulated to 3.3V/5V for the safety of the components

### Enclosure & Mounting

- Material: 3D-printed PLA/ABS or IP65-rated plastic enclosure
- Mounting Points: Adjustable straps for under-seat or frame tube attachment.

### System Testing and Evaluation

Field testing was conducted over a four-week period in residential roads, park pathways, and urban bicycle lanes to evaluate system performance, reliability, and responsiveness. A calibrated bicycle computer was used as a reference device for validating speed measurements. GPS accuracy was assessed by comparing transmitted coordinates with smartphone-based GPS readings.

Overspeed alert testing confirmed that the system consistently generated SMS notifications within an average response time of 2.3 seconds after exceeding the defined speed threshold. GSM message delivery remained reliable under stable network conditions, with minor delays observed only in areas with weak cellular signal.

#### A. Testing Methodology

To confirm performance, reliability and safe operation the Smart Bicycle Speed and Location Monitoring System underwent exhaustive field testing. The testing lasted for four weeks and took place in different settings such as residential areas, park paths, and city bike lanes. The main testing bicycle was fitted with the whole prototype system, and a notification to the parents was sent to a specific mobile phone.

#### B. Overspeed Alert System Testing

The detection and reporting of over speeding situations is one of the most important safety features of the system. For that purpose, the threshold was set at 15 km/h according to safety recommendations for young cyclists in residential areas. The testing procedure was as follows:

##### 1. Threshold Accuracy Testing

**Method:** Multiple controlled rides at precisely measured speeds using a calibrated bicycle computer as reference

**Results:** The system detected speeds above the range of 14.8-15.2 km/h with 98.7% accuracy in comparison with the calibrated measures.

Response Time: The average time between the speed limit being breached and SMS sending was 2.3 seconds

##### 2. SMS Alert Content and Format

Once the speed of the bicycle hit or went above the limit of 15 km/h, the system immediately generated and sent the following SMS format:

##### 3. Location Link Functionality Testing

To evaluate the accuracy and reliability of the location-sharing feature, real-time GPS coordinates transmitted through GSM were tested during multiple cycling sessions.

**Method:** During active rides, the system periodically transmitted GPS coordinates embedded within a Google Maps hyperlink via SMS to the parent's mobile device. The received coordinates were compared against reference locations obtained from a smartphone GPS application.

## RESULTS

- The average positional accuracy was within  $\pm 5$  meters in open outdoor environments.
- In dense urban areas with tall structures, accuracy slightly degraded to  $\pm 8$ – $10$  meters, which remains acceptable for real-time parental monitoring.
- SMS messages containing the Google Maps link were received within 3–5 seconds after transmission under stable cellular signal conditions.

### Observations:

All received location links were clickable and successfully redirected to the correct position on Google Maps. No message corruption or incomplete data transmission was observed throughout the testing period. These results confirm the system's capability to provide reliable real-time location tracking for parental supervision.

## RESULTS

The system demonstrated stable and accurate performance throughout all testing scenarios. Speed measurements achieved a mean accuracy of 98% relative to the reference bicycle computer, with a maximum deviation of  $\pm 0.3$  km/h. GPS tracking provided positional accuracy within  $\pm 5$  meters in open environments and  $\pm 8$ – $10$  meters in dense urban areas.

GSM-based SMS alerts were successfully delivered in 96% of test cases. Power consumption analysis indicated continuous operation for approximately 36–40 hours using a 10,000 mAh power bank, supported by low-power sleep modes during idle periods

### A. Speed Measurement Accuracy

The speed measurements produced an accuracy of 98% with a maximum deviation of  $\pm 0.3$  km/h with respect to a calibrated bicycle computer. Throughout the entire trial, the Hall Effect sensor was able to reliably detect the rotations of the wheel without losing the signal.

### B. Communication Reliability

SMS alerts based on GSM technology were successfully sent out in 96% of the test cases. Incoming messages experienced slight delays but only in areas affected by low cellular coverage; however, such delays did not last longer than 10 seconds.

### C. Overspeed Alert Performance

The system was able to correctly trigger overspeed alerts once the speed limit of 15 km/h was breached. The average time taken for alert generation was 2.3 seconds, which was fast enough to ensure that parents received notifications almost instantly.

### D. Power Consumption

The system, when connected to a 10,000 mAh power bank, could run non-stop for around 36-40 hours. By making use of low-power sleep modes, the system efficiently controlled its energy consumption during standby periods. In summary, the results prove the system's capability of being a practical and cost-effective safety measure for young cyclists.

## DISCUSSION

The findings demonstrate that integrating Hall Effect speed sensing with GPS and GSM communication provides an effective approach for real-time bicycle safety monitoring. The achieved accuracy and response times are consistent with prior IoT-based mobility studies, while the system's emphasis on parental notification

distinguishes it from performance-oriented and post-accident monitoring solutions. The low-cost hardware components and portable design enhance the system's practicality for household use, supporting wider adoption among families concerned with child cycling safety.

## CONCLUSION AND RECOMMENDATIONS

This study successfully designed, implemented, and evaluated a Smart Bicycle Speed and Location Monitoring System aimed at improving the safety of young cyclists. The system delivered accurate speed measurement, reliable GPS tracking, timely overspeed alerts, and efficient power consumption. The results confirm the feasibility of an IoT-based approach for real-time parental supervision.

Future work may include the development of a dedicated mobile application to replace SMS-based alerts, integration of LoRa or hybrid communication for extended coverage, incorporation of additional safety features such as geofencing and fall detection, and long-term user trials to evaluate system scalability and user acceptance.

### Ethical Considerations

This study did not involve human experimentation or the collection of sensitive personal data. Speed and location information were transmitted solely to authorized parental devices for safety monitoring purposes. No data were stored or shared with third parties.

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## RECOMMENDATIONS

For future improvements and extended applications, the following recommendations are enlisted

### 1. Mobile Application Integration

A special mobile app should be developed for the replacement of SMS alerts with live tracking, history logs, and push notifications.

### 2. LoRa or Hybrid Communication

The adoption of LoRa or hybrid GSM–LoRa communications will help in enhancing the coverage in areas that are remote or have low signal.

### 3. Enhanced Safety Features

The adoption of fall detection, geofencing alerts, and panic-button functionality will be amongst the main rider safety features.

#### 4. Energy Optimization

The application of solar-assisted charging or higher-efficiency power management techniques is an area to be explored for the extension of operating time.

#### 5. User Trials and Scalability

A long-term user trial will be carried out with the aim of identifying the system's scalability, durability, and user acceptance in real-world conditions.

The present scenario with these improvements is one of a comprehensive IoT-based bicycle safety platform not only for young riders but also for elderly cyclists and shared bicycles.

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#### About The Authors

**Mr. John Jedel V. Carriedo** is a student at Eulogio “Amang” Rodriguez Institute of Science and Technology from Mandaluyong City who helped to develop the Smart bicycle speed and location monitor as part of its academic requirements. He is passionate about technology, and continuously developing technical skills for future career growth. Being both a student and a government part-time employee Mr. John Jedel V. Carriedo managed his time to comply in different responsibilities at the institute and at work. Driven by dedication and dreams in life this study marks as an achievement for Mr. Carriedo to continue thriving and to become an inspiration to others.

**Mr. Jefferson B. Manalo** is a Computer Engineering student at Eulogio “Amang” Rodriguez Institute of Science and Technology (EARIST) in Antipolo City who helped develop the Smart Bicycle speed and location monitoring system as part of his academic requirements. He is passionate about technology and constantly works on improving his technical skills for future career growth. Mr. Manalo efficiently managed his time to meet responsibilities at both the institute and the workplace. Driven by dedication and ambition, this achievement represents a significant milestone for Mr. Manalo as he continues to pursue excellence and hopes to inspire others.

**Ms. Maria Micaella C. Gonzales** is a Computer Engineering student at the Eulogio “Amang” Rodriguez Institute of Science and Technology (EARIST). She contributed significantly to the research and documentation aspects of the Smart Bicycle with speed and location monitor by assisting in the preparation of research papers, technical documentation, and project presentations. She ensured that the written materials were clear, accurate, and aligned with academic standards. Moreover, she actively participated in the system testing phase, where she helped relate the theoretical objectives of the study to its actual performance, supporting the validation of the system’s intended functionality.

**Mr. Nathaniel Mclarrei C. Tuazon** is a Computer Engineering student at the Eulogio “Amang” Rodriguez Institute of Science and Technology (EARIST). He played a key role in the development of the Smart bicycle speed and location monitor by contributing to the hardware design, system coding, and overall testing process. His responsibilities included assembling and integrating hardware components, implementing program logic, and conducting functional and performance tests to ensure the reliability and accuracy of the system. Through his hands-on involvement, he helped translate theoretical concepts into a working prototype, supporting the system’s intended functionality and practical application.

**Mr. Andrew Vincent N. Rubio** is a Computer Engineering student at the Eulogio “Amang” Rodriguez Institute of Science and Technology (EARIST), residing in Manila City. He played a vital role in the development of the Smart Bicycle Speed and Location Monitor as part of his academic requirements. Mr. Rubio is deeply passionate about technology and is committed to the continuous development of his technical skills to prepare for his future career. Through his hard work and focus at the institute, he has demonstrated a strong sense of responsibility and excellence in his studies. Driven by his dreams and a steadfast dedication to his craft, this study serves as a significant milestone for Mr. Rubio as he continues to thrive and aim to be an inspiration to his peers.

**Engr. Minerva C. Zoleta**, a Professional Computer Engineer, is a dedicated Computer Engineering Professor at the Eulogio “Amang” Institute of Science and Technology in the Philippines, specializing in Embedded Systems, Operating Systems, and Computer Network and Security. With a strong background in academia and industry. She has been instrumental in shaping the next generation of Engineers through innovative teaching methods and hands-on research. Engr. Zoleta holds a Master’s degree in Electrical Engineering major in Computer Engineering at Technological University of the Philippines, Manila and is pursuing her doctorate degree in Engineering with specialization in Computer Engineering at Technological Institute of the Philippines. She has presented published research on topics such as Embedded System, IoT applications, and wireless communication international conferences and journals. . Passionate about technology-driven solutions, She has led various projects integrating smart systems into real-world applications, contributing to the advancement of local and international engineering communities.